SNSIM

Volume 8, Issue 3, 2021

ISSN: 2392 – 9537
ISSN-L: 2392 – 9537

P - ESEM

Procedia Environmental Science, Engineering and Management

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

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Volume 8, Issue 3, 2021

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Environmental Science, Engineering and Management

24th International Trade Fair of Material & Energy Recovery and Sustainable Development,
ECOMONDO, 26th-29th October, 2021, Rimini, Italy

Selected papers

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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.

P - ESEM facilitates rapid dissemination of knowledge in the interdisciplinary area of environmental science, engineering and management, so conference delegates can publish their papers in a dedicated issue. This journal will cover a wide range of related topics, such as: environmental chemistry; environmental biology; ecology geoscience; environmental physics; treatment processes of drinking water and wastewater; contaminant transport and environmental modeling; remediation technologies and biotechnologies; environmental evaluations, law and management; human health and ecological risk assessment; environmental sampling; pollution prevention; pollution control and monitoring etc.

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 EDITOR

Fabio Fava, born in 1963, is Full Professor of "Industrial & Environmental Biotechnology" at the School of Engineering of University of Bologna since 2005.

F. Fava published about 250 scientific papers, 180 of which on medium/high IF peer-review international journals of industrial and environmental biotechnology and circular bioeconomy. He has 8680 overall citations, a h-index of 55 and an i10 index of 145 (Google Scholar) along with 180 papers quoted by Scopus. He is actively working in the fields of environmental, industrial and marine biotechnology and of the circular bioeconomy in the frame of a number of national projects and collaborative projects funded by the European Commission. Among the latter, he coordinated the FP7 collaborative projects NAMASTE, on the integrated exploitation of citrus and cereal processing byproducts with the production of food ingredients and new food products, and BIOCLEAN, aiming at the development of biotechnological processes and strategies for the biodegradation and the tailored depolymerization of wastes from the major oil-deriving plastics, both in terrestrial and marine habitats.

He also coordinated the Unit of the University of Bologna who participated in the FP7 collaborative projects ECOBIOCAP, ROUTES, MINOTAURUS, WATER4CROPS, ULIXES and KILL SPILL.

F. Fava served and is serving several national, European and international panels, by covering, among others, the following positions:

• Member of the Scientific Committee of the European Environmental Agency (EEA), Copenaghen, for the "Circular economy and resource use" domain (2021-);

• Italian Representative in the "European Bioeconomy Policy Forum" and the "European Bioeconomy Policy Support Facility" of the European Commission (2020-);

• Italian Representative in the Horizon2020 Programme Committee of Societal Challenge 2: European Bioeconomy Challenges: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and inland water research" (European Commission, DG RTD) (2013-);

• Italian Representative in the "States Representatives Group" (SRG) of the Public Private Partnership "Biobased Industry" (PPP BBI JU) (Brussels) (2014-); he is chairing the SRG since October 2018;

• Italian Representative in the BLUEMED WG of the EURO-MED Group of Senior Officials (EU Commission DG RTD and Union for Mediterranean) (2017-);

• Italian Representative in the initiative on sustainable development of the blue economy in the western Mediterranean the "Western Mediterranean Initiative" WEST MED, promoted by the EU Commission (DG MARE) in close cooperation with 10 countries of the area (2016-);

• Italian Representative in the "Working Party on Biotechnology, Nanotechnology and Converging Technologies" of the Organization for Economic Co-operation and Development (OECD, Paris) (2008-);

• Chair (2011-2013) and currently Deputy Chair of the "Environmental Biotechnology Section" of European Federation of Biotechnology (EFB) (2013-).

Finally, he is the scientific coordinator of the International Exhibition on Green and Circular economy ECOMONDO held yearly in Rimini (Italy)

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LIFE CYCLE ASSESSMENT– APPLIED TO THE CO-PRODUCTS OF A LIVESTOCK COMPANY*

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Abstract

The products lifecycle is extended to ensure a new use. In the present report the LCA approach was developed according to the specifc International Standards 14040-44: 2018, to highlight environmental hotspots of sewage produced by the livestock company Azienda Agricola Mulinello ltd, 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, a wastewater treatment plant and a composting plant. The entire establishment has got a circular economic system. In this contest an additional anaerobic digestion system could bring further benefits in the circular view, as it allows the transformation of processed effluents and organic waste into biogas and bio-fertilizers. Currently, the company confers processed effluents and organic waste to the pilot plant built at the Assoro biomethane company located in the province of Enna, which is one of the main plant sites in Italy.

Keywords: biomethane; LCA; circular economy; sustainable production; zootechnical waste

1. Introduction

Circular Economy represents a theoretical concept whose purpose is to create an industrial system thought to self-regenerate. In-fact recyclable materials are reintegrated into

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*Selection and peer-review under responsibility of the ECOMONDO

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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* (Cecchi et al., 2005).

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. 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 (Amon et al., 2001). 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 (Zilia et al., 2021). 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 (Spadaro et al., 2020):

• 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 describe the anaerobic co-digestion techniques that will be used to obtain biogas by the livestock company Azienda Agricola Mulinello ltd.

With this paper is undoubtedly critical as it determines all subsequent LCA planning. It is evident, in fact that every application of the method corresponds to a different approach to the problem and, therefore, a different implementation of the same LCA: the way of proceeding is different, depending on whether there is a production process at the centre of the evaluation or a product or if the use is business or strategic planning. In this phase the following will be defined: the goal of the study, the functional unit, the boundaries of the analysed system, the necessary data (Ingrao et al., 2021).

The aims of the study should provide the intermediate steps that need to be defined to avoid any vagueness establishing on the contrary exactly what is expected. At this stage, it is difficult to choose the functional unit as a parameter which all the elements that make up the environmental performance of the system being examined refer to. The functional unit is the measure of the service that the system performs which the single, or multiple systems, report to. To assume a specific functional unit means standardizing the system studied to a certain function. The choice must be made by remembering that by functional unit the quantified performance is meant, and therefore what is measurable and objectively verifiable in a product, to be used as a reference unit in an LCA.

The case is about the Mulinello Farm l.t.d is a *National Pig* meat production and processing company located in the territory of Assoro (EN), was founded in 1976, as a closed-cycle pig breeding company, and is a small business with 35 employees. It has a sow park of 500 heads, and produces an average of 12,000 pigs per year. Figure 6 shows a top image of the company. The company, particularly careful in the selection of the breed, is the only one in Sicily to have a cross between the Italian large white and pietrain species, the result of a collaboration between the Universities of Messina, Turin and Lyon. The reproduction system takes place exclusively through artificial fertilization, carried out by a specialized technician, with the help of a group of selected breeders of the highest genealogy. An element that distinguishes the company is the attention to animal welfare. In fact, the entire animal park is subjected to rigorous checks on a daily basis by specialized veterinarians and followed in growth by food technicians, who monitor the health and well-being of the animals.

To this end, despite the 2008/120113 regulation relating to animal welfare in intensive farms, which came into force on 1 January 2013, the company designed the production structure in 1999 according to the legislation, ensuring decent living conditions for all. the leaders in every phase of growth. Over the years the company has evolved through a process of integration of the entire supply chain, passing from an initial phase in which it turns out to be a simple farm, to today where the direct production of feed for consumption has been implemented within the company, internal and an animal waste management system for obtaining compost. Today the company represents an excellent example of the circular economy. Over the years it has evolved through a process of integration of the entire supply chain, passing from an initial phase in which it turns out to be a simple breeding, to today where the direct production of feed for internal consumption and a animal waste management system for obtaining compost. Today the company represents an excellent example of the circular economy.

2. Materials and methods

The LCA is a technique aimed at assessing the environmental performance of a product from a global point of view, through all the steps that accompany the product from the cradle to the grave (cradle-to-grave assessment), and in less than ten years after its definition, it has become an appreciated and credible environmental analysis instrument, thanks to the formalization of procedures and guidelines.

The study takes into account the whole life of a product, from raw materials, their processing and transformation, as well as the energy needed to reach the finished product. The analysis continues evaluating the phases of transport and utilization, predictable maintenance, to final disposal, not to mention the potential reuse and recycling of components or parts of the product. An LCA is basically a quantitative technique that allows the input factors to be determined (raw materials, use of resources, energy, etc.) and output (energy consumption, waste generation, emissions) from the lifecycle of each product, evaluating the subsequent environmental impacts.

Through a study of LCA the stages and the moments when more environmental problems are concentrated can be identified and at the same time, those who will have to take responsibility (producer, user and so on.). By using this type of analysis, the information necessary to achieve the improvement is obtained. Moreover, the attention of companies to environmental issues is greatly appreciated, both by institutional lenders, who reward these efforts by granting favourable conditions and rates for eco-efficient businesses; by commercial partners, who prefer to have relationships with companies that implement 'responsible' management systems.

Finally, it should be emphasized that a voluntary adaptation of all regulations related to the control of pollution, allows companies to avoid administrative penalties and fines envisaged in the case of non-compliance (Dai et al., 2015). One of the limitations of LCA lies, however, in the difficulty of comparing the results from different studies. This is due to the use of different approaches and methodologies, depending on the products or processes being studied, and the difficulty of finding the data, since there are no real data banks (Bonanno et al., 2018). To overcome the shortcomings mentioned above in 1997 ISO 14040 was published. It describes the general criteria and methodology to carry out a LCA analysis with. It is an essential cornerstone for the dissemination of such studies because it is developed and internationally recognized. It should also be noted that this standard is the progenitor of a whole series of documents dedicated to these studies.

Table 1. Description of environmental impacts

Input	***Units***	***Quantities***
Number of sows	No.	500
Water (beverage)	m^3/year	21 300
Electricity consumption (total)	kW/year	650 000
Feed	tons	458 (Sows) +1739 (Others)
Establishment	Mq	20 000
Electricity consumption (purification plants + processes	kW	196200
Water consumption (purification plants + processes)	m^3	1 065

3. Results and discussion

The livestock company *Mulinello ltd* 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 (Basile et al., 2020). It is an aerobic fermentation plant, controlled by an Internet system, for the autonomous production of electricity, heat and digestate effluents. The potential is identified in a range of 25-30 cubic meters of biogas per ton of sewage. *Mulinello ltd* 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 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 (Di Leo et al., 2020).

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.

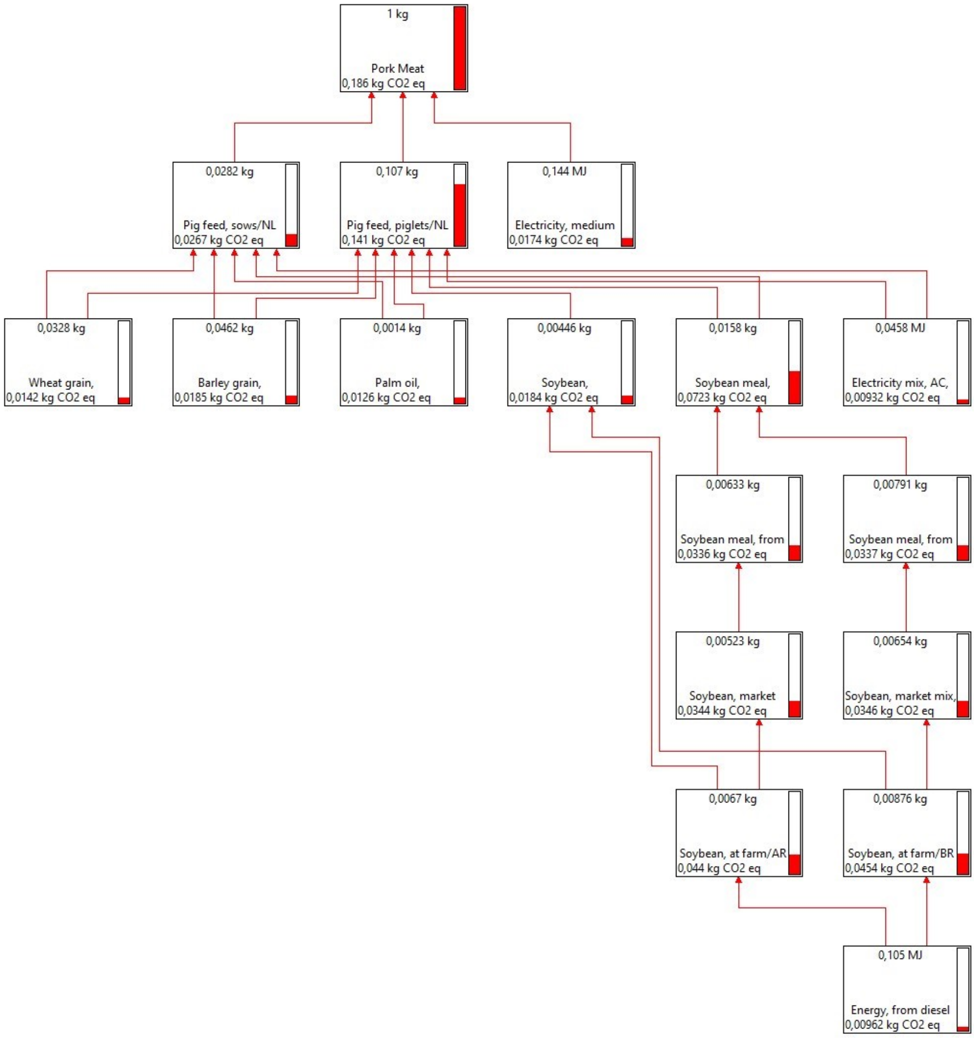

Fig. 1. Network of the production of 1kg of pork meat. The impact category is global warming potential (GWP) measured in CO_2 eq.

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.

4. Concluding remarks

In this research there is an analysis about 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 to produce 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.

Acknowledgements
This paper is research done by an International Internship agreement between the University of Catania, and NTNU: NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 613-621

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

PROSPECTS FOR REDUCTION ATMOSPHERIC EMISSIONS FROM IRON AND STEEL PLANTS*

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Abstract

Global climate change and air pollution represent one of the greatest challenges of the 21st century. The main source of greenhouse gas emissions (GHG) is represented by the steel industry. In addition, from an integrated cycle steel plant, such as the one in Taranto, other compounds, harmful to human health and the ecosystem, are released into the atmosphere in relation to polluting plants, such as those of the coke oven and sintering. Polychlorinated dioxins and furans are formed in the sintering plant while polycyclic aromatic hydrocarbons in coke oven processes. Although various technologies have been adopted in recent years to reduce the emissions of these compounds, the current challenges concern the modification of the steel production process. The green transition to clean energy production and decarbonisation to reduce greenhouse gas emissions is one of the hottest topics in heavy industry. In this direction, various technologies have been developed to reduce the environmental impact such as the recovery of gas (CO_2 and CO), the elimination of the coking plant and the direct use of coal for the reduction of iron ores (Corex and Finex technologies). The use of natural gas (methane) to produce reducing gas (Midrex process) was found to be effective to reduce CO_2, benzopyrene and dioxins emissions. But it is the "green steel", produced with the use of hydrogen from renewable sources, which could be the future also for the historic steel mill in Taranto. Among the different ways in which hydrogen can be produced, the use of renewable energy combined with electrolysis processes could be the priority way to drastically reduce emissions into the atmosphere. In this paper, all the strategies described above are discussed.

Keywords: air pollution, greenhouse gas, steel industry, hydrogen production

*Selection and peer-review under responsibility of the ECOMONDO

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1. Introduction

The 2018 report from the IPCC (The Intergovernmental Panel on Climate Change) set goals to limit global warming to 1.5 °C by 2050 (Chen et al, 2018). To achieve this goal it is required "rapid transitions" in both power generation and the steelmaking industry, which is projected to grow by 25-30% in 2050. Today the production through blast furnaces is an energy-intensive process based on the consumption of fossil fuels. The steel sector is responsible for about 7% of all CO_2 emissions of anthropogenic origin: the specific emissions of “world steel” are currently 1.8 t CO_2 / t of steel produced. To reach the targets set for 2050, emissions would have to decrease significantly. In this regard, several research and development programs have been launched in recent years in steel producing countries and in the EU. These projects involve improving energy efficiency, modernizing plants and adopting the best available technologies at all stages of production to reduce emissions by 15-20% (Holappa, 2020).

Replacing carbon (natural gas or coke) with hydrogen as a reducing agent of iron could significantly reduce both CO_2 emissions and of other pollutants. Direct iron reduction (DIR) processes and the possibility of CO_2 capture or storage (CCS) have recently become popular for reduce emissions. By modifying production plants and energy systems and adopting new pioneering methods, the "world steel" could reach the level of 0.4-0.5 t CO_2 / t of produced steel: this could reduce current annual emissions by two thirds.

The annual production of steel reached 850 Mt in 2000 due to the production "boom" especially in China. Since then, world production has doubled, reaching 1,869 Mt of steel in 2019, with China's share exceeding 50%. At the same time India has strongly increased production, becoming the second largest producer in the world with 111 Mt in 2019. It is plausible that in the near future the consumption of steel in developing countries can increase, with an estimated 2500 Mt of steel for 2050. In this scenario, the adoption of "green technologies" is absolutely necessary.

The main objective of this study is to analyze the environmental sustainability of the current steel production system and evaluate the different alternatives to steel production by means of integral cycle systems based on blast furnaces with a view to reducing atmospheric emissions, especially greenhouse gases. In this context, different alternative technologies are illustrated, which offer guarantees not only for the reduction of the environmental impact but also for the production of high quality steels.

2. Methodology

For the assessment of the environmental impact of atmospheric emissions, different technologies for the reduction of iron in steel production were compared. In particular, starting from the analysis of the emissions of an integral cycle steel plant such as the one in Taranto (Apulia Region, Southern Italy) (Galise et al., 2019), the most polluting production processes have been identified with particular reference to formation of chlorinated dioxins in the sintering plants and of polycyclic aromatic hydrocarbons in the coking plants.

The analysis of alternative iron reduction processes conducted by analyzing various industrial projects allowed to identify the possibility of reducing emissions using hydrogen as a reducing reagent of iron, in the perspective that the production of "green hydrogen" becomes economically advantageous.

3. Results and discussion

3.1. Integral cycle steel plants

In an integrated industrial plant, like that of Taranto (Italy), the production of steel involves a series of processes whereby iron is extracted from ores and converted to steel (ILVA, 2008). Steel production from iron ore, based on indirect reduction, essentially consists of the following plants: mineral parks (coal and additives), coking plant, sintering plant, blast furnace, steel mill, rolling mill. The iron ore from the parks is sent to the sintering plant. Similarly, coal feeds the coking plant for its transformation into coke. The sintering plant is necessary because the iron ore, coming from the mines, consists largely of very fine parts, incompatible with the feeding in the blast furnace. In the same way it is necessary to feed the blast furnace with coke and not with coal, which at the temperatures involved, would tend to soften and not have the necessary mechanical characteristics, as well as contain pollutants that are harmful to the quality of the cast iron, such as sulfur. The sintering plant and the coking plant are therefore the two most polluting plants present in an integral cycle steel plant. The sintering plant is responsible for the emissions of dioxins and chlorinated furans, dust and carbon oxides. The coking plant emits PAHs (Polycyclic Aromatic Hydrocarbons), in particular benzo(a)pyrene. In the iron sintering, the processes by which dioxins/furans are formed are not completely understood yet. Most information about formation during combustion processes has been obtained from laboratory experiments, pilot-scale systems, and municipal waste incinerators.

However, any thermal process that proceeds in the presence of carbon, chlorine, oxygen and metal catalyst has the potential to generate dioxins. The mechanism of formation may be due to condensation reactions, substitution reactions, radical reactions, “de novo” synthesis. The condensation reaction is one of the best known formation mechanisms. The process derives from the thermal breakdown and molecular rearrangement of precursor compounds, such as chlorinated benzenes, chlorinated phenols (eg pentachlorophenol). Dioxins appear to form after the precursor has been adsorbed to the surface of particles, such as fly ash. These reactions are catalyzed by inorganic compounds (e.g. copper chloride). Copper chloride promotes the condensation reactions on fly ash through the Ullman reaction (Addink and Olie, 1995; Born et al., 1993). In the past years, the addition of urea in the sintering plant has been used to reduce the formation of chlorinated dioxins and furans.

The emission reduction effect with the use of urea (or other amines) is explained by the reducing power of urea and its ability to form stable complexes with metals thus reducing the catalytic, oxygenating and chlorinating power (Xhrouet et al., 2002; Lechtańska. and Wielgosiński, 2014). Furthermore, the alkaline nature of urea tends to neutralize the acidity of Cl_2 and HCl which are responsible for the chlorination reactions of dioxins and furans. In summary, the use of urea allowed an average reduction of emissions from the Taranto sintering plant, of approximately 52%, with a variation in the average concentration of PCDDs/Fs from 6.91 ng I-TE / Nm^3 (without urea) at 3.32 ng I-TE / Nm^3 (with urea) (Arpa Puglia, 2008).

Starting from January 2011, the urea technique was replaced with the injection of activated carbon powder upstream of the electro filters for an adsorbing action of dioxins and furans (Ooi et al., 2011). The coal dust, together with the dust from the fumes from the agglomeration process, were then removed in the electro filter, bringing PCDDs/Fs emissions into the atmosphere in 2012 to an average value of 0.35 ng I-TE / Nm^3 (Esposito et al., 2014).

3.2. Decarbonization strategies of the steel industry

In the steel industry, carbon compounds are the raw material used both as a reducing agent and for generating energy. To reduce atmospheric emissions of CO_2 and other pollutants, decarbonization strategies should be adopted following the directives of the Paris Climate Change Conference of December 2015 (Bataille et al., 2018; Kinley, 2017). For this purpose, it is often necessary to completely or partially modify the steel production process. Second, production can be decarbonized by increasing iron scrap usage and carbon-free production electricity.

A blast furnace uses coal to chemically reduce iron ore, which is then further processed into steel. This process releases a large amounts of greenhouse gases (CO and CO_2) in the atmosphere. In Europe, some steelmakers capture these by-product gases, transforming them into electricity and useful heat. That makes integrated steel plants a key area for decarbonization. Different projects being tested involve the capture of CO and CO_2 emitted from the blast furnaces and their transformation into ethanol, through a gas fermentation process that uses microorganisms (Carbalyst® project, 2015). This technology was developed by the US firm LanzaTech in collaboration whit ArcelorMittal. With the post-combustion capture of greenhouse gases it is possible to reduce both combustion and process emissions without modifying existing industrial plants. Decarbonization in integral cycle steel production can take place also by drastically modifying the production process. Today, iron ores are smelted and converted into iron in the blast furnace (which uses coke as a fuel and reducing agent). The iron is then converted to steel in the oxygen converter (a furnace that uses coke oven gas as a fuel). The blast furnace could be eliminated by a direct reduction of iron (DRI) process where methane (DRI-CH_4) or hydrogen (DRI-H_2) can be used as reducing agents. In this case, the subsequent transformation of iron into steel can take place in electric arc furnaces. The DRI-H_2 process with subsequent electric furnace is now an option for the complete decarbonization of steel production. In recent years, various technologies have been adopted to eliminate polluting plants such as the coking plant and the sintering plant. Particularly:

- Direct reduction processes (Midrex®, HYL® or Finmet® processes that use methane or hydrogen as a reducing agent of iron minerals (Babich et al., 2008);
- Corex® and Finex® technologies (Hasanbeigi et al., 2014) in which coal is still used as a reducing agent, but the agglomeration plant and coking plant are eliminated and therefore most of the polluting emissions;
- Electric ovens, eliminating the whole hot area; however, this solution requires to be competitive large quantities of iron scrap as raw material and low-cost electricity.

3.3. Direct reduction processes

Direct reduction processes are those processes that lead directly from the mineral to the non-carburized or low-carbide ferrous product, without passing the metal into a liquid state. Direct reduced iron (DRI), also called sponge iron is produced from the direct reduction of iron ore (in the form of lumps, pellets, or fines) into iron by a reducing gas or elemental carbon produced from natural gas or coal. Many ores are suitable for direct reduction. Direct gas reduction technology is a production alternative characterized by CO_2 emissions that are 50% lower than those typical of the blast furnace (Bhaskar et al., 2020).

The reducing gas consists of a mixture of CO and H_2, obtained from methane reforming and injected hot into the reactor. The product consists of Pre-Reduced Iron (DRI), with an iron content of 90-94% which can directly feed an electric furnace for the production of steel. The chemical characteristics make DRI suitable for the production of quality steels at the typical levels of full cycle plants. The pre-reduced can also be used in blast furnaces to use less coke, or it can be fed into converters, without using scrap or it can be introduced into electric furnaces instead of scrap to obtain cleaner steel. Using the pre-reduced not only eliminates the coking plant, but also the coal deposits in the mineral parks. The direct reduction technology is therefore of particular strategic interest as it is potentially predisposed to an evolution towards an entirely reduction process with hydrogen, and therefore "Carbon-free", at least to the extent that hydrogen will be entirely “green” if its production will be obtained by through electrolysis powered by electricity from renewable sources.

The development of the latter technology will obviously require time, planning and economic commitment for the construction of infrastructures and new "green" power plants. However, this can be considered a path for achieves the set environmental protection objectives. Currently, there are two technologies for the production of the pre-reduced iron: 1) the American Midrex technology, which uses natural gas to produce reducing gas and 2) the Italian-Mexican Hyl technology, in which CO is produced by gasification of coal. The Midrex process (Fig. 1) uses as a reducing gas a mixture of CO and H_2 which are produced by reacting natural gas (methane) with carbon dioxide from recovery gas:

$$CH_4 + CO_2 \rightarrow 2\ CO + 2\ H_2$$

Today there are more than 60 plants that use the Midrex process which, with a total production of 500 million tons (approximately 76% of the world production of pre-reduced obtained from natural gas). Countries with large natural gas reserves such as Saudi Arabia, Qatar, USA and Iran have implemented this technology for steel production (MIDREX, 2013; Sarkar et al. 2018). In the HyL process (Hojalata y Lamina, Monterrey, Mexico), the reduction of iron is achieved by gas resulting from the steam reforming of methane with nickel catalyzed water:

$$CH_4 + H_2O = CO + 3\ H_2$$

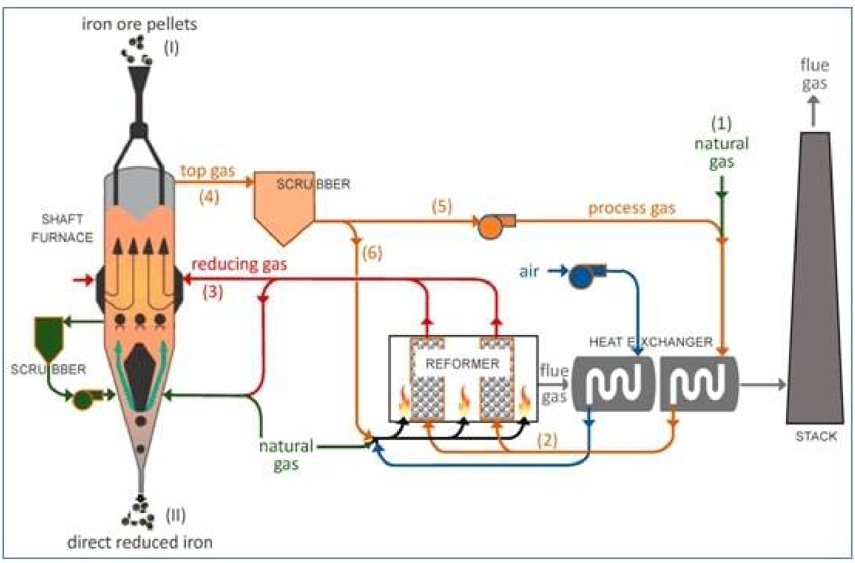

Fig. 1. The MIDREX-type direct reduction process (Béchara et al., 2020)

Energiron is the innovative HYL Direct Reduction Technology jointly developed by Tenova S.p.A and Danieli S.p.A. Under the alliance, the two companies have combined their know-how and technology for the design and construction of gas-based DRI plants, offered worldwide under the Energiron trademark. The Energiron direct reduction process (HYL process) uses a reduction furnace designed to convert iron or iron ore pellets into metallic iron by the use of reducing gases (Duarte et al., 2010). The reduction circuit easily accepts any source of reducing gas (H_2 and CO) to produce a highly metallized, high carbon DRI products. A removal system captures CO_2 from the recycle gas, restoring its full reduction potential. Sulfur is removed together with the CO_2 to prevent any sulfur buildup in the circuit, and any remaining tail gas goes to the process gas heater as fuel. The process is easily the most energy– efficient and versatile DR technology on the market.

3.4. Corex® and Finex® technologies

Corex® and Finex® technologies (Fig. 2 a, b) do not use the coking plant and the iron ore agglomeration plant. The difference between the two Corex and Finex technologies is that the first uses iron oxide pellets, the second fine powder (Ziebik et al., 2008; Yi et al., 2019). The Corex process is based on the use of hard coal (instead of coke) and iron ore. This technology no longer requires the passage of coal in the coking plant and iron ore in the sintering plant. The cost reduction is 20% and the environmental advantage with the reduction of CO_2 emissions is significant. Siemens has built the largest Corex plant in the Shanghai steel plant of the Chinese Baosteel. The plant with a production of 1.5 million tons of steel per year has already been in operation since November 2007. Smaller plants had been built in South Korea, South Africa and India.

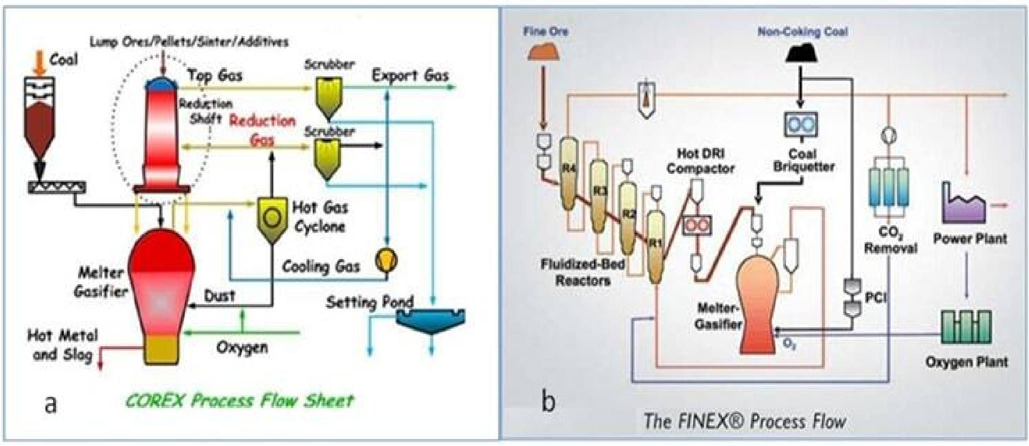

Fig. 2. Corex (a) and Finex (b) process diagrams

Corex technology for the production of cast iron uses two reactors: a melter / gasifier and a reducer (Fig. 2a). Coal and oxygen enter the melter / gasifier to reach a temperature of 1,000 ° C and produce a reducing gas (CO and H_2) which enters the second reactor, where iron ore also enters, which is reduced by more than 80%. The reduced iron enters the regasification plant where it melts and exits as molten iron from below. The co-produced fuel gas can be reused to power combined cycle power plants.

The Finex technology (Fig. 2b), on the other hand, uses iron ore in the form of fine powder and coal dust and always uses a gasifier / melter, but, unlike the Corex, it uses four fluid beds in series for the hydrogenation of the iron ore. Thanks to the recovery and reuse of the substances formed during the process, the Finex technology - compared to the traditional blast furnace - reduces pollution (90% less toxic-harmful substances and 98% less water contamination), energy consumption and production costs (minus 15%).

Many of the carcinogenic substances emitted using the conventional cycle are - with the Finex process - eliminated at source. Without sintering and coking plants, emissions into the atmosphere of: dioxins, benzene, toluene, xylene, polycyclic aromatic hydrocarbons, coke dust are eliminated. The emissions of phenols, ammonia and cyanides are eliminated in the water cycle. In addition, other emissions of substances harmful to health and the environment are significantly reduced: CO_2, carbon monoxide, sulfur dioxide, nitrogen oxides, coal dust, heavy metals etc.

3.5. Electric oven technology

Steel production can be achieved with electric furnaces that use electric arc technology (the most widely used) or induction technology (Saboohi et al., 2019). These technologies use iron scrap as raw material with small additions of coal or cast iron to provide the carbon necessary to produce steel, but they could also use pre-reduced iron, coming from other processes. Oxygen also enters the electric oven to oxidize nitrogen and phosphorus and thus facilitate their separation. The electric arc provides the energy to bring the iron to a liquid state at 2000 °C. The possible use of pre-reduced iron instead of scrap, as a raw material, has the advantage of obtaining cleaner steel.

The reasons for the use of electric furnaces for the production of steel as opposed to blast furnaces derive not only from the reduction of polluting emissions, but also from the lower investment costs and flexibility of the plants. It is also possible to use both large and small furnaces and various types of scrap melting materials.

Electric arc technology does not produce polluting emissions and has lower CO_2 emissions, and if electricity were produced from renewable sources it could be considered a technology in complete line with COP21, with a view to decarbonising the planet.

3.6. Options for decarbonization: the use of hydrogen

For the purpose of reducing emissions by 2050, one of the fundamental actions is the switch from fossil fuels to renewable fuels such as hydrogen, bioenergy and synthetic fuels. On the basis of these prospects, the consumption of fossil fuels in the industrial sector could decrease by 50-60%, depending on the technologies adopted in some production sectors, starting with the steel industry. In particular, hydrogen is in perspective the alternative energy vector for the production of steel. In the event that a complete replacement of the integrated cycle steel plants with pre-reduced iron with hydrogen (DRI-H_2) is considered, this would allow the elimination of CO_2 capture and storage plants. Hydrogen is therefore a valid alternative for replacing natural gas. To date, however, replacing coal with hydrogen would raise the price of a ton of steel by about a third. This gap is likely to narrow in the next few years, both because coal prices could rise and because the costs of hydrogen production could become competitive.

Most hydrogen is currently produced by steam reforming, a process that uses natural gas and emits CO_2 as a by-product. Hydrogen can also be produced through water electrolysis: this allows the production of "green" hydrogen not from carbon (Hybrit Project, 2020). It takes 50 to 55 kilowatt hours (kWh) to produce 1 kg of hydrogen. The cost of producing green hydrogen has decreased by 60% over the last decade, and is now typically between 3.6 and 5.3 € / kg. This price could further decrease also due to the reduction in the costs of producing electricity from renewable sources, such as wind and solar power.

4. Concluding remarks

From the analysis of the different technologies it is evident that the reduction of emissions into the atmosphere, especially of greenhouse gases, requires a modification of the current steel production. Much has already been done with the replacement of coke or coal with other carbon sources with a lower environmental impact: however, it seems that in the near future hydrogen will be the reducing reagent in steel plants.

However, this implies an advancement of research to produce green hydrogen at lower costs using alternative energies based on renewable sources. The decrease in the availability of raw materials such as coal and the reduction of hydrogen production costs will make steel processes increasingly ecologically sustainable in the near future.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 623-628

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

THERMAL BOILERS FOR CIVIL USE: STUDY ON ORDINARY MAINTENANCE*

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Abstract

The aim of the present research was to study the role played by the ordinary maintenance of thermal boilers for civil use on the reduction of emissions into the atmosphere. For this purpose, the flues gas emitted by a sample of 20 boilers, different by brand name and by date of installation, were compared before and after ordinary maintenance.
The flues gas of the boilers were measured by the particle analyzer (Seitron). The parameters measured were different such as: flue gas temperature, carbon monoxide (CO), carbon dioxide (CO_2). The set of data obtained shows that an adequate routine maintenance of civil heating systems is of fundamental importance and it can guarantee a reduction in emissions. Boilers with the same year of installation and the same commercial brand showed different emissions, highlighting that a young age, a particular commercial brand of a boiler are not enough to guarantee a lower environmental impact but a regular maintenance checks and an appropriate use are always necessary.

Keywords: air pollution, gas boiler, maintenance

1. Introduction

It is known that the energy used in the civil sector, both residential and tertiary, for space heating and sanitary water represents an important share of the total energy consumption. Most of this consumption is due to buildings poorly insulated and not designed to exploit free heat inputs, but also to obsolete systems and generators with very low efficiency values compared to those obtainable with more modern appliances.

Most of these have been designed without any attention to the containment of energy consumption (Al-Ghandoor et al. 2009; Chwieduk, 2003; Gillingham et al., 2006). Many of

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*Selection and peer-review under responsibility of the ECOMONDO
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the existing houses have not undergone any type of intervention over time and this does not refer exclusively to more recent buildings but to the complex of existing buildings. The extent of the interventions in the field of existing residential construction can therefore achieve important results for a decisive reduction in overall consumption, according to the objectives already set by the Kyoto protocol which provides for a progressive reduction of carbon dioxide emissions into the atmosphere, as an overall action of fight against climate change.

Due to these ambitious objectives, in recent years increasing attention has been paid to the use of new technologies to improve the energy situation of the building park, both in terms of energetic consumption and in terms of production of new materials with low environmental impact (De Luca et al., 2017). Most of the housing park is heated by autonomous systems, equipped with a generator and a distribution system for each housing unit. In particular, in the specific case of methane boilers, the correct management of fuel/comburent ratio can help not only to reduce carbon monoxide emissions, but also to improve efficiency and increase economic savings (Cirillo et al., 1990; Jain, 2012; Lazzarin, 2014). The lack of optimization of energy consumption and control of systems risks making domestic homes significant sources of pollution, which together with other sources such as those of urban traffic (Mazza et al., 2020; Filice et al., 2009) can contribute to making our cities more and more polluted (Borrego et al., 2006; Liang and Gong, 2020). In this reference context, this research aims to show the importance of the periodic maintenance of heating systems on the process of reducing the environmental impact, both in terms of energy consumption reduction and in terms of emissions reduction into the atmosphere.

2. Experimental

A sample of 20 methane gas boilers, different by brand name and by date of installation, was compared before and after ordinary maintenance. The boilers are aged between 1989 and 2008. This choice was dictated by the need to study whether adequate routine maintenance on boilers with more obsolete technologies can guarantee a reduction in both emissions and the gap between new and old technologies. The following Table 1 shows the year of installation and the commercial brand of the twenty boilers.

Table 1. Year of installation and commercial brand of the twenty gas boilers considered

Boiler	*Commercial brand*	*Year of installation*	*Boiler*	*Commercial brand*	*Year of installation*
1)	Chaffotaux-ET-Maury (a)	1989	11)	Hermann (d)	1997
2)	Chaffotaux-ET-Maury (b)	1989	12)	Fer	2001
3)	Chaffotaux-ET-Maury (c)	1989	13)	Hermann (a)	2000
4)	Ankrus (a)	1990	14)	Hermann (b)	2000
5)	Ankrus (b)	1990	15)	Beretta (a)	2005
6)	Lamborghini (a)	1990	16)	Beretta (b)	2005
7)	Lamborghini (b)	1990	17)	Beretta (c)	2005
8)	Hermann (a)	1994	18)	Immergas (a)	2008
9)	Hermann (b)	1994	19)	Immergas (b)	2008
10)	Hermann (c)	1997	20)	Immergas (c)	2008

The flues gas from the boilers were measured before and after routine maintenance operations. The latter were carried out by checking the most used parts of the heating system and most subject to degradation phenomena. A general cleaning of the appliance was then carried out. The flues gas were analyzed by the particle analyzer (Seitron). In this context, for reasons of synthesis, only parameters such as the flue gas temperatures, the quantities of carbon monoxide and carbon dioxide are taken into consideration.

3. Results and discussion

The following Figures 1 (a), (b), (c), respectively report the concentration of CO, CO_2 and the flue gas temperature, before and after ordinary maintenance operations.

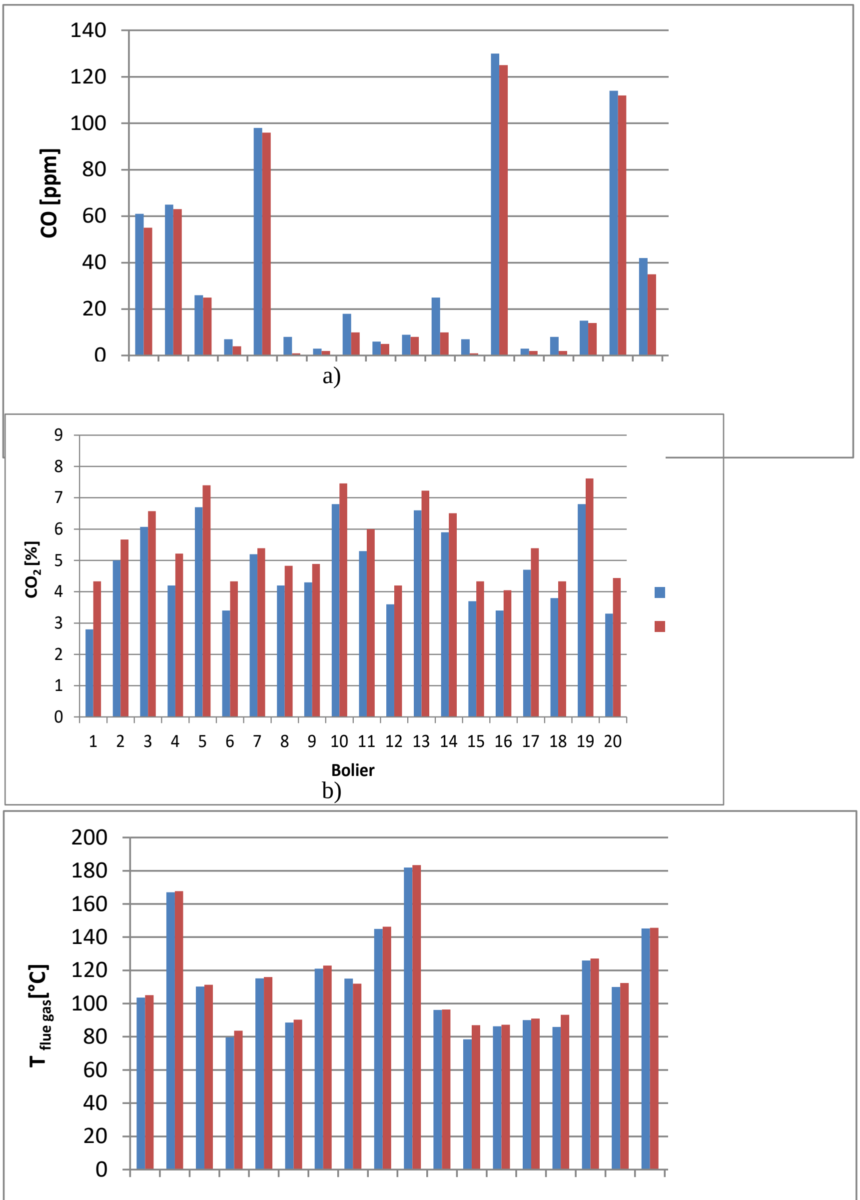
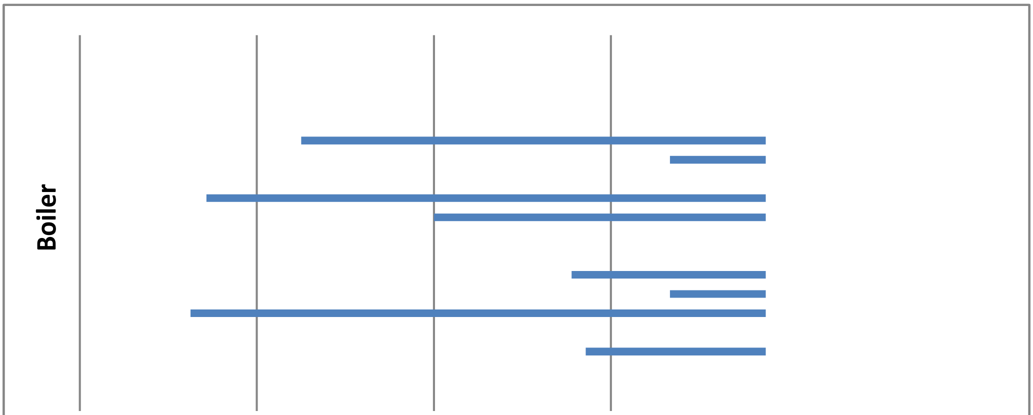


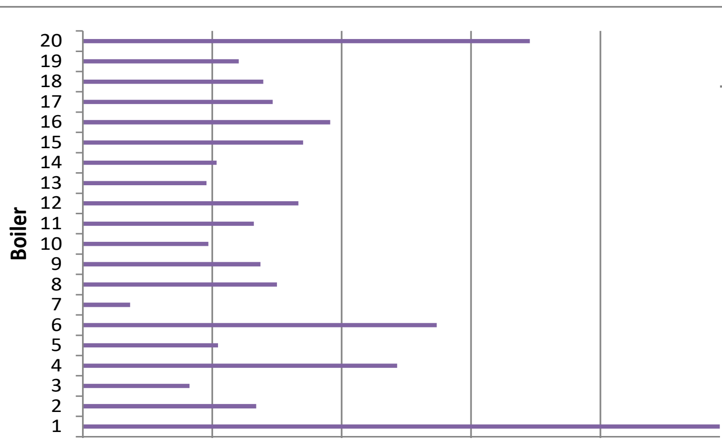
Fig. 1. Concentration of (a) CO, (b) CO_2 and (c) flue gas temperature, before and after routine maintenance operations.

From the data reported it is clear that for all the boilers analyzed, after ordinary maintenance, there is a reduction in the concentration of carbon monoxide, accompanied instead by an increase in the percentage of carbon dioxide and the temperature of the fumes due to greater efficiency and better combustion. All this confirms how maintenance brings a substantial improvement on combustion and therefore on the performance of all the boilers analyzed. The data do not show a linearity between the age of the boiler and the concentration of carbon monoxide. For example the boilers, (13) (17) (19) respectively with installation years of 2000, 2005, 2008 respectively, appear to emit more CO than other older boilers such as (6), (9) respectively of 1990 and 1994. This underlines how a younger boiler does not always guarantee a lower environmental impact. Furthermore, the comparison between boilers with the same commercial brand and with the same year of installation, as in the case of boilers (18), (19) and (20), showed concentrations of carbon monoxide very different in the flues gas.All this emphasizes that the external and operating conditions, a regular and periodic maintenance during life cycle of the boiler, are crucial.

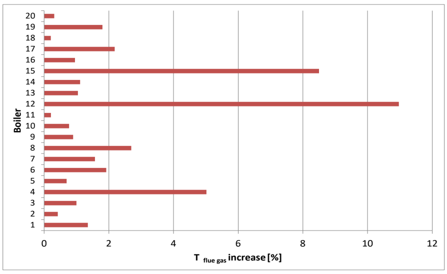
The following Figures 2 (a), (b) and (c) quantize the percentage variation of the three parameters considered before and after maintenance. The data shown that in some cases, as for the boilers (6), (12) and (15), maintenance leads to a reduction of carbon monoxide respectively by 87.5, 85.7 and 75% followed by an increase in the concentration of CO_2 and the flue gas temperatures.



b)



c)



c)

Fig. 2. Percentage variation of parameters: (a) carbon monoxide; (b) carbon dioxide and (c) flue gas temperatures, after maintenance operations

4. Conclusion

The data showed that for all boilers, after maintenance, a substantial decrease in carbon monoxide and an increase in the concentration of CO_2 in the flues gas, accompanied by an increase in the flue gas temperatures, confirming an improvement in combustion and therefore in efficiency.

Comparing boilers with the same commercial brand and with the same year of installation it emerged that, in some cases, they presented very different emissions.

All this leads us to say that although the technology, the age, the commercial brand of the boilers are aspects that are not of second importance, ordinary maintenance and conditions of use are equally important, influencing significantly the quality of flues gas, the energy saving and therefore on the environmental impact.

A young age, a particular commercial brand of a boiler alone are not enough to guarantee a lower environmental impact, but regular maintenance checks and appropriate use are always necessary. The set of results obtained highlights how the efficiency of the boilers are extremely sensitive to the operating conditions of maintenance.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 629-638

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

RECENT DEVELOPMENTS IN SITE SPECIFIC RISK ASSESSMENT FOR POLLUTED SITES*

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Abstract

The present note highlights the role of geotechnical expertise for Risk Assessment of contaminated sites and illustrates specific aspects related to migration modeling. Implications of neglecting the time variable and the advantages of the direct measurements of vapors, performed by application of different techniques, are described and discussed. The comparison between direct measurements of vapor emissions and modeling outcomes show how the use of measured data is able to overcome the limitations deriving by restrictive model assumptions and effectively helps in obtaining more realistic results.

Keywords: polluted site, risk assessment, site conceptual model, migration models

1. Introduction

Among the challenges that the future poses to geotechnical engineers, the safeguard and the preservation of the environment are surely included (Viggiani, 2015). In this perspective, the study of the effects of pollution on soil and groundwater behavior is one of the main topic for geotechnical researchers. Polluted sites represents a topical problem all over the world and risk assessment (RA) for contaminated sites is the tool that allows for verifying that risks associated with contaminated soil or groundwater at a particular site are tolerable.

In Italy, as in other countries, after a triggering initial comparison with screening levels (JRC, 2007), the need of a remediation action and the related remediation goals are

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defined by means of the site-specific RA procedure. The specific procedure for RA, initially developed in the United States, was subsequently adopted in Europe, where about 2.5 millions contaminated sites were estimated in 2011 by the European commission EIONET (Panagos et al., 2013). In Italy, where about 15000 polluted sites were assessed by the National Environmental Protection Agency (ISPRA, 2012), RA was allowed by regulations on contaminated sites since 1999 (Legislative Decree 471) and became mandatory in 2006, after the Legislative Decree 152. The first version of guidelines for RA application was issued in 2005 and the latest update was released in 2014.

The RA procedure starts from the construction of the Site Conceptual Model (SCM), which consist of three components: source of contamination, migration paths and targets (or receptors) and then enables the risk/hazard index calculation. The migration mechanisms of contaminants from the source to the targets represent the core of the procedure and are modeled through analytical models in which site-specific parameters are used (Tier 2 RA) (ASTM E2081-00; APAT, 2008). The selection of appropriate migration models and the use of site-specific measurement of parameters help obtain a more realistic risk estimate.

At present, special efforts are needed from researchers, aiming at both the improvement and the refinement of the migration models, basing on solid scientific fundamentals and validating the proposals with site data. The main objective of this study is to examine the major factors affecting the assessment outcomes, by analyzing some of the existing migration models and proposing alternative models.

To this aim (1) the leaching process was analyzed by comparing stationary and transient models of migration, (2) a case study including the comparison of stationary and transient lateral transport in groundwater and sensitivity analyses is described (3) direct measurements of vapor emissions were discussed and compared with the predictions of an analytical model with reference to a second actual polluted site.

2. Site-specific health and environmental risk assessment

Risk assessment is the estimate of the effect on human health of a potentially harmful event, in terms of probability that the effects themselves occur (APAT, 2008). RA calculations with reference to polluted sites start from the definition of the Conceptual Site Model (CSM) and the description of the three components: source of contamination, migration paths and targets of contamination. Based on the CSM and through the migration models, it is possible to calculate the exposure of the targets to contamination (E). In particular, in addition to the direct exposure of targets (i.e. ingestion of contaminated soil and dermal contact), chemicals could reach the different targets via volatilization (from soil or from groundwater), leaching from soil with lateral transport in groundwater and particulate emission from surface soil. These different types of migration are described by the fate and transport factors (FT) that directly derive from the analytical models of migration and whose formulations include site-specific parameters. Each different FT, multiplied by the representative source concentration (RSC) gives the concentration at the point of exposure (C_{POE}). The product between C_{POE} and the specific exposure, EM (characteristic of each type of target) gives, in turn, the exposure, E.

The definition of "risk" related to contaminated sites is derived from the general formulation of risk as the product of the damage connected with the occurrence of an event, D, and the probability of the event to happen, P, that is equal to 1 (contamination has already happened = certain event). The damage, D, is in turn defined as the product of a factor of danger, FD, represented by the toxicity of the contaminant, T, and a contact factor, FC, represented by the exposure, E, calculated with the CSM, as previously mentioned. The specific expression of risk for contaminated sites is then:

$$R = P \cdot (FD \cdot FC) = T \cdot E \qquad (1)$$

Risk values are differentiated between risk, R (for carcinogenic effects), and hazard index, HI (for toxic not carcinogenic effects). Backward application of the RA procedure allows calculating the Clean Up Levels (CLs) by fixing maximum tolerable risk values (target values for backward application) suggested by regulations (Italian values: R=1·10-6; HI=1). Beside the risk assessment for human targets (i.e. Health RA), Italian regulations require to consider also the groundwater as a receptor, calculating the related risk as the ratio of the concentration at the site boundary to the regulatory screening level (CTC). The risk is tolerable if the ratio is lower than 1: this last calculation type is named “Environmental RA”. The backward application can be also performed, calculating the CLs in soil for groundwater protection.

In other jurisdictions (e.g. USA), contaminated groundwater can reach human targets and the related risks (e.g., through ingestion of contaminated water or showering) must be taken into account, in some countries concentration limits in groundwater are prescribed to protect the ecosystem (JRC, 2007). For both the forward and the backward applications, additional criteria are defined in the guidelines to consider more than one exposure type at a time and the presence of more than one contaminant in the same site (APAT, 2008; ASTM, 2010).

3. Geotechnical aspects of the risk assessment application

The geotechnical expertise, as well as the geological and the eco-toxicological ones, is essential to build up a CSM that suits well with the framework of the Reasonable Maximum Exposure philosophy suggested by the RA main guidelines. In particular, the CSM should be set up on the basis of a site characterization that includes:

- topographic survey;
- boreholes and soil sampling following the environmental sampling procedure, to define the geotechnical model, the contaminant distribution in soil and soil chemical characteristics (e.g. fraction of organic carbon);
- in-situ tests to outline the geotechnical model such as Lefranc or Lugeon tests to assess the different type and permeability levels of an aquifer (Di Sante et al., 2012) or CPT equipped with special sensors to rapidly detect the presence of pollutant (Fratalocchi and Pasqualini, 2007);
- piezometers for groundwater sampling and hydrological measurements to know the aquifer type, groundwater flow, hydraulic gradient;
- geophysical surveys if the presence of buried waste or tanks as primary sources of contamination is suspected.

The site model for risk assessment is based on classical geotechnical investigation techniques coupled with environmental investigation and analysis methods as it also aims at quantifying the contamination and its spatial distribution both in the unsaturated zone and in groundwater. In fact, sampling procedures are different from that of typical geotechnical investigation: undisturbed sample are usually not required but the sampling must comply with protocols for contaminant substances (APAT, 2008) and each borehole represents an area defined by means of Thiessen polygons. The risk of contaminant diffusion due to investigation activities is possible (e.g. cross-contamination between two aquifers during piezometers installation), therefore, particular precautions should be taken during installation of the investigation points. In addition, if volatile compounds are present, the installation of investigation points that allow the sampling of vapors is considered worthwhile and the screening of the piezometers should be extended to the unsaturated level.

Subsoil conditions can often significantly differ from the ideal ones considered in the RA applications (Figure 1) and in these cases, the definition of the geotechnical model has a key role in the procedure.

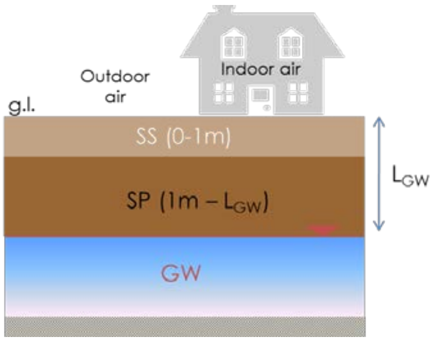


Fig. 1. Standard subsoil model for RA and related environmental media (i.e. surface soil, SS, and deep soil, SP, groundwater, GW, outdoor and indoor air); L_{GW}= depth of groundwater table from g.l.

The number of investigation points is usually much higher than that of typical geotechnical studies because they are essential to describe the contaminants distribution and to draw detailed geological sections. These sections are especially useful to (Di Sante et al., 2019):

- verify the spatial continuity of low permeability deposits affecting migration of contaminants;
- detect a non-horizontal ground surface and multi-layered aquifers, with the possible presence of lenses, that sometimes prevents adopting the simplified subsoil configuration;
- identify the possible presence of a fractured aquifer (e.g. calcareous rocks) needing the use of numerical modeling in place of the analytical ones.

In all these cases, the assessor should be aware of all the modeling possibilities offered by different computer codes to select the most suitable model to represent the actual site conditions and the possible migration modes.

In defining the representative depth of the phreatic level, L_{GW}, it is important to consider its seasonal variability. Therefore, multiple surveys are recommended, at least over a year, so that a cautionary value can be selected by the assessor for each migration model (e.g., volatilization from groundwater requires to consider the minimum L_{GW}, while lateral transport in groundwater requires to minimize the thickness of the groundwater body, thus to consider the maximum L_{GW}).

4. Fate and transport models

Analytical migration models of contaminants have the great advantage to be simple, thus easy to use. This latter feature is ensured by the simplifying assumptions on which the models are based (such as homogeneous physical, mechanical and hydraulic characteristics of the media involved, no source depletion and no biodegradation), but due to these hypothesis, analytical models may sometimes provide unrealistic or too conservative predictions (Bretti and Zanetti, 2014; Verginelli and Baciocchi, 2014). The use of site-specific parameters (i.e. measured on soil samples or derived from in-situ investigations) surely helps in making model results closer to reality.

Environmental Protection Agencies are also aware of this occurrence; in fact, the latest update (2014) of instructions for RA application allows the use of measured in situ volatilization data (with multiple lines of evidence) to verify the results of the analytical models. Moreover, the possibility to exclude the leaching path in particular conditions (i.e., geological and hydrogeological characteristics of the subsoil that prevent migration, absence of correlation between contamination in unsaturated soil and in groundwater, execution of standardized and validated leaching tests) is introduced.

5. Steady-state and transient leaching and lateral transport models

In Italy, groundwater bodies are considered of intrinsic environmental value regardless of their use and therefore, according to Italian regulations, have to be protected. If the contaminant source is located in the vadose zone, the risk assessment requires analytical modelling of contaminant leaching due to percolating rainwater and subsequent mixing with groundwater and lateral transport to the control point (located at the site boundary in the direction of groundwater flow). If the source is already dissolved in groundwater, only lateral transport considering advection, dispersion, diffusion and adsorption has to be simulated.

The guidelines and the commonly used risk assessment codes (e.g. ASTM E2081-10) adopt a steady-state approach to model transport of contaminants to/in groundwater.

If the source is located in the vadose zone, after linear equilibrium partitioning in the source, generic attenuation of the concentration is assumed along the path towards the groundwater by means of the Soil Attenuation Model coefficient (SAM < 1) which decreases with increasing path length. Dilution of the contaminant in groundwater is accounted for by a Leachate Dilution Factor (LDF > 1) which divides the source concentration and is related to the infiltration rate and to the permeability value of the aquifer.

A transient model developed by the writers and fully described in Mazzieri et al. (2016) takes into account:

- depletion of source concentration with time due to volatilization and leaching losses;
- one dimensional (vertical) advective-dispersive flux of the dissolved contaminant with linear sorption and first order biodegradation along the path;
- transient dilution of the contaminant front in groundwater.

With reference to a hypothetical site configuration, shown together with the graph in Fig. 2, the trend of the results of both the steady-state and the transient model is observable, in case of migration of benzene.

Both models predict that the screening level (CTC) for groundwater prescribed by the Italian regulations (0.001 mg/L for benzene) is exceeded. However, the transient approach (grey lines) predicts that the CTC would be exceeded after 12 years from the end of characterization, and this time interval is sufficient to design and to undertake the site remediation, in addition the peak of concentration (0.33 mg/L) at the POC (Point of Compliance) is reached after 53 years. On the contrary, by adopting the steady-state approach, no information can be obtained on the time at which the threshold concentration is exceeded, the concentration value at the POC is 0.606 mg/L (dotted black line in Figure 2). Moreover, the transient approach predicts a significant reduction in the dissolved source concentration (grey solid line in Fig. 2) whereas in the steady-state approach the source concentration is assumed to remain constant (black solid line).

Although steady-state models are simpler and easier to be applied, taking into account the time variable is essential in order to obtain information about the time span during which soil remediation activities must be concluded. If the source is located in the saturated zone, i.e. the contaminant is already dissolved in the groundwater and its concentration exceeds the CTC within the site boundary, the model suggested by the Italian guidelines to simulate the dispersion in the groundwater is the Domenico equation (Domenico and Shwarz, 1998). It generally derives the concentration distribution in a 3D domain and different solutions of the equation are possible depending on different boundary conditions applied. Beside this stationary model, in the software RISC, the migration through groundwater from an already dissolved source is modeled with a transient analytical model with a mass loading rate from the source zone calculated as a function of hydraulic conductivity (Yeh, 1981).

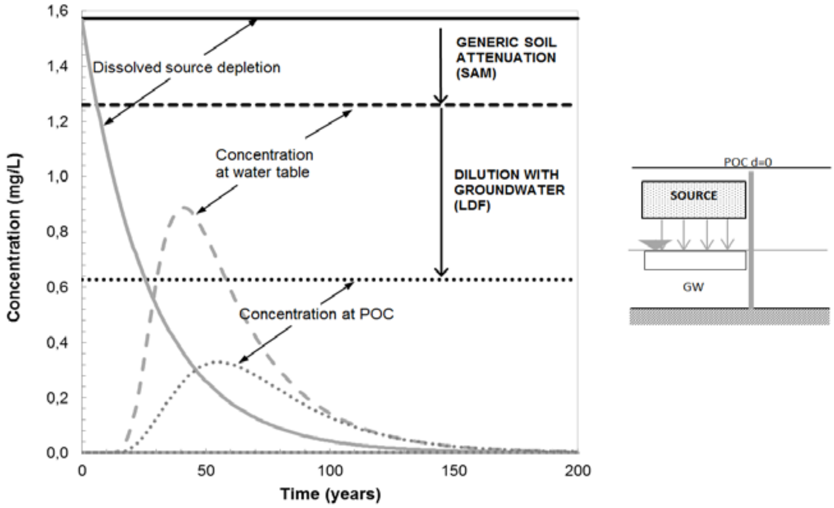
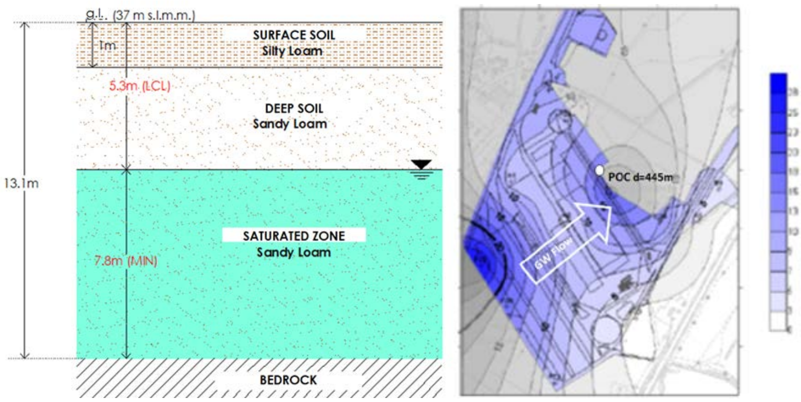


Fig. 2. Comparison between steady state model (black lines) and transient model (grey lines) referred to the shown example site configuration and to leaching of Benzene, starting from a representative soil source concentration of 1 mg/kg.

In order to compare the models' outcomes and to quantify the influence of changes in input parameters on the model results, a peculiar case study with a sensitivity analysis is considered in the following. The site is located on an alluvial deposit (left bank of a river) and the current activity developed on the site is that of an Intermodal Logistics Centre. In the past, agricultural activity was carried out in the site. During monitoring controls required by legislation to evaluate the environmental impact of new buildings to be constructed within the site boundaries, some pollutants whose concentrations exceed the screening levels (SLs) were detected in groundwater. Among them, Nickel was found to exceed the CTC of 20μg/L in 1 out of 14 available monitoring wells (6 already present in the site plus 8 boreholes equipped as wells during the characterization activities).

The subsoil conditions are schematically depicted in Fig. 3a. The permeability of the alluvial layer was characterized by means of 3 Lefranc tests. Only one test gave results for *k*, that was equal to $1.5 \cdot 10^{-5}$ m/s. During the other two tests it was not possible to measure hydraulic levels due to the high permeability of the aquifer, therefore the measured value was assumed to represent the lower boundary of permeability, not ensuring cautionary results if used in the simulation. This represent one of the major uncertainties in predicting contaminants concentration at POC, as required by the RA procedure in this case.

L_{GW} ranged from 5 to 7m and the isophreatic contours suggested that the main drainage axis direction is SW-NE (Fig. 3b). Another peculiar aspect of the site was that soil concentrations (including Nickel) were found to be lower than the threshold concentrations (CTCs) in all the taken samples. In 2011-2012 local Environmental Agencies found the same contaminant exceeding CTCs in the upstream groundwater flow during periodic monitoring, as demonstrated by publicly available records. This evidence together with the complete absence of contamination in the unsaturated soil led to the hypothesis that the contamination was entering the site with the groundwater flow.



a) b)

Fig. 3. a) Schematics of the subsoil stratigraphy adopted for the site conceptual model and b) plan view with concentration contour curves

The conceptual model for the site of concern starts form a source, represented by the polluted groundwater plume, which was geometrically defined as the most external CTC contour (drawn by means of surface modeling software Surfer ver.8.0 – Figure 3b). The representative source concentration was 28 μg/L and the physico-chemical and toxicological properties of Nickel were assumed from ISS and INAIL (Italian National Institute for Health protection of citizens and workers) (database ISS, 2013). The lateral transport in groundwater was simulated as possible migration path using both the stationary and the transient model previously described. Site-specific parameters used in the simulation are listed in Fig. 4. The only receptor considered for Nickel contamination was the groundwater at the POC (Nickel is not volatile, therefore human receptors cannot be reached through the "volatilization from groundwater" path).

The results of both the transient model of migration of Nickel implemented by RISC and of the stationary model suggested by Italian guidelines were obtained by varying the value of saturated hydraulic conductivity, *k*, from the measured value to higher ones (maximum k value= $2.3 \cdot 10^{-4}$ m/s, suggested by RISC manual for Gravel deposits). The distance, d, of the source to the control point is depicted in Fig. 3b. At this point, according to RISC results, using the *k* value from Lefranc test the contaminant will not be detected before 10000 years, while considering the maximum value of *k*, no Nickel will be detected until 3700 years. A concentration value of $2.4 \cdot 10^{-7}$ mg/L will be reached at the end of the simulation; this maximum value is far lower than the threshold limit for groundwater for Nickel, highlighting a tolerable value of risk.

Comparing the results from the two types of model (Figure 4) for the control point, the stationary model predicts a concentration of $1.58 \cdot 10^{-2}$ mg/L, 5 orders of magnitude higher than the maximum concentration value given by the transient model, but still lower than the CTC for groundwater too. This extremely slow migration is probably due to the high value of Nickel soil-water partition coefficient, k_d, that was estimated with the correlations suggested in the database ISS-INAIL (2018) as a function of pH (pH measured during characterization = 7.9 – estimated as LCL 95% of the Mean). The employed k_d is equal to 1400 ml/g, thus substantial adsorption on soil particles occurs along the migration pathway.

It is important to point out that monitoring of concentration at control point (an additional well was installed, as requested by the local Environmental Protection Agency) was scheduled and, during the subsequent 2 years, values always lower than the CTC were detected.

Parameter	units	value
Height of capillary fringe	m	0.25
Soil bulk density [a]	g/cm^3	1.7
Total porosity [a]	-	0.45
Vol water content [a]	-	0.255
Vol air content [a]	-	0.195
Soil bulk density [b]	g/cm^3	1.7
Total porosity [b]	-	0.41
Vol water content [b]	-	0.194
Vol air content [b]	-	0.216
Vol water content cap fringe[b]	-	0.288
Vol air content cap fringe[b]	-	0.057
Soil bulk density [c]	g/cm^3	1.7
Effective porosity [c]	-	0.41
Fraction of organic carbon [c]	-	0.0004
Hydraulic conductivity (x 10^{-5})	m/s	5
Hydraulic gradient	%	0.37
Dominant wind speed	m/s	0.81

[a] values for SS; [b] values for SP; [a] values for GW

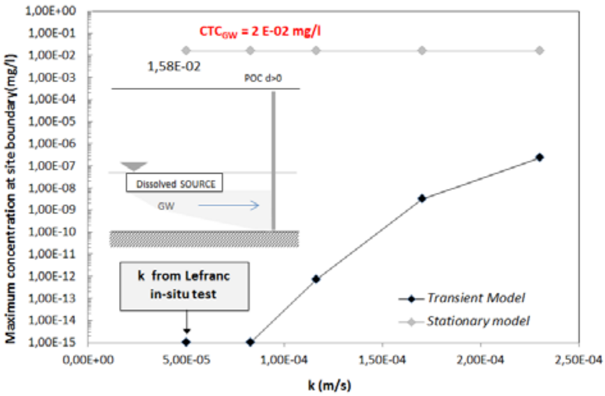


Fig. 4. Site specific parameters and comparison between maximum values of Nickel concentration predicted by the transient model and the results of stationary model at control point, referred to the depicted site configuration

6. Direct measurements and theoretical models of contaminant volatilization

Analytical models typically used to simulate the volatilization of contaminant from soil may significantly overestimate the emissions and thus the exposure of human targets (Bretti and Zanetti, 2014; MATTM, 2014; Verginelli et al., 2014). They consist in a partition of the contaminant in the source zone, a diffusion mechanism based on the Fick's law to reach the ground level and a subsequent box model to simulate the mixing of the vapors with the outdoor air. Verginelli et al. (2017) demonstrated that the assumption of considering a mixing height of 2m in the box model leads (especially in the case of large sources) to an overestimation of the risk of outdoor volatilization and developed a model able to calculate (using an "equivalent height of the mixing zone") the dispersion in the atmosphere as a function of the dimension of the source and of the atmospheric stability class.

As reported in section 5, the possibility to measure the actual vapor emissions is now permitted and standardized by Italian regulatory Agencies (SNPA, 2018). Direct measurements of vapor flux by dynamic open flux chambers allow quantifying the vapor emissions and to compare them to modelling results. Flux values up to 4 orders of magnitude lower than those predicted by volatilization models have been observed (Verginelli et al., 2018).

The assessment of volatile emissions can be carried out by measuring their concentration in the pore air (by Soil Gas Survey, SGS) or their flux from the ground surface (by open dynamic flux chambers). Finally, migration modelling can be entirely avoided by measuring the concentration of volatile compounds in outdoor air. As an alternative, the site-specific measurement of additional parameters that affect volatilization mechanism, such as the soil- water partition coefficient, k_d, can be of help to obtain a more realistic risk estimate.

Figure 5 shows a comparison between the results of direct measurements of mercury emissions and those predicted by different models for volatilization from soil medium, with reference to an actual site in Italy (Di Sante et al., 2016). In particular, Fig. 5 compares the values of mercury concentration at the Point Of Exposure (C_{POE}, i.e., in the air inhaled by the target):

- determined by direct measurement of concentration in outdoor air;
- determined by the direct measurement of flux by open dynamic flux chamber (FC),;
- predicted by the Farmer model and Jury model (APAT, 2008);
- predicted by the Farmer model implemented in the software RISC;

- predicted by the models using the measured k_d value (603 l/kg determined by leaching test) instead of the regulatory default value (52 l/kg - ISS-INAIL (2018), Database).

The value of C_{POE} from direct measurements is significantly lower than that estimated by volatilization models, particularly if the default value of k_d is used. It is important to underline that, based on the acceptable value of HI = 1 (according to the Italian legislation), the corresponding risks would result to be acceptable or unacceptable whether direct measurement or theoretical models are applied.

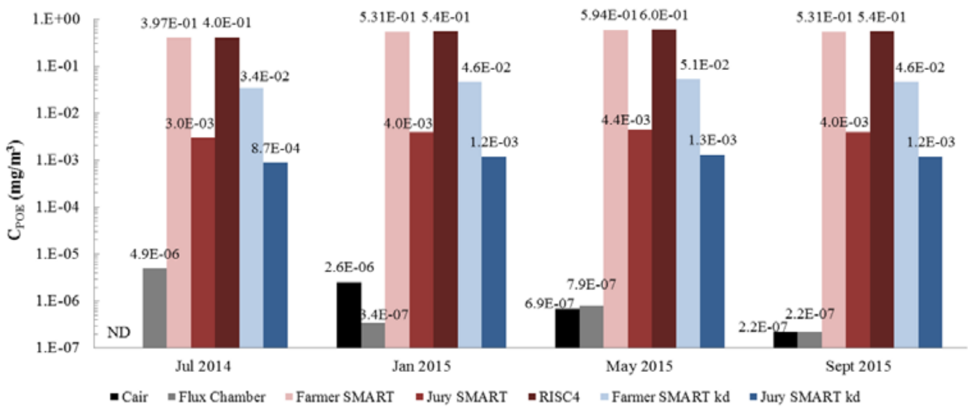


Fig. 5. Concentrations at point of exposure, CPOE

The great differences among the results of the histogram in Fig. 5 can be due to:

- the overly conservative assumptions adopted in the theoretical models
- the properties of the considered contaminant. The most volatile form of mercury is the elemental form (zero-valent). If analytical models of volatilization are applied to the total concentration (i.e. the one determined by standard chemical methods for mercury analysis in soil) all the mercury in the soil is considered to be volatile. Direct measurements of emissions offer the advantage to consider the fraction of mercury that is actually volatile, able to effectively reach the outdoor air and to pose a real hazard to human beings.

6. Concluding remarks

Geotechnical skills are essential for the application of the RA procedure because they are involved in the entire process from site characterization to migration modeling. The modeling of the migration pathways represents the core of the site conceptual modeling thus strongly affecting the RA outcomes. The environmental geotechnics expertise allows a critical view on the contaminant migration phenomena.

Although steady-state migration models are easier to apply, the presented results show that taking into account the time variable offers the advantage to know the time span during which soil remediation works must be concluded or protection measures adopted.

In addition, some of the available models to estimate contaminant volatilization may lead to overestimation of the exposure of targets; in these cases, direct measurements of vapor emissions (today admitted and standardized by the Italian Environmental Protection Agencies) can effectively help obtain more realistic results.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 639-649

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

SUSTAINABLE LEATHER FOR SUSTAINABLE FASHION*

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Abstract

Sustainability has today assumed a centrality in the fashion industry. Conceria Nuvolari is an Italian innovative SME founded in 2009 and specialised in the production and sale of animal leathers. Since 2015 Conceria Nuvolari has been in the search for more sustainable materials, to obtain a leather product that could meet the needs of a transforming market. Indeed, today we observe consumer trends, new technologies and innovative business models helping to lead the future of fashion towards a more sustainable runway. In 2017 Conceria Nuvolari has developed an innovative process to obtain a high-quality leather, named Nature-L®, Chromium free, with low use of heavy metals and biodegradable.
A Life Cycle Assessment in compliance with European PEFCR and a Durability Analysis have been carried out, in collaboration with Politecnico di Milano, Innovhub – Stazioni Sperimentali per l'Industria and Larix Italia. Through Life Cycle Assessment the full list of impact categories in the common context of the European Market for Green Products has been evaluated.

Keywords: Environmental impact, Life Cycle Assessment, Product Environmental Footprint, Leather, Tanning Industry

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*Selection and peer-review under responsibility of the ECOMONDO
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1. Introduction

Today, the theme of environmental sustainability in the leather sector is tremendously increased, due to the pressing demand of all operators of the fashion industry for eco-friendly materials, pushed by the environmental regulations and the growing market demand for green products. In particular, in the leather sector the traditional tanning process that converts the protein of the raw hide into a stable material which will not putrefy, has high environmental and human health impacts, due to:

- the heavy use of polluting chemicals and metals: the most commonly used tanning material is hexavalent Chromium. Chemicals are also azo dyes, free formaldehyde, pentachlorophenol, tetra chlorophenols; other metals that are extractable with human sweat are nickel, cadmium, cobalt and lead;
- air pollution due to the transformation process, producing hydrogen sulphide during dehairing and ammonia during deliming, and solvent vapours.

Therefore, the traditional tanning process causes ecological imbalance and the spreading of different kinds of serious and contagious disease among the tannery workers and other individuals involved in the process. When inhaled, Chromium acts as a lung irritant and carcinogen, affecting the upper respiratory tract and obstructing airways. In addition, tanning 1 ton of hide typically results in 20 to 80 cubic meters of waste water with Chromium concentrations around 250 mg/L, and sulphide concentrations at roughly 500 mg/L (Borrely et al., 2018). It is therefore urgent to turn towards leather products and processing methodologies more sustainable and safer for the operators' and people health.

Nature-L® leather is the answer to the compelling needs of the fashion industry for environmental sustainability and is a brand-new alternative business model throughout the leather tanning value chain. Actually, this innovative process is able to obtain a unique certified biodegradable leather according to ISO 14855 (tested by University of Bologna - Dipartimento di Scienze Agrarie in 2018) and to ISO 20136 (tested by Italian Leather Research Institute in 2020), in which high quality hides are tanned using biodegradable, organic elements and without dangerous heavy metals like Chromium. The hides have been tested and passed standard requirements for abrasion resistance, colour fastness, grab strength, and dry and wet crocking for footwear and fashion needs. Indeed, Nature-L® can be used in the fashion industry for footwear and accessories as first market and for clothing as secondary market.

Conceria Nuvolari's business model, based on patent protection and licensing to certified production partners, aims to spread our innovation not only at European level, but also in non-European countries, where damages from environmental pollution can threaten a large number of people. The model Conceria Nuvolari has chosen for their value chain is that of "short-chain", maximising the environmental sustainability of their products.

Naturel-L® responds to the pressing need of greening the leather manufacturing process, coherently with the UN Sustainable Development Goal Number 12 - Ensure sustainable consumption and production patterns, aimed to reduce environmental impact of any human activity. In addition, it responds to the increasing demand of an exigent market, increasingly driven by environment-friendly products while maintaining the highest quality and performance levels.

The main objective of this project has been to fully evaluate all the environmental impacts of metal-free and biodegradable Nature-L® leather (bovine-caprine-ovine), in accordance to the PEFCR – Product Environmental Footprint Category Rules for the production of leather, published in April 2018 on behalf of the European Commission's Joint Research Centre (De Rosa-Giglio et al., 2018).

Another objective has been to carry out the analysis of durability for Nature-L® (Innovhub - Stazioni Sperimentali per l'Industria, 2019), assessing:

- the physical-mechanical characteristics of the leather (maximum strength and stretching with traction according to UNI EN ISO 13934-1:2013, i.e. stress test, colour and temperature resistance test);
- the resistance of the leather to mildew, fungii and bacteria (according to AATCC 30/2013);
- the soil burial test according to AATCC 30;
- aging due to temperature, humidity, light.

This work is divided in two main parts:

- evaluation of all the environmental impacts of metal-free and biodegradable Nature-L® leather (bovine-caprine-ovine), in accordance to the PEFCR. The evaluation has been performed by Prof. Giovanni Dotelli, full Professor of Materials Science and Technology at Politecnico di Milano;
- analysis of durability. The analysis has been performed by Innovhub-Stazioni Sperimentali per l'Industria, Milan.

2. Materials and methods

Every step of the LCA study has been performed as much in accordance to the PEFCR – Product Environmental Footprint Category Rules for the production of leather, published in April 2018 on behalf of the European Commission's Joint Research Centre.

Nature-L® is modelled as bovine or caprine or ovine leather belonging to the Representative Product category RP2 for footwear and leather goods. A cradle-to-gate approach is followed in the study: upstream (farming, slaughtering and preservation) and core (tanning) processes have been identified within the system boundary. The core process has been divided into eight unit processes where the main production phases of Nature-L® are performed.

For every unit process, data about the required material, energetic and logistic input and output flows have been collected and modelled using the PEF-compliant datasets included in the Environmental Footprint EF2.0 database. The obtained information has been processed using the PEF-compliant Environmental Footprint EF2.0 Impact Assessment methods.

The evaluation of the environmental impacts has been mainly based on company-specific data collected from the industrial realities where the leather tanning process for Nature-L® (bovine-caprine-ovine) is performed. Figure 1 illustrates the system boundary for the production of Nature-L® (caprine-ovine) with the main unit processes.

3. Results and discussion

Following the PEF guidelines, the environmental impact of 1 square metre of Nature-L® (bovine-caprine-ovine) is quantified through characterization for every PEF-compliant impact category. However, the PEF Category Rules for leather don't allow the evaluation of the environmental benefit guaranteed by the biodegradability of the product. It is so since leather is an intermediate product and the PEF-compliant cradle-to-gate approach implies a system boundary ending with the production of leather in the industrial facilities, thus not considering downstream processes as B2B distribution, further manufacturing into finished consumer products, distribution to customers, use phase and end-of-life treatment of used products. The results of the PEF-characterization step are illustrated in Tables 1-3.

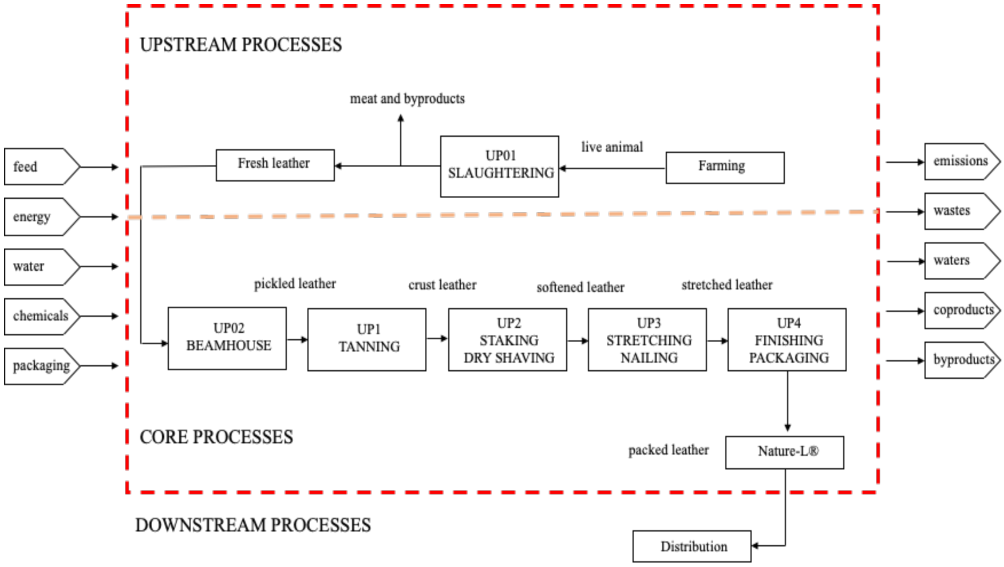

Fig. 1. System boundary for the production of Nature-L® (caprine-ovine) with the main unit processes

The climate change category presented in this study indicates the GWP – Global Warming Potential of the analysed process in terms of fossil, biogenic and land use/transformation contributions. It is expressed in kg CO_2 eq and it's a good measure of the Carbon Footprint of Nature-L® (Bovine-Caprine-Ovine), indicating the quantity of GHG – Green House Gases emitted during the production.

Non-cancer and cancer human health effects belong to toxicity categories, expressed in the study in Comparative Toxic Unit for human (CTUh). This unit indicates the estimated increase in morbidity in the total human population per unit mass of the chemicals emitted. Ecotoxicity freshwater indicates the impact of the studied production process in terms of toxicity in the environmental matrix of freshwaters. It's expressed in Comparative Toxic Unit for human (CTUh). Land use is expressed in dimensionless points. This impact category is related to the soil quality index. Water scarcity is a measure of the user deprivation potential in terms of relative available blue water remaining. It is expressed therefore as cubic meters of water deprived by the studied processes. Fig. 2 compares the climate change impact on wheat bread, beef fillet and Nature-L® leather (bovine, caprine, ovine).

Normalization and weighting are optional Impact Assessment steps; both have been performed using PEF- compliant factors. Normalization is the calculation of the magnitude of each category indicator with respect to the global impact per person considering the world's population. Weighting is used to create a single score value by correlating every impact assessment result with a set of factors that reflect the perceived relative importance of the impact categories. Fig. 3-5 illustrate the results of the PEF-normalization step.

After normalization, the most relevant impact categories are the toxicity ones, represented by "Non-cancer human health effects", "Cancer human health effects", "Eutrophication terrestrial" and "Ecotoxicity freshwater".The most relevant impact categories included in the PEF Category Rules document (as acidification, climate change, terrestrial eutrophication, particulate matter, resource use – fossils and water use) present little normalized contribution for the production of Nature-L® (Bovine-Caprine-Ovine).

Table 1. Results of the PEF- compliant characterization step – Bovine Leather

Impact category	***Unit of measure***	***Total***
Climate change	kg CO2 eq	4.15E+01
fossil		1.72E+01
biogenic		1.56E+01
land use and transformation		8.75E+00
Ozone depletion	kg CFC11 eq	1.86E-07
Ionising radiation, HH	kBq U-235 eq	6.72E-01
Photochemical ozone formation, HH	kg NMVOC eq	6.41E-02
Respiratory inorganics	disease incidence	4.15E-06
Non-cancer human health effects	CTUh	3.11E-05
Cancer human health effects	CTUh	6.48E-07
Acidification terrestrial and freshwater	mol H + eq	5.48E-01
Eutrophication freshwater	kg P eq	4.73E-03
Eutrophication marine	kg N eq	1.54E-01
Eutrophication terrestrial	mol N eq	2.32E+00
Ecotoxicity freshwater	CTUe	1.20E+02
Land use	Pt	3.70E+03
Water scarcity	m3 deprived	2.22E+01
Resource use, energy carriers	MJ	1.73E+02
Resource use, minerals and metals	kg Sb eq	6.33E-05

Table 2. Results of the PEF- compliant characterization step – Caprine Leather

Impact category	***Unit of measure***	***Total***
Climate change	kg CO2 eq	2.02E+01
fossil		9.7E+00
biogenic		9.9E+0
land use and transformation		6E-01
Ozone depletion	kg CFC11 eq	1.69E-07
Ionising radiation, HH	kBq U-235 eq	4.94E-01
Photochemical ozone formation, HH	kg NMVOC eq	2.79E-02
Respiratory inorganics	disease incidence	2.41E-06
Non-cancer human health effects	CTUh	2.21E-05
Cancer human health effects	CTUh	3.68E-07
Acidification terrestrial and freshwater	mol H + eq	3.41E-01
Eutrophication freshwater	kg P eq	9.44E-04
Eutrophication marine	kg N eq	5.89E-02
Eutrophication terrestrial	mol N eq	1.45E+00
Ecotoxicity freshwater	CTUe	3.77E+01
Land use	Pt	2.43E+03
Water scarcity	m3 deprived	5.75E+00
Resource use, energy carriers	MJ	1.01E+02
Resource use, minerals and metals	kg Sb eq	2.42E-05

Table 3. Results of the PEF- compliant characterization step – Ovine Leather

Impact category	***Unit of measure***	***Total***
Climate change	kg CO2 eq	2.21E+01
fossil		1.11E+01
biogenic		1.03E+01
land use and transformation		7.06E+00
Ozone depletion	kg CFC11 eq	1.98E-07
Ionising radiation, HH	kBq U-235 eq	5.89E-01
Photochemical ozone formation, HH	kg NMVOC eq	3.15E-02
Respiratory inorganics	disease incidence	2.56E-06
Non-cancer human health effects	CTUh	2.32E-05
Cancer human health effects	CTUh	3.96E-07
Acidification terrestrial and freshwater	mol H + eq	3.61E-01
Eutrophication freshwater	kg P eq	1.05E-03
Eutrophication marine	kg N eq	6.32E-02
Eutrophication terrestrial	mol N eq	1.52E+00
Ecotoxicity freshwater	CTUe	4.17E+01
Land use	Pt	2.58E+03
Water scarcity	m3 deprived	6.39E+00
Resource use, energy carriers	MJ	1.22E+02
Resource use, minerals and metals	kg Sb eq	2.94E-05

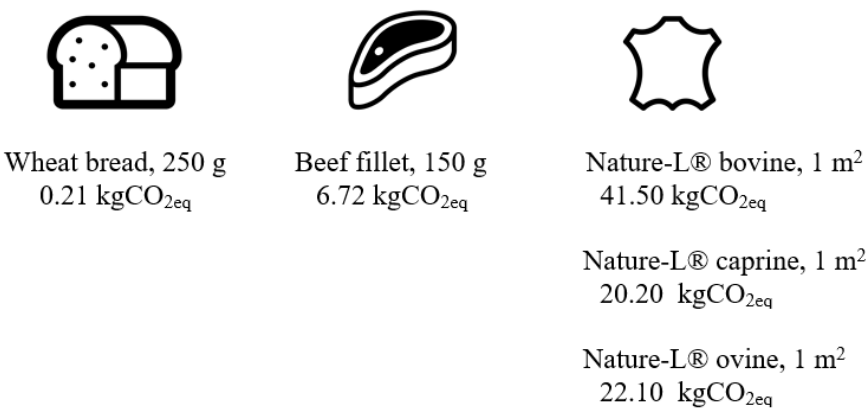

Fig. 2. Climate change impact comparison (LCA Food Database)

The process has been divided into the PEF-compliant sections of upstream and core. Farming, slaughtering and preservation are upstream processes and contribute to the majority of the impacts. Thanks to the specific recipe used in the production process of Nature-L® leather, the core tanning process presents lower impact than the upstream one, as illustrated in Tables 4-6.

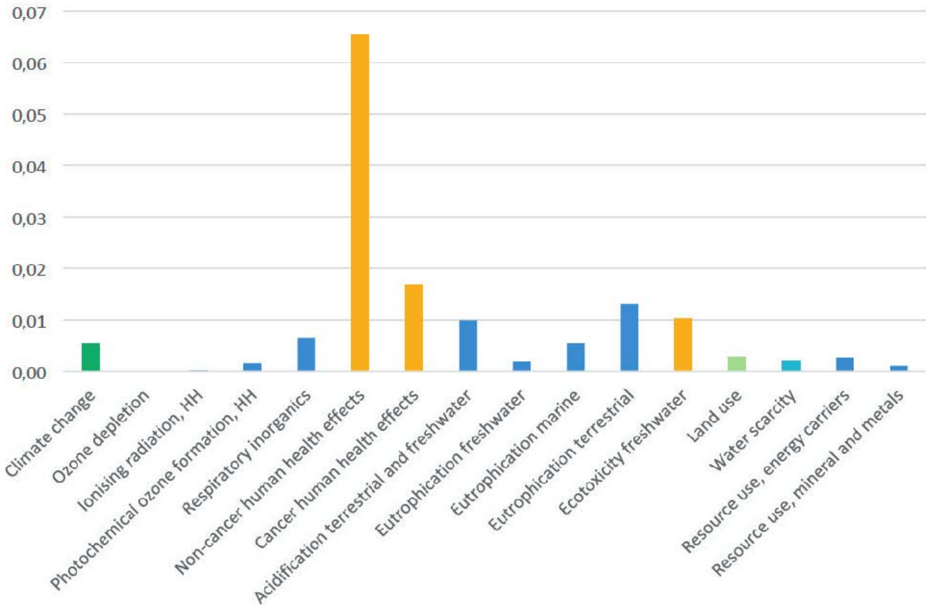

Fig. 3. Results of the PEF-compliant normalization step – Bovine Leather

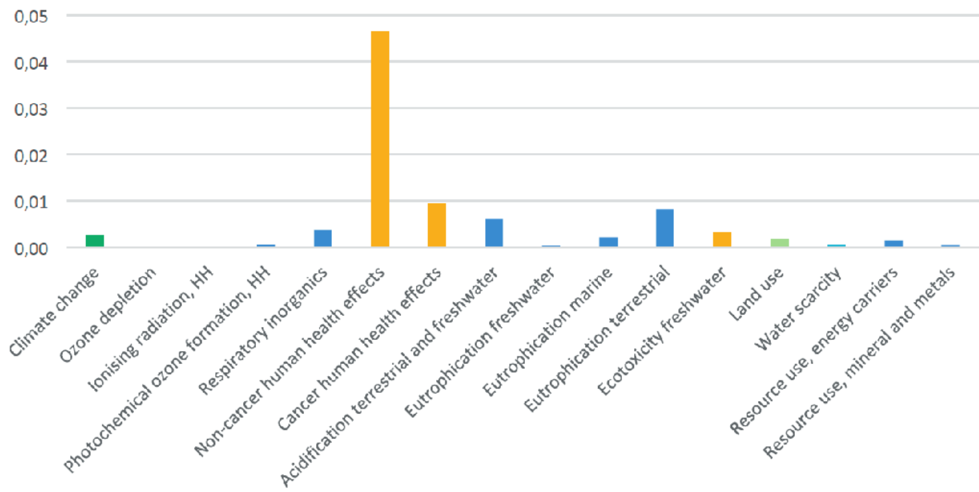

Fig. 4. Results of the PEF-compliant normalization step – Caprine Leather

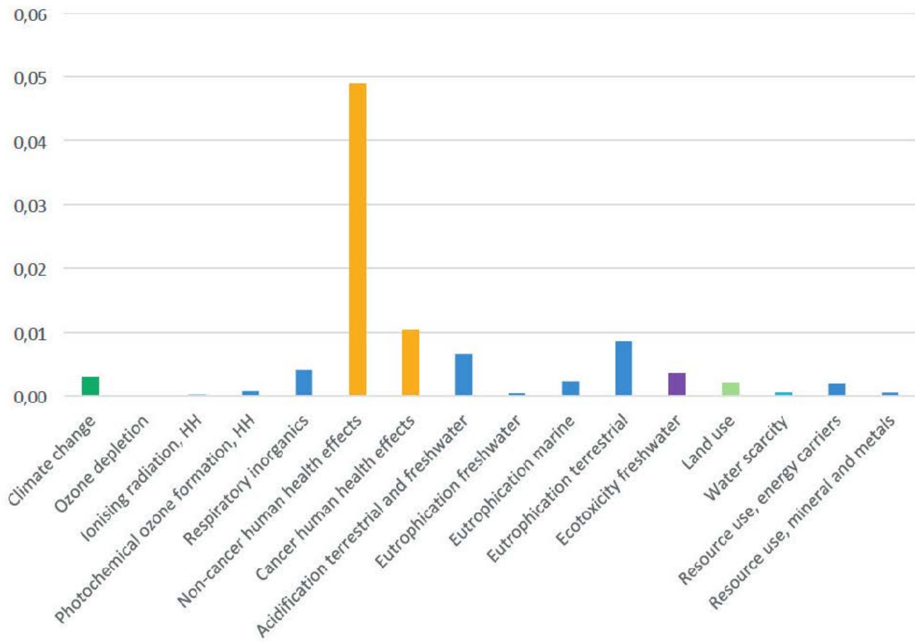

Fig. 5. Results of the PEF-compliant normalization step – Ovine Leather

Table 4. Relative contribution to the characterization and single score weighting results for core and upstream processes – Bovine Leather

	Upstream %	***Core %***
Climate change	89.01	10.99
Non-cancer human health effects	97.34	2.66
Cancer human health effects	91.12	8.88
Ecotoxicity freshwater	92.87	7.13
Land use	95.45	4.55
Water scarcity	71.11	28.89

Table 5. Relative contribution to the characterization and single score weighting results for core and upstream processes – Caprine Leather

	Upstream %	***Core %***
Climate change	71.18	28.82
Non-cancer human health effects	94.84	5.16
Cancer human health effects	80.45	19.55
Ecotoxicity freshwater	65.29	34.71
Land use	88.66	11.34
Water scarcity	25.62	74.38

Table 6. Relative contribution to the characterization and single score weighting results for core and upstream processes – Ovine Leather

	Upstream %	*Core %*
Climate change	67.73	32.27
Non-cancer human health effects	93.91	6.09
Cancer human health effects	77.76	22.24
Ecotoxicity freshwater	61.40	38.60
Land use	86.65	13.35
Water scarcity	23.98	76.02

From the data obtained, farming, slaughtering and preservation phases in the production of raw hides and skins have a higher environmental impact than the core tanning process for the production of Nature-L®: 91.6% of the impacts for Nature-L® Bovine Leather, 81.73% for Caprine Leather, 79.20% for Ovine Leather come from the upstream processes, while tanning activities occurring in Italy accounts for 8.4% (for Bovine Leather), 18.27% (for Caprine Leather), 20.8% (for Ovine Leather) of the total environmental burden. The results of the PEF-contribution analysis are illustrated in Figs. 5-7.

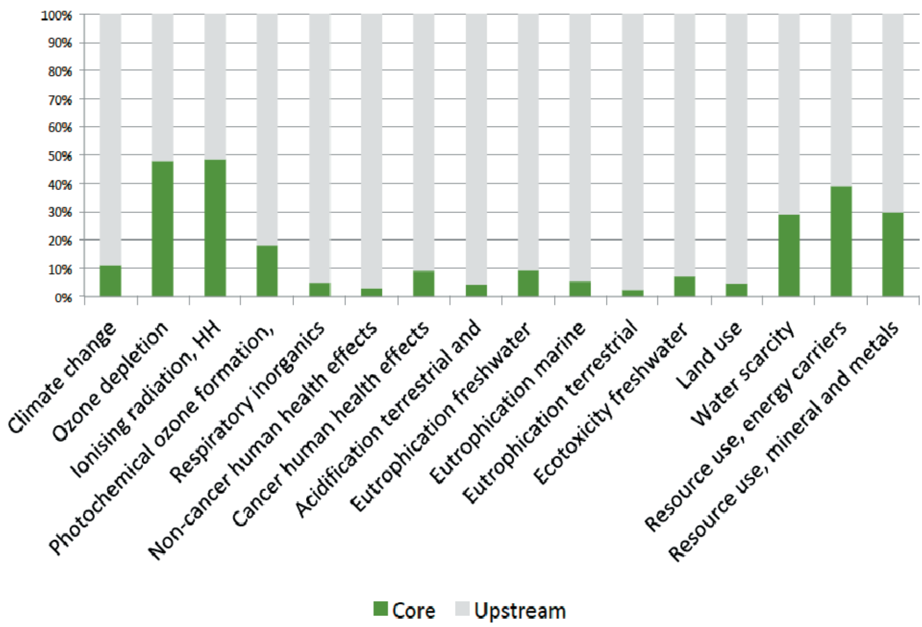

Fig. 5. Results of the PEF-compliant contribution analysis – Bovine Leather

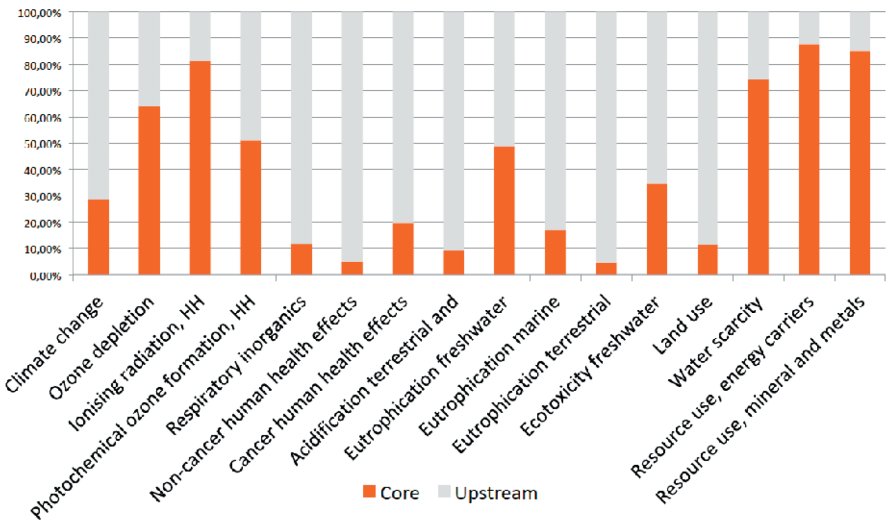

Fig. 6. Results of the PEF-compliant contribution analysis – Caprine Leather

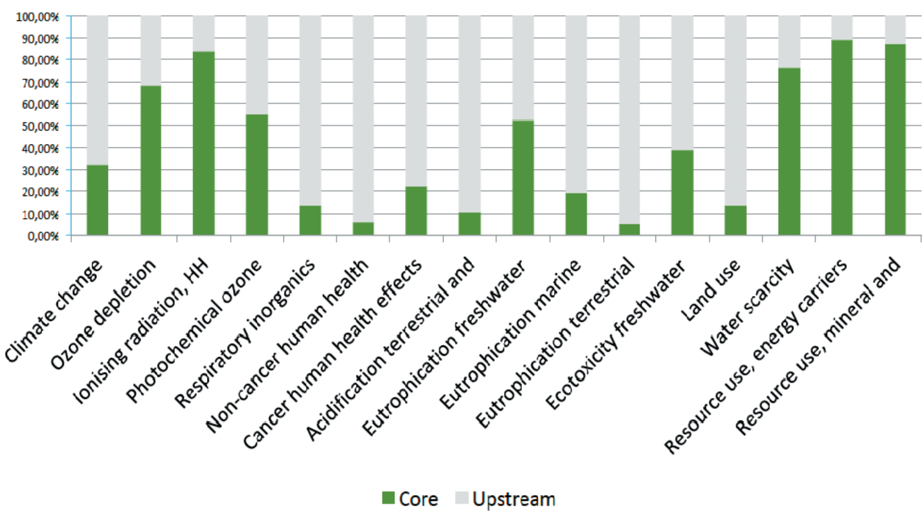

Fig. 4c. Results of the PEF-compliant contribution analysis – Ovine Leather

6. Concluding remarks

Conceria Nuvolari through its metals-free biodegradable leather products contributes actively to support Sustainable Development Goals (SDG): 12 (Responsible consumption and production), 13 (Climate action), and 15 (Life on Land).

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LCA Food Database, Bread; Meat, hiip://lcafood.dk

Procedia
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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 651-656

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

TECHNOLOGICAL INNOVATION APPLIED TO THE PRODUCTION OF CUSTOMIZED PADEL RACKETS*

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Abstract

The current economic system must reintegrate material and energy resources internally and eliminate the concept of waste to replace it with technological innovations based on terms such as recovery, hedgehog and reuse with a view to the circularity of the economy. Through technological innovations it is thus possible to obtain more durable, versatile and innovative products, capable of reducing environmental impact and waste of resources, while providing savings and improvements in the quality of life of consumers. Currently padel rackets, being made up of about 60/70% of expanded polyesters (not recyclable, with methods conventionally opposed to sustainable environmental recycling issues) and 30/40% of composites (also recyclable with non-recyclable costs sustainable) are difficult to recycle except at high costs.
3D printing FDM (acronym for Filament Deposition Molding), or deposit of molten filament, uses thermoplastic materials that can be easily disposed of, recovering over 80% of the manufacturing material, with sustainable technologies. The aim of this paper is to present a new technology based on additive manufacturing (AM) to produce limited edition padel rackets. The current technologies used for the production of racquets are designed only to obtain large volumes which make costs prohibitive for small series of customized products. This is applied to replace the current metal or fiberglass mold with a manual lamination procedure on the spindle itself to obtain the product.

Keywords: additive manufacturing, business plan, circular economy, composite materials, padel

*Selection and peer-review under responsibility of the ECOMONDO
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1. Introduction

Currently, the tendency to replace metallic materials with composite materials is becoming increasingly evident, especially in sectors with a strong technical value. In the aeronautical, aerospace and civil fields, a lot has been spent in economic and manpower terms for the discovery of new materials in order to obtain the best compromise between mechanical/physical performance (strength, weight, durability, etc.) and cost of aeronautical structures. Metallic materials, such as aluminum alloys and titanium, despite having been not discovered recently, did not completely satisfy the researchers for corrosive problems or durability, heaviness, etc. It is precisely the study of new solutions to obtain unattainable performance in terms of absolute value and energy saving in the same conditions of use, which led to the discovery of composite materials (Marchetti and Cutolo, 1991; Visconti, 1975).

Thus, an important way out is born, that of dematerializing the economy: decreasing the demand for materials of entire economies, reducing the intensity of resources in products and services, by increasing the efficiency of materials (Berglund, 1975). In concrete terms, all this can be done by reducing the consumption of materials, by recycling and reusing secondary materials. It is a necessary (but not sufficient) condition for achieving sustainable economic development. To achieve its transformative promise, Agenda 2030 calls for a new approach to address the interconnectivity of today's challenges. With this aim, human security provides an effective analytical lens and programming framework. Initiatives applying the approach engage closely with people to uncover their specific needs and vulnerabilities, and advance policies and actions based on their priorities. This results in development that is more inclusive and sustainable (Ciampaglia, 2003).

Padel is a tennis-derived ball sport. It is practiced in pairs in a rectangular field closed by walls on four sides, except for two side doors. The game is played with a rigid plate racket with which you exchange a ball aesthetically identical to the tennis one, but with a lower internal pressure, which allows greater control of shots and rebounds on the banks (Li et al., 2000). Proper equipment improves results during the game. Therefore, the racket (and equipment in general) is a determining factor in improving one's performance on the court. However, the correct choice must be made in the midst of a truly infinite proposal. The padel racket is divided into three macro categories based on its shape. Round is the form recommended for players approaching the padel the balance is low, therefore towards the handle and allows for greater maneuverability and control of shots. Also taking into account that where there is more control, there is also less power. A teardrop also called a teardrop, instead offers a good mix between power and control and for this reason it is particularly bitter from a wide range of players, especially those of the intermediate level. Balance is shifted higher than the round one and therefore requires a little more thrust to make the ball travel (Bertolini et al., 2001).

A diamond shown instead for advanced level players, who already have good control and excellent control technique for maneuvering a tool that has the balance on top, and then moved towards the test. There the main feature is the power but you still need to be able to have good control.

2. Case study: CNR Catania/Messina

The headquarters of the Institute, which is part of the National Research Council (CNR), deals with translational research and technological development in the field of intelligent systems for health, neuroscience and child neuropsychiatry. The aim of this project is to develop a new technology based on additive manufacturing (AM) to produce limited edition padel rackets. The current technologies used for the production of rackets are designed only for the production of large volumes which make costs prohibitive for small series of customized products (Grasso and Calabretta, 2002).

In addition, the use of standard manufacturing techniques hinders design freedom. The aim of the project is to develop a new approach that manages to combine additive manufacturing technology, also called 3D printing, composite materials will make the production of limited numbers (<1000 rackets per year) technically and economically feasible without design constraints.

3. Materials and methods

In the project, reinforced commercial materials suitable for AM production will be tested with regard to their mechanical properties and, in particular, to take into account the effect of printing parameters and anisotropic behavior. The CAD derived from the state of the art of construction will serve as the basis for the racquet design. The logic will be to review / replace the use of the metal and / or fiberglass mold, in which the composite is cured for the realization of the product, with the design of only the "customized" mandrel in CAD and produced in AM where the usual lamination of the composite will then proceed (Perviaz et al., 2016). Depending on the information obtained from this design phase, the current polymer formulation will be optimized by creating mixes for the mandrel with customized properties. These blends, in order to ensure the industrial scalability of the developed system, will always be based on the use of commercially available materials and mixing techniques (Matarazzo and Baglio, 2018).

An FEA study will then be carried out, to evaluate the mechanical resistance of the racket with respect to the mechanical properties of the AM polymers selected and developed. Should any structural deficiencies be measured, especially in relation to the most critical areas such as the handle and belly and to ensure higher performance, we will proceed with the use of composite materials integrated into the racket during the lamination phase.

4. Results and discussion

Most padel players and practitioners do not know how snowshoes (padel rackets) are made and what materials are used in the process. They are therefore not aware of the advantages or disadvantages of using a racquet model depending on the components. Here is the list of materials that can be found in a racket, multiplicative parameters have been inserted due to the processing carried out in a prototype printed in PLA filament. The details are present in Table 1.

Carbon fiber: more familiar, the essence of graphite particles. It is expensive, but offers excellent results in terms of lightness and strength, hence its use in Formula 1, motorcycles and many other sports. Few brands produce 100% carbon rackets because the cost is very high (Arfò et al., 2019).

Glass fiber: the material par excellence in the manufacture of Padel rackets, a little softer than carbon, but less light. Combined with graphite or carbon it offers exceptional qualities with excellent impact resistance. It is more elastic than carbon fiber, so it provides more depth at the output but less power. Having flexion qualities, it is ideal to incorporate it on the surface of the racquets allowing to absorb more impacts and also on the frame as additional protection (Visco et al., 2011, 2012). Fiberglass is used by most padel brands. The strengths of this material mainly concern the economic savings compared to the more expensive carbon fiber (Vazquez et al., 1999).

Table 1. Economics data of padel racket technology production.

Material	***Price per unit***
Vacuum bagging	0.3x4.4€
Laminating raw materials	1h x (10€ - 15€)/h
Carbon fiber prepegs	0.3x54€
Sealant tape	0.1x8€
Freezer -18°C	-
Vacuum pump, tube hoses connectors/valves Vacuum regulator	0.01x480€
Laminating tools	0.01x150€
Dremel, accessories, flexible mandrel	0.01x120€
Air Compressor filters	0.01x200€
Mask	0.1x50€
Gloves Overalls Trimming box Painting Box	0.1x12€
Spry paint	0.1x40€
3D printing filament mandrel	0.5x24€
	Total Price: 44,05 € -

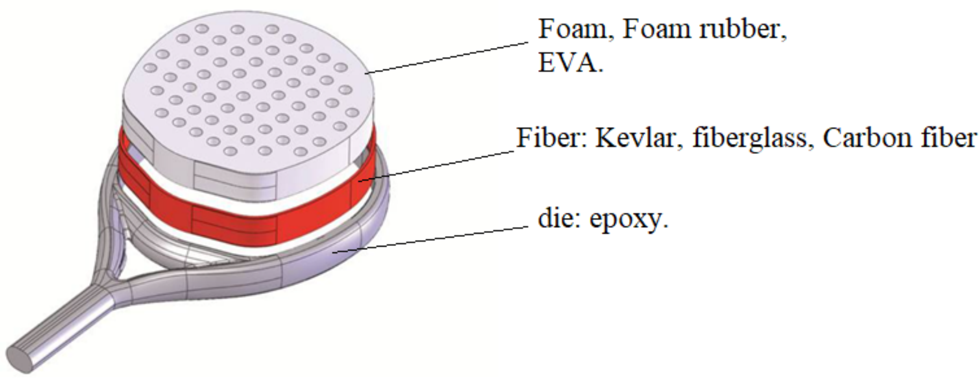

Fig. 1. Tipical materials of a padel racket (www.padelpaddle.it).

Graphene: is a two-dimensional crystalline carbon material. It is the finest component known (with a single atom thickness), the lightest (1 square meter of graphene weighs 0.77 milligrams), the best conductor of heat at room temperature, and is also the best conductor of electricity. Another property of graphene is its strength, it is the strongest material discovered with a much higher tensile strength than steel and Kevlar. Graphene is currently very expensive and difficult to obtain artificially although production techniques are constantly improving. By reducing costs and complexity. Very resistant, very hard and very strong but expensive and of dubious effectiveness. Brands like Head now feature rackets that incorporate graphene on its high-end models (Anastasi et al., 2020; Gentile et al., 2019).

Foam: with Eva Rubber, the most used material in the production of racquets. It is a rubber whose main property is that of shock absorption and its main component is latex, a resin that is extracted from trees or oil. We can meet an EVA racquet with different density and quality, which makes it more or less compact, rigid, flexible, flexible, elastic, etc.. The effects on a racquet would be more or less flexible to impact with the ball, giving us different sensations of strokes, power, control ... sometimes mixed with other materials in the end to get more lightness, the mixing will still lose its original properties against shock absorption. In theory, EVA rackets have greater control and longer durability, as they are a less elastic material. They have a lower bullet output than FOAM and polyethylene rackets. In EVA rubber there are different hardnesses: EVA Hyperasoft (softer), EVA Supersoft ... the rubber deforms very little in contact with the ball, forcing us to hit harder to get the same speed as the ball, but with the advantage that we will not have a limit to the hitting point, with respect to the speed that we can print on the ball, as in the case of FOAM. In addition, the snowshoes are more durable, and these finishes are of better quality.

Aluminum fiber: also called Alufiber, it is a harder material than fiberglass, but more flexible than carbon. Blended with carbon, this fiber offers excellent results in terms of power and control, producing a very characteristic metallic noise (alternative to fiberglass). It is little used, it depends a lot on the blends on which the fiber is mixed.

Kevlar: it is a fabric with a special treatment that gives it a very strong resistance, one of the most resistant materials. Being very stiff, it is very expensive to work with this material, but it can be added as an additional reinforcement in a part of the racquet. Carbon-woven Kevlar offers exceptional durability results. Currently only a few brands use it because it is too difficult to work with, but given its much stronger strength than carbon and glass, it offers amazing power and good control. On the other hand, no elasticity and therefore no effect of balls (ball exit). Compared to carbon fiber, it has better control but considerably reduces the impact power with the ball and also the lamination processing is more difficult. It is used as a reinforcing factor in the most critical areas as an alternative to carbon fiber (Munda and Matarazzo, 2020).

5. Concluding remarks

The continuous technological evolution that has made it possible to create innovative composite materials with increasingly performing characteristics and the growing sensitivity of the market for energy saving, have made composites particularly versatile and suitable for different applications. The 3D printed mandrel facilitates the lamination operation and allows product customization. The cost, compared to the state of the art, differs by about 12-15 compared to the use of the metal or fiberglass mold. This innovation also makes it possible to consider the possibility of disposing of thermoplastic in a more sustainable way.

The contribution of new technologies has also given rise to new composites with highly interesting functionalities. It is possible to develop completely new products or solve specific project problems or even create products with materials that require less energy in their production and transformation into semi-finished products. Finally, we can affirm that advanced composite materials will make it possible in the future to face the important challenges of energy and environmental sustainability linked to the production and end-of-life phases.

As a demonstrative result of the project, the aim of the project will be to provide the prototyping of six padel rackets (2 for each common shape found in commercial literature) to measure critical processing parameters such as variations in production times. The rackets will also be used to evaluate, on the basis of qualified tests, properties such as mechanical impact / impact and impact / impact resistance, static and degradative traction studies in UV and wet conditions. Smart manufacturing systems of the future must be adaptive, self-autonomous but also resource-efficient in their own manufacturing process as well during their utilization phase. To reach this target within a cost-efficient development and production process, holistic and integrated development methodologies are necessary. We show that it is possible to combine different development methodologies at an early stage to achieve a cost reduced lightweight design.

The combination of the analytical methods function mass, requirement and value analysis with simulation-based topology and frequency optimization in the product development process leads to a resource-efficient and economic manufacturing system in lightweight design. Using the example of a corrugated board conversion machine, this article shows the implementation of this combined development approach regarding lightweight design. A few examples of the estimated costs that are included and considerate in the project:

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Environmental Science, Engineering and Management
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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 657-666

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26^{th}-29^{th} October, 2021, Rimini, Italy

MEASUREMENT OF WATER SALINITY USING A CAPACITIVELY COUPLED CONTACTLESS CONDUCTIVITY SENSOR*

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Abstract

Salinity represents a measure of the salt content present in fresh water and sea water. The variation of water salinity with time can have different causes, such as natural events like weathering of rocks, rain deposits and floods, as well as human induced causes like the removal of deep-rooted native plants and irrigation. Altered values of water salinity can result in important economic, environmental and health consequences, such as the corrosion of metal infrastructures, the reduction of crops yields, the alteration of the ecosystem and effects on the human health in the case of drinking water.
Thus, water salinity is a parameter of primary importance that must be regularly monitored. The two methods to evaluate the salt concentration in water are the measurement of total dissolved solids (TDS) and electrical conductivity (EC). While TDS measurements are generally considered a more accurate method to measure water salinity, EC is a much simpler method and many commercial portable instruments exist to make water EC measurements in-the-field.
In this study, a capacitively coupled contactless conductivity detection (C4D) sensor for water EC measurement is presented and its performance compared with a traditional conductivity sensor where the electrodes are in direct contact with the water sample. Both the C4D sensor and the traditional conductivity sensor have been characterized using Electrical Impedance Spectroscopy with a set of water samples featuring different concentrations of salt. The results have shown that both methods can accurately and reliably measure water salinity with advantages in the case of the C4D sensor since the absence of contact with the electrodes strongly reduces the chance of sample contamination.

Keywords: water salinity, electrical conductivity, impedance spectroscopy, C4D sensor

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*Selection and peer-review under responsibility of the ECOMONDO
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1. Introduction

Salinity is defined as the amounts of dissolved salts in water and can be expressed in parts per thousand (ppt) or as percentage (%). Different types of water can be characterized by very different values of salinity: for example, freshwaters are normally characterized by values of salinity not higher than 0.5 ppt, while sea waters feature values of salinity higher than 30 ppt.

Water salinity can change with time due to different causes, such as natural events like weathering of rocks, rain deposits and floods, as well as human induced causes like the removal of deep-rooted native plants and irrigation. Strong changes of water salinity that lead to abnormal salinity levels can produce important economic, environmental and health consequences. For example, altered water salinity produces the corrosion of metal infrastructures in contact with water. Smith et al. (2020) investigated the effects of water salinity on the corrosion rate of one low-alloy steel (UNS G43400) and three stainless steels (UNS S15500, UNS S31600 and UNS S32760) and found that the corrosion rate increased with salinity in the range 0.05% to 3.5%. Ibrahim et al. (2018) modeled the effect of salinity on mild steel corrosion rate by carrying out experiments on water solutions with different saline concentrations. Cheng and Huang (2017) analyzed the corrosion rate of DH36 steel in sea water and found that the corrosion rate first increased and then decreased with salinity. Rajput et al. (2020) investigated the corrosion rate of three types of steel in fresh water and sea water at low temperatures and found the highest corrosion rate at room temperature (18°C).

Altered values of water salinity can have a negative impact on agriculture with the reduction of crops yields. Cucci et al. (2019) investigated the effects of water salinity and irrigation regime on maize yield in Southern Italy and found that increased salinity resulted in a 34% decrease of crops yield. Kurunc et al. (2020) presented a work on the effects of water salinity on the growth, yield and quality parameters of *Stevia Rebaudiana* Bertoni. Different salt types were considered and the results have shown that the salt type play a major role on the effect on the crops yield. Mehdi-Tounsi et al. (2017) presented a study on the response of pistachio to irrigation water salinity. The results have shown how the crops yield was not affected by moderate salinity levels but the response changed at higher salinity. While some aquatic environments have adapted to a range of salt concentration and can tolerate periods of high salinity, abnormal salinity values can produce negative effects on most species of the aquatic ecosystem. Russel and Randall (2017) studied the effect of increased water salinity in Swartvlei Lake (South Africa).

The increased value of water salinity due to the 2007 floods produced a 99% reduction of macrophytes and a corresponding 95% reduction in the presence of waterbirds. Booth and Thomas (2021) investigated the effects of reduced salinity on the health of bottlenose dolphins. Klop-Toker et al. (2017) carried out experiments to investigate the health conditions of green and golden bell frogs when exposed to freshwaters of different salinity levels, in particular in the case of healthy frogs and frogs infected by a fungal pathogen. Moreover, the total amount of salts in drinking water can affect the taste of water but can also produce health problems. Rosinger et al. (2021) presented a study on the health effects of salinity of drinking water in Northern Kenya. The results have shown that water salinity can have critical health implications for blood pressure and kidney function with an increase of hypertension and hyperdilute urine. Chakraborty et al. (2019) investigated the health implications of drinking water salinity in coastal areas of Bangladesh.

The study on 157 partecipants has shown that increased water salinity is associated with cardiovascular diseases, diarrhea, abdominal pain and resulted in higher frequency of hospital visits. Hossain and Haque Khan (2020) presented a study about the effects of drinking water salinity on the pressure status of adolescent school children in Bangladesh.

Tests on 528 partecipants confirmed that increased drinking water salinity represents a risk factor for high blood pressure.

Thus, water salinity is a parameter of primary importance that must be regularly monitored. The two methods to evaluate the salt concentration in water are the measurement of total dissolved solids (TDS) and electrical conductivity (EC). TDS measurements are carried out by evaporating water to dryness and weighing the solid residue. TDS is generally considered a more accurate measurement to evaluate water salinity, however the analysis must be carried out in a laboratory by trained personnel. EC measurements, on the other hand, are carried out by applying a test voltage signal to a couple of electrodes in direct contact with the water sample and measuring the current through the sample. While not as accurate as TDS measurements, EC measurements are much simpler and can be easily implemented in the form of a portable electronic instrument for in-the-field measurements outside a laboratory. Research works on novel devices for water salinity determination using EC measurements have been recently reported. For example, Grossi et al. (2019a) presented a low-cost portable measurement system for the characterization of saline solutions. A microcontroller based electronic board has been designed to perform Electrical Impedance Spectroscopy (EIS) measurements in the frequency range 10 Hz – 100 kHz and the results have shown how the saline concentration can be estimated with good accuracy and different salt types can be discriminated. Kadairova et al. (2018) presented a two-electrode conductivity cell for salinity measurement based on a single-step laser irradiation process on flexible polyimide substrate. The measurement is performed at 1 MHz frequency with an accuracy of ±0.5 psu and in-the-field tests in the Red Sea have shown how the sensor materials are corrosion resistant and can withstand the harsh environment.

In this paper, a novel sensor for water salinity measurements is proposed. The sensor is based on capacitively coupled contactless conductivity detection (C4D), where the water sample under test is not in contact with the electrodes, thus avoiding problems of sample contamination. The proposed sensor has been tested with water samples featuring different values of saline concentration and its performance compared with a traditional conductivity sensor where the electrodes are in direct contact with the sample. The results have shown that the proposed C4D sensor can be effectively used for in-the-field water salinity measurements with good accuracy.

2. Materials and methods

The measurements have been carried out using Electrical Impedance Spectroscopy (EIS), a very popular technique used for electrical characterization in a wide range of applications (Grossi and Riccò, 2017), such as bacterial concentration measurements in different types of media (Grossi et al., 2013; Grossi et al., 2018; Grossi et al., 2019 b), corrosion analysis of metal surfaces (De Motte et al., 2020; Mishra et al., 2020), quality characterization of different food products (Grossi et al., 2012; Grossi et al., 2014), evaluation of the charge state of batteries (Qiu et al., 2020), analysis of human body composition (Mialich et al., 2014).

In EIS measurements, a sinewave voltage signal $V_{IN}(t)$ is applied to the sample and the current $I_{IN}(t)$ through the sample is measured (Eqs. 1, 2).

$$V_{IN}(t) = V_{DC,IN} + V_{M,IN} \cdot \sin(\omega t) \quad (1)$$

$$I_{IN}(t) = I_{DC,IN} + I_{M,IN} \cdot \sin(\omega t + \varphi) \quad (2)$$

The sample impedance $Z(j\omega)$ is then calculated as given by Eq. (3).

$$Z(j\omega)=\frac{V_{M,IN}}{I_{M,IN}}\cdot e^{-j\varphi}=\mathrm{Re}(Z)+j\,\mathrm{Im}(Z)=|Z|\cdot e^{jArg(Z)} \quad (3)$$

The sample electrical parameters |*Z*| and *Arg(Z)* or, alternatively, *Re(Z)* and *Im(Z)* are calculated in a wide range of frequencies (ω=2πf) and such electrical parameters are used to estimate the parameter of interest of the sample under test (in our case the salinity level). In the presented study, EIS measurements have been carried out using a commercial impedance analyzer (Agilent E4980A) in a two-electrodes configuration. The impedance analyzer is controlled by a laptop PC using the USB port and the measured data transferred to the PC for data analysis. Water samples featuring different salinity levels (0.1%, 0.25%, 0.5%, 0.75%, 1%) have been artificially created by mixing distilled water with different concentrations of sodium chloride (NaCl).

Two different impedance sensors have been investigated and their performance compared. The first sensor, hereafter referred as contact electrode (CE) sensor, is shown in Fig. 1. It consists of a 50 mL polypropylene vial modified to feature a couple of stainless steel electrodes (diameter 5 mm, spaced 12 mm) in direct contact with the sample under test. This sensor can be modeled from an electrical point of view as the series of an electrical resistance (*R*) and a constant phase element (*CPE*) (Eq. 4).

$$Z_{CE}=R+Z_{CPE}=R+\frac{1}{Q\cdot(j\omega)^{\alpha}} \quad (4)$$

where *Q* is the interface capacitance and *α* is an empirical parameter that models the non-ideal electrode-electrolyte interface. As shown in Fig. 1, the application of the voltage test signal to the electrodes leads to the formation of an electrical double-layer at the electrode-electrolyte interface.

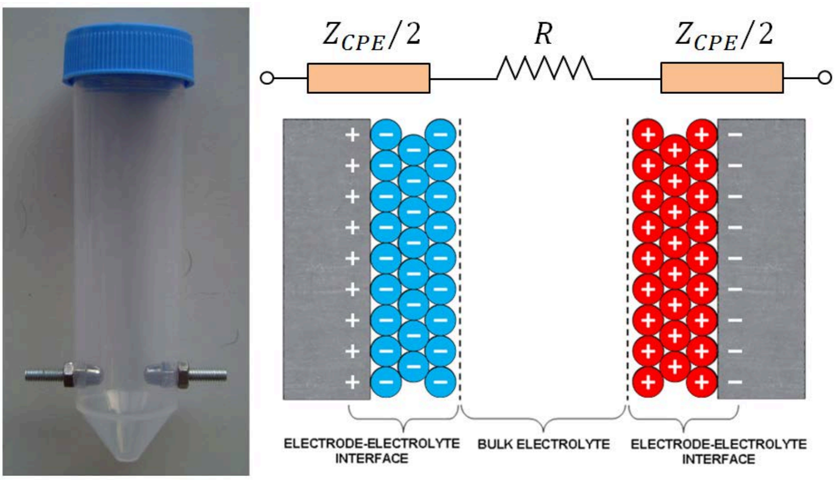

Fig. 1. Photograph of the CE sensor and the corresponding equivalent electrical circuit.

From this point of view, the CPE impedance models the non-ideal capacitance of the electrode-electrolyte interface, while the resistance R models the opposition to current flow of the electrolyte. The CE sensor has been investigated in the frequency range 20 Hz – 10 kHz. The other investigated sensor, hereafter referred as capacitively coupled contactless conductivity detection (C4D) sensor, is shown in Fig. 2. In this case, the water sample is hosted in a 15 mL polypropylene vial that is placed in a structure (built using a 3D printer) featuring two cylinder shaped electrodes (diameter 18 mm, height 10 mm) and a Faraday shield. The sinewave test voltage is applied to the two electrodes (that are not in contact with the water sample) and the Faraday shield voltage is set to ground to allow the generated electric field to be confined inside the sensor vial (where the water sample is present). This sensor can be modeled from an electrical point of view as the series of an electrical resistance (R) and an electrical capacitance (C_i):

$$Z_{C4D} = R + \frac{1}{j\omega C_i} \tag{5}$$

where R models the opposition to current flow of the electrolyte and C_i models the electrical capacitance between the electrodes and the water sample. The C4D sensor has been investigated in the frequency range 100 kHz – 2 MHz.

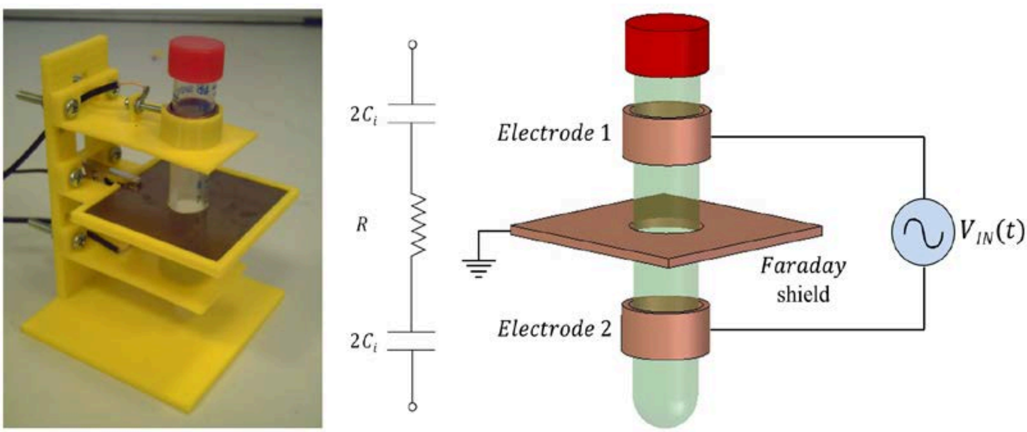

Fig. 2. Photograph of the C4D sensor and the corresponding equivalent electrical circuit.

The performance of the two sensors (CE sensor and C4D sensor) has been investigated for the estimation of water salinity from the measured electrical parameters and the measurement accuracy has been evaluated in terms of Mean Square Error (*MSE*) that gives information on the mean quadratic discrepancy between the target values and the predicted ones and is defined by the following equation:

$$MSE = \frac{1}{N} \cdot \sum_{i=1}^{N} (Y_i - X_i)^2 \tag{6}$$

where N is the number of tested samples (five in our case) and Y_i and X_i represent the estimated and real water salinity for sample i, respectively.

3. Results and discussion

The two investigated sensors (CE sensor and C4D sensor) have been tested with five different water samples featuring different levels of salinity (0.1%, 0.25%, 0.5%, 0.75%, 1%). Each measurement has been carried out in triplicate and the corresponding measurement results averaged.

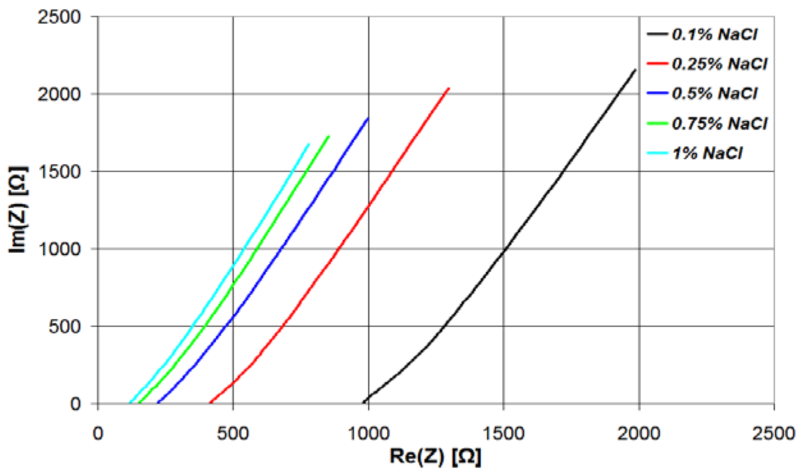

Fig. 3. Nyquist plot for the CE sensor for the investigated water samples

Table 1. Equivalent circuit parameters for the CE sensor

NaCl concentration (%)	*R (Ω)*	*Q (μF)*	*α*
0.1	985.32	19.12	0.6534
0.25	419.08	18.217	0.6778
0.5	222.14	19.28	0.6858
0.75	152.94	19.88	0.6943
1	118.01	19.94	0.7005

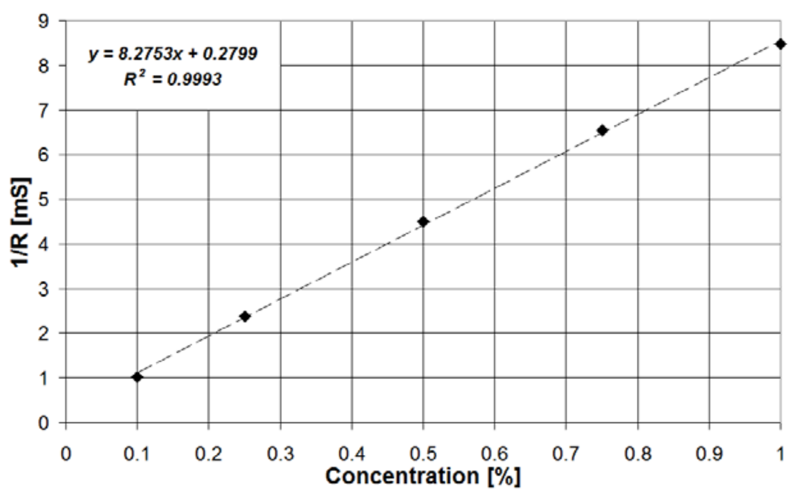

Fig. 4. Scatter plot for the CE sensor for the investigated water samples

Table 2. Estimated salt concentration accuracy using the CE sensor.

NaCl concentration (%)	*Estimated NaCl concentration (%)*
0.1	0.088818
0.25	0.254526
0.5	0.510165
0.75	0.756300
1	0.990171

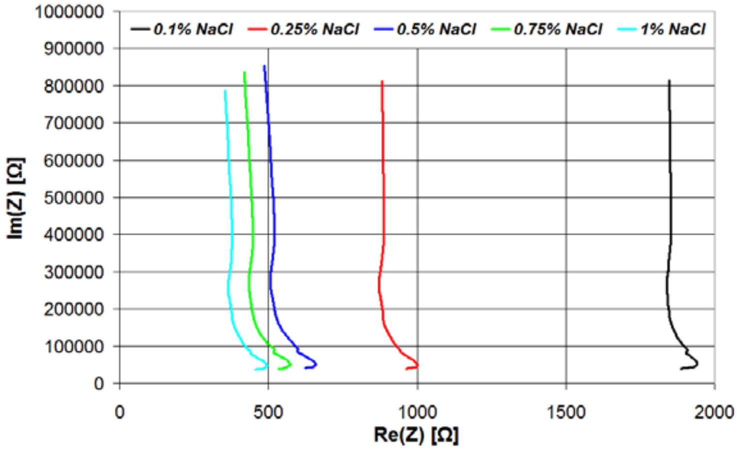

Fig. 5. Nyquist plot for the C4D sensor for the investigated water samples.

Table 3. Equivalent circuit parameters for the C4D sensor.

NaCl concentration (%)	*R (Ω)*	*C_i (pF)*
0.1	1852.32	1.956
0.25	887.93	1.964
0.5	519.34	1.865
0.75	447.97	1.905
1	376.63	2.022

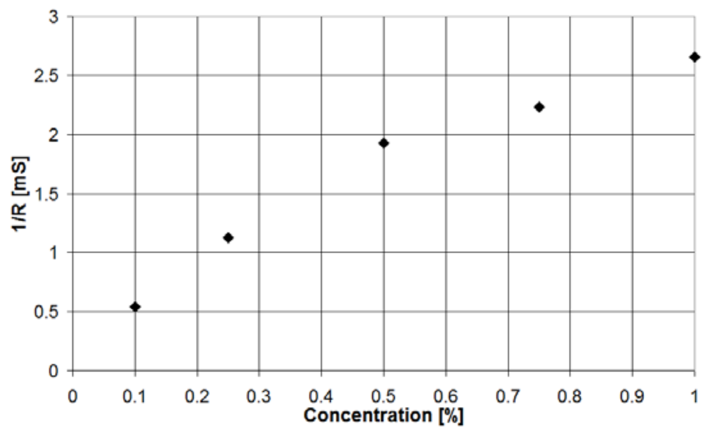

Fig. 6. Scatter plot for the C4D sensor for the investigated water samples.

Table 4. Regression equation and coefficient of determination (R^2) for the polynomial models used to fit the C4D sensor data.

Model order	*Regression equation*	*R^2*
1	$y = 2.2862x + 0.507$	0.9536
2	$y = -1.8332x^2 + 4.2924x + 0.1549$	0.9926
3	$y = 2.8001x^3 - 6.4912x^2 + 6.3961x - 0.0586$	0.9973
4	$y = 10.906x^4 - 20.774x^3 + 10.18x^2 + 2.0947x + 0.2483$	1

Table 5. Estimated salt concentration accuracy using the C4D sensor for the different polynomial models used to fit the data.

NaCl concentration (%)	*Estimated NaCl concentration (%)*			
	n = 1	*n = 2*	*n = 3*	*n = 4*
0.1	0.014375	0.093411	0.104063	0.099993
0.25	0.270846	0.253795	0.236016	0.249994
0.5	0.620466	0.534521	0.530365	0.499993
0.75	0.754655	0.683475	0.723998	0.750028
1	0.939609	1.088460	1.004790	1.000030

The CE sensor has been investigated in the frequency range 20 Hz – 10 kHz. The Nyquist plot for the acquired impedance spectrum in the case of the five water samples is shown in Fig. 3. The impedance spectrum has been fitted to the equivalent circuit defined by Eq. (4) and the corresponding circuit parameters have been calculated and presented in Table 1. The resistance R presents a strong correlation with the water salinity while the capacitance Q initially decreases and then increases with water salinity and the empirical parameter α presents a weak correlation with water salinity. This is expected, since the reciprocal of the resistance R (i.e. the electrical conductance G) is the parameter used to estimate the salinity of water. The reciprocal of the electrolyte resistance R is plotted vs. the water salinity for all water samples in Fig. 4 and this results in a very good linear correlation (R^2 = 0.9993) between the two variables. The linear regression equation presented in Fig. 4 has been used to estimate the water salinity from the measured electrolyte resistance and the results are presented in Table 2, where the estimated water salinity is compared to the real water salinity for all the five water samples. The resulting *MSE* is $7.7029 \cdot 10^{-5}$.

The C4D sensor has been investigated in the frequency range 100 kHz – 2 MHz. The Nyquist plot for the acquired impedance spectrum in the case of the five water samples is shown in Fig. 5. The acquired impedance spectrum presents a deviation from the electrical model defined by Eq. (5) (series of a resistance R and a capacitance C_i) at high frequency (f > 1 MHz). This can be related to parasitic components of the impedance occurring at high frequency. Thus, the circuit electrical parameters have been calculated by fitting the impedance spectrum in the frequency range 100 kHz – 1 MHz and are presented in Table 3 for all the five salinity concentrations. As expected, the interface capacitance C_i is not affected by the water salinity, while the electrical resistance R presents a good correlation with the water salinity. The reciprocal of the electrical resistance R has been plotted as function of the water salinity and the corresponding scatter plot is presented in Fig. 6. As can be seen, while the CE sensor presents a very good linearity between the electrical conductance and the water salinity, in the case of the C4D sensor the sensitivity is higher in the salinity range 0 – 0.5 % and lower in the salinity range 0.5 % – 1 %. Thus, the relation between the reciprocal of the electrical resistance R and the water salinity has been modeled with polynomials of different order (n). The cases n = 1, 2, 3 and 4 have been investigated and the corresponding regression equation and coefficient of determination (R^2) are reported in Table 4.

As can be seen, the correlation between the reciprocal of the electrical resistance R and the water salinity increases with the polynomial order. The regression equations of Table 4 have been used to estimate the water salinity from the measured electrical resistance R and such values are reported in Table 5 for all the five samples and the four polynomial models n = 1, 2, 3 and 4. The calculated MSE is $5.19 \cdot 10^{-3}$ for n = 1, $2.70 \cdot 10^{-3}$ for n = 2, $3.67 \cdot 10^{-4}$ for n = 3 and $3.65 \cdot 10^{-10}$ for n = 4. The results show that the C4D sensor is characterized by lower linearity if compared to the CE sensor. However, if a suitable model is used, a good accuracy can be achieved in the estimation of water salinity that can be as good or even higher than the CE sensor. Moreover, the lack of contact between the sensor electrodes and the water sample strongly decreases the chance of sample contamination and the need of electrodes cleaning after each measurement.

4. Concluding remarks

Water salinity is a parameter of primary importance since altered values can result in important economic, environmental and health consequences, such as the corrosion of metal infrastructures, the reduction of crops yields, the alteration of the ecosystem and effects on the human health in the case of drinking water.

The most used technique for in-situ monitoring of water salinity is the measurement of electrical conductivity, that is carried out by applying a voltage test signal to a couple of electrodes in direct contact with the water sample and measuring the current through the sample.

In this paper, a sensor for water salinity measurement, based on capacitively coupled contactless conductivity detection (C4D), has been presented and its performance compared with a standard electrical conductivity sensor where the electrodes are in direct contact with the sample. Tests carried out on water samples of different salinity have shown that the C4D sensor is characterized by lower linearity than the standard sensor but, once calibrated with a polynomial model, can estimate the water salinity with very good accuracy.

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Procedia
Environmental Science, Engineering and Management
hiip://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **8** (2021) (3) 667-672

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

IMPLEMENTATION OF A PHOTOVOLTAIC PLANT IN THE BUTERA TERRITORY AS A TOOL TO REDUCE ATMOSPHERIC POLLUTION*

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Abstract

The goal of the paper is to apply social indicators in an innovative way in the assessment procedure of the environmental, social and health impact resulting from the construction of a photovoltaic system. It can be seen as a means of protecting human health in the face of almost zero emissions into the atmosphere and the use of an inexhaustible source such as the sun. The implementation of photovoltaic systems is an ideal tool to achieve the goals of the 2030 Agenda, in particular Goal 7: production of clean and accessible energy. The aim of this work is to know the advantages deriving from the construction of a photovoltaic system in the territory of Butera in social, environmental and health terms. A tool used in this regard is the study on the Environmental Impact Assessment to determine the repercussions during the construction and operation phases of the plant. In order to achieve this goal, a case study was carried out on Ambiens Srl, located in Valguarnera Caropepe (EN) and founded in 2006.

Keywords: atmospheric pollution, environmental impacts, health impact, photovoltaic plant, renewable energy source

1. Introduction

Renewable energy are energy sources derived from resources from nature which, to their intrinsic peculiarity, regenerate at the end of their cycle. Unlike non-renewable energy sources, they do not involve the destruction of natural resources and guarantee greater

*Selection and peer-review under responsibility of the ECOMONDO

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respect for the environment, benefiting not only current generations but also future generations (Bartolazzi, 2006). Renewable energy sources can be used to produce clean electricity and help protect the environment and human health (Matarazzo, 2016). In fact, the use of these sources does not involve the emission of pollutants such as fine dust, which, if inhaled by humans, can cause almost permanent respiratory damage (Di Leo et al., 2020).

Among sustainable energy sources, the sun plays a primordial role; indeed, it could be considered the origin of all other energy sources both directly and indirectly. Solar energy, by definition, is energy derived from solar radiation. Well, with the advent of technology, it has been possible to convert the power of the sun into electrical energy by means of photovoltaic systems (Sumner and Layde, 2009). A major advantage is the fact that sunlight is infinite, which means that exploiting this resource could make fossil fuels obsolete and thus improve public health and environmental conditions (Zeman, 2007).

In this context, the 2030 Agenda is of great importance. In the preamble of the UN General Assembly document, the 2030 Agenda is defined as "an agenda for action for people, planet and prosperity. It also pursues the strengthening of universal peace in greater freedom. We recognize that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and a prerequisite for sustainable development". The 2030 Agenda consists of 17 Sustainable Development Goals, which in turn are divided into 169 targets to be achieved by 2030 (Wilkinson et al., 2017). The goal that espouses the present study is *Goal 7: Clean and Affordable Energy*. It aims at improving energy efficiency and strengthening international cooperation in order to facilitate access to clean technologies and increase investment in renewable energy (Gentile et al., 2020).

The objective of this study is to learn about and emphasize the advantages of implementing a photovoltaic system in social, environmental and employment terms. In order to achieve this objective, a case study was carried out on the company Ambiens S.r.l., located in Valguarnera Caropepe (EN) and founded in 2006. It is an engineering company operating in the design of environmental, utility, hydraulic and electricity network works and plays a key role in advising public and private entities in the field of environment, regional development, safety and quality. It is qualified in the manufacture of numerical models for the simulation of hydrological and hydraulic phenomena and the construction of geographical information systems for the storage, simulation, design and optimal management of commercial, technological, urban and natural networks, to managers of services, companies and societies.

This work is divided in three main parts:

- selection of case studies: the company Ambiens S.r.l. has been selected to carry out this paper. Ambiens, founded in 2006 by the idea that common experiences help to realize large projects and synergies to overcome obstacles and fears (www.ambiens.it), is an engineering company that operates in the design of environmental works, hydraulic services, electricity networks and plays a key role in consulting public and private bodies in the fields of environment, regional development;
- It is going to be analysed the authorization process for renewable energy plants and what peculiar documents are required in order to get the approval. There will be a specific focus on social and economic features and indicators;
- Analysis of results, drawing conclusion and formulation of recommendations for policy were analyzed with a view to continuous improvement in the context of the green economy.

2. Materials and methods

The authorization process for renewable energy plants in Sicily is regulated by national legislation, together with some regional and provincial provisions concerning certain types of plants (Jaus et al., 2010). Single Authorization is the measure introduced by Legislative Decree 387/2003 for the authorization of electricity production plants powered by renewable sources, above the power threshold of 20 kW (Moya et al., 2018). Plants must not be built on existing buildings or roofs. The single authorization constitutes a license for the construction and operation of the plant and, if necessary, becomes a variant of the urban planning instrument. The single procedure should last a maximum of 90 days, without considering the time required for the Environmental Impact Assessment (E.I.A.). The Region or the eventually delegated province are responsible for issuing the Single Authorization. The main limit of this procedure is a big one: E.I.A. is an expensive and long document where a lot of information must be provided (Bosio et al., 2020). The review and evaluation of this assessment usually takes a huge amount of time and makes the authorization procedure always longer than it should be (Ligabò, 2008).

The Environmental Impact Assessment is a technical report, drafted by the developer or proposer of the work, in which the main characteristics of the project and its repercussions on the environment are described. In the E.I.A. there is a complete summary of the situation prior to the realization of the work and a forecast of the future conditions (Wu et al., 2020). The E.I.A. includes not only environmental aspects, but also economic and social aspects (Fattoruso et al., 2021). It must include a description of the direct and indirect environmental impact of the project and list some possible alternatives to the project. Environmental Impact Assessment originated in the United States in 1969 with the National Environment Policy Act. Europe introduced this procedure through EU Directive 85/337/EEC (Directive, 1985). Last adjustment of E.I.A. has been made by the EU Directive 2014/52/EU (Directive, 2014), enacted in Italy through Legislative Decree 104 (2017). Legislative Decree 152 (2006) reorganized Italian environmental legislation and aimed to overcome all incompatibilities with the European directives' framework. To conclude, the directive requires Member States to hold a consultation procedure, in which the authorities likely to be concerned by the project and the public are invited, respectively, to give their opinion, the fact remains that such a procedure is carried out, necessarily, before consent is granted (Mareddy et al. 2017). Such opinions form part of the consent process and are aimed at assisting the competent body's decision on granting or refusing development consent. They are therefore preparatory in nature and not, generally, subject to appeal.

3. Results and discussion

The photovoltaic plant under study will be built on the ground, in the municipality of Butera (CL), more precisely in the locality of "Pozzillo", on land duly registered in the land register. The land is hilly and lies at an altitude of about 205 meters above sea level. The land on which the plant is planned is in the north-western part of the municipality of Butera, in an area occupied by agricultural land and far from residential agglomerations or scattered houses. The site is accessible from the local road network, consisting of municipal and nearby roads. Construction phase of the plant will last approximately 3.5 months. During this period the atmospheric emission sources are heavy transport vehicle, construction site operating machinery, heaps of excavated material, heaps of construction material. Dust will be produced by the operations of excavation and backfilling for levelling the cabin area, excavation and backfilling for levelling the cable duct trenches, beating of roadways inside the camp and handling of vehicles used on the site.

As regards the chemical substances emitted into the atmosphere, these are generated by the internal combustion engines used: vehicles, compressors, generators. For all categories of vehicles, the main climate-altering compounds emitted from the exhaust pipe during their operation and therefore subject to regulation are essentially nitrogen oxides, nonmethane volatile organic compounds, carbon monoxide and particulate matter (Table 1).

Table 1. Quantification of the emission of chemical compounds

g/kg fuel	*NOx*	*NM-VOC*	*CO*	*PM*
Construction machinery	48.8	7.08	15.8	5.73
Heavy transport vehicles	42.3	8.16	36.4	2.04

Regarding possible emissions during operation, it should be noted that photovoltaic systems, by their very constitution, do not involve atmospheric emissions of any kind and therefore have no impact on local air quality (Constantino et al., 2018) (Table 2).

Table 2. Emissions avoided into the atmosphere

g/kg fuel	*CO2*	*SO2*	*NOX*	*Powders*
Specific emissions into the atmosphere	333.1	0.84	0.79	0.27
Emissions avoided in 1 year (kg)	58756530	146412.00	137697.00	47061
Emissions avoided in 20 years (kg)	1081120152.00	2693980.80	2533624.80	865922.40

As far as the production of waste is concerned, no waste is expected during the plant operation phase, except for waste generated during repair or maintenance operations, which will be managed directly by the contractors and regularly recovered or disposed of off-site.

About the socio-economic aspects, we must say they are always the most underrated ones when drafting the E.I.A. document. On one hand, it should always be borne in mind that the construction of the plant would lead both Italy and Sicily into line with the demands of the Green Deal and the 2030 targets in general. On the other hand, the construction of a plant to produce electricity from renewable sources offers the chance of raising awareness regarding energy issues with particular emphasis on renewable sources. It is going to be shown a tab with some relevant information about fiscal entries for the municipality, number of green jobs, land profitability, number of companies involved (Tenuta, 2009) (Table 3).

Table 3. Summary table of socio-economics analysis included in the Alternative Zero

N°	*Indicator*	*Building Option*	*Do Nothing Option*
1	Total amount of companies involved	About 25	0
2	Total amount of workers involved	About 620	0
3	Use of land	Energy production	Potentially agricultural use
4	Land profitability	Right of surface payment	0
5	Main fiscal incomes	TARI, IVA, IRES	IMU paid by landowner

1. Total amount of companies involved: During the period of building activities several operations have to be completed, meaning that different companies would operate: agricultural work, site cleaning, construction work, earthmoving, construction of metalwork, panel assembly, connection of electrical works, construction of substation, site perimeter, video surveillance, monitoring, creation, and maintenance of tree belts. Expected loss for the companies involved in the construction and development of the site is €59.449.180.86, plus possible additional expenses that would constitute a further loss. To this amount should be added extraordinary or periodic revenues for maintaining the site or make extraordinary changes, for a total amount of €20.000.000.

2. Total amount of workers involved: at least 2 consulting firms (with 5 work units each) and 20 companies with an overall of 600 work units. The most important feature about the construction and following operation of the plant is the creation and development of green

jobs. “The “greening” of occupations refers to the extent to which green economy activities and technologies increase the demand for existing occupations, shape the work and worker requirements needed for occupational performance, or generate unique work and worker requirements.

3. Use of land: The possibility of not building the plant would appear to be at odds with Sicily's serious deficit of regional electricity production, considering the need of importing electricity from other regions and from neighboring countries. Energy considerations need to be combined with the environmental need to maintain a high quality energy and support the reproducibility of natural resources. First of all, the energy needs of the population living in the vicinity of the photovoltaic field must be examined. An annual electricity consumption of a typical family is about 3000 kWh a year. The photovoltaic field would be easily able to supply about 57,000 kWh of electricity, corresponding to a population of about 172.705 people. Therefore, installation of an electric generator in Butera would be able to supply 63.55% of the entire population of the province of Caltanissetta.

4. Land profitability: landowner would receive an annual payment in the form of a right of superficies. Annual fee would amount to €1300 per hectare. Since the total surface of the area involved is 158.73 hectares, the total income for the landowner would be €206.349. Therefore, without the approval of the project there are not any economic advantages for the owner either. The possible agricultural use of the land would not surely be as profitable as carrying out an agricultural activity because, just as explained before, soil has been altered.

5. Main fiscal incomes: production activities (but also citizens) have to pay a tax concerning waste management called TARI. This fee will consist in a payment of €4000 per MW for a total amount of €634.920 per year, which contributes directly to municipality’s coffer. The operating plant would also provide an obvious inflow of IRES and V.A.T. (I.V.A.) revenues, which will not be discussed since they are difficult to estimate and contribute to State coffers rather than municipal tax revenues.

4. Concluding remarks

During the construction phase of the plant there will be atmospheric emissions. However, these emissions are easily absorbed by the local atmosphere, both because they are temporary and because of the large space available for constant dispersion and dilution by the wind. In addition, they are confined to an area of almost zero population density, so the modest impacts will in fact affect only the workers involved in the site activities and the environmental components of the site.

Regarding possible emissions during the operation of the plant, it should be noted that photovoltaic plants, by their very constitution, do not involve atmospheric emissions of any kind and therefore have no impact on local air quality, not affecting human health. As far as the production of waste is concerned, this is not expected during the plant's operation phase, except for waste generated during repair or maintenance operations, which will be managed directly by the contractors and regularly recovered or disposed of off-site at authorized third-party plants. The type of professional figures required in the plant construction phase are, in addition to the plant supervision technicians and surveillance personnel, electricians, construction workers, craftsmen and agricultural workers/gardeners for the maintenance of the plant grounds. Some of these professionals will be employed on a continuous basis while others will be employed occasionally.

It is reasonable to conclude that the modest impacts on the environment are compensated by the positive aspects of the project, such as the avoided emissions and the achievement of the regional objectives of electricity production from renewable sources. The impacts assessed and quantified are largely bearable by the environmental context and are appropriately and effectively minimized and mitigated by the techniques and design solutions chosen.

Acknowledgements
Authors wish to acknowledge the support of the Italian Ministero dell'Istruzione, dell'Universita e della Ricerca (MIUR) trought the project "Ottimizzazione delle Prestazioni di Turbine Eoliche e loro Impieghi Particolari- Analisi di Fattibilità Tecnico-Economica ed Ambientale" of the Department of Civil Engineering and Architecture and Department of Economics and Business of the University of Catania- Piano di incentivi per la Ricerca 2020/2022 (PIA.CE.RI).

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 673-679

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

APPLICATION OF ENVIRONMENTAL AND ETHICAL DISCIPLINARY RULES IN AN AGRI-FOOD COMPANY*

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Abstract

Within the agri-food sector, we have often heard of certifications; in fact, they are considered an added value for any company that wants to enhance itself, stand out and convey a careful, dynamic and innovative corporate image to all stakeholders. This paper aims to provide a general overview of the dynamics after the application of an Environmental and Ethical Disciplinary, based on an LCA Analysis. The company used as a case study is EcoFarm S.r.l. o.p. located in Caltanissetta, which, through an integrated production system, supplies various varieties of high-quality fruit to large distributions in both national and European markets. The study of the application of the specification will allow the company to understand how to modify its production to meet the parameters required for certification but also how to maintain them in the long term through an analysis of costs and critical issues. At the end, specific enhancements and improvements will be developed and proposed to implement a management system prepared for certification.

Keywords: Environmental Sustenibility, New Green deal, Agrifood sector, Supply chain, LCA

1. Introduction

In the national agri-food panorama, which includes several hundreds of typical products (cold cuts, cheeses, wines, fruits, appetizers, etc.) whose brand is recognized by the

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current legislation (D.O.P. Products; I.G.P.; S.T.G.; I.G.; etc.), stand out three regions - among which Sicily - which largely exceed those of all other regions covering almost 40% of all Italian agri-food products DOP and IGP. Each typical food product represents the final result of a millenary history made of continuous attempts to make the best use of food resources provided by its own territory in accordance with the various needs, beliefs and historical events of the people who lived in that environment. Nowadays, however, many Sicilian products are subjected to a ruthless competition caused by globalization which puts the consumer in a situation of confusion due to the overcrowding of products difficult to distinguish among them.

Fortunately more and more consumers tend to reward, in a competitive way, that product for which it is declared that, in the process of production of the same, it has been taken into account the need to preserve the quality and integrity of the environment. It is for this reason that more and more Sicilian agri-food companies are undertaking particular paths of product certification, quality and environment that allow the company to amplify and improve its corporate image and also reduce costs and production expenses in the long run.

On the other hand the most burdensome and urgent regulatory gap to be filled mainly concerns the absence of official voluntary standards for products and services that are in line with the peculiarities and processes of environmentally and socially sustainable production. From this derives:

- the frequent difficulty on the part of the consumer to recognize products and services deriving from production processes that comply with limited regulatory emission standards according to the most modern eco-compatible techniques;

- the need to protect not only consumers but also the remaining actors in the supply chain (producers, transporters, distributors, etc.) who use raw materials deriving from certified quality excellence, produced at "zero kilometer", through socially compatible techniques and production processes with low environmental impact, in the various sectors analyzed.

The environmental and ethical disciplinary traces the guidelines to be followed in the various stages of production, transformation, transport, marketing, consumption of the product deriving from the agri-food sector and services related to rural tourism.

This paper is a focus on the disciplinary document which aims to:

• first and foremost guarantee a level of safety and reliability higher than the normal environmental parameters inherent in products and services deriving from supply chains in the agri-food sector;

• define a higher level of guarantee and reliability regarding the services and structures relating to the conventional rural tourism sector, which meet the expectations of the ecologically conscious customer of compliance with voluntary environmental and ethical requirements, in particular regarding the management of water and resources energetic.

Finally, establish a link between products deriving from environmentally and socially sustainable production and the services offered by rural accommodation facilities, with the aim of promoting the use of organic and zero-kilometer raw materials compared to non-indigenous supply chains; where possible, by investing in the production chain, it is necessary to try to reduce the environmental impact, also promoting the use of recyclable and biodegradable primary and secondary packaging, ensuring transparency for the consumer, through a clear and exhaustive communication system, in line with the dynamics concerning environmental and ethical sustainability. To this end, the “ethical” behavior of workers can be increased, making them more aware of production techniques and selection criteria relating to organic and natural products, through specific sectoral training courses aimed at diversified objectives; encourage the use of biofuels in the transport phase by land and by sea between the different categories of transport companies involved in the analyzed supply chains; ensuring a voluntary certification system of all phases of the production chains and accommodation facilities involved: from cultivation in the field, to product transformation, to transport, to marketing, in order to guarantee the consumer a product deriving from environmentally and socially sustainable processes; respecting all ethical compliance standards that go beyond the mandatory sector regulations, in order to protect the rights and well-being of workers and other parties, see stakeholders.

The products/services, processes and certified rural structures must meet the following fundamental general requirements, peculiar to this specification:

• *Ecologicity and sustainability*: the use of raw materials, semi-finished products, finished products and techniques deriving from environmentally and socially sustainable production, packaging rapidly and easily biodegradable, completely reintegrating into natural biological cycles and without toxicity and harmfulness for the user must always be preferred and for the environment. The production and marketing phases must also respect the principles of sustainability and social equity;

• *Territoriality*: it is preferable to use raw materials, semi-finished products and finished products deriving from local and indigenous agriculture, which emphasize the certified qualitative excellence of the reference area (certified organic products, DOP, IGP, etc.).

This paper aims to apply a new environmental and ethical sustainability specification specially drawn up for companies in the agri-food sector. This Disciplinary specification arises from the need to incorporate, integrate, with original elements, and further disseminate the greater sensitivity of the consumer of the possible customer towards sustainability. To date, there is a partial absence of both Community and national legislation on the subject. This document therefore seeks to provide a solution to the gaps related to the processes of production, transformation, transport, marketing, consumption and disposal of products deriving from the agri-food sector and services related to rural tourism.

2. Case Study: EcoFarm l.t.d o.p.

EcoFarm l.t.d o.p. was founded in 1994 near Butera, the hilly center north of the Gela plateau, sixty kilometers from Caltanissetta, characterized by an economy still strongly agricultural (cereals, citrus fruits, carobs, almonds and fruit). Located in Caltanissetta, Viale della regione, n.232, 93100, is a farm consisting of about 30 entrepreneurs who deal with the production, harvesting, processing and marketing of agricultural products of high-quality profile. Through exclusive regimes of integrated production, the company has reached excellent quality standards that have allowed it to conquer important national and European markets. The company mainly produces peaches, vines, melons, apricots and khaki apples obtained with integrated cultivation methods on calcareous-clayey soils for the most part, of medium texture in some cases, rarely sandy, located in hills (from 200 to 400 meters above sea level) that benefit from a mild climate. As far as the processing of the products is concerned, Ecofarm owns a plant of about 3000 square meters equipped with 1000 square meters of cold rooms used for the refrigeration and preservation of the products.

The company, through strong injections of innovation, has kept pace with the times: integrated into the territory, technologically advanced, strongly projected on Italian markets but especially abroad, with valuable fruit productions traced, certified and guaranteed. It already has several certifications such as: Product certifications on apricots, table grapes, peaches and pears, "Global Gap risk assessment on social practice (GRASP)", "IFS FOOD certificate", "BRC FOOD certificate". The company's objective is to continue the certification process in order to improve more and more the company's performance and its image: for this reason it has been selected for this case study.

3. Materials and methods

The environmental and ethical sustainability specifications, proposed by Ecogruppo Italia S.r.l., a control and certification body, flexibly outlines the guidelines to be followed in the various phases of production, processing, transport, marketing and consumption of the product in order to achieve a given certification. The proposed certification system "Environmental Sustainability and Ethics" represents a flexible framework that allows the various actors in the supply chain to certify their activities. The rating system is structured in three levels, each of which is achieved if and only if the operator demonstrates that he meets the requirements, divided into nine criteria, gradually more stringent.

The three levels of certification are described as follows:

- *Basic "C" certification level*, with at least two requirements, from those "present" for that level, met for each criterion;

- *Intermediate certification level "B"*, with at least half requirements plus one satisfied for each criterion;

- *More sophisticated certification level "A"*, with all requirements met for each criterion (modifiable if too complex to achieve, e.g. 75 % of requirements);

The nine criteria of the disciplinary are:

1. Water Resources Management;

In this table are identified all the data related to the use of water by the operator: presence of purifiers, monitoring (BOD-COD) and the way of reuse.

2. Use of energy from renewable energy sources;

In this table are identified all data relating to the consumption of electricity: the quantity, the presence of solar systems and appliances class A++ and any energy efficiency

3. Waste and by-product management;

This table identifies the quantity of waste produced, the type and treatment for each of them

4. Use of environmental and social accounting tools

This table collects all the data concerning environmental accounting: investments, training, presence of "environmental and social performance indicators" and presence of social balance sheets.

5. Management of pollutant emissions into the atmosphere;

This table examines the various pollutant emissions produced by the operator: the quantity, incentives for sustainable mobility, adoption of filters in chimneys, monitoring and management of acoustic and electromagnetic emissions.

6. Use of environmentally friendly materials and resources;

This table analyzes the use of non-impacting materials and resources: the adoption of recycled material, adoption of wood material, water heating techniques (passive house) and use of natural insulation such as sheep wool, mushrooms or hemp.

7. Certified environmental and safety management systems;

This Table gathers all the data regarding certifications: training on environmental management standards ISO 14001, training on health and safety at work standards ISO 45001, presence of certifications, presence of risk/environmental impact analysis and existence of environmental and social policy manuals.

8. Regional and local priority of raw materials;

This table collects data regarding the location of the producer: the presence of zero kilometer products, the presence of DOP, IGP or organic products.

9. Supplier Management;

This Table analyses the data relating to relations with suppliers and, in particular, the presence of certifications such as SGA, SA8000, GPP, ECOLABEL

4. Results and discussion

In this paragraph we report some Tables of the disciplinary in which the data inherent to the business case have been inserted.

5. Concluding remarks

There are several advantages deriving from the application of this experimental specification in agri food sector companies, in particular, operators carrying out the transport phase must demonstrate that they use biofuels and bioliquids for the production of electricity, heat, or for cooling the vehicles: use methods of control, quantification and reduction of greenhouse gas emissions (GHG), for example through Carbon Footprint and LCA; use high percentages of biomethane and other advanced biofuels in their means of transport; encourage the use of sustainability criteria and the use of biofuels and bioliquids in the delivery chain, in order to increase the decarbonization process; promote the choice of "Motorways of the Sea" rather than the current road system, if a lower environmental impact in terms of CO_2 emissions is demonstrated; have the means of transport certified according to the sustainability criteria for biofuels.

Table 1. Example of the first table of the disciplinary

Requirements	***Level C***	***Level B***	***Level A***
Water consumption (Liters/Year/output)	573 MC	12.000	10.000
Purifier's Installation	Absent	-	-
Process of Monitoring BOD	Absent	-	-
Process of Monitoring COD	Absent	-	-
Process of Monitoring of Chlorine	Absent	-	-
Process of Monitoring of Heavy Metal	Absent	-	-
Treatment of sewage sludge	Absent	-	-
Water reuse technologies	Absent	-	-
Application of Water Footprint	Absent	-	-

Table 2. Example of the second table of the disciplinary

Requirements	***Level C***	***Level B***	***Level A***
Consumption of electricity from traditional sources (MWh/Year/Final Output)	464 206 kW	25.000	10.000
Photovoltaic Panels	Present	-	-
Consumption monitoring analysis and energy efficiency plan	Absent (in fase di lavorazione)	-	-
Adoption of lighting design strategies in line with the energy efficiency plan	Absent	-	-
Solar thermal system	Absent	-	-
Small wind plant	Absent	-	-
Purchase of electricity from renewable sources	Absent	-	-
Fixtures and other insulating materials	Present	-	-
Appliances class A+++	Present	-	-

Table 3. Example of the third Table of the disciplinary

Requirements	***Level C***	***Level B***	***Level A***
Quantity produced (kg/year/output)			
% of separate collection/total waste disposed of	-	-	80%
% of wet waste collected/total waste disposed of	-	-	100%
% recyclable materials present in the packaging of company products	-	-	100%
Type of selective collection adopted	-	-	Ritiro azienda specializzata
Adoption of special waste collection techniques	-	-	Absent
Adoption of appropriate medical waste collection	-	-	Absent
Encouragement of alternative humanitarian uses of waste, returns, by-products or unsold products	-	-	Present
Adoption of packaging derived from PLA	-	-	Absent
Adoption of by-product/biomass collection techniques	-	-	Absent (in fase)
Proximity to ecological islands	-	-	Absent
Adoption of home composting techniques	-	-	Absent
Adoption of WEEE management techniques (separate collection and transfer to appropriate bodies)	-	-	Absent

Table 4. Example of the seventh table of the disciplinary

Requirements	***Level C***	***Level B***	***Level A***
Hours of voluntary management systems training (hours/month)	-	-	-
Adoption of training on environmental management standards ISO 14001	Absent	-	-
Adoption of ISO 45001 occupational health and safety training	Absent	-	-
Environmental risk/impact analysis	Absent	-	-
Workplace safety risk analysis	Absent	-	-
ISO 14001 Certification	Absent	-	-
ISO 45001 Certification	Absent	-	-
Adherence to voluntary environmental agreements	Absent	-	-
Existence of documentation and environmental policy manual	Absent	-	-
Existence of documentation and social policy manual	Absent	-	-

Furthermore, this specification has the purpose of: defining a higher level of guarantee and reliability regarding the environmental and ethical parameters inherent to the products and services deriving from supply chains in the agri-food sector, which protect consumers with regard to the organic raw materials used, the environmentally friendly cultivation methods used, the types of packaging and production processes used, the type of fuel used during the transport phase, the waste management techniques deriving from the use of the product or from the use of the service; define a higher level of guarantee and reliability regarding the services and structures relating to the conventional rural tourism sector, which meet the expectations of the ecologically conscious customer in compliance with voluntary environmental and ethical requirements, in particular regarding the management of water and energy resources; establish a link between products deriving from environmentally and socially sustainable production and the services offered by rural accommodation facilities, with the aim of promoting the use of organic and zero-kilometer raw materials compared to non-indigenous supply chains; intervene, as far as possible, on the production chain, in order to reduce the total environmental impact, also promoting the use of recyclable and biodegradable primary and secondary packaging; ensure transparency towards the consumer/customer through a clear, exhaustive and truthful communication system, which encourages proactive behavior, in compliance with the concepts of environmental and ethical sustainability.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 681-688

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

ECOLOGICAL FOOTPRINT AS A MANAGEMENT TOOL APPLIED IN AGRI-FOOD MARKETS IN LIFE CYCLE PERSPECTIVE*

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Abstract

The Ecological Footprint is considered as a method of measuring environmental impacts in a life cycle perspective that evaluates the environmental footprint of a product or service. The calculation of the Ecological Footprint is made according the possible impacts of the activity of a general economic sector resulting from: energy use, consumption of matter, use of land to absorb emissions produced during processing, surface occupations for infrastructure.. The Ecological Footprint has been applied experimentally to the MAAS and in this study will be deepened precisely this objective. The MAAS is the Agro-food center of the city of Catania, was founded in 1989 in implementation of Law 41/86 for the creation of fruit and vegetable, fish and horticultural markets. The main benefits deriving from the adoption of this indicator for a company are related to a reduction of the environmental impact and at the same time a reduction of the costs related to the production process thanks to the use of renewable energy and resources.

Keywords: Ecological Footprint, sustainability, environmental impact, environmental advantages, economic advantages

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1. Introduction

The Agrifood sector with over €140 billion in turnover is one of the key sectors not only in Italy but also in Europe. In particular, in Italy the food industry ranks third for added value created with an incidence of 11% and employment level of 12%. At European level, however, the socio-economic relevance is even more strategic as it appears as the first industry in the manufacturing sector with an aggregate turnover of over 1,200 billion euros (Corrado et al., 2018)

The outbreak of the Pandemic from Covid-19 has brought to light even more the strategic importance of this sector, which is undergoing significant structural changes, including changes in the channels and methods of distribution of agri-food products, but also the occasions of consumption of the same (Gosetti, 2020; Russo, 2020). Made in Italy plays a crucial role in the world economy and in the proliferation of new job opportunities for the import and export of everything that is produced in Italy, the so-called Bel Paese, known abroad for being home to excellent craftsmanship (Ginanneschi, 2020).

Therefore, it is a key sector for the economy, but at the same time it must deal with a great impact on the environment, with 7% of the national greenhouse gas emissions generated (Condor and Vitullo, 2010). Even globally the situation is not better, given that the sector contributes up to 37% of greenhouse gas emissions and uses 70% of all available water (www.fao.org). Agri-food is one of the sectors with the highest social and environmental impact, but it plays a key role in the sustainable development of the entire planet. The waste of food is one of the most felt challenges (Torrisi, 2018). In Italy, about 5.1 million tons of food are wasted each year, while 4.5 million people live in poverty. Around 815 million people worldwide suffer from hunger, but 1.3 billion tons of food are wasted each year, a third of the total food produced (Serrano et al., 2020).

Hence the need to rethink the way food is produced and distributed, privileging new financial strategies that allow you to take a greener direction (Manservisi, 2017; Persico and Rossi, 2016). In this way, the results are positive also in the economic field, so that the European Commission estimates that more sustainable food systems can create a new economic value of over 1.8 trillion euro (EC, 2020; Iraldo, 2007).

As emerges from the report of the Observatory Smart Agrifood 2021 in the Italian agri-food chain, digital innovation is increasingly spreading to try to promote more sustainable and green food systems (www.agrifood.tech). Different solutions are implemented, from traceability of products to precision agriculture, technologies that improve the collection, the exploitation and sharing of data along the supply chain and many other technologies such as blockchain and digital solutions such as Iot, Big Data and Cloud (Treiblmaier, 2018; Russo, 2020).

All these elements are fundamental to contribute to the achievement of the objectives set out in the 2030 Agenda, in fact, food is a common thread that links all 17 sustainable development objectives (Colglazier, 2015). Over the next 25 years, land degradation could reduce global food productivity by up to 12%, leading to a 30% increase in world food prices. Indeed, the conservation and sustainable use of terrestrial ecosystems and the promotion of soil resilience and quality (SDG15) are the basis for food security and nutritional diversity for present and future generations. They are also decisive factors in combating climate change (SDG13): agriculture today causes one fifth of global greenhouse gas emissions (Maracchi, 2018).

Feeding the population without degrading the planet's environmental resources can reduce poverty (SDG1) and food insecurity (SDG2) (Clasadonte et al., 2013); in addition, sustainable agriculture systems can reduce migration and conflict (SDG16) caused by stress on water and land. To ensure a healthy life (SDG3) we need new reflections on people's food choices and diets, orienting the food culture towards diets that provide food with low environmental impact (Matarazzo, 2012). Therefore, intensive research and training across the value chain will be needed to integrate sustainable practices (SDG4) and fill gender gaps, including in terms of agricultural inputs (SDG 5) (Filho, 2017). Fundamental to achieve these changes also public policies that can be strengthened by collaboration between different actors in the agrifood chain (Ingrao et al., 2015; Suriano et al., 2016).

The main objective of this study is to go and measure the Ecological Footprint, considered a method to measure environmental impacts in a life cycle perspective to assess the environmental footprint of products or services. In an experimental way the Ecological Footprint has been applied to the MAAS agri-food center, inside which there are the wholesale fruit and vegetable and fish markets, located in Catania in via Passo del Fico SP70 / IC / da Jungetto, connected to the service axis and the airport of the city of Catania. The objective is precisely to calculate the Ecological Footprint within the structure, considering the possible impacts of the activity of the sector, resulting from the use of energy, the quantity and type of goods and services produced, emissions per product, from imports with foreign countries or other Italian regions, from areas dedicated to agriculture, livestock and infrastructure and any waste products.

- In order to achieve this goal, we propose a case study in the MAAS Agro-food center (www.maas.it). MAAS is a joint stock consortium company, founded in 1989 in implementation of Law 41/86 (Law, 41/86) for the creation of fruit and vegetable, fish and horticultural markets. The founding members are the Sicilian Region and the Federmercati Association (representation of fruit and vegetable wholesalers). It is the Agri-food center of the city of Catania and logistic hub of the Mediterranean, based in Catania in via Passo del Fico SP70 / IC / da Jungetto, it covers an area of about 1,100,000 square meters and hosts 78 companies in the fruit and vegetable sector, 20 companies in the fishing sector and other activities including refreshment areas, tobacconists, packaging companies and special vehicles. The company aims to guarantee the distribution of fruit and vegetables, agro-fish-food and horticultural products in general in the best state of freshness, conservation and sanitary conditions, in relation to current laws; maximum dissemination of information with reference to the quantities of product marketed and their prices; the conditions for the formation of prices in the most balanced way and in accordance with the cost components (MAAS, 2020).
- From the demand side, the ecological footprint measures the demand of an individual or a population for food and vegetable fibres, animal and fish products, timber and other forest products, space for urban infrastructure and forests to absorb its carbon dioxide emissions from fossil fuels. On the supply side, the biocapacity of a city, state or nation represents its land and biologically productive marine area, including forest land, pastures, cultivated land, fishing grounds and built-up land. The Ecological Footprint can be calculated for a single individual, city, region, country and the entire planet (Mancini et al., 2016).

For the calculation of the Ecological Footprint is used the method that allows to calculate the unsustainable components of the socio-economic system and goat the origin. This formula takes into account the consumption of the individual production sectors in the area where sustainability is to be calculated.

- Knowing the level of emissions is fundamental as a starting point to be able to activate reduction projects, identify margins for improvement and implement solutions in line with technological innovations (Cerrutti et al., 2012).

On the basis of the Ecological Footprint, companies, in fact, can define a carbon management system to identify and implement emission reduction interventions, economically efficient, using low-carbon technologies. Reduction measures may be complemented by measures to neutralise emissions (carbon neutrality), which can be achieved through activities aimed at offsetting emissions by equivalent measures aimed at reducing emissions through actions that are more economically efficient or more expendable in terms of image.

2. Materials and methods

The Ecological Footprint is a synthetic index on the state of human pressure on natural systems, a way of estimating the amount of renewable resources that a population uses to live, calculating the total area of terrestrial and aquatic ecosystems necessary to provide, in a sustainable way, the resources used and to absorb the emissions produced (Iannetta and Padovani, 2015). All food goods require to be supported upstream by a productive surface. The sum of all the hectares of land needed to support an individual's life represent his ecological footprint. Normally, therefore, the ecological footprint is calculated in terms of hectares per capita, but from this value it is also possible to trace the ecological footprint of an entire population, simply by multiplying the average per capita value by the size of the population (Ascione and Campanella, 2011). In the classical formulation, proposed by Wackernagel and Rees, the calculation of the Ecological Footprint is based on the average consumption of the population and develops according to the following formalism. Consider a region whose total Ecological Footprint you want to evaluate. If C_i represents the total average consumption, expressed in kilograms, of the i^{th} product category within the territory under consideration, the total Ecological Footprint F is estimated using the formula (1):

$$F=\sum E_i =\sum C_i q_i \qquad (1)$$

where E_i represents the Ecological Footprint deriving from the consumption of the i^{th} product and q_i is the conversion factor, expressed in hectares/kilogram, which coincides with the inverse of the average productivity for the i^{th} product category. This conversion factor represents the area of productive land needed to produce one kilogram of the i^{th} product. Starting from equation (1) it is easy to derive the Ecological Footprint per capita f = F/Np. (Eq. 2).

$$f =\sum e =\sum E_i/NP \qquad (2)$$

where E_i represents the Ecological Footprint per capita resulting from the consumption of the i-th product and Np the resident population in the considered region (Salomone, 2005).

Its reference standard is contained in UNI EN ISO 14026:2018 which provides principles, requirements and guidelines for the communications of the footprint of products that have an influence on the environment. Unlike the previous version of 2017, this one also specifies the ways in which the related communications related to the ecological footprint must be carried out and those of a non-environmental type, that is, the footprints that deal with social and economic problems (Gregori et al., 2011). The requirements for the verification procedure are also considered, always in the same standard.

3. Results and discussion

This paper presents an important study regarding the environmental impact of ecological footprint of MAAS. For the calculation, this time, a formula different from the classical one is used, which allows to identify the non-sustainability components of the socio-economic system and to diagnose its origin**.** The new formulation, instead of the calculation based on the average consumption of the population, considers the consumption of the individual productive sectors of the economic system present in the area whose sustainability is to be measured, from which (Eq. 3):

$$F = \sum H_n \tag{3}$$

where H_n represents the Ecological Footprint of the n^{th} economic sector.

The data used for the calculation of the Ecological Footprint by economic sector can be grouped under the following headings:

1. population and employees.
2. energy consumption;
3. Emissions;
4. quantity and type of goods and services produced;
5. imports and exports of goods and services with foreign countries and with other Italian regions;
6. areas dedicated to agriculture and livestock, extraction, infrastructure

from which derives the final formula used for the calculation of the ecological footprint of the MAAS (Eq. 4):

$$H_n = ENERGY + MATTER + EMISSIONS + INFRASTRUCTURE + INPORT - EXPORT - WASTE / N_a \tag{4}$$

where N_a represents the number of employees in the economic sector n^{th} (IRES, 2001).

In particular, the calculation was carried out considering the data of the fruit and vegetable sector relating to the periods January / February 2020 and January / February 2021, comparing the data obtained by performing a pre- and post-COVID analysis.

Table 1. Data used to calculate the Ecological Footprint at MAAS

DATA	***JAN. 2020***	***JAN. 2021***	***FEB. 2020***	***FEB. 2021***
Employees	72	72	72	72
Energy	457850 kWh	412754 kWh	439684 kWh	397402 kWh
Quantity of goods	609 931 kg	412 982 kg	669 522 kg	447 142 kg
Import	377 071 kg	238 394 kg	390 010 kg	141 031 kg
Infrastructure	136000 MQ	136000 MQ	136000 MQ	136000 MQ
Waste	8616 kg	5801 kg	8562 kg	8357 kg
% Donations	6%	5.25%	7%	7.5%
Emissions	228.93 kg	206.38 kg	219.84 kg	198.70 kg

Source: personal elaboration

From the Table 1 it can get the data of fruit and vegetables during the period under consideration. At this point, it was possible to determine the ecological footprint of the MAAS, before the period covering 2020 and then the period of 2021.

HnJan/feb2020=[(457850+439684)+(609931+869522)+(228.93+219.04)+136000+ (377071+390010) – (8616+8562]/ 72= 42.546,37 hectares

HnJan/feb2021=[(412754+397402)+(412982+247142)+(206.38+198.70)+136000+ (238394+141031) -(5801+8357)] / 72= 27.388,22 hectares

The ecological footprint concept is closely linked to the carrying capacity concept; therefore, a comparison was made between the value obtained from the calculation of the

Ecological Footprint and the load capacity value of the region in which the MAAS operates, that is Sicily. Considering the total hectares of Sicily of 2,583,200, the value of H_n obtained can be refuted with this value, in order to understand how much the activity of the MAAS affects the territory in question.

HnJan/Feb2020/ carrying capacity: 42.546,37/2.583.200= 0.0164 = 1.64%

HnJan/Feb2021/ carrying capacity: 27.388,22/2.583.200=0.0106 = 1.06%

Thus, in the periods considered, the activity of the MAAS accounts for 1.64% and 1.06% respectively on the carrying capacity of Sicily. In conclusion the activity of the MAAS as a whole in the months considered possesses a rather low Ecological Footprint, although, by improving some aspects of its management, this value could even lower to zero and consequently impacting even less.

4. Concluding remarks

The calculation of the Ecological Footprint is considered fundamental in order to monitor the quality and environmental sustainability of an enterprise and leads to numerous benefits. In fact, companies are committed to defining a system aimed at identifying and implementing effective interventions to reduce energy waste and emissions, achieving economically efficient and environmentally sustainable results. The main benefits can be divided into three categories:

- Environmental: less air and water pollution, energy saving and LCA integration in the company strategy;
- Economic: cost reduction, stimulation of innovative strategies and creation of new market outlets;
- Social: better organization of the company and improved relations with all categories of stakeholders.

But, at the same time, it contributes to increasing professional opportunities and collaborations, to technological updating, to increasing revenue, to access to tax benefits, to have greater awareness of the company's environmental performance and the increase in the company's green reputation.

By measuring this indicator, the MAAS will be able to keep up with a constantly evolving and increasingly environmentally friendly world, in fact, the company will have the opportunity to gain a competitive advantage within the market in which it operates compared to its competitors, but, at the same time, must ensure a certain level of sustainability and compliance with standards.

Thus keeping a rather low footprint will help in its small to achieve higher level goals. In addition, the Ecological Footprint is also considered a tool of communication and awareness from which the company can also benefit from the point of view of its image and therefore from the point of view of Corporate Social Responsibility.

In conclusion, we can say that there are solutions to reduce the environmental impact and if companies are able to keep up with the technology, they will be able to implement them. To this end, it is important to make companies increasingly aware of important issues, including their activities.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 689-695

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

APPLICATION OF SOCIAL LCA TO A PILOT PROJECT MONITORING THE CHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLES*

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Abstract

In recent years, the issue of mobility has taken on a prominent position in the international debate. The movement of people and goods is essential to meet the needs of the community, but the progressive growth of the propensity to move involves a series of negative effects from an economic, social and environmental point of view. For this reason, one of the main tools for improving the environmental and energy efficiency of transport is the electrification of vehicles. The growth of the electric mobility market does not depend exclusively on the development of electric vehicles but involves an investment and a management component that refer to the installation of recharging points at specific stations and related maintenance. This paper is based on BaxEnergy Italia S.r.l., a technological company, which evaluated, through the S-LCA, the social and socio-economic aspects of the software solution designed and developed to monitor the functioning of public charging infrastructures for electric vehicles.

Keywords: electric mobility, s-LCA, software solutions, sustainable mobility

1. Introduction

In the current historical moment, the issue of mobility assumes a dominant role in the political, economic, social and environmental landscape, including one of the most important sectors of a country's development, that of transport (Ingrao et al., 2021).

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The transport sector, if on the one hand it allows to satisfy the need to move from one place to another and to contribute to the personal, social and economic growth of the individual and of the community to which he belongs, on the other it is the main responsible emissions of greenhouse gases into the atmosphere, which alter the climate, and other negative impacts, including air and noise pollution, road congestion, the increase in diseases associated with the breathing of unhealthy air, the high number of accidents, damage to the soil and the historical, artistic, landscape and cultural heritage and the strong dependence on non-renewable energy sources, such as oil.

Among the various forms of pollution, atmospheric pollution is the most worrying. The engine of the vehicles, currently in circulation on the road, is powered by fuels, such as gasoline and diesel, which through the high temperature combustion of fossil fuels generate energy by releasing CO_2 and other pollutants into the atmosphere (La Cagnina et. al, 2020). The data show that the transport sector is responsible for 30% of total CO_2 emissions in Europe, of which 72% comes from road transport alone and, specifically, 60.7% is determined by the circulation of private vehicles (Guillot, 2019).

For this reason, the European Union (EU), over the last few years, has been working to ensure that the transport sector contributes to accelerate the energy transition process, through less dependence on fossil fuels and a significant reduction of emissions (Regulation 2019/631/EU). One of the main tools to achieve this goal is represented by the electrification of vehicles. On the one hand, the recent evolutions of the reference context, such as climate change, energy security and the increase in oil prices, have favored the electric transition, but on the other hand, the high costs to produce electric vehicles, the lack of development of innovative technologies and the absence of a capillary charging network requires the establishment of coordinated action between car manufacturers, battery manufacturers, energy suppliers and distributors (Ingrao et al., 2019).

Sustainable mobility, in this sense, can represent a virtuous tool for ensuring sustainable development, through a fair balance between meeting current needs, protecting the environment and protecting future needs. According to the "World Business Council for Sustainable Development", "sustainable mobility means giving people the opportunity to move freely, communicate and establish relationships without ever losing sight of the human and environmental aspects, today as well as in the future" (Federazione Internazionale dell'Automobile, 2015).

Among the 17 Sustainable Development Goals (SDGs), contained in the 2030 Agenda, approved by the United Nations General Assembly in September 2015, SDGs 7, 11 and 13 are perfectly linked to the theme of sustainable mobility (Cavalli, 2018). In particular, Objective no. 7 "Clean and Accessible Energy" highlights that the use of fuels from nonrenewable sources damages the quantity of consumption and the quality of the atmosphere. Energy efficiency and the fight against climate change have been achieved through an energy transition that sees the use of sustainable energy sources with low or even zero carbon emissions as a protagonist. Thus, energy is a central, cross-cutting issue in modern economies and, in particular, within the European Union. Among the Green Deal's objectives, it is particularly important to raise the level of ambition in cutting emissions from 40% to 50%-55%, which, together with the goal of climate neutrality by 2050, has a strong impact on energy policies, involving in particular the building and transport sectors, manufacturing and industry (Di Marco, 2020). Objective no. 11 "Sustainable Cities and Communities" provides for a change in urban space as it is the main responsible for energy consumption, waste accumulation and various forms of pollution, such as atmospheric and acoustic pollution. Finding the right balance between mobility, movement of goods and people, protection of the environment and public health is the key to ensuring urban sustainability. It is important to point out that the urban population has reached 55% of the world's population today and is expected to reach 66% by 2050: an almost unstoppable process, dictated by the many opportunities that cities offer, including education and employment, access to social services, cultural and political participation (Cavalli et al., 2019). Finally, Objective no. 13 "Fight Against Climate Change" provide for the adoption of tools to raise awareness in the community and intervention policies aimed at combating climate change. The causes of this phenomenon can be traced back to some processes, such as the combustion of fossil fuels, deforestation, livestock farming and the emission of greenhouse gases into the atmosphere deriving from human daily and work activities (ASVIS, 2015). According to scientists, the risk of irreversible large-scale changes increases dramatically beyond this threshold, which is why countries have agreed to aim to limit warming to 1.5 °C to significantly reduce the risks and impacts of climate change (Commissione Europea, 2018).

The objective of the paper is to deepen the theme of sustainable mobility, environmental, economic and social assessment tools, such as the "Social Life Cycle Assessment" (S-LCA), based on UNI EN ISO 26000:2010 and UNI EN ISO 14040:2006.

This study understands how the design and implementation of technological and innovative solutions are able to favor the ecological and digital transition of the transport sector. To achieve this result, a case study was conducted at BaxEnergy Italia S.r.l., a technological company, located in Catania, specialized in the design and development of software solutions to interconnect, visualize, analyze and control critical infrastructures, mainly in the field of energy, telecommunications and transport.

This work is divided in three main parts:

- selection of case study: BaxEnergy Italia S.r.l, founded in 2010 in Hannover, Germany, is a technology company specialized in the design and development of software solutions to interconnect, visualize, analyze and control critical infrastructures, mainly in the energy, telecommunications and transport. With reference to the electric mobility market, the apparently simple recharging infrastructures from a technological point of view present the need to respond to precise requirements of functionality, operation, reliability and safety. In this context, BaxEnergy Italia S.r.l. has dedicated itself to a project that involves the creation and development of a software solution to monitor the operation of the charging infrastructures for electric vehicles. Furthermore, BaxEnergy Italia S.r.l. has been involved in identifying the social and socio-economic aspects of the software that have a positive impact on the stakeholders involved in the sector;
- the identification of the social and socio-economic aspects of the project was carried out through the application of the Social Life Cycle Assessment (S-LCA) to the software. The S-LCA is an assessment tool, used to examine the real and potential social impacts deriving from the life cycle of a product. The use of social performance indicators provides useful information from a social point of view to support decision-making and improve production and consumption systems to ensure the well-being of society, with a view to continuous improvement;
- analysis of results, drawing conclusion and formulation of recommendations for policy. In recent years, the electric vehicles market has achieved important results, destined to grow. A significant increase in the number of electric vehicles on the road will help achieve, according to the Green Deal Strategy, the ambitious goal of becoming the first continent with zero $CO2$ emissions by 2050. From this point of view, electric mobility represents one of the greatest challenges in the transport sector to combat the climate crisis. With 2.8 million electricity columns by 2030, compared to around 250 thousand today, software will be able to monitor in real time the operational and maintenance activities of the charging infrastructures to optimize the use of human resources with the growing number of installed electric vehicle charging stations (EVCs), reduce the reaction time of the maintenance team, scale the operation and management activities, implement sustainable

structures and processes, increase the EVC time availability to avoid production losses, centralize information to be available for analytics, optimize and automatize data exchange.

2. Materials and methods

The "Social Life Cycle Assessment" (S-LCA), based on UNI EN ISO 26000: 2010 (International Organization for Standardization, 2010) and UNI EN ISO 14040: 2006 ((International Organization for Standardization, 2006), is an assessment tool used to examine the real and potential social impacts deriving from the cycle life of a product (Norris et al., 2020).

The S-LCA has a structure characterized by the following four phases:

- Goal and scope definition;
- Social Life Cycle Inventory (S-LCI);
- Impact assessment;
- Interpretation of results.

The first phase consists in defining the purpose, object and methodological framework of the S-LCA. The second phase consists in the elaboration of an inventory characterized by a series of data collected on the main stakeholders of reference. The third phase consists in calculating, understanding and evaluating the social impacts deriving from the life cycle of a product. The last phase of implementation of the S-LCA aims to interpret the results deriving from the process of evaluating the life cycle of a product (Norris et al., 2020).

It is important to highlight that the S-LCI provides for the development of a series of social performance indicators to describe the impact categories linked to five main groups of stakeholders:

- Workers (sub-categories: child labor, fair wages, working hours, health and safety);
- Consumers (sub-categories: healthiness, transparency, waste management, feedback mechanisms);
- Local community (sub-categories: access to resources, relocation and migration, local employment);
- Society (sub-categories: contribution to economic development, technological development, corruption);
- Actors of the value chain (sub-categories: promotion of social responsibility, relations with suppliers, respect for intellectual properties) (Dreyer et al., 2006).

The main categories of impact, on the other hand, are:

- Protection of human rights;
- Working conditions;
- Well-being and safety of workers;
- Socio-economic repercussions on local communities and on society in general (Andrews et al., 2009).

As part of a social analysis, the use of social performance indicators is useful for making decisions, monitoring progress over time, considering alternative processes for the realization of a product and evaluating the social impacts on the well-being of the parties concerned (Kuhnen and Hahn, 2017)

3. Results and discussion

The application of the S-LCA, to the project carried out by BaxEnergy Italia S.r.l., made it possible to identify the social and socio-economic aspects of the software that have a positive impact on the following categories of stakeholders:

- workers;

- consumers;
- local community;
- society;
- actors of the value chain.

The "Workers" category refers to technicians who carry out maintenance and, in the event of anomalies, restore normal operation of the charging columns. The related analysis was carried out taking into consideration the sub-categories "Health and safety" and "Working hours".

The "Consumer" category refers to the owners of electric vehicles who use the recharging service. The related analysis was carried out taking into consideration the subcategory "Feedback mechanisms" to understand the level of satisfaction following greater accessibility and efficiency of the service.

The categories "Local community" and "Company" were analyzed jointly to understand how software can contribute, directly and indirectly, to improving Italy's economic and technological position within the international context and to increasing commitment public for issues concerning sustainability, in terms of reducing pollution and protecting biodiversity.

The subcategories of the "Local community" considered are "Local work", "Access to intangible resources", "Access to material resources" and "Healthy and safe living conditions" while, the subcategories of the "Society" of reference are "Contribution to economic development" and "Technological development".

The "Actors of the value chain" involved in the electric vehicle charging chain are:

- Technology Provider, the provider of the technology and the charging service;
- Car Manufacturer, the electric car manufacturer;
- Utilities, producers and distributors of electricity;
- Site Host, the owner of the site where the charging points are installed.

The software supports not only electric mobility, but also the business of the "Technology Provider" and the "Car Manufacturer".

As regards the impacts on "Utilities" it must be considered that as the number of electric cars increases, there is an increase in the demand for energy. In this regard, to respond adequately to this request and to make the green supply chain even further upstream, it is necessary to link the energy consumption of electric vehicles to production from renewable plants.

Charging stations can be installed not only in public areas, but also in private areas with public access, such as retail chains, hotels, restaurants, large-scale distribution, shopping centers and parking operators. The owners of these places, called "Site Hosts", can acquire a competitive advantage over their competitors as the offer of the recharge service, in addition to the activity focused on their core business, can represent a discriminating element for the choice to go to one place rather than another by consumers.

In particular, the results obtained from the application of this methodology were measured using the following quantitative and qualitative indicators:

- Improvement of the organizational efficiency of the recharge service by 15%.
- Reduction of the number of technical interventions in the field by 10%.
- Reduction of accidents at work by 5%.
- Reduction in the number of service anomalies by 15%.
- Improved customer support service by 20%.
- Prevention of malfunctioning situations of the recharge service by 15%.
- Optimization of human resources with a reduction in personnel costs of 15%.
- Reduction of the reaction time of the maintenance team by 20%.
- Reduction of service interruptions by 10%.
- Reduction of the number of complaints by 10%.

- Support for the growth of the electric vehicle market with consequent CO2 reduction of 15%.
- Increase of the employment level of 5%.
- Recovery of the transport sector hard hit by the COVID-19 pandemic.
- Support for the creation of a recharging network distributed throughout the Italian territory.
- Relaunch of the Italian economy.
- Acceleration of economic growth and development.
- Creation of technological and innovative development opportunities.
- Stimulation of collaboration between the public (universities, research centers) and the business world for investment in research and development.

4. Concluding remarks

The case study highlighted that the use of software solutions, capable of collecting and processing an enormous amount of data, leads to the analysis, management and enhancement, from an economic, environmental and social point of view, of a significant amount of information.

The goal of a company that operates in the field of "Big Data Analytics", such as BaxEnergy Italia S.r.l, is to draw, starting from a set of heterogeneous data, useful information to effectively support the decision-making process of organizations, which require this specific advice. In particular, the software in question allows, through the interpretation of the data and the performance of predictive analyzes, to prevent problems related to the provision of the recharge service. Real-time monitoring of data from columns, information on recharging sessions and alarms to detect abnormal operating conditions as well as scheduling ordinary and extraordinary maintenance, managing customer assistance and creating reports based on the Calculation of “Key Performance Indicators” (KPI) makes it possible to measure performance levels, to respond promptly to events and to find and resolve any bottlenecks.

Furthermore, the study conducted highlighted that especially in the context in which we live today, measuring exclusively the economic impacts, leaving aside the environmental and social ones, does not allow us to achieve the desired business results. Attention to the ecosystem that surrounds us, the protection of biodiversity, the protection of human health and the guarantee of fair working conditions are all essential issues for achieving the profit objectives of any organization.

The "Corporate Social Responsibility" (CSR) tools, such as the "Social Life Cycle Assessment" (S-LCA), by allowing an overall assessment of the reference area, represent not only a necessity, but also an opportunity to improve the reputation of a company, develop products compatible with the needs of the environment and society, attract qualified, motivated and loyal workforce, manage the relationship with current and potential customers, have greater access to credit, increase efficiency of its production processes, incentivize investments in Research & Development (R&D) and, finally, be competitive thanks to the high levels of innovation.

The reforms of recent years, both nationally and internationally, with reference to the adoption of the 2030 Agenda by the United Nations and the Italian Government's National Recovery and Resilience Plan (PNRR), stimulate and support development processes and future economic and social growth based on the green revolution and the ecological and digital transition.

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Procedia
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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 697-704

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

A DIGITAL CRYPTO ASSET BASED ON ECOLOGICAL FOOTPRINT TO ACHIEVE CLIMATE NEUTRALITY*

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Abstract

Climate change and the depletion of natural resources will trigger increasingly dramatic change. To undertake the ecological transition, it means adopting a new economic and social model that it is both a goal and a method. A crypto currency, based on Ecological Footprint reduction, can be used to support sustainable behaviors among people, enterprises and towns. The Ecological Footprint measures human consumption of natural resources against the Earth's ecological capacity (bio-capacity) to regenerate them. A win win model can be applied, by crypto assets, at regional, local and groups level in order to boost cooperation, compromise and bottom up participation to leads all stakeholder benefits. This new economical approach, we used to called Eco-Mutualism, can increases investments to achieve climate neutrality.The purpose of this paper is to briefly draft and mention risks about a digital blockchain token aiming to generates positive environmental impacts. Introducing crypto asset to meet climate and sustainable goals could represent an opportunity on gathering new private investments to modernize the agrifood industries and probably open a new digital market focus on monitoring the state of the health of the Earth.

Keywords: crypto currencies, ecological footprint, climate neutrality, global hectar, eco-mutualism

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*Selection and peer-review under responsibility of the ECOMONDO
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1. Introduction

The role of agriculture and land use sectors in achieving climate neutrality for 2050 in the European Union is an important issue for European, national and regional policy makers. On 14 July 2021, the European Commission adopted a series of legislative proposals setting out how it intends to achieve climate neutrality in the EU by 2050 detailing the intermediate target of an at least 55% net reduction in greenhouse gas emissions (GHG) by 2030 (COM, 2021). The package proposes to revise several pieces of EU climate legislation, including the Agriculture and Land-use Sectors, but it does not mention crypto currency initiative's to support the green transition. Improvements to the way we grow food is essential to be able to feed a growing population while also reducing emissions (Folke and Rockström, 2011). With agriculture being one of the main drivers of deforestation, the sector of agriculture, forestry and other land use is the largest contributor of global direct GHGs emissions: 24% or 11.76 Gt CO_2e/yr (IPCC, 2014). That's why it crucial to figure out new operative strategies in order to reach carbon zero emission in all their operations globally, from their production sites to their logistic transportation, as soon as possible. In the legislative proposals for the CAP 2021-27, Member States are each required to prepare a CAP Strategic Plan (CSP) that encompasses the measures to achieve climate neutrality (COM, 2018). But in the European Commission legislative proposal, mentioned above, it seems they have not yet caught the reforming power of the Decentralized finance (DeFi), based on crypto-currencies. The realization of these targets is feasible through funding and facilitating measures, based on a new emerging economy that can really support the necessary investments for the operators of the agri-food chain.

Crypto-currencies are opening new economical perspectives, also based on a win-win model. The term can be applied to many aspects of daily living, and it is contrasted to the zero sum game or win-lose situation, where dominant factor is that at least one person wins while another loses. This new philosophical perspective, known as "Eco Mutualism", describes a symbiotic relationship, producing mutual benefits between human and nature. According to this point of view, some crypto emerging economic initiatives can be addressed to finance healing "Pro-Nature" human activities, instead personal business ventures. That's because crypto currency represents the cornerstone of a new political and economic paradigm (Russo 2020, a, b, c).

The final purpose of our emerging method is related to support those economic reforms in the path of the "doughnut ecomomic theory", published by Oxford economist prof. Kate Raworth. The Doughnut consists of two concentric rings: a social foundation, to ensure that no one is left falling short on life's essentials, and an ecological ceiling, to ensure that humanity does not collectively overshoot the planetary boundaries that protect Earth's life-supporting systems (Raworth, 2012). Between these two sets of boundaries lies a doughnut-shaped space that is both ecologically safe and socially just: a space in which humanity can thrive (Fig. 1).

The main objective of this study is to present a brief overview of cutting edge method, based on a win-win model. A new digital crypto currency based on ecological footprint reduction could be a valid tool to finance the agri-food chain's players ecological transition. Going through a quick overview of former applications, of the last decade, we will try shortly the Eco-mutualist's business model. From this point of view a crypto-currency based on ecological footprint reduction can become a strategic tool to gather more investments and support a European and national green conversion. This work includes the following 3 main topics:

- brief literature overview's of the current crypto currencies and blockchain solution focus on facilitating climate action;

- outline an experimental project: a fungible token, based on ecological footprint, that could represent a solution on gathering fund and reaching climate neutrality goals;
- conclusion, with a brief analysis about risks and limits, for entrepreneurs, stakeholders, policy and decision makers interested on introducing blockchain innovation.

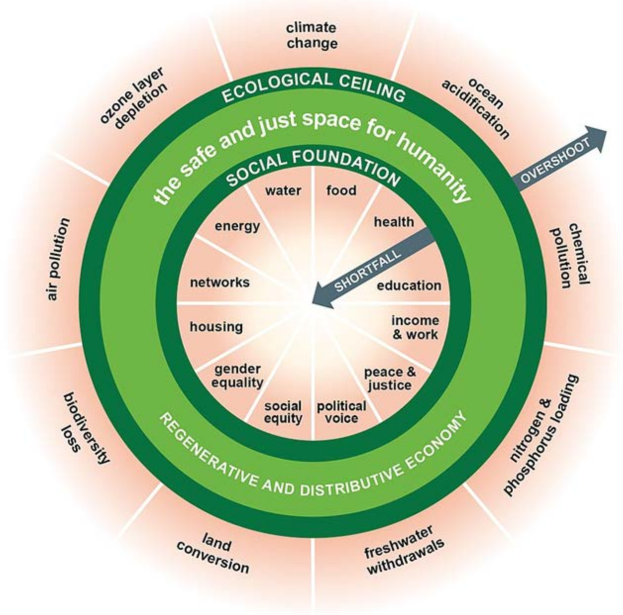

Fig. 1. Planetary boundaries and the doughnut model (Raworth, 2012)

2. Materials and methods

What is Crypto-currency? Crypto-currency is a digital currency which allows two people to transfer money to each other without it going through a central authority (such as a bank). It is secured by cryptography (hence the name), which makes it almost impossible to counterfeit. Where once crypto-currency was a niche subject, it has exploded into the mainstream in recent years (Colucci and Moiso, 2014; UNFCCC, 2021).

What is the blockchain? Blockchain is a distributed ledger technology (DLT) that connects different parties over the internet to provide a reliable record of transactions, without giving control to a third part or authorities. The 'block' refers to the individual record of each transaction, while the 'chain' refers to the fact that those records are linked in one chain (Atzori, 2015). Each time a transaction occurs, a record of that transaction is added to every participants' ledger. This allows public transparency, efficiency and security. Data are encapsulated in "blocks", which are chronologically ordered and cryptographically chained to form the immutable chain. To facilitate transactions, blockchain technology has evolved to power the smart contract, which is generally considered to be the second generation of blockchain applications. "Blocks" can contain data, for example emissions reduction or carbon footprint reduction, in a Smart Contract, which is stored on a blockchain and executed by nodes when the predefined trigger occurs. Therefore, smart contracts on blockchain are executed and enforced automatically, facilitating collaboration among not trusted peers without requiring a central agency (Zhao, Chan 2020).

Recently the topic of carbon neutrality supported by cryptographic assets has received increasing prominence, creating a veritable related literature that we will briefly report as follow. As early as 2012, the early work on the topic focused on the conceptualization and direct implementation of existing blockchain systems in carbon emissions trading (Alkawasmi et al., 2012). In 2016 SolarCoin was released. It is a blockchain system where people producing solar electricity are rewarded with crypto-currency and traded through the transparent consensus ledger.

In this project, it was shown that a 99% reduction in electricity consumption could be achieved by replacing a token's method of calculation on blockchain based on Proof of Work (PoW) with the Proof of Stake Time (PoST) consensus protocol (Johnson et al., 2015). Robert Leonhard in 2017, focused on voluntary personal carbon trading systems and proposed a hypothetical carbon marketplace on blockchain in which individuals conducting emission reduction activities are issued with carbon credits by virtual associations composed of climate scientists (Leonhard, 2017a). Another conceptual model, studied by the above-mentioned Robert Leonhard, is a smart contract-based carbon market, where companies voluntarily offset their emissions by funding carbon offset projects controlled by universities. He also identified some problems with blockchain-based carbon markets blockchain-based, such as administrative costs, verification costs, legal liability, insider trading, tokens such as securities, and crypto-currency price volatility (Leonhard, 2017a, b). Macinante (2017) studied how the networking of carbon exchange systems from different jurisdictions and related institutional framework in which the "transaction unit" functions as a means of inter-jurisdictional exchange. In Italy, more precisely in San Marino Republic, one of the best-known applications of the Blockchain to support zero-carbon policies is the Carbon Token developed on VeChain technology in San Marino. The project, presented in May 2020, aims to promote the adoption of virtuous behaviors by citizens, finalized to the reduction of CO_2 emissions. The project launched by San Marino Innovation - Istituto per l'Innovazione della Repubblica di San Marino S.p.A., in collaboration with the international certification company Dnv-Gl and the Chinese technology solutions provider VeChain.

What is the ecological footprint? The ecological footprint is a complex indicator used to assess human consumption of natural resources relative to the Earth's ability to regenerate them (Living Planet Report - www footprintnetwork org). The digital asset suggested in this article is a currency that pursues the clear and ultimate purpose of being a currency able of capitalizing beneficial actions for the planet, thus helping to accelerate the transition towards circular economy, reducing carbon emission and a sustainable future. The assessment of ecological footprint of an agri-food company has to be carried out for each location taken in analysis, using methodologies proposed by Global Foot Print Network. A key notion on Ecological Footprint is '*global hectare*' (gHa) that is defined as a hectare that is normalized to have the world average productivity of all biologically productive land and water in a given year (Global Footprint Network, 2006). The global hectare represents the world average bio-productivity; Since a single global hectare represents a single use, all the total global hectares added together represent the same amount of bio-productivity, and they can be added together to obtain an aggregate indicator: the Ecological Footprint. Humanity's demand, expressed as gHa, can be directly compared to nature's supply (bio-capacity), when both are expressed in global hectares. The demanded area may exceed the supply area if the demand for an ecosystem exceeds its regenerative capacity (Cancila et al., 2010). This is called an "overshoot" situation that produces an ecological deficit (Fig. 2).

Regarding the topic issued on this paper a noteworthy project, called Efforce can be considered a strinking representative case study, in the perspective of a ecomutualistic win win model related with decentralize finance (Efforce, 2021). This company aims to bring more liquidity, transparency, accessibility to energy savings market, minting a token on blockchain and financing directly the energy saving implementation. This idea is different by the other application mentioned above, especially because they aim to create positive benefit performance for the planet on the field of energy consumption. Efforce platform allows contributors to benefit from the energy savings generated by energy efficiency projects. The mechanism is the follow: Contributors can participate in energy efficiency projects by acquiring tokenized future savings.

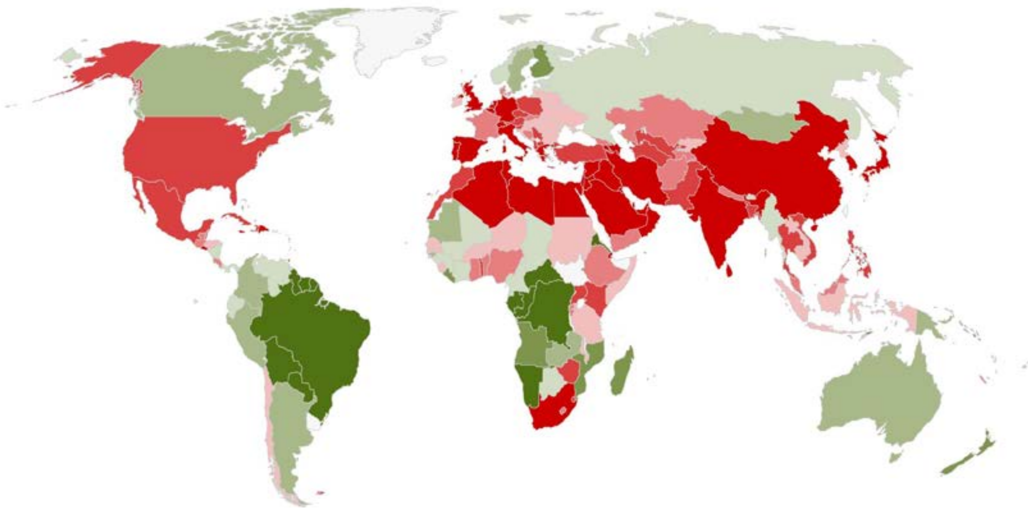

Fig. 2. Global ecological footprint map. In red countries with ecological deficit.

Companies benefit from energy efficiency improvements at no cost and the resulting savings are converted and written in real time on the blockchain. The resulting savings are redistributed by crypto token to the system's participant. By this way Efforce is able to gather financial investors willing to gain profits buying their crypto currency while helping companies interested on modernize their energy's implants. The tokenization of the energy saving, just like the carbon emission reduction, are possible by several smart contracts method, based on different crypto currencies such as Ethereum, Cardano, Algorand, etc.

3. Results and discussion

This paper suggests an experimental win-win scheme that underline three main key role of a blockchain-based ecological footprint reduction crypto-currency. Pursuing a new symbiotic interaction between human kind and nature, ecomutualist business model is focus on creating mutual benefit: on human side to develop sustainable business and on the "environmental" side to reduce their ecological footprint. The above mention Efforce token is drawing up a case study on this new economic framework. By following the same business model it is possible to figure out a strategy that it could be able to modernize agri – food company, going one step beyond the energy savings, but using their ecological footprint indicators in order to find financial contributors, willing to offset their carbon emission.

There are three main players that allow to develop this ecosystem:

1. *Contributors and consumers of carbon credit* (i.e., carbon emitters or polluters of any kind such as the energy industry): these are big companies who need to offset their ecological debit. They can participate in reducing ecological footprint projects by acquiring tokenized future reductions.

2. *Companies benefit from Ecological Footprint* reducing improvements at no cost and the resulting savings are written in real time on the blockchain. Improvements can be:

- fully circular packaging machines and process,
- optimize production while minimizing food waste, through intelligent technology and close collaboration with customers, NGO (as food banks) and suppliers,
- Carbon farming. Implementing carbon neutral organic production. Implementing new technology and process to reduced greenhouse gas emissions as much as they can,
- Switching to renewable energy and implementing energy saving projects,
- Offset GHG emissions. The compensation can be done, for instance, by planting trees, protecting rainforest, promoting biodiversity's projects, nurturing bee colonies or supporting similar no profit activities displayed in the CryptoCurrency Platform.
- *Company in Agrifood sector can also:*
- Cropland management (improved varieties, crop rotation, efficient use of fertilizer, reduced tillage, water harvesting, timing & precision)
- Grazing land management (deep rooting grasses, appropriate stocking densities, animal waste management)
- Livestock (improved feed and dietary additives to reduce emissions form enteric fermentation, improved breeds).

3. *Blockchain*. A smart contract redistributes the resulting savings to token holders, a percentage goes to the companies who are committed on reducing their ecological footprint and to the platform ecosystem (Atzori, 2015). Blockchain technologies "Validators" are an essential part of this ecosystem. They are accredited, globally distributed, technically competent consultants are incentivized to parametrize appropriately and onboard projects to an open architecture marketplace that matches interested parties generating and reducing footprint and carbon emissions.

Mechanism: how does it work? The higher the reduction of their ecological footprint will be, the greater the value that the crypto tokens will acquire on the market. In relation to the national biocapacity's curve, the greater the value the crypto asset will acquire on the market (Russo, 2020a) (Fig. 3).

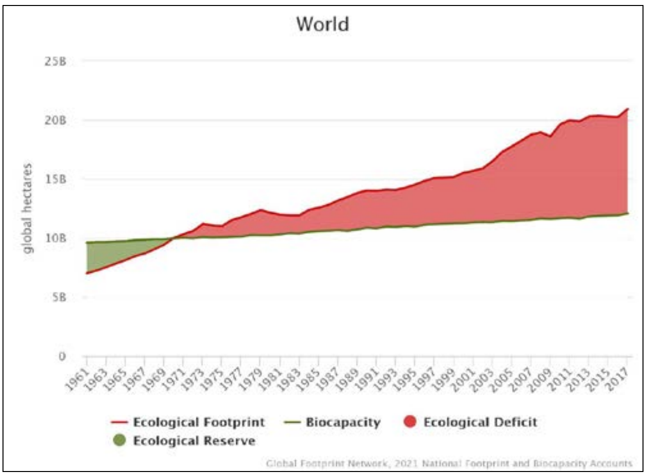

Fig. 3. Ecological Footprint vs. Biocapacity

The mechanism innovation of developing an ecological footprint reduction market open a particularly new financial channel, simple and accessible for all. Thanks to this crypto-currency, any economic company that wishes to implement solutions on its Ecological Footprint Reduction, will be able to meet other financial partner to accelerate their ecological savings directly. Throughout tokenization of the Ecological Footprint reduction, will be possible to meet other financial partner to accelerate the ecological transition of agri-food and diary industries.

4. Concluding remarks

This initiative aims to bring more liquidity, transparency, accessibility, and standardization to the agrifood sector opening a new worldwide economical perspective. Going one step beyond the carbon market, the Ecological Footprint Reduction with a clear minting and a tradable benchmark can become a helpful strategy to accelerate not only climate neutrality, but the achievements of sustainable global goals.

In conclusion according with Zhao and Chan (2020) research, for a comprehensive point of the topic discussed, despite the listed of benefits that blockchain could bring, there are also many risks raised as a result, especially in the design, engineering and management phase of blockchain technology. New risks associated with incorporating blockchain include:

1. Legal Risk

Blockchain protocols could be non-compliant with legislations and regulations; the right of ownership of carbon credits on a blockchain needs further legal enforcement. This is not the case with regard to Ecological Footprint credits as they are not precisely regulated; without a central authority, the legal responsibility for improper and incorrect operation of the blockchain remains unclear; there are potentially illicit activities on blockchains, such as money laundering.

2. Technical risk

Technical challenges, such as large-scale communication, big data storage, and imperfect cryptographic technologies hinder blockchain performance.

3. Protocol risk

Implementation of business and stakeholder agreements is based on predefined blockchain protocols. All terms and conditions of the scheme should be consistently applied and enforced by the protocol. Any errors in the protocol can lead the system astray or even against the initial purpose of the program. Poorly designed protocols also incur scalability, security, and data integrity issues.

4. Cyber risk

Insufficient crypto-currencies are at risk from hackers; external oracles - smart devices and production software are vulnerable to malicious attacks and malfunctions, resulting in corruption of data entered into the blockchain; key pairs representing identities on the blockchain can be stolen or destroyed.

5. Privacy risk

If automated carbon accounting is conducted, commercially sensitive data, such as production and operational data, is stored on the blockchain, which imposes the risk of information leakage.

6. Market Risk

As a fledgling technology, blockchain can be subject to user resistance. Insufficient transactions on blockchain would harm market liquidity.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 705-714

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

AN INTEGRATED MODEL FOR SUPPORTING AWARE DECISIONS OF COMPANIES IN A CIRCULAR AND SUSTAINABLE ECONOMY TRANSITION*

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Abstract

The world of business is rapidly changing, not only thanks to digitization and technological transformation, but also to address challenges related to the environment and climate change, and to reduce its impact in terms of waste, emissions, and raw materials. The COVID-19 crisis and the European Green New Deal have also accelerated this transformation process. In this context, companies must be able to evaluate their commitment and contribution to sustainable development, and to adopt lower impact business models. To achieve this aim, companies need easy and accessible measurement tools. The tools currently available are based on quantitative or statistical approaches and require the process of large amounts of data. This approach is easily accessible to large companies, while small companies or craft businesses may be scared off, as they may lack the structures and expertise. This study fills this gap by presenting an innovative and easy-to-access methodology for assessing sustainability in companies. Through a qualitative assessment of interdependence among nine categories grouping multiple environmental, social, and governance indicators, companies can evaluate their impact on the 17 SDGs and on the 3 ESG dimensions. The result can be used by the companies to design strategies for their businesses and plan future actions to improve circular models, thanks to the awareness and benefits gained from the analysis. The methodology has been applied to the case study of Ohoskin.

Keywords: sustainability, decision support systems, circular economy, ESG, SDG

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*Selection and peer-review under responsibility of the ECOMONDO

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1. Introduction

Nowadays companies operate in a changing and challenging world. While on the one hand there is the need to pursue a lasting profit and ensure satisfactory economic survival, on the other hand companies cannot ignore the necessity to protect our planet and the economic system requires to be changed accordingly (Lacy and Rutqvist, 2016). In this metamorphosis, sustainability, digitalization, and intelligent technological transformation are the three main trending drivers. Finally, the market environment is also changing in terms of what consumers are looking for. Indeed, it is clear that they seek sustainable products and services, and they are sensitive to the sustainable behavior of companies on environmental, social and governance issues (Buerke et al., 2016). Therefore, sustainability is now an essential factor for any company offering products or services.

Since the third industrial revolution, the linear economic model, based on the logic of “take, make and dispose”, has led to growth and prosperity, improving the living conditions of millions of people; however, some critical issues are currently present. The unsustainability of this economic model has been widely reported, as it conflicts with nature's prosperity and jeopardizes human survival and quality of life (Andrews, 2015; Jørgensen and Pedersen, 2018; Sariatli, 2017). Additionally, the COVID-19 pandemic has highlighted the necessity to change the economic paradigm. Never as in the last year we have been able to "*reflect and understand how necessary is to rethink the economy, in an attitude of greater proximity to the resources that the territories can give, aimed at reducing waste, to manage energy and materials more efficiently, to recover what can be recovered, to develop synergies and symbiosis between supply chains, industries and businesses*” (Bompan and Brambilla, 2021).

In the ongoing transformation, we are rethinking our economy, shifting from the linear to the circular economic model. Circular economy is based on the idea of restoration and regeneration, that is economic activities should strengthen rather than break down social and environmental resources (McDonough and Braungart, 2010). In the circular model, products and services are designed considering their relationships with resources and environment, so that their life cycle will make them returning matter and energy. In this way it is possible to reactivate a new life cycle without using new resources or expending energy for disposal. In the circular economy model the concept of waste disappears since they become new resources (secondary raw materials), closing the supply chain loop (Jawahir and Bradley, 2016; Jørgensen and Pedersen, 2018). Moreover, from the point of view of the companies, the circular economy model can contrast resource depletion, reduce pollution, and represents a source of cost reductions, new revenue streams and better risk management (Jørgensen and Pedersen, 2018).

In this framework, companies should be able to evaluate their commitment and contribution to sustainable development and adopt lower impact business models. Suitable measurement tools represent a helpful and useful way to reach this aim. Currently, the available tools, such as Life Cycle Assessment (LCA), SDG Action Manager and Cradle to Cradle (C2C), involve quantitative or statistical approaches and are usually accessible to large companies, as they require the processing of large amounts of data (Hauschild et al., 2018; McDonough and Braungart, 2010). Therefore, small companies or craft businesses may be scared off, as they may lack money, structure, and expertise to afford such measurement tools.

In this paper we present an innovative and easy-access methodology to evaluate sustainability in companies. Through a qualitative assessment of interdependence among nine categories grouping multiple environmental, social, and governance indicators, companies can assess their impact on the 17 Sustainable Development Goals (SDGs) and on the three Environmental, Social and Governance (ESG) dimensions. Our approach is grounded on a model-based decision support system (DSS) (Fabbri et al., 2011; Fei et al., 2009), for business management strategic initiatives and (Casini et al., 2009; Casini et al., 2015; Viaroli et al., 2012), for management of environmental ecosystems) having the SDGs framework, the Global Reporting Initiative (GRI) standard and indicators from the United Nations and the World Health Organization as knowledge base. More specifically, we use the Sparse Analytical Hierarchy Process (SAHP) method, which represents a novel and flexible instrument for the decision taking task, when only partial information on the problem is available.

2. Materials and methods

The assessment on sustainability reported in this paper is carried out through a methodology based on system thinking approach which helps us to analyze the complexity and delicate balance of the socio-political and natural ecosystems in which our businesses operate (Raworth, 2020). The method is based on the view of economic systems as complex systems (Arthur, 1999, 2015); more specifically, a company is viewed as a combination of human, technical resources, production processes and relationships working together to carry out a specific activity.

Standing in contrast to positivist and reductionist thinking, system thinking analyzes the linkages and the interactions between the elements that comprise the whole of the system. The approach is based on the belief that each single element of the complex system will act differently when isolated from the system's environment or other parts of the system (Senge, 2006; Stalter et al., 2016).

The evaluation process directly involves the managers of the companies and is based on an in-depth interview. The objective of the interview is to analyze the whole company by focusing on three macro areas: Corporate, Processes and Products, Relations. Approaching this process with a proper system thinking method allows us to find a list of identity labels for each macro area.

The next sections report the entire structure of the process.

2.1. Structure of the evaluation process

Moebeus (hiips://www moebeus com), an innovative start-up and benefit corporation which promotes circular economy models, has developed a dedicated web application to support the evaluator throughout the entire assessment process. Fig. 1 reports the functional diagram describing the software implementation.

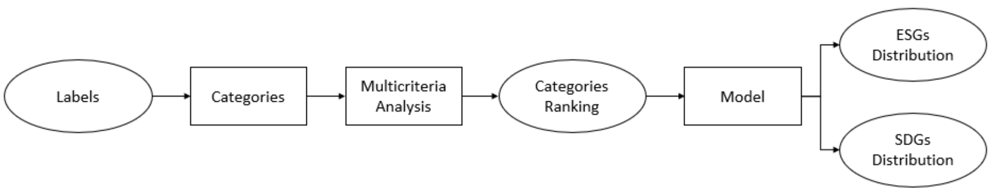

Fig. 1. Software functional diagram

As a first step, the labels identified through the analysis of the Company's corporate context are used as the business' knowledge base and distributed on a set of nine categories (see paragraph 2.1.1) representing themes and issues investigated by SDGs and GRI. This phase deeply involves interviewees, so that they are empowered in the evaluation of the current and potential value of the company's sustainability. In the next stage of the evaluation process, a self-assessment questionnaire is administered: the interviewees are asked to give a qualitative assessment by comparing selected pairs of categories. Then, multicriteria analysis is applied to rank the categories based on their utility/importance. The output of this phase is used as input for the model that will give the final distribution of companies' sustainable impact on SDGs and ESGs.

2.1.1. Categories

The first block of the evaluation process represents the set of categories used for the analysis. GRI standards and a set of indicators from the United Nations and the World Health Organization reported in SDG Compass (hiips://sdgcompass.org) have been analyzed and divided into nine clusters with respect to sustainability, ethics, and business issues they deal with. The resulting clusters were associated with 9 categories defined according to the literature (Ivanova et al., 2020), namely: Energy, Emissions, Waste, Infrastructures, Product, Social Ethics, Education, Governance, Environment.

By definition of the problem and from the structure of the data reported in SDG Compass (hiips://sdgcompass.org), it is easy to define a category as:

$$CAT_n = \{BT_{n,1}, BT_{n,2}, \dots BT_{n,m_n}\}, \qquad with\ 1 \le n \le N,\ N = 9, \tag{1}$$

where CAT_n is the set of all m_n Business Themes covered by Category *n*. Notice that Business Themes in CAT_n are not covered by any other categories.

Categories are used as alternatives in the multicriteria analysis.

2.1.2. Multicriteria analysis

The final scope of a multicriteria analysis method is the ranking and selection of the available alternatives based on their preference value. Additionally, to the scientific meaning, the multicriteria approach consists with a political exercise of negotiation and trade-off among necessarily subjective values and beliefs, which makes the direct involvement of end-users mandatory to reach meaningful and practical results.

In a real case, the ranking associated with an alternative might be unknown or difficult to determine directly. Indeed, it is often necessary to infer the intrinsic value of each alternative based on information about the relative importance of pairs of alternatives (i.e., if an alternative A has greater utility than B and B has greater utility than C then A has greater utility than C). The solution to this problem can be achieved by using specific decision-making tools implementing multicriteria analysis methods. Additionally, the number of pairwise comparisons among alternatives can be very high, and the assessment may require several times to be completed, or it can be difficult to measure the relative importance of certain couples of heterogeneous categories.

In the process object of this paper, we use the Sparse Analytic Hierarchy Process (SAHP) (Menci et al., 2018; Oliva et al., 2017; Oliva et al., 2018), a sparse and distributed approach to the centralized decision making AHP introduced by Saaty (1997). In particular, it is applied as an effective tool to make decisions when multiple and conflicting criteria are present. Both qualitative and quantitative aspects of a decision need to be considered and in scenarios characterized by partial information and local/distributed computing and decision-making capabilities (Oliva et al., 2017; Saaty, 1980). Indeed, SAHP extends the standards AHP method by accounting for situation where there is a lack of information, i.e., not all the pairwise comparisons are available due to their high number or to difficulty to compare heterogeneous categories.

Let's consider a set of *n* alternatives, each characterized by an unknown utility or relevance $w_i > 0$. In order to compute the value of such utilities, we start by creating a *pairwise comparison matrix* **S**. The matrix **S** is a $n \times n$ real matrix, where *n* is the number of alternatives considered. Each entry s_{ij} of the matrix **S** represents the importance of the *i*th alternative relative to the *j*th alternative, namely:

$$s_{ij} = \frac{wi}{wj} \qquad (2)$$

If $s_{ij} > 1$, then the *i*th alternative is more important than the *j*th alternative, while if $s_{ij} < 1$, then the *i*th alternative is less important than the *j*th alternative. If two alternatives have the same importance, then the entry s_{ij} is 1. The entries s_{ij} and s_{ji} satisfy the following constraint:

$$s_{ij} \cdot s_{ji} = 1 \qquad (3)$$

Obviously, $s_{ii} = 1$ for all *i*. The relative importance between two alternatives is measured according to a numerical scale from 1 to 9, as shown in Table 1, where it is assumed that the *i*th alternative is equally or more important than the *j*th alternative. The phrases in the "Interpretation" column of Table 1 are only suggestive and may be used to translate the decision maker's qualitative evaluations of the relative importance between two alternatives into numbers. It is also possible to assign intermediate values which do not correspond to a precise interpretation. According to equation 3, the entries of matrix **S** are by construction pairwise consistent. On the other hand, the ratings are unknown and should be estimated.

Table 1. Table of relative scores used for pairwise comparisons

Value of s_{ij}	***Interpretation***
1	*i* and *j* are equally important
3	*i* is slightly more important than *j*
5	*i* is more important than *j*
7	*i* is decisively more important than *j*
9	*i* is absolutely more important than *j*

The original AHP method consists in a way to compute the weights of the alternatives given the comparison matrix **S**. The problem can be easily solved by computing the dominant eigenvector of the matrix (Saaty, 1977).

Unfortunately, in a real context, as the number of alternatives grows, the data collection procedure may require a nontrivial effort and it becomes harder and harder to obtain complete information (Saaty, 1977; Liang et al., 2008). For this reason, we adopt the SAHP method that is able to deal with sparse information. In other words, instead of knowing the complete information on all pairwise comparison, we know only some decision maker's qualitative evaluations related to some alternatives, which lead to a sparse matrix **S**. If the comparison between *i* and *j* is not available, then s_{ij} is set equal to 0.

To solve the SAHP problem we use the sparse logarithmic least squares (SLLS) method (Menci et al., 2018; Oliva et al., 2018). With the SLLS algorithm we find a logarithmic least squares approximation $\hat{w}$ of the unknown utility vector w, such that:

$$\hat{w} = arg\ min_{q \in \mathbb{R}^n_+} \left\{ \sum_{i=1}^{n} \sum_{j=1}^{n} s_{ij} \left(ln(s_{ij}) - ln\left(\frac{q_i}{q_j}\right) \right)^2 \right\} \qquad (4)$$

In the case of $s_{ij} = 0$, the value of the corresponding summand $0\ln(0)$ is taken to be zero which is consistent with the limit:

$$\lim_{x \to 0^+} x\ln(x) = 0 \qquad (5)$$

This leads to the final ranking of alternatives.

2.1.3. Model

The evaluated ranking of available categories is then used as input for the model in order to retrieve the weights that the sustainability-oriented actions the company performs have on ESGs and SDGs.

Let's define the set of SDGs as $SDG = \{SDG_1, SDG_2, \ldots SDG_Z\}$, where $Z = 17$. From data structure reported in SDG Compass (hiips://sdgcompass.org), we can associate to each $BT_{n,i}$ a subset $SDG_{n,i} \subset SDG$. Using the definition of category reported in Equation 1 it is possible to build a directed acyclic graph $G = \{V, E\}$, reported in Figure 2, which allows us to map categories into SDGs.

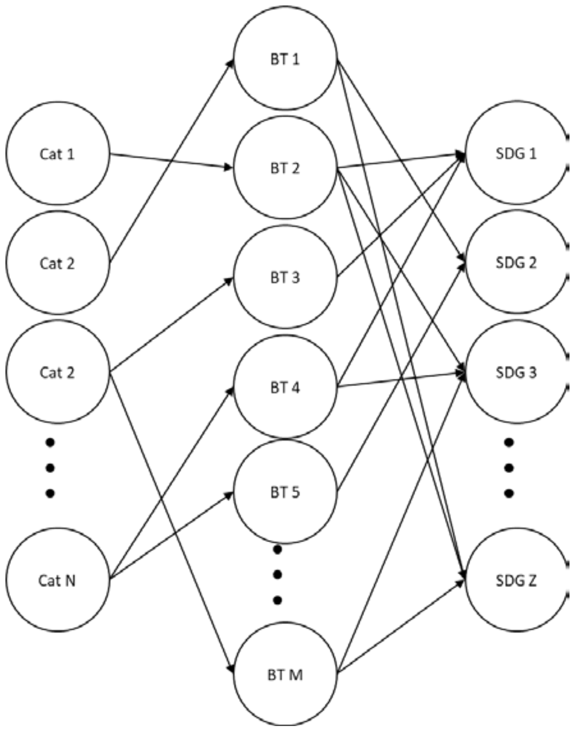

Fig. 2. Structure of the network

Each category CAT_n can be represented by a node of the graph. From the definition of category reported in Equation 1, we introduce m_n outgoing edges from CAT_n to all its elements $BT_{n,i}$, also represented as nodes of the graph. Additionally, from each $BT_{n,i}$ starts a certain number of outgoing edges towards the elements of $SDG_{n,i}$, which are also nodes of the graph. From the graph theory we can easily note that categories are the sources (i.e. the number of in-going links, represented by the in degree $\delta^{in}(CAT_i)$, is equal to zero), Business Themes represent the middle layer and SDGs are the sinks (i.e. the number of out-going links, represented by the out degree $\delta^{out}(SDG_i)$, is equal to zero) of the network defined on the graph. The defined network can be used to propagate the category weights $WCAT = [WCAT_1, WCAT_2 \ldots, WCAT_N]$, obtained as output of the multicriteria analysis, to SDGs by defining the weights of the nodes as follows:

$$WBT_{n,i} = WCAT_n, \quad \forall\, i = 1, \ldots m_n \tag{6}$$

$$\widehat{WSDG}_j = \sum_{BT_{n,i} \in n^{in}(SDG_j)} WBT_{n,i}, \quad \forall\, j = 1, \ldots Z \tag{7}$$

$$WSDG_j = \frac{\widehat{WSDG}_j}{\sum_{z=1}^{Z} \widehat{WSDG}_Z}, \quad \forall\, j = 1, \ldots Z, \tag{8}$$

where $N^{in}(SDG_j)$ represents the in-neighbors of node SDG_i (i.e., the set of nodes with outgoing edges toward SDG_j).

This leads to a ranking for SDGs, which represents the distribution of companies' sustainable impact on SDGs. Equation 8 is used to normalize between 0 and 1 all the weights associated to each SDG.

Finally, to obtain the ranking of the ESGs, the map reported in (Berenberg, 2018) has been used, by assuming that the SDGs are associated to the three ESGs factors. Following this association, the weight of each ESG can be easily calculated as the average of the weights included into the SDGs.

3. Case study

Ohoskin (hiips://www ohoskin com) is an Italian startup that has developed and patented a made-in-Italy, cruelty-free, sustainable alternative to quality leather made with oranges and cacti. The vision of the company is to become the new circular-economy landmark for an ethical, sustainable, and guilt-free luxury. Ohoskin works from the design stage to create a sustainable product, protect the environment, and generate a circular economy without waste. Thanks to chemical, system design and agrotechnical skills, Ohoskin is able to transform by-products of the squeezing of oranges and cacti from the food and cosmetic industry into a biopolymer. The leather is then obtained by adding a phthalate-free PVC to the biopolymer to extend the life cycle of the product.

The goal of Ohoskin is to ensure a sustainable model of production and consumption, which encourages lasting, inclusive, and sustainable economic growth, enhancing the value of typical Sicilian products. This is obtained also thanks to the alliance with other Italian companies operating in chemical, system design, and agrotech industries and through the implementation of a circular business model that gives new life to what would otherwise be destined to waste.

5. Results and discussion

In order to evaluate Ohoskin's positioning on ESGs dimensions and its contribution in achieving SDGs, the entire evaluation process described in Section 2 has been applied. At first, an in-depth interview was conducted: the three macro areas, Corporate, Processes/Products and Relations, were analyzed and discussed with company's managers. This first step of our evaluation process led to the definition of the main identity labels which have been used as a useful knowledge base for the self-assessment questionnaire. The evaluation of interdependence performed through the Moebeus' web application led to the following pairwise comparison matrix (9):

$$S = \begin{pmatrix} 1 & 1/5 & 1/5 & 5 & 1/7 & 0 & 0 & 0 & 1/7 \\ 5 & 1 & 1/3 & 5 & 1/3 & 3 & 1 & 5 & 1/3 \\ 5 & 3 & 1 & 7 & 1/3 & 3 & 1 & 5 & 1 \\ 1/5 & 1/5 & 1/7 & 1 & 1/7 & 0 & 0 & 0 & 1/5 \\ 7 & 3 & 3 & 7 & 1 & 3 & 1 & 5 & 1 \\ 0 & 1/3 & 1/3 & 0 & 1/3 & 1 & 1 & 1/3 & 0 \\ 0 & 1 & 1 & 0 & 1 & 1 & 1 & 3 & 0 \\ 0 & 1/5 & 1/5 & 0 & 1/5 & 3 & 1/3 & 1 & 0 \\ 7 & 3 & 1 & 5 & 1 & 0 & 0 & 0 & 1 \end{pmatrix} \quad (9)$$

Solving the SAHP problem by using the SLLS method reported in Equation 4 led to the following ranking of categories (10):

$$WCAT = \begin{pmatrix} Energy \\ Emissions \\ Waste \\ Infrastructures \\ Product \\ Social\ Ethics \\ Education \\ Governance \\ Environment \end{pmatrix} = \begin{pmatrix} 0.0384 \\ 0.1136 \\ 0.1701 \\ 0.0224 \\ 0.2255 \\ 0.05 \\ 0.1249 \\ 0.0465 \\ 0.2085 \end{pmatrix} \quad (10)$$

This result is used in Equations 6, 7 and 8 to obtain SDGs and ESGs rankings, according to Fig. 3. The results show that Ohoskin is a company which has a more relevant contribution to the environmental dimension than to the social and the governance ones. From our evaluation process, it is clear that the main SDGs impacted by Ohoskin are: 15 - “Life on land”, 6 - “Clean water and sanitation”, 12 - “Responsible consumption and production”, 8 - “Decent work and Economic growth” and 13 - “Climate action”. Figure 2 highlights also all the identity labels impacting the three ESG dimensions and the effects they have on the major SDGs. Moreover, Ohoskin shows a good propensity towards Environmental (39%) and Social issues (36%), and a good, although slightly lower, interest for Governance topics (25%). Overall, the company exhibits a well-balanced distribution on the ESGs, thus certifying its ability to correctly allocate resources on the relevant sectors analyzed in this work.

These results were discussed and validated with company’s managers, who confirmed the validity of the results obtained as they are in line with Ohoskin sustainable objectives. Thanks to our evaluation process, Ohoskin has gained a clearer understanding and awareness of the value of its product and of its contribution to promote sustainable development. Considering this new information, Ohoskin is now able to provide to its customers qualitative insights into the product as well as the ethical and social commitment of the company.

Moreover, identifying the labels that mostly impact on ESGs and SDGs can help Ohoskin to design strategies and to plan future actions to improve its circular business models in terms of both efficiency and eco-design of processes.

Fig. 3. Case study results: identity labels and ESG, SDG ratings

4. Concluding remarks

Moebeus' innovative evaluation method is an important and powerful tool for any company to acquire greater self-awareness regarding the principles of sustainable development and the transition to the circular economy. Through the identification of the distribution on ESGs and the contribution on the SDGs, the company itself acquires a new perspective of development and growth. Moreover, it can identify strategies to be implemented in order to improve its efficiency and effectiveness and to respond more competitively to the current market, while at the same time, ensuring the environmental sustainability. This change of perspective can give back to the company identification of the advantages and opportunities that the circular economy offers.

Acknowledgements

We thank the Prato Museo del Tessuto for facilitating stakeholders networking within the "Stand Up! Capacity building program" project, and Adriana Santanocito and Roberto Merighi from Ohoskin for being evaluated by Moebeus.

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Procedia Environmental Science, Engineering and Management **8** (2021) (3) 715-724

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 26th-29th October, 2021, Rimini, Italy

VALORIZATION OF WASTE PLASTICS IN DURABLE ASPHALT CONCRETE: THE GENOVA SAN GIORGIO BRIDGE*

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Abstract

As is well known, Genoa San Giorgio is the motorway viaduct that crosses the Polcevera torrent and the Genoese districts of Certosa, Sampierdarena and Cornigliano.
Inaugurated on August 3rd, 2020, the architecture of the new bridge was designed by the architect Renzo Piano (Studio Renzo Piano Building Workshop) and donated to the city of Genoa. The project was developed by Italferr (Gruppo delle Ferrovie dello Stato Italiane) and carried out by the PerGenova consortium.
Less known is the fact that the highway pavement was made with a new technology that allows to reuse hard plastics which normally end up in waste-to-energy plants because they are not reusable within the traditional recycling processes. Properly selected and treated, these plastics are mixed according to a patented formulation that includes the use of graphene. The graphene-enhanced modifier allows to significantly improve the physical-mechanical characteristics of the asphalt pavement, increasing its service life and reducing the need for maintenance.
Donated to the city of Genoa by Iterchimica, with reference to the wearing course only (4 cm), the new technology has allowed to recover plastics otherwise sent to waste-to-energy plants, significantly reducing the environmental impact and ensuring user safety over time.

Keywords: waste plastic, environmental impact, Genova Bridge, asphalt concrete

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*Selection and peer-review under responsibility of the ECOMONDO

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1. Introduction

Addressing climate change and promoting sustainability are becoming worldwide needs that must be taken into account with respect to every human activity. Many countries are adopting containment policies and some governments are introducing incentives to encourage the use of sustainable products. One of the most popular and used materials in the world is plastic because it is light and easy to handle and quite cheap. The correlated problem is due to its management at the end of life. In fact, less than 10% of plastic is reused or recycled, even though it would be the best method thanks to its lower environmental impact. It should be considered that not all plastic is nowadays recyclable and about 60% of the plastic used has ended up in either a landfill or it is incinerated. Plastic waste management is demonstrated to be different from State to State, depending on local regulations, even though recycling plastic allows to reduce the atmospheric emission (D'Ambrières, 2019).

Nowadays, about 300 million tons of waste plastic are produced every year. The major pollution source in the oceans is represented by the 8 million tons of plastic that every year are carried by rivers from deep inland to the sea. Most plastic items never fully disappear but become micro-plastics that are eaten by fishes and consequently by humans (UNEP, 2018).

Reducing directly the use of plastic would clearly be the most direct way to reduce plastic waste. Due to its heterogeneity, it is fundamental to recycle waste plastic considering the inherent complexity and the variable chemical nature of the plastic waste (generally referred to as plast mix). Many industries have been working to find new methods to recycle the plast mix exploring alternative methods to repurpose waste plastics that can be utilized in civil infrastructures, such as wood-plastic composites, concrete blocks and mortar.

With respect to asphalt pavements, one of the ways of achieving sustainable infrastructures and enhance the field performance of pavements is the addition of selected polymer types to the asphalt concretes. The traditional solution consists of the use of Polymer modified Bitumen (PmB) that is produced using Styrene-Butadiene-Styrene (SBS). The innovative one involves the direct incorporation of polymers or polymeric compounds during the asphalt concrete production phase.

Today, recycled plastic includes multiple major categories such as polyethylene terephthalate (PETE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), acrylonitrile butadiene styrene (ABS), ethylene vinyl acetate (EVA), polycarbonate (PC), and polyurethane (PU) (Kalantar, 2012).

Since the early 2000s, different methods were attempted to include plastic material in asphalt concrete constituting the so-called "plastic roads" (Wu, 2020). Different trials were conducted around the world: Australia, Indonesia, India, United Kingdom, Netherlands and United States. Overall, such experiences had questionable outcomes and it became clear that not all polymers are suitable for asphalt concrete (AC) modification. According to the different type of polymers, it is known that the performance and the service life can increase the pavement when adequately blended with asphalt at the optimum conditions. However, it should be noted that not every kind of plastic, including waste plastic, are suitable for AC (Kamala, 2021). While the use of some types of plastic contributes to achieve performance improvements, other types may result ineffective or even detrimental. It is of the utmost importance to include the material in the most effective way, considering method of incorporation (either wet or dry), dosage, mixing temperature, chemical nature and compatibility and recyclability.

If the use of waste plastics for asphalt concrete has been known for more than 20 years, it was not until 2014 that recycled specific and selected waste plastics were combined with graphene and other products, such as the Graphene-enhanced Waste Plastic super-Modifier (GWPM), to improve significantly the physical-mechanical properties of asphalt pavements, when compared to the technologies which are currently in use. The production process and formulation of GWPM are protected by patents.

GWPM allows therefore to enhance the service life and reduce the maintenance of asphalt pavements. In fact, due to the rise in traffic volumes and vehicles' weight, the requested performances of asphalt concrete have significantly increased. The GWPM was used in several projects for improving durability and reducing environmental impacts and one of the most important applications was in the Genova San Giorgio Bridge project.

2. Genova San Giorgio Bridge

The Genova San Giorgio Bridge (Fig. 1) is a crucial part of the motorway E25 (the European road that crosses Belgium, Netherland, Luxembourg and Switzerland) and it represents the nerve center for connecting north-central Italy with southern France. Also, the bridge constitutes the main infrastructure element between the eastern area of Genova, the PSA Genova Prà port terminal, the Cristoforo Colombo airport and the Genova industrial area. The Genova San Giorgio bridge replaced the Polcevera viaduct, also called Morandi bridge, which was inaugurated in 1967 and collapsed on August 14th, 2018 and was finally demolished in 2019. The short timing used for design and reconstruction represents a model for the future Italian infrastructure in light of its social, economic and strategic significance.

Inaugurated on August 3rd, 2020, the architecture of the new bridge was designed by the Renzo Piano Building Workshop considering the anthropized area and the condition of urban bridge. The project was led by Italferr and it was constructed by the companies Webuild S.p.A. and Fincantieri Infrastructure S.p.A. The bridge consists of a steel-concrete structure, it is 1,067 m long, approximately 31 m wide and 45 m high. The structure is composed of 19 spans supported by 18 piles of reinforced concrete. Each pile is positioned at a 50 m interval with the exception of three central spans, which correspond with the crossing of the Polcevera River. The bridge is regularly monitored by four robots designed by the Italian Institute of Technology that inspect the lower structure of the bridge.

With respect to the pavement structure, the construction was aimed to:

- Ensure the safety of users;
- Increase the service life and reduce the maintenance;
- Improve the resistance to traffic-induced tangential actions;
- Reduce the environmental impacts in general;
- Reduction of the spray effect caused by the rainwater;
- Improve the load distribution and protection of the support surface;
- Reduce noise emitted by tyre rolling.

The pavement structure was designed using the Mechanistic-Empirical Pavement Design Guide (MEPDG) with a 20-year analysis period. Developed by the National Cooperative Highway Research Program (NCHRP), the MEPDG method consists of the empirical-rational evaluation of the performances that the pavement will be able to offer when subjected to the traffic conditions foreseen in the project and in the specific local climatic conditions of the worksite.

Fig. 1. Laying of the asphalt mixes on the Genova San Giorgio Bridge (July, 2020)

The inputs of the calculation are material properties, thicknesses, sub-base characteristics, climate and traffic information. The MEPDG method allows to compute the progress of different types of deterioration over time (e.g., fatigue cracking and rutting) based on the load-induced stresses, strains and displacements of the pavement. The overall damage expected in the structure during the analysis period is used to either approve or modify the initial design. In line with the provisions of the most recent European legislative guidelines in terms of saving natural resources, recycling and long-lasting materials, the technical proposal was based on the possibility of implementing innovative technology to modify the asphalt concrete and therefore enhancing the physical-mechanical behaviour of the asphalt pavement.

Therefore, for the design of the bridge pavement, two different strategies were compared: on one side the one with original mixtures that featured the use of PmB, on the other side the one with the proposal mixtures that used GWPM (Kamala, 2021). The innovative AC produced with neat bitumen and GWPM was also checked through multiple laboratory tests such as wheel tracking test (EN 12697-22), indirect tensile strength (EN 12697-23), fatigue resistance (EN 12697-24), and stiffness modulus (EN 12697-26). The laboratory mechanical results confirmed the improved performances (Marradi, 2020).

In light of what was observed, the use of GWPM appeared as the most effective solution to achieve the required targets in terms of both field performances and sustainability. Given the structure of the bridge and its connecting ramps, three different types of sections were designed embankment (46 cm), viaduct (12 cm), and ramp (39 cm). The structure details of each section type are listed in Table 1. In order to achieve the performance and sustainability goals the use of GWPM was planned for the wearing course layer (tyre rolling surface). According to the original design, it is important to highlight that a Stone Mastic Asphalt (SMA) was used for the wearing course. As reported by the European Asphalt Pavement Association (EAPA) SMA-type wearing layers are the most suitable AC surfaces for bridge decks (EAPA, 2013).

Table 1. Summary of the planned section of the project

Layers	*Embankment (cm)*	*Viaduct (cm)*	*Ramp (cm)*
Wearing Course – SMA (Neat bitumen + GWPM)	4	4	4
Intermediate Course – AC (traditional PC)	7	7	7
Asphalt Waterproofing Membrane	-	1	-
Base Course – AC (traditional PC)	15	-	13
Highly ductile subbase layer in cement mix	20	-	15
TOTAL	46	12	39

In addition, it has been reported that adopting the SMA-type wearing course guarantees not only high resistance to permanent deformation and to fatigue, but also a reduction of the acoustic emissions if compared to traditional surfaces, according to its particular “negative” texture (SILVIA, 2006). Figure 2 shows how the pavement structure appears in excellent condition one year after the construction, confirming the promising impact of adding GWPM to the AC mixtures performance.

Fig. 2. Genoa Bridge pavement (2021)

3. GWPM and Ecopave Project

The development of GWPM was conducted as part of the Ecopave Project: “Development of super modifier for asphalts produced by using plastics from industrial waste and separate waste collection, usually sent to waste-to-energy plants, and graphene-based materials additive, for the construction of ecological, long-lasting and endlessly recyclable roads”. The project was funded by Lombardy’s 2014-2020 Regional Operational Programme (ROP), under the European Regional Development Fund (ERDF).

The main goals of the program were multiple, including strengthening research, technological development, innovation processes, encouraging the competitiveness of small and medium-sized enterprises and promoting sustainable urban development.

Iterchimica was the leading partner of Ecopave Project and the other partners involved were: G.Eco, a company with public and private capital jointly owned by the A2A Group which deals with the separate collection, recovery, management and disposal of all kinds of waste; Directa Plus, one of the world’s largest producers and suppliers of products based on 100% pure graphene nanoplatelets; the University of Milan Bicocca (UNIMIB) with the Department of Environmental and Earth Sciences (DISAT).

The main research objectives were to:

- Reuse the plastic normally sent to waste-to-energy plants;
- Determine the limits of the “plast mix”, deriving from Municipal Solid Waste (MSW), and to define the applications of technical selection;
- Determine the chemical formulation of the new super modifier GWPM;
- Exploit the mechanical performances of graphene;
- Substantially increase the performance of ACs with respect to both the use of neat bitumen and PmB;
- Improve the Life Cycle Assessment (LCA) of asphalt pavements in comparison to the current technologies (e.g., neat bitumen and PmB).

The research ended with the filing of two patents: one for the product and one for the production process.

In general, the main AC mixture modification techniques with polymers are two:

- Wet method – based on the bitumen modification (e.g., PmB), in which the rheology of the neat bitumen is modified by using one or more polymers (UNI EN 12597, 2004). The performance is increased in comparison to the neat bitumen, which is ensured by the phase inversion obtaining through the processing in a specific modification plant. The modified bitumen is then mixed with aggregates during the AC production phase;
- Dry method – based on the direct AC modification, in which the performance improvement is achieved by adding the selected polymer or polymeric compound (also recycled) directly during the AC production phase through the mixing with aggregates and neat bitumen (e.g., crumb rubber and polymeric compound).

The GWPM was studied for dry method production. It appears in the form of grey-black coloured granules with an average diameter of 1÷4 mm, as shown in Fig. 3, and it is innovative because it is composed by:

1. Selected recycled plastics deriving from the recovery of objects composed of “hard plastics” (for example toys, bins, boxes, tubes, tables, and chairs, etc.) that are industrially treated according to a patented process that includes the selection depending on the specific physical-chemical characteristics;

2. Functional base composed of different nature additives and its physical-chemical composition is protected by industrial secret;

3. Graphene pure nanoplatelets.

Generally, the GWPM amount is 4÷10% on the weight of bitumen, depending on the type of pavement to construct and the relevant performance to achieve, but it is always advisable to determine the optimal percentage through laboratory tests, as it may differ from the indicated ranges. The apparent density at 25°C of the product is 0.4-0.6 g/cm^3. The softening point corresponds to160-180 °C and the melt flow index (MFI) at 190°C with a load of 5 kg is 4-10 g/10’.

4. Environmental benefits of AC modified with GWPM – San Giorgio Bridge

In addition to ensuring the physical and mechanical performances required, depending on the quantities of the super modifier used, the AC with GWPM also allows to obtain various environmental benefits. In particular it allows to:

- Reuse hard plastics – approximately 9300 kg of hard plastics were used instead of being sent to waste-to-energy plants;
- Avoid emissions into the atmosphere – thanks to the lack of incineration 25110 kg of CO_2eq were not produced;

- Avoid the introduction of microplastics and toxic substances into the environment – leaching and Fish Embryo Acute Toxicity (FET) tests were performed on the materials;
- Reduce emissions during the production phase of the AC – the environmental performance of GWPM was compared to traditional technologies (i.e., GWPM vs. SBS) using Life Cycle Assessment (LCA) methodologies.

Fig. 3. GWPM granules

4.1. Life Cycle Assessment (LCA)

Through the Ecopave Project, the environmental benefits of GWPM were demonstrated using the Life Cycle Assessment (LCA). The LCA methodology was realized according to standards ISO 14040 and ISO 14044. The main phases were goal and scope definition, inventory analysis, impact assessment and interpretation. The three different technologies compared were AC with neat bitumen, AC with PmB, and AC with neat bitumen plus GWPM. The analysis was realized using OpenLCA 1.10 software and Ecoinvent 3.5 database with the impact methodology CML-IA baseline. The primary data was obtained by the asphalt concrete modifier manufacturer.

Two different analyses were done: "GWPM vs. SBS" (only comparing the polymers' production processes) and "GWPM AC pavement vs. PmB AC pavement vs. AC pavement" (comparing the performances and the service lives of the road pavement structures). The comparisons were done analysing the carbon dioxide equivalent (CO_2eq - "metric measure of the emissions from various greenhouse gases based on their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential") (Eurostat Statistics Explained) produced by different polymers (GWPM and SBS). The calculation for the production of GWPM includes production and packaging of recycled and raw materials, transportation to the production site, production and packaging of the final product, electrical energy and water and packaging disposal. The result is 305 kgCO_2eq per ton of GWPM, compared to 4000 kgCO_2eq per ton of SBS (Wildnauer et al., 2019). Considering the dimension of the San Giorgio Bridge, the new technology allows to reduce substantially the emissions by approximately 16654 kgCO_2eq, only for the replacement in the 4 cm of wearing course.

Although it would be necessary to conduct a dedicated LCA, with reference to the atmospheric emissions of the road pavement, it is nevertheless interesting to highlight the results obtained with Ecopave Project. One of the main scenarios was “pavements realized with three different technologies but with the same section and thickness”. Also considering the increase of performance and the reduction of maintenance needs using GWPM technology, potential environmental impact is reduced for all categories (abiotic depletion, acidification, eutrophication, global warming, human toxicity, marine aquatic ecotoxicity, ozone layer depletion, photochemical oxidation and terrestrial ecotoxicity) from 57% (vs PmB) to 70% (vs neat bitumen) (Capuano et al., 2020).

4.3. Leaching test – microplastic determination and toxicological analysis

Also for the leaching test, the three different formulations were checked: neat bitumen, PmB and neat bitumen plus GWPM. All AC mixtures were subjected to the same procedure for preparing the leaching samples: production of AC in the laboratory, simulation of aging with laboratory accelerated method (5 days in the oven at 85°C) ad production of leaching (UNI EN 12457-2, 2004).

For determining the possible presence of microplastic, a $ZnCl_2$ brine solution (1.73 g/cm^3) and cellulose nitrate filter were used. The procedure allows the extraction of plastic particles ranging from large fragments to microplastic particles. The samples were analysed with an infrared micro-spectroscopy (50-500 μm). The spectra results were obtained using diamond attenuated total reflection (ATR) and mercury cadmium telluride (MCT) single detector. The spectra were recorded in the range of 4000–600 cm^{-1} with a spectral resolution of 4 cm^{-1}, and the measurements were taken with 32 co-added scans. The counts did not display any significant presence of microplastics (Saliu et al., 2020).

The negative toxicological assay was determined using the Fish Embryo Toxicity Test (FET). In particular, it was used zebrafish embryos (OECD 236-2013 standard). The test allows to determine acute toxicity of chemicals on embryonic stages of fish. After filtering of leaches (0.45 μm), the total test timing is 96 hours and every 24 hours some observations are recorded for verifying the lethality, controlling coagulation of fertilized zebrafish eggs, lack of somite formation, tail-bud detachment and heartbeat. At the end of the exposure period, the eventual toxicity is determined based on the observations.

The tested leachates have not highlighted substantial effects of malformation or mortality on zebrafish embryos, showing no toxicological condition (hatching should be analysed better) (Saliu et al., 2020).

4.4. Waste hard plastics recycled

The use of GWPM in the wearing course (4 cm) would not only allow to guarantee the requested pavement performances and the less environmental impact indicated above, but it also allows to recycle about 9.300 kg of hard waste plastics, avoiding their disposal in waste-to-energy plants. Focusing on plastics, according to the report “Greenhouse gas emissions and natural capital implications of plastics (including biobased plastics) – European Topic Centre Waste and Materials in a Green Economy (2021)”, the Greenhouse Gas (GHG) emission of plastics depends on their chemical nature and conversion technique. In particular, 1 kg of plastic placed on the market causes an average of 2900 gCO_2eq and the incineration of the same plastic’s kilogram causes in addition 2700 gCO_2eq emission on average (Vanderreydt et al., 2021). With respect also to Municipal Solid Waste (MSW), the CO_2eq produced during the incineration depends on its composition and corresponds to about 673-4605 gCO_2eq/kg_{MSW} (Eriksson and Finnveden, 2009).

Therefore, considering the GWPM amount used for San Giorgio Bridge, the new technology has saved the emission of about 25110 kg of CO_2eq, just by the exclusion of incineration. It is also important to highlight that the GWPM-modified pavement is completely recyclable and it can be considered as any other type of Reclaimed Asphalt.

5. Conclusions

If, on the one hand, the world is trying to reduce environmental impacts through new sustainable production technologies, on the other hand, it is trying to recycle as much as possible the materials at the end of their service life. Recycling plastics is definitely one of the most challenging targets, both because not all plastics are easily recyclable and because the plast mixes that result from the recovery of municipal solid waste are inherently too heterogeneous to be reused directly without specific treatments.

The San Giorgio bridge in Genoa, inaugurated in August 2020, is best known for the reasons linked to its reconstruction, but less known are the environmental benefits obtained through the construction of the innovative asphalt pavement.

Through a dedicated design improvement proposal, the asphalt concrete with modified bitumen (PmB) have been replaced by the new technology that involves the use of neat bitumen and GWPM. GWPM is the result of ROP-ERDF 2014-2020 research which has allowed the development and patenting (formulation and production process) of the super modifier, through the recycling of hard plastics (normally sent to incinerators) and the addition of graphene.

Throughout the research that supported the development and the employment of GWPM in road pavements, it was possible to observe physio-mechanical improvement behaviour, comparing the AC produced with traditional technologies (neat bitumen and PmB) and environmental benefit (positive LCA, no microplastic production, and no toxic impact).

With respect to the San Giorgio Bridge in Genoa, the addition of GWPM to the surface layer allowed to ensure safety and to achieve both significant improvements in terms of performances and important environmental advantages: from the recycling of plastic otherwise sent to waste-to-energy plants to the reduction of CO_2eq emissions.

Acknowledgements

The extensive work done on this project required a collaborative approach from all the parts that were involved, from the project to the construction. Therefore, the authors would like to thank: Italferr, Webuild S.p.A., Fincantieri Infrastructure S.p.A., Giuggia Costruzioni S.r.l., Dynatest Italia, Iterchimica S.p.A., Poliedro S.r.l., and PerGenova Consortium.

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