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**Environmental
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**18th International Trade Fair of Material & Energy Recovery
and Sustainable Development, ECOMONDO,
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Selected papers (3)

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

Dr. Fava is the coordinator of the FP7 projects NAMASTE (on the integrated exploitation of citrus and cereal processing by-products with the production of ingredients and new food products) and BIOCLEAN (aiming at developing biotechnological processes and strategies for the bioremediation and the tailored depolymerization of major oil-deriving plastics). He also coordinates the Unit of the University of Bologna participating in the FP7 projects ECOBIOCAP and ROUTES (on the production of microbial polymers from different organic waste and food processing effluents).

Other projects are MINOTAURUS and WATER4CROPS (on the intensified bioremediation of contaminated waste- and ground-water and the integrated decontamination and valorization of wastewater of the food processing industry and of biorefineries), and ULIXES and KILL-SPILL (on the development of strategies for intensifying the in situ bioremediation of marine sediments polluted by (chlorinated)hydrocarbons and for the isolation and industrial exploitation of microbes from those matrices). He is the Past- and the current vice-chairman of the "Environmental Biotechnology" section of the European Federation of Biotechnology (EFB). He is member of the "Task Force on Industrial Biotechnology" of the Working Party on Biotechnology of the Organisation for Economic Co-operation and Development (OECD, Paris). Further, he is joining the "High Level Group on Key Enabling Technologies" and the "Expert Group on biobased products" of the DG-Enterprise and Industry of European Commission (Brussels), as well as the "Expert Group on eco-industries" of the JRC Directorate at the European Commission. Finally, he is the Italian Representative for Bioeconomy in Horizon2020 Programme Committee.



Grazia Totaro, born in 1976, has a degree in Chemistry (University of Ferrara), a Master's Degree in Science, Technology & Management with a specialization in Environmental Chemistry (University of Ferrara) and a PhD in Materials Engineering, about modification, characterization and applications of technopolymers (University of Bologna). She worked at the R&D Centre of Basell Polyolefins in Ferrara for 2 years in the frame of a project addressed to the development of a novel methodology for qualitative and quantitative analysis of additives in polymers. She also worked at ARPA, Regional Agency for Environment in Ferrara, division Water Analysis. Then she started working at the school of Engineering of the University of Bologna for a Ph.D. in Materials Engineering (2007-2010).

After that she had a scholarship "Spinner 2013" in cooperation with Reagens spa (San Giorgio di Piano) on novel PVC nanocomposites. Now she is post doc fellow at the same school on new polymer-based nanocomposites from renewable sources and inorganic fillers. She also worked at the laboratoire de Chimie et Biochimie Pharmacologique et Toxicologique (Université René Descartes) in Paris in 2001 and was visiting professor at the Ecole Nationale Supérieure de Chimie (Université Blaise Pascal, Clermont Ferrand, FR) in 2012. Dr. Totaro has about 13 scientific papers and several participations at conferences and scientific schools.

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ECO-PROFILES OF INNOVATIVE ENERGY SYSTEMS FOR DOMESTIC AND RESIDENTIAL APPLICATIONS*

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Abstract

The growth of distributed generation systems and the new release on energy markets of new generation technologies, on a small scale, causing advancements in research of new priorities in innovative energy systems "Smart buildings", able to generate, store and manage energy flows will become the starting point of the future distribution networks (smart buildings to smart grid). The goal of this study is to assess the eco-profile of 1 kWh of electricity, selected as a functional unit, generated by a solid oxide fuel cell system. The analysis was performed by applying the Life Cycle Assessment methodology, which allows to compare different products and services with the same function and to identify the most significant impacts to focus on, in order to improve the energy and environmental performance of the examined products/services. The study was performed by examining the entire life cycle of the devices, from cradle to grave.

Keywords: energy systems, greenhouse gas emissions, LCA, SOFC

1. Introduction

European energy policy has three objectives: fighting climate change, limiting Europe's dependence on imported hydrocarbons, and providing secure and affordable energy to consumers (European Commission, 2007).

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The great development of technologies powered by renewable energy sources in the latest years, has paved the way for a larger diffusion of distributed generation systems (European Commission, 2012a) and to a potential contribution to wards the reduction of CO₂ emissions and to the improvement of energy conservation (Beccali et al., 2012a; Beccali et al., 2012b; Beccali et al., 2013; Yadav and Srivastava, 2014). The distributed generation concept has changed the idea of the single user, who has become more of a “presumes”, or in other words both a consumer, as well as a producer of energy (Cellura et al, 2011; Cellura et al., 2013; Chiredeja, 2009). By doing so, the consumers tend to reduce energy consumption, energy import from grid and increase the level of load match between generation and consumption (European Commission 2010a; Guarino et al., 2015). The “smart” management of distributed energy generation systems is a priority, in order to properly manage the flows of energy and to handle the interaction of non-constant production of energy with the grid (Cellura et al., 2015). To manage the aleatory generation of such renewable generation systems, according to the current practice, one of the more suitable systems is a micro smart grid. A micro smart network is defined by a set of devices that produce energy and the loads of the system. This structure can be designed either as a standalone unit, or as a sub-unit of the main network. The main quality of the micro network system is the internal capacity of managing the flow of energy through a smart control system. A “smart building”, able to generate, store and manage information and energy flows can be considered as a micro smart grid and is becoming the base unit for future distribution networks (Calvillo et al., 2013). A “smart building” is therefore expected to manage production (for example associated with a storage system) and the consumption of energy, and to manage the exchange with the grid in order to minimize energy wastes (Longo et al., 2014).

2. Energy analysis of an innovative housing system

The starting point of this study is the monitoring of energy consumption of an existing building. The preliminary energy and market analysis on the currently available size for commercial fuel cells SOFC, allowed choosing a SOFC with a rated power of 1 kW. According to the monitored data, and assuming a constant hourly production rate of the fuel cell of 0.8 kWh the fuel cell is properly sized to fit the energy of the apartment. Table 1 shows the hourly consumption of a single apartment, the hourly electricity generation of the SOFC (constant), the energy delivered and imported to/from the grid from the SOFC.

3. Case study: LCA of 1 kW SOFC

3.1. Goal and scope definition

3.1.1 Goal of the study

This study aims to assess the eco-profile of 1 kWh of electricity, generated by a SOFC for residential applications. The analysis was performed using the Life Cycle Assessment methodology in compliance with international standards of the series ISO 14040 (ISO 14040, 2006; ISO 14044, 2006); and the follows, and attritional approach in which the life cycle is modeled by depicting the existing supply-chain of the product and including the input and output flows of all system processes as they occur (European Commission, 2010b).

3.1.2. Functional unit and system boundaries

The functional unit is 1 kWh of electricity generated by the system. The technical features of the fuel cell are shown in Table 2. System boundaries are shown in Fig. 1.

The main assumptions made in the study are the following: the impact of land use or of equipment used for the construction of a fuel cell system have been neglected; the

efficiencies of production processes have been considered by reference to literature data (Karakoussis et al., 2000); the waste materials resulting from the treatment of the materials were not included; the recycling and energy recovery system have been neglected; the eco-profiles of materials and energy sources used to produce the SOFC and the impacts related to the transportation step and to the end-of-life processes of packaging materials were based on the Ecoinvent database (Frischknecht et al., 2007a).

Table 1. Analysis of the energy needs of an apartment energy generation of the SOFC

<i>Hourly energy consumption [kWh]</i>	<i>Hourly energy generation [kWh]</i>	<i>Energy delivered to the grid [kWh]</i>	<i>Energy imported from the grid [kWh]</i>
0.81	0.8	0	0.01
0.89	0.8	0	0.09
0.92	0.8	0	0.12
0.72	0.8	0.07	0
0.56	0.8	0.23	0
0.65	0.8	0.14	0
0.56	0.8	0.23	0
0.41	0.8	0.38	0
0.47	0.8	0.32	0
0.32	0.8	0.47	0
0.73	0.8	0.06	0
0.31	0.8	0.48	0
0.74	0.8	0.05	0
0.31	0.8	0.48	0
0.82	0.8	0	0.02
0.98	0.8	0	0.18
0.23	0.8	0.56	0
1.01	0.8	0.	0.21
0.81	0.8	0	0.01
0.57	0.8	0.22	0
0.90	0.8	0	0.10
1.06	0.8	0	0.26
0.89	0.8	0	0.09
0.66	0.8	0.13	0
TOTAL 16.47	TOTAL 19.2	TOTAL 2.72	TOTAL 1.15

The direct emissions during the manufacturing process of the stack and BoP were not included, as well as the end-of-life phase since the technology is not yet mature and inventory data on the above processes are not available.

Table 2. Specifications for the system analyzed

<i>Characteristics</i>	<i>Units</i>	<i>Value</i>
Number of cells		72
Rated power stack	kW	1
Rated current	A	20
Cell size	mm	152 X 70
Active area	cm ²	50
Working temperature	°C	800
Fuel		hydrogen or NG desulfurized
Input air temperature	°C	700-800
input temperature fuel	°C	700-800

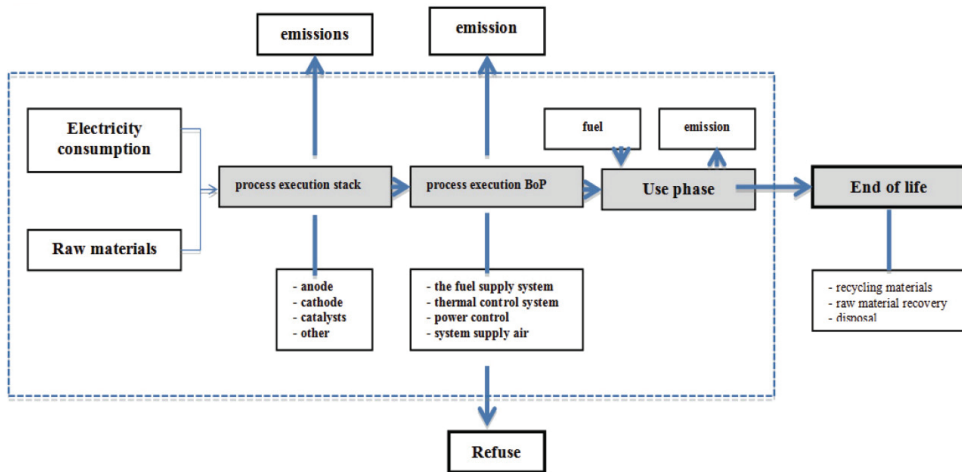


Fig. 1. Scheme of system boundaries

3.1.3. Impact assessment methodology and impact categories

The following energy and environmental indexes were selected to describe the performance of the investigated system: Global energy requirement (GER); Non-renewable energy requirement (NRE); Renewable energy requirement (RE); Global Warming (GWP100); Ozone Layer Depletion Potential (ODP); Human toxicity (HT); Photochemical ozone formation (POF); Acidification (Ac); Terrestrial eutrophication (TE); Freshwater eutrophication (FE); Marine eutrophication (ME); Land use (LU); Water resource depletion (WRD).

The characterization models used for the impact calculations are Cumulative Energy Demand method (Frischknecht et al., 2007b) which allows the assessment of renewable and non-renewable primary energy consumption, and the ILCD 2011 Midpoint impact assessment method, elaborated by Prè (2012) according to the European Commission (2012c).

3.2. Life cycle inventory analysis

3.2.1. Data collection

The description of the data collection is critical to ensure the reliability of the results. For this reason, the LCA studies must clearly indicate the sources of data and data collection procedures (Ardente et al., 2004; Cellura et al., 2011).

Therefore, the authors describe in the following paragraphs, the process of data collection, and the main hypotheses on the modeling of the manufacturing and operation steps. The collected data were processed to calculate the consumption of energy and raw materials, emissions to air, water and soil, and waste production (Prè-Product Ecology Consultants, 2012).

3.2.1.1. The examined product

Fuel cells are among the most promising systems for the production of electricity, both for their positive environmental and performances in comparison to combustion-based systems and for the wideness of possible applications. The technology is used in fields ranging from distributed generation for power companies, to residential and industrial co-generation, to portable generation and traction. Fuel cells represent the key technology for the development of hydrogen as energy carrier.

The SOFC operates at temperatures between 650°C and 1,000°C such high temperatures determine fast kinetics reactions in which the CO, poison to the cells at a low temperature, can be exploited as extra fuel. The SOFC generates heat, recovered by exhaust gases at high temperature. This heat is partially used to preheat the flow of the reactants, (air and natural gas), to feed the reforming reactions and generate. The remaining heat may be used to generate thermal energy for cogeneration.

The examined SOFC has a rated power of 1 kWe. The stack is composed of planar cells connected to each other through the metal interconnections which have the purpose of ensuring the electrical contact between the cells and evenly distribute the reaction gas on the cells (air or fuel). The system is powered by natural gas and it includes the stack, the air handling unit, a DC/DC converter and a device for temperature control of the stack.

Before entering into the stack the natural gas is treated by a desulphurization unit to reduce the content of sulfur compounds that would poison the anode catalyst and a unit of the external reformer to convert the methane, the main component of natural gas, in a gas - rich hydrogen. The unit can be powered directly with the gas at the exiting the reformer without the need for further purification systems (e.g. CO purification unit). The working temperature is between 700-850°C.

3.2.1.2. The SOFC life-cycle

The data collection, useful for performing the LCA, was conducted with both the analysis of the manufacturing process and using data available in literature (Karakoussis et al., 2000; Pehnt, 2001; Pehnt, 2003) in particular for defining the eco-profiles of the materials used for the realization of SOFC components.

The research activity was also focused on the analysis of the use phase, in order to identify the main functional parameters such as power global efficiency, and the quality of electricity and heat generated by the system. Table 3 shows the main flows of materials taken into account in the LCA. The input/output during the use step of the SOFC system have been calculated, such as shown in Table 4.

Table 3. Main material flows for the SOFC system

<i>Product</i>	<i>Component</i>	<i>Main materials</i>	<i>Output</i>
Stack SOFC	Anode, cathode, electrolyte, interconnects, current collectors, insulators, flanges	ZrO ₂ (Y ₂ O ₃), PVB, Cr, Fe, Y, Ethanol LaCrO ₃ , LSM, HCl, He, Ar, Al ₂ O ₃ , MgO	Emissions
BoP	Houses, air supply system, fuel system, desulphurization, Pre reformer / gas burner, heat exchangers, system power conditioning	Steel, Ni-Cr alloys	Emissions
Operational and maintenance phase		Natural gas	Emissions

3.3. Life cycle impact assessment: results and discussion

Energy and environmental impacts of the SOFC life cycle for the operation step are shown in Table 5. The analysis of the energy and environmental impacts due to the production of auxiliary components, to shows that the main impacts are caused by the manufacturing process of the gas traditional heating units. In detail, for the impact category GER (MJ), whose total value is about 0.13 MJ, the gas traditional heating units are responsible of about 0.06 MJ of GER, as shown in Table 6.

Table 4. Material input and output during the use step

<i>Chemical compound</i>	<i>Input [g/kWh]</i>	<i>Output [g/kWh]</i>
Natural Gas	380.8	-
Air	22379	-
H ₂ O	-	790.6
CO	-	0.624
NO _x	-	0.128
CO ₂	-	962
N ₂	-	17164.4
O ₂	-	3779.4

Table 5. Energy and environmental impacts of the SOFC life cycle for the operation step

<i>Impact category</i>	<i>Total</i>
GER (MJ)	12.23
NRE (MJ)	12.21
RE (MJ)	0.02
GWP (kg CO ₂ eq)	0.60
ODP (kg CFC-11 eq)	9.32E-08
HT (CTUh)	8.28E-09
POF (kg NMVOC eq)	6.24E-04
Ac (mole H ⁺ eq)	6.64E-04
TE (mole N eq)	1.26E-03
FE (kg P eq)	3.69E-06
ME (kg N eq)	1.16E-04
LU (kg C deficit)	0.59
WRP (m ³ water eq)	4.61E-03

Table 6. GER and GWP of the SOFC life cycle for the production auxiliary components

<i>Impact category</i>	GER (MJ)	GWP (kg CO ₂ eq)
Total	0.13	0.008
Case (SOFC)	0.01	4.6E-05
Air supply system (SOFC)	0.01	0.0008
Fuel supply system (SOFC)	0.01	0.0008
DESULFURIZER (SOFC)	9.1E-04	5.6E-05
Pre-reformer/ gas burner (SOFC)	0.01	6.5E-04
Heat exchanger (SOFC)	0.01	5.9E-04
Power conditioning system (SOFC)	0.001	9.8E-05
Traditional gas heating units (SOFC)	0.06	0.004
Electricity. medium voltage at grid/IT U	0.006	3.7E-04

Reforming to the impact category GWP (MJ) about 90% of the total (0.008) is due to the gas traditional heating units, as shown in Fig. 5. The gas traditional heating units are also responsible of about 90% of ODP (total value of 1.2 E-10 kg CFC-11_{eq}), about 37% of HT (total value 1E-08 CTUh), about 40.6% of POF (total value 8.4E-06 kg NMVOC_{eq}), about 35% of TE (total value 6.5 E-06 Mole N_{eq}), about 40.6% of FE (total value 8.4E-06 kg P_{eq}), about 35% of ME (total value 0.4 kgN_{eq}), about 44% of LU (total value 0,009 kg C deficiency). The impact on WRP whose total value is 0.01 mq water_{eq}, is cause for 20% by the manufacturing of the pre-reformer/gas burner, and for 20% by the manufacturing of the heat Exchanger.

Table 7. GER and GWP of the SOFC life cycle for the industrial production stack

Impact category	GER (MJ)	GWP (kg CO ₂ eq)
Total	0.078	0.004
<i>Zirconium oxide, at plant/AU U</i>	0.013	7.5E-04
<i>Ethylene glycol, at plant/RER U</i>	4.7E-04	1.4E-05
<i>Iron-nickel-chromium alloy, at plant/RER U</i>	0.051	0.0029
<i>Ethanol from ethylene, at plant/RER U</i>	0.0016	4.2E-05
<i>LaMnO₃</i>	5.7E-04	3.04E-05
<i>Trichloroethylene, at plant/WEU U</i>	0.003	3.3E-05
<i>PVB industriale</i>	4.9E-04	5.7E-05
<i>Dibutylphthalate industriale</i>	0.010	5.0E-05
<i>Ni-ZrO₂(Y₂O₃) industriale</i>	8.2E-05	9.5E-06
<i>Electricity, medium voltage, at grid/IT U</i>	0.004	2.6E-04

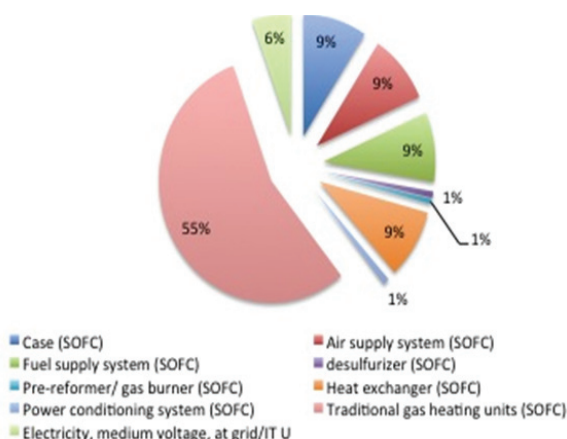


Fig. 4. Share of each life-cycle step on the total GER: production of auxiliary components

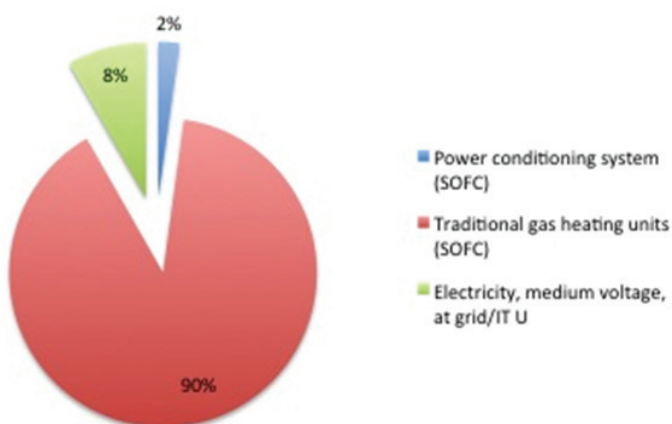


Fig. 5. Share of each life-cycle step on the total GWP: production of auxiliary components

The analysis of the energy and environmental impacts due to the life cycle of the fuel cell for the production of the industrial stack shows that for the impact category GER (MJ),

whose total value turns out to be equal to 0.078 MJ, the main contribution is given by the process Iron- nickel-chromium alloy with a value equal to 0.051 MJ, as shown in Table 6; for the impact category GWP (MJ), it can be observed that 70% of the total value (0.004) is due to nickel-chromium alloy iron processing, as illustrated in Fig. 7.

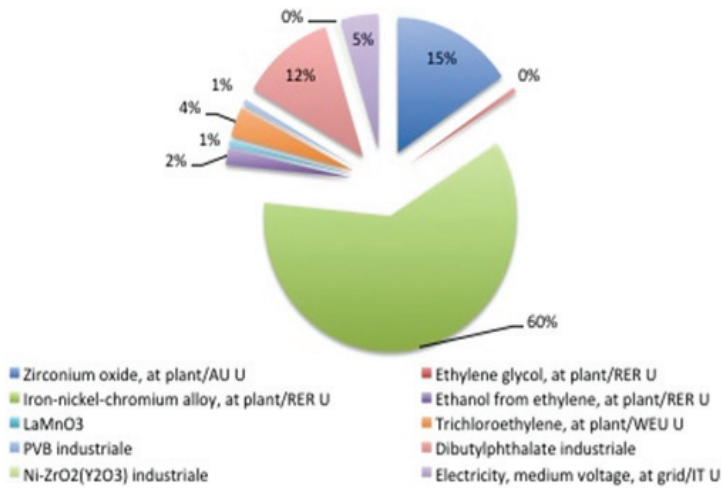


Fig. 6. Share of each life-cycle step on the total GER: industrial stack

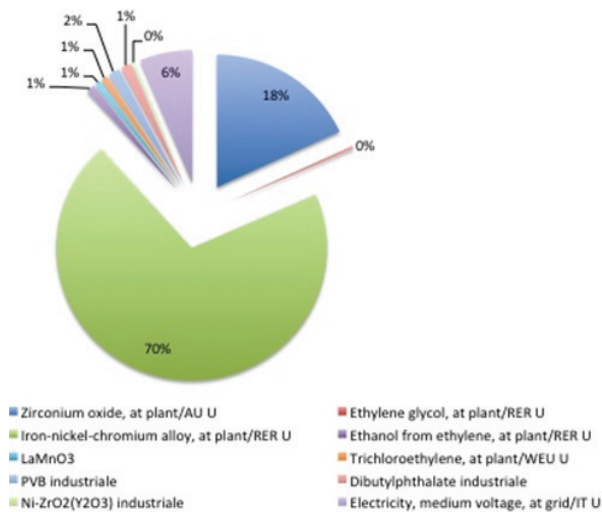


Fig. 7. Share of each life-cycle step on the total GWP: industrial stack

4. Conclusions

The goal of this study was to calculate the ecoprofile of 1kWh of electricity produced by a fuel cell for residential house which is both a producer and consumer of energy, thus causing an intense energy with the grid that therefore may supply energy when generation

on-site is low and vice-versa. The obtained results showed that the use phase has the highest energy and environmental impacts.

The future development of the research will be a hybrid system, with the introduction of an electricity storage system for an easier management of the load, and the comparison between the two different systems.

References

- Ardente F., Beccali M., Cellura M., (2004), F.A.C.A.D.E.: A fuzzy software for the energy and environmental balances of products, *Ecological Modelling*, **176**, 359-379.
- Beccali M., Cellura M., Finocchiaro P., Guarino F., Longo S., Nocke B., (2012a), Life cycle assessment performance comparison of small solar thermal cooling systems with conventional plants assisted with photovoltaics, *Energy Procedia*, **30**, 893-903.
- Beccali M., Cellura M., Longo S., Nocke B., Finocchiaro P., (2012b), LCA of a solar heating and cooling system equipped with a small water-ammonia absorption chiller, *Solar Energy*, **86**, 1491-1503.
- Beccali M., Cellura M., Finocchiaro P., Guarino F., Longo S., Nocke B., (2013), Life cycle performance assessment of small solar thermal cooling systems and conventional plants assisted with photovoltaics, *Solar Energy*, **104**, 93-102.
- Cellura M., Longo S., Mistretta M., (2011), Sensivity analysis to quantify uncertainty in life cycle assessment: the case study of an Italian tile, *Renewable and Sustainable Energy Reviews*, **15**, 4697-4705.
- Cellura M., Guarino F., Mistretta M., Longo S., (2013), Energy life-cycle approach in net zero energy buildings balance:operation and embodied energy of an Italian case study, *Energy & Buildings*, **72**, 371-381.
- Cellura M., Guarino F., Longo S., Mistretta M., (2015), Different energy balances for the redesign of nearly nets zero energy buildings: An Italian case study, *Renewable & Sustainable Energy Reviews*, **45**, 100-112.
- Cellura M., Campanella L., Ciulla G., Guarino F., Lo Brano V., Nardi Cesarini D., Orioli A., (2011), *A Net Zero Energy Building in Italy: Design Studies to Reach the Net Zero Energy Target*, *Proceedings of Building Simulation*, 12th Conference of the International Building Performance Simulation Association "Driving better design through simulation", An IBPSA – AIRAH Conference, Sydney, Australia.
- Calvillo C.F., Sánchez A., Villar J., (2013), *Distributed Energy Generation in Smart Cities*, International Conference on Renewable Energy Research and Applications (ICRERA), Madrid, Spain.
- Chiradeja P., (2005), *Benefit of Distributed Generation: A Line Loss Reduction Analysis*, IEEE/PES Transmission and Distribution Conference and Exhibition, Asia and Pacific Dalian, China.
- European Commission, (2007), 1 Final Communication from the Commission to the European Council and the European Parliament, An Energy Policy for Europe SEC (2007) 12. Brussels.
- European Commission, (2010a), 639 Final Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions e Energy 2020 a Strategy for Competitive, Sustainable and Secure Energy (SEC(2010) 1346), Brussels.
- European Commission, (2010b), ILCD Handbook International Reference Life Cycle DataSystem. General Guide for Life Cycle Assessment e Provisions and Action Steps, Joint Research Centre and Institute for Environment and Sustainability, ISPRA, Rome, Italy.
- European Commission, (2012a), Commission Staff Working Document Accompanying the Document Council and the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and Renewable Energy: A Major Player in the European Energy Market SWD (2012) 164 Final, Brussels.
- European Commission, (2012c), Characterization Factors of the ILCD Recommended Life Cycle Impact Assessment Methods, Database and Supporting Information, DG Joint Research Centre - Institute for Environment and Sustainability, EUR 25167, Publications Office of the European Union, Luxembourg.

- Frischknecht R., Jungbluth N., Althaus H.J., Doka G., Dones R., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G., Spielmann M.,(2007a), Overview and Methodology, Ecoinvent Report No. 1, ver.2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland.
- Frischknecht R., Jungbluth N., Althaus H.J., Bauer C., Doka G., Dones R., Hischier R., Hellweg S., Humbert S., Köllner T., Loerincik Y., Margni M., Nemecek T., (2007b), Implementation of Life Cycle Impact Assessment Methods, Ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf.
- Guarino F., Cassarà P., Longo S., Cellura M., Ferro E.,(2015) Load match optimizations of a residential building case study: A cross-entropy based electricity storage sizing algorithm, *Applied Energy*, **154**, 380–391.
- ISO 14040, (2006), Environmental Management - Life Cycle Assessment - Principles and Framework, International Institute of Standardization, Geneva, Switzerland.
- ISO 14044, (2006), Environmental Management - Life Cycle Assessment - Requirements and Guidelines, International Institute of Standardization, Geneva, Switzerland.
- Karakoussis V., Leach M., Van der Vorst R., Hart D., Lane J., Pearson P., Kilner J., (2000), Environmental emissions of sofc and spfc system manufacture and disposal, Report F/01/00164/REP Imperial College of Science, Technology and Medicine, Energy Technology Support Unit, Harwell, Didcot, Oxfordshire, UK.
- Longo S., Antonucci V., Cellura M., Ferraro M.,(2014) Life cycle assessment of storage systems: the case study of a sodium/nickel chloride battery, *Journal of Cleaner Production*, **85**, 337-346.
- Pehnt M., (2001), Life-cycle assessment of fuel cell stacks, *International Journal Hydrogen Energy*, **26**, 91-101.
- Pehnt M., (2003), Assessing future energy and transport systems: the case of fuel cells. part I: methodological aspects, *International Journal of Life Cycle Assessment*, **8**, 283-289.
- Prè-Product Ecology Consultants, (2012), Software SimaPro7.
- Yadav A., Srivastava L., (2014), *Optimal placement of distributed Generation: An Overview and Key Issues*, International conference on Power, Signals; Controls and Computation, Thrissur, India.



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INDUSTRIAL SYMBIOSIS IN EMILIA-ROMAGNA REGION: RESULTS FROM A FIRST APPLICATION IN THE AGROINDUSTRY SECTOR*

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Abstract

An Industrial Symbiosis application was developed within the "Green Economy and Sustainable Development" project in Emilia-Romagna region (IT), promoted by Unioncamere Emilia-Romagna and ASTER, with the technical and scientific coordination of ENEA. Aim of the project was the development of cross-relations between production sectors, industrial research and territory and boosting circular economy. It was the first application of Industrial Symbiosis in Emilia-Romagna with the involvement of 13 companies from agro-industry and 7 laboratories. The main steps were: (1) selection of companies and research laboratories to be involved into the project; (2) focus group, for companies and labs, where ENEA presented Industrial Symbiosis and contribution asked at each participant; (3) companies were requested to fill-in input-output tables, for sharing information about resources used and waste/by-products generated; (4) elaboration of collected data and feedback to labs for asking their contribution in looking for potential applications for shared resources; (5) data elaboration for identifying potential synergies between companies; (6) labs were requested to fill-in "origin-destination" data tables, for identifying feasible valorization processes for valorizing shared waste and by-products streams; (7) meeting with companies and labs for presenting results and having their feedback; (8) data elaboration highlighting most interesting synergies; (9) final meeting with results presentation open to participants and stakeholders. The project identified 8 main resource streams, 28 feasible destinations, and 90 potential synergies involving not only companies participating in the project, but also other companies in Emilia-Romagna. The development of each single synergy, identifying conditions for its actual implementation is the object of the second phase of the project which is ongoing (October 2014 – June 2015).

Keywords: agro-industry, circular economy, Emilia-Romagna, industrial symbiosis

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1. Introduction

Industrial Symbiosis (IS), as tool and methodology finalized to optimize the use and re-use of resources, reduce waste amount and make related environmental improvement an attractive process for industrial stakeholders, is gaining more and more attention by national and supranational institutions.

At European level, indeed, this instrument is strongly encouraged and cited in many documents regarding the EU Cohesion Policy and the European growth strategies. With reference to the Italian case this is reflected in the Italian Regional Policies, resulting from the new rules and legislation governing the next round of EU Cohesion Policy investment for 2014-2020. In more detail, recent European policy documents have identified IS as a fundamental part not only of environmental policy, but also of economic policy: the Roadmap for a Resource Efficient Europe, part of the Europe 2020 Strategy (the aforementioned growth strategy), explicitly mentions IS as priority tool for all member states in order to exploit resource efficiency gains (EU Communication, 2011).

Actions in favor of IS are also cited in the context of several European programs: Horizon2020 Societal Challenges (Climate Action, Environment, Resource Efficiency and Raw Materials), Climate-KIC (Bio-economy challenge platform, Industrial Symbiosis challenge platform), European Innovation Partnership (EIP) Raw Materials. All in all, "an increasing number of global, international, and national institutions and representative groups are championing further development and support of IS" (Laybourn and Lombardi, 2012). Also the Organization for Economic Co-operation and Development (OECD) cited IS as a form of systemic eco-innovation "vital for future green growth" (OECD, 2011). These indications at the level of European policies have effects also at the national level. The new European "Cohesion Policy 2014-2020 Programming Cycle", that contains the new rules and legislation governing the next round of EU Cohesion Policy investment for 2014-2020, expects, as an "ex-ante" condition for the use of community resources, that national and regional authorities develop research and innovation strategies aimed at the "smart specialization".

In Italy, this activity was implemented by the Department for Development Policies and Economic Cohesion (DPS) of the Italian Ministry of Economic Development (MISE), with the support of local Governments. Every region has worked in order to bring out the excellence of the territory with the prospects of success on the global market and to identify more effective instruments for economic and territorial growth. Two Italian regions, Emilia-Romagna (Invitalia, 2014) and Lazio (Regione Lazio, 2014) have inserted Industrial Symbiosis in their strategic plans, as a tool able to reduce waste quantity and to increase regional sustainability, materials reuse and raw materials saving. Developing operationally the aforementioned Smart Specialization Strategies, in Emilia-Romagna five technological specializations were decided to be strategic and considered most relevant for a growth strategy of the territory (Iacondini et al., 2014).

Every specialization is characterized by key-subjects decided to be implemented (Invitalia, 2014):

- agrifood (Industrial Symbiosis, biomasses management, smart water management, sustainable production systems, smart packaging);
- building (waste valorization, energy efficiency, renewable resources);
- mechatronics and motor design and manufacture (ecodesign, energy efficiency, critical materials and substitutive);
- healthiness industries;
- creative and cultural industries.

As can be seen, in the first three specializations, Industrial Symbiosis and resources management are included as important tools to increase efficiency and sustainability in industrial processes.

At institutional level, the interest about Industrial Symbiosis in Emilia-Romagna is also demonstrated by the inclusion of this methodology in the Waste Management Plan of Emilia-Romagna Region, as “instrument for the amount and hazard reduction of special wastes and for the re-use of materials from production processes”. Emilia-Romagna Region “is considering whether to activate work tables to study the conditions facilitating the use of by-products and identify possible agreement conditions between involved actors” (RER, 2014). In Emilia-Romagna an Industrial Symbiosis pilot action was realized: the “Green Project”, developed by Unioncamere Emilia-Romagna and Aster with the scientific support of ENEA. This project has been aimed at the dissemination of an Industrial Symbiosis culture in the regional territory, involving traditionally separate industries in a collective approach. Since it was a pilot project (the first in the region) was decided to focus it on the chain of reuse and enhancement of agro-industrial waste and residues, with particular (but not exclusive) interest towards solutions aimed at the production of materials with high added value. The choice of this sector was primarily due to the existence of a favorable local context, also entrepreneurial.

In Emilia-Romagna the annual production of biomass waste arising from agro-industrial residues is estimated at around 20 million tons per year. Only a small part of this important availability is used for the production of energy, and is even more limited the fraction of this biomass flow addressed to the production of high added value materials (ASTER, 2014).

In the region also operate important actors to which a significant production of agro-industrial wastes is connected, as well as several developers of technologies for the exploitation of biomass.

Just as there are the industries that have represented the upstream and downstream elements of the sector that has been realized, similarly are present on the territory of the “facilitators” of the process. In Emilia-Romagna there is an important reservoir of technological and research skills, both in the High Technology Network, both in the remaining public and private fields. In addition to these considerations, it is worth highlighting that another project on sustainable agriculture (CSA Project) studied the management of agro-waste in order to produce selected compost. The study has been performed by the Province of Rimini, AUSER Emilia-Romagna, together with University of Bologna - CIRI Energia Ambiente (CSA Project, 2014), and it’s a further evidence of the importance of agro-industrial chain in the regional context.

The preliminary phase of the project was dedicated to the identification of enterprises more appropriate for the purposes: the action involved different subjects, in order to identify and study complete symbiosis patterns. The pool of companies, all based in Emilia-Romagna, has been segmented into three main categories:

- **upstream:** companies operating mainly in the agro-food sector, producing streams of products for reprocessing and enhance;
- **processors:** industries with the technologies to transform and enhance the byproducts coming out of the upstream companies, which are then reused by downstream subjects;
- **downstream:** this group consists of the subjects that reuse by-products, after they have been reprocessed and valued.

These are the companies for which the outflows from upstream companies (possibly transformed) become secondary raw materials input, assuming a value.

After this first selection stage, the involvement has been carried out: 13 companies took part in the project, 5 “Upstream”, 1 “Processor” and 7 “Downstream”.

2. Materials and methods

The application of Industrial Symbiosis has been developed in 9 months, from end of June 2013 to the beginning of March 2014. Main steps of the project were (starting from the first in October 2013 to the last, March 2014):

1. Selection of companies and research laboratories to be involved into the project (Table 1); this task was finalized by Aster, which was the local organizer and promoter of the project and which has a deeply knowledge of the industrial network in Emilia-Romagna region; in particular 13 companies were invited to take part to the project, 7 research labs, 1 local authority; promoter, organizer and technical and scientific coordinator closed the group (Unioncamere, Aster, ENEA);

2. Focus group, addressed at companies and labs, where Aster presented methodology, ENEA presented Industrial Symbiosis concept and ENEA's activity in that sector and contribution asked at each participant in the project;

3. During the focus group companies were requested to fill-in input-output tables (Cutaia et al., 2014) (Fig. 1), for sharing information on resources used and waste/by-products generated by their companies; those tables have been elaborated by ENEA and already used in an ongoing project for the implementation of the first Industrial Symbiosis platform in Italy (ENEA, 2011-2015). This step was realized using ENEA's know-how and tools: in particular the <origin-destination> string's logic (Fig. 2) and the <origin-destination> strings info collection Tables (Fig. 3) was used. In other words, labs, starting from resources shared by companies, gave their contribution filling-in a <origin-destination> string for each resource, shared by companies as an output, for which they could provide one or more than one productive potential destination or, vice-versa, one or more than one potential origin for resources requested by the companies as an input; Labs filled-in some <origin-destination> strings and returned them to ENEA for data elaboration.

4. After the focus group 10 out of 13 companies provided requested information filling-in input-output Tables (Table 2); for the development of the project each company were identified with a code (ID code), useful both for data elaboration and for assuring data confidentiality. Companies sent to ENEA and Aster input-output Tables filled-in and ENEA elaborated those data in order to send those data to the Labs in order to ask them their contribution; labs' role into the project were, in fact, provide indications in how valorize resources shared by companies, showing technologies and valorization processes for a productive reuse of productive scraps. This step was realized using ENEA's know-how and tools: in particular the <origin-destination> string's logic (Fig. 2) and the <origin-destination> strings info collection Tables (Fig. 3) was used. In other words, labs, starting from resources shared by companies, gave their contribution filling-in a <origin-destination> string for each resource, shared by companies as an output, for which they could provide one or more than one productive potential destination or, vice-versa, one or more than one potential origin for resources requested by the companies as an input; Labs filled-in some <origin-destination> strings and returned them to ENEA for data elaboration.

5. Starting from resources shared by companies and <origin-destination> strings accordingly compiled from Labs, ENEA elaborated data provided in order to identify potential synergies between companies;

6. Identified potential synergies were presented during a meeting organized by Aster with companies and labs in order to have their feedback and their actual interest in exploring potential synergies addressed by the project;

7. According feedback given by companies and labs in the previous step, ENEA provided a further elaboration with the suitable potential synergies.

Results of the project were presented in a final meeting organized by Aster, open to participants and to stakeholders.

Table 1. Companies, Labs, local authorities, research centres, organizers participating to the Focus Group held in Bologna on 10.10.2014

Companies
ARP Agricoltori Riuniti Piacentini
Barilla G&R fratelli
CCPL
CGM
Cielle
Ciri Agroalimentare
Coop Formula Ambiente
Cormatex
Irci
Opoe
Schmack Biogas Viessmann
Softer
Valfrutta - Conserve Italia
Laboratories
CIRI Agroalimentare (CIRI Agro)
CIRI Agroalimentare (CIRI Agro)
CIRI Energia Ambiente – Unità Operativa Ecodesign (CIRI EA)
CIRI Energia Ambiente – Unità Operativa Ecodesign (CIRI EA)
CIRI Energia Ambiente – Unità Operativa Biomasse (CIRI EA)
CIRI Energia Ambiente – Unità Operativa Biomasse (CIRI EA)
CIRI Meccanica Avanzata Materiali (CIRI MAM)
Siteia.Parma – CIPACK
Mat-ER – LEAP
Biosphere
Institutions
Province of Rimini - Office of Regional Planning
Research centers
ENEA - Environmental Technologies Technical Unit
Organization
ASTER
Unioncamere

Resource (description)	Resource (trade name)	Resource (type)	Resource (ProdCom code) [if type a)]	Resource (NACE code) [if type c)]	Type of quantity	quantity	unit of measure		
input									
		a) material			annual				
		b) energy carrier			batch				
		c) service							
		d) skill							
output									
Resource (description)	Resource (trade name)	Resource (type)	Resource (type 2 - a)	Resource (code) [ERC - if waste]	Resource (code) [ProdCom - if sub-product]	Resource (code) [NACE - if service]	Type of quantity	quantity	unit of measure
		a) material	waste				annual		
		b) energy sub-product	sub-product				batch		
		c) service							
		d) skill							

Fig. 1. Input-output data collection sheet (Cutaia et al, 2014)

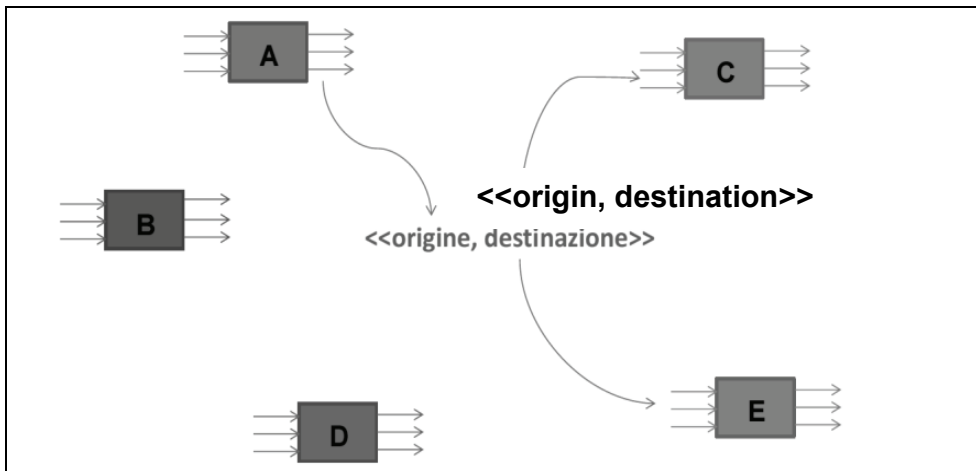


Fig. 2. Origin - destination strings logic (Cutaia et al., 2014)

Arch <origin, destination> type <output, input>			Arch <origin, destination> type <input, output>		
Resource code		(link to column B sheet output)	Resource code		(link to column B sheet input)
Resource description		(link to column C sheet output)	Resource description		(link to column C sheet input)
Possible destinations (ATECO code)			Possible origins (ATECO code)		
ATECO codes of possible areas of use es. 41, 42, 43	Description of possible areas of use Construction sector	Description of the potential input Recycled aggregates	ATECO codes of possible areas of sought input	Description of possible areas of sought input	Description of the potential output
Note: Any rules and technical reference standards xxx Any necessary intermediate yyy enhancement processes			Note: Any rules and technical reference standards xxx Any necessary intermediate yyy enhancement processes		

Fig. 3. Origin - destination strings data collection tables (Cutaia et al., 2014)

Table 2. Companies participating in the project, their sector of activity, input and/or output tables filled-in, code of identification into the project

Company	ATECO	Input	Output	ID
Arp Agricoltori Riuniti Piacentini	10.39	X	X	A01
Barilla G&R Fratelli	10.7	X	X	A02
Coop Formula Ambiente	38.110	X	X	A03
Opoe	10.3	X		A04
Softer	20.16.0	X	X	A05
CCPL	41.2	X		A06
Irci	43.21.01	X	X	A07
Ciri Agroalimentare		X		A08
CGM	22.29.09	X		A09
Schmack Biogas Viessmann		X		A10

3. Case study presentation

3.1. The first meeting of the working group

The first internal meeting of the project took place in June 2013 as the organizers, laboratories, institutions and scientific coordinator made up the "Technology Board", a working group which met in order to plan scientific activities. Business plan, milestones, meeting dates and deadlines of the different project's phases were settled during this first session.

Earliest milestone event, the "Focus Group", was scheduled between late September and early October, preceded by a series of conference calls that would lead to its definition and organization: ASTER was responsible for organization of meetings' spaces, methodology and contacts with companies and laboratories, while ENEA provided the scientific and technical agenda. In September the final program was proposed and agreed, outlining a first draft of the methodology to be used, divided in three steps for each of the project's phases:

- Pre-event: methodology and document preparation,
- Event: summary of the results of the meeting,
- Post-event: data processing, material arrangement, solutions to possible problems.

3.2. Focus Group preparation

The Focus Group was the first meeting with companies and labs organized in order to present a general introduction to key concepts of Industrial Symbiosis, in addition to the project timeline and methodology. The experience of ENEA on Industrial Symbiosis and the experience of Aster in technology transfer were adapted to the current project: first essential step is to deal with data collection from companies involved. The quality of the data must be as objective and appropriate as possible: the way in which information is requested and collected is therefore essential to achieve this purpose.

Simplicity was deemed essential, because involved companies would have to fill in data schemes without direct help from the experts, as the only support was provided via e-mail or telephone. In addition, also the short delivery times suggested an approach that did not add difficulties to data collection process. Input-output data collection tables (Cutaita et al., 2014) (Fig. 1) are divided into input (resources that enter into a production system) and output fields (products that come out from a production system). The main aim of these data collection tables is to ask companies only the very important information for building synergies among companies participating to the network and available into the local area of the project, using a common language and as much as possible codes already used by companies. For this project, similarly at what done within the ENEA's project (ENEA, 2011-2015), the term "resource" includes:

- a) materials;
- b) energy;
- c) service/capacity;
- d) skills.

3.3. The focus Group held in Bologna on 10/10/2013

The priority of the Focus Group was to explain key concepts about Industrial Symbiosis to companies involved and understand the importance of the project. During the first phases of the project, the European Union identified six strategic markets to promote the development and adoption of innovative technologies by European industry, targeting investments in six specific sectors: Industrial Symbiosis was chosen as one of these best

practices. The news helped to emphasize weight and relevance of the topic.

It was considered necessary at first to explain to the event's participants, both companies and laboratories, what Industrial Symbiosis is, which are the different approaches used in the world and specifically in Italy, what are the results in countries where this methodology is already applied. In order to get a better engagement of the companies involved, both environmental and economical issues were highlighted, such as:

- savings in landfill disposal of waste materials and purchase of raw materials;
- reduction of CO₂ production and pollution derived from landfill disposal;
- opportunities to enable synergies and economy of scale in areas not usually interconnected.

In addition, several real case studies were presented, both Italian and foreign, to show the real applicability of this methodology: in particular, the "Platform of Industrial Symbiosis", project currently in development by ENEA with European funds for the Sicily region (ENEA, 2011-2015).

Several companies and regional laboratories expressed their interest in participating into the project, as shown in Table 1. After presenting the project and basic concepts of Industrial Symbiosis, mechanisms regulating the Symbiosis itself were explained. Input and output materials are often not obviously related, as they can have different characteristics, appearance, shape and nouns. Nevertheless, after proper analysis done by symbiosis experts, it is possible to identify solutions able to transform waste resources and make them suitable to enter into a new production cycle; in order to do that, it is critical to recognize their basic nature, characteristics and correspondence, in order to identify potential new inputs in the outputs of some production process.

The Figure that expresses this concept and highlights the algorithm of the whole methodology is the "<origin-destination> string" (Fig. 2).

The <origin-destination> strings are information tables that describe the potential fields of productive use of an industrial waste. In practice, they are tables containing data about possible matches of output and input of industrial processes, built based on the expertise, research and scientific literature data. Even if some complex software, with an updated database of case studies and potential matches, exists on the market, experience of experts who are able to recognize the potential of the various resources is still needed.

For the practical "Application of Symbiosis" phase it was required not only the symbiosis experts' advice, but also the contribution of research laboratories, providing their knowledge on potential sector of productive re-use of productive scraps, to suggest potential synergies.

Having explained the applied methodology, the actual contribution required from companies was shown, in particular the material that would be sent to the participants and they would have to fill-in:

- company identification card: with some relevant data of the company (company's registry data collection sheet);
- input-output sheets.

In the filling of input-output data, companies should report flows of resources they could make available as output and / or materials that they need as input. They were also invited to fill in the input-output forms with the most information on the flows of reference, always bearing in mind that it was not necessary to "inventory" all streams for input and output of the company, in order to encourage participation and not to create the idea that it was necessary to retrieve all company production strategic data. It was also asked to attach any analytical details that could be useful for the purpose of improve understanding of the resources listed on input/output templates.

Data confidentiality and non-disclosure was also guaranteed.

3.4. Data collected and feedback to the labs

Almost all the requested information was returned on time by 10 companies, out of the 13 participants in the Focus Group. The response was very positive, both for the number of participants and amount of data collected: except for a few companies that have returned only little information, others have been very exhaustive in both the number and the details for each input and output shared (providing, in some cases, even chemical analysis of shared resources). Data received from companies are provided in Table 3.

As can be seen from the table, codes have been associated with companies, to be able to report on the resources without having to explicitly specify their origin and preserving confidentiality. It is also shown what kind of data has been provided, if input or output or both. The ATECO codes were also required to propose possible synergies not immediately recognizable from the received data. Data were arranged in a single Excel document, divided into two pages, one for input and one for output. Original heading of the tables sent to companies was maintained. The following is an example of how the data were organized and after sent to the Labs in order to ask them their expert contribution in order to find potential solutions for productive re-use for companies' scraps.

The first column shows the company code, the second the code of the specified resource: the first part indicates the code of company of origin of the material, IN stands for input (if the material was an output we would have found the initials OUT), the last digit is a serial number assigned to that particular resource. The following columns have already been explained previously and are easily readable. Overall, data were collected regarding 62 inputs and 42 outputs. Moreover, other two pages were added in the Excel document, to be filled specifically by laboratories; below the four pages of the document are summarized:

1. Data input (contains all the input provided by the companies)
2. Data output (contains all output provided by the companies)
3. Form arch <origin, destination> type <output, input> - TO BE COMPLETED
Form arch <origin, destination> type <input, output> - TO BE COMPLETED.

The laboratories were asked to fill properly the Tables 3 and/or 4 for the types of output and / or input provided by the companies for which the labs could suggest a productive sector of possible destination or possible origin (“<origin, destination> strings”, Fig. 3). The table “<origin, destination> string - type <output, input>” requires choosing an output of a company to analyze the possible production sectors in which reuse the resource, specifying group of companies potentially affected with an ATECO code or a simple description and indicating what possibly would be the required input corresponding to that output. In the notes, it is required to describe any intermediate processes necessary to enhance the sub-product and any technical reference standards.

Table 3. Resources shared by companies – part of the database containing all resources (as input or output) provided by companies

Company code	A01
Resource code	A01/IN/01
Description INPUT	tomato
ProdCom code INPUT	10391710 Canned tomatoes, whole or in pieces (excluding prepared vegetable dishes and tomatoes preserved by vinegar or acetic acid)
Quantity	200000
Unit of measure	ton
Type of quantity	batch
Laboratory Analysis	

The Table “<origin, destination> string - type <input, output>” requires to make hypothesis on what could be the possible origins of a specific input, in order identify companies that could offer a product with those features in their outputs. The form requires specifying intermediate processes and technical standards as the previous one. Project participants did not found this last module easy to use and fill in, in fact only one laboratory was able to report some data, which however were found not useful for further development.

3.5. Processing performed by laboratories

The forms to be filled by the laboratories were sent November 20, asking to reply and send them back to ENEA by 6 December. Responses were received only from some laboratories (out of 7), presented in Table 4.

The results proposed by laboratories are summarized below. The specialists of **LEAP** (Laboratory for Energy and Environment of Piacenza), have proposed various solutions:

- screening to determine the possibilities for energy recovery in biomass plants of the outputs of A01 and A04 companies;
- feasibility study of anaerobic digestion / material recovery of output A01 and A02 (specific assessment for each stream) into A07 company input;
- analysis of available technologies and technical-economic feasibility study for the stabilization and recovery of energy from output A05 with possible additions of the plastic material of A01 and A03;
- study of technical, environmental and economic feasibility (LCA) concerning production of fertilizer from output of A07;
- activities of environmental characterization of the energy recovery technologies of all materials listed above. Possibility of preliminary assessments based on literature data and previous measurement campaigns done by LEAP;
- activities of temperature measurement with a suction pyrometers for large heat generators (for example, ref. A03 output) for energy recovery through combustion, with the objective of improving calibration of conventional thermocouples installed on the system in order to gain better control of the temperature of post-combustion, in compliance with relevant regulatory requirements;
- tracking of the temperature profile in the various sections of passage of the fumes. Interventions aimed at limiting polluting compounds in the fumes.

LEAP also proposed another specific knowledge deemed relevant to the topic of symbiosis: the possibility of sampling gaseous emissions from the systems, in relation to the main pollutants identified by law and particulate air pollution, including ultrafine and nano-particulate components.

The Ciri Agroalimentare (Interdepartmental Centre for Industrial Research Agribusiness) laboratory has focused its interest in particular on output A03/OUT/03 (Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing and food preparation). The solution proposed was to make use of the resource selecting active bio-molecules such as antioxidants, fiber, sugar, lipids and biopolymers in order to use in the industry of animal feeding, food, chemical and pharmaceutical, packaging and cosmetics. Based on these information, areas where the resources could be employed had been identified via ATECO codes representing different industrial sectors:

- Industry animal feed and food: ATECO 10 - Food Industries,
- Chemical and pharmaceutical industry and cosmetics: ATECO 21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations,
- Packaging: ATECO 14 - Packaging of clothing; manufacture of articles of leather and fur and ATECO 22:22 - Manufacture of plastic packaging.

Table 4. Labs contributing into the project

LABORATORY	ID
Ciri Agroalimentare	LAB 02
Ciri Energia Ambiente	LAB 03
LEAP	LAB 01
Cipack-Siteia.Parma	LAB 04

Through ATECO codes we were able to identify solutions that the laboratory could not find, not having available the data about the companies. In this way were found to be both direct symbiosis and possible connections, based on area of production, to be submitted to companies for validation, even if they had not made available the data of those specific inputs.

Table 5. Summary of identified synergies

<i>Company code OUTPUT</i>	<i>Resource code OUTPUT</i>	<i>Description OUTPUT</i>	<i>Company code INPUT</i>	<i>Resource code INPUT</i>	<i>Description INPUT</i>
A01	A01/OUT/02	Tomato pomace	A04	A04/IN/01	By-products of processing tomatoes (peels, berries outsized, etc.)
A01	A01/OUT/02	Tomato pomace	A08	A08/IN/02	By-production processing agro industry
A01	A01/OUT/02	Tomato pomace	A08	A08/IN/01	Agro industrial refuse
A01	A01/OUT/02	Tomato pomace	A10	A10/IN/01	Organic matrices not lignified
A01	A01/OUT/03	Pea hulls	A04	A04/IN/05	Products of processing of various vegetables (conditioning, peeling, packaging, etc.)
A01	A01/OUT/03	Pea hulls	A08	A08/IN/01	Agro industrial refuse
A01	A01/OUT/03	Pea hulls	A08	A08/IN/02	By-production processing agro industry
A01	A01/OUT/03	Pea hulls	A10	A10/IN/01	Organic matrices not lignified
A01	A01/OUT/04	Bean pomace	A04	A04/IN/05	Products of processing of various vegetables (conditioning, peeling, packaging, etc.)
A01	A01/OUT/04	Bean pomace	A08	A08/IN/01	Agro industrial refuse
A01	A01/OUT/04	Bean pomace	A08	A08/IN/02	By-production processing agro industry
A01	A01/OUT/04	Bean pomace	A10	A10/IN/01	Organic matrices not lignified
A01	A01/OUT/05	Seeds and peels of tomato	A04	A04/IN/01	By-products of processing tomatoes (peels, berries outsized, etc.)
A01	A01/OUT/05	Seeds and peels of tomato	A08	A08/IN/01	Agro industrial refuse
A01	A01/OUT/05	Seeds and peels of tomato	A08	A08/IN/02	By-production processing agro industry
Company's A01 output can enter the production cycle of the companies listed on the right without any transformation, from the descriptions of the materials the features are similar and meet the requirements. This does not exclude that, based on further characterizations of output, additional processing may be required.					
A02	A02/OUT/01	Middlings of durum wheat	A04	A04/IN/08	By-products of grain processing (middling, bran, gluten, starch,

					broken beans, etc.)
A02	A02/OUT/01	Middlings of durum wheat	A07	A07/IN/07	By-products of food and agro-industrial activities
A02	A02/OUT/02	Chopped of durum wheat	A04	A04/IN/08	By-products of grain processing (middling, bran, gluten, starch, broken beans, etc.)
A02	A02/OUT/02	Chopped of durum wheat	A07	A07/IN/07	By-products of food and agro-industrial activities
Even in this case additional transformations may not be necessary, since descriptions between output and input seems to coincide.					
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/01	By-products of processing tomatoes (peels, berries outsized, etc. ..)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/02	Products of processing of olives (olive residues, olive pomace)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/03	Sub-products of processing of grapes (marc, stalks etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/04	Sub-products of fruit processing (conditioning, peeling, coring, citrus pulp, squeezing of pears, apples, peaches, stones, shells, etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/05	Products of processing of various vegetables (conditioning, peeling, packaging, etc.)

Industrial symbiosis in Emilia-Romagna Region

A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/06	Sub-products of processing of sugar beet (stillage, molasses, beet pulp exhausted dried, fresh suppressate, suppressate silage, etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/07	Sub-products derived from the processing of the rice (middling, bran, husk, etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/08	Sub-products of grain processing (middling, bran, gluten, starch, broken beans, etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A04	A04/IN/09	Sub-products of the processing of fruits and oil seeds (panels germ of maize, flax, grape seed oil, etc.)
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A05	A05/IN/13	Miscanthus fibers and fibers of esparto / alpha grass waste or recycled
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A05	A05/IN/14	Fibers from sugar cane

A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A05	A05/IN/20	Fibers or flour from the skins / parts dried vegetables or fruit
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A05	A05/IN/23	Excerpts from plant fibres
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A07	A07/IN/06	By-products of farming, breeding, management of green and forestry
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A07	A07/IN/07	By-products of food and agro-industrial activities
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A08	A08/IN/01	Agro industrial refuse
A03	A03/OUT/03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	A08	A08/IN/02	By-products of agro industry processing

The description of the output in the cases above is not very precise, so the connection between input and output are possible, but the synergy cannot be actually implemented unless the output description is more precise.					
A03	A03/OUT/04	Wastes from wood processing and the production of panels and furniture	A05	A05/IN/09	Wood fibers
A03	A03/OUT/04	Wastes from wood processing and the production of panels and furniture	A05	A05/IN/12	Bamboo fibers
The output material seems to have the characteristics required by the company that would receive it, the only change needed is a reduction in size up to the fiber.					
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/04	Textile fibres
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/05	Wool fibres
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/06	Hemp and kenaf fibres
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/07	Rattan, ramie, raffia, kapok fibres
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/08	Jute fibres

A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/10	Hemp flour
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/11	Cellulose fibres
A03	A03/OUT/16	Packaging waste, rags, filter materials and protective clothing (not otherwise specified)	A05	A05/IN/15	Flax fibres
Characteristics of the output should be better verified, in case they fulfil to the requirements of one of the different inputs proposed it would be necessary a pre-processing in order to reduce the material in the requested dimensions.					
A03	A03/OUT/21	Municipal waste (household waste and similar products as well as commercial and industrial wastes)	A07	A07/IN/08	Sub-products of industrial activities
Both output and input are very general, so it is not possible to find a transformation or a transfer of the resource without further specifications by both companies.					
A05	A05/OUT/06	Recoverable paper packaging	A02	A02/IN/02	Cardboard
A05	A05/OUT/07	Recoverable plastic packaging	A02	A02/IN/01	Polypropylene
A05	A05/OUT/07	Recoverable plastic packaging	A09	A09/IN/01	Thermoplastic biopolymer in granule / powder (no PET or PVC)
In these last three output a transformation is needed, in the first two cases it could be a material selection and treatment to obtain the required dimensions. In the third case there will certainly be a reduction in size of the granules and a selection of the type of plastic. It may also be required, however, a more thorough material processing.					

The third workshop participant, Ciri Energia Ambiente (Center for the Study of Industrial Energy and Environment), proposed several solutions for some specific outputs:

- For A01 / OUT / 01 (sludge) the proposal was to use it in the manufacturing sector (specifically for sectors with ATECO code 19 - Manufacture of coke and products derived from oil refining - and 20 - Manufacture of chemicals) after a transformation into a bio-oil

similar to biodiesel and a refractory carbon residue (biochar) usable for obtaining electrical energy from an internal combustion engine;

- A01 / OUT / 01 (sludge): another proposal for the same output is utilization in the agricultural sector; in fact, biochar can be used as a soil amendment/fertilizer that has been associated with the code ATECO 01.

For these two proposals, the intermediate processes to enhance the original sub-product would be a pyrolysis, specifically the process of reforming technology “pyro-baf” which was successfully tested at the Fraunhofer Institute UMSICHT - collaborating with the CIRI Energia Ambiente.

- A02 / OUT / 01 (middling of durum wheat): being sub-products of grain processing (middling, bran, gluten, starch, broken beans, etc.), it is probable that they could be used as input for company A04 (A04 / IN / 08), without further processing, as data collected in previous experiences might suggest;

- A03 / OUT / 18 (wastes from construction and demolition, including soil from contaminated sites): it was proposed their reuse as aggregate concrete in three sectors of construction with code ATECO 41 (Civil Engineering), 42 (Construction of buildings), 43 (specialized construction work) as required by the Italian Legislative Decree 152 of 2006.

The last laboratories that responded and filled in the forms were Cipack and Siteia.Parma, with the following proposals:

- A01 / OUT / 02 (grilled tomatoes), A01 / OUT / 03 (grilled peas), A01 / OUT / 04 (grilled beans): it was proposed a reuse in the field of Food / Feed, for reuse of pectin and amino acid mixtures, with a technological preliminary treatments of stabilization of waste / sub-products (dehydration with different techniques, fermentation, acidifying treatment, etc.) and digestion (technological, with hydrothermal treatment or extrusion or biotechnology, with biochemical treatment, digestion enzymatic, or fermentation, treatment with microorganisms) in order to obtain complex mixtures treated for reuse in the Food / Feed industry. For the biorefinery, every sub-product / waste must be characterized molecularly to see which component may be of industrial and economic interest.

- A01 / OUT / 05 (skins and seeds of tomato): it was also proposed in this case a reuse in the Food / Feed industry, even if in this case the potential inputs are vegetable oils and amino acid and peptide mixtures, the intermediate treatment is the same as the previous synergy.

- A02 / OUT / 01 (hard wheat bran), A02 / OUT / 02 (chopped hard wheat): the productive sector proposed for reuse of the product is again that of the Food / Feed industry, in this case with the selection of hydrolyzed carbohydrate with low molecular weight, using as intermediate enhancement process the same proposed in the first synergy.

- A03 / OUT / 03 (Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing): reuse could take place in the area of Feed industry, hydrolyzing low molecular weight carbohydrates and protein hydrolysates. The proposed treatment is the same as the previous resources.

- A01 / OUT / 06 (used aseptic bags), A01 / OUT / 07 (tomato plants), A01 / OUT / 08 (irrigation hoses), A03 / OUT / 04 (waste from wood processing and production of panels and furniture), A05 / OUT / 01 (mixed paper/PE or aluminum/PE packaging), A05 / OUT / 03 (wooden packing: damaged pallets), A05 / OUT / 06 (recoverable paper packaging), A05 / OUT / 07 (recoverable plastic packaging): it was proposed a reuse as filler, in the form of shredded components, for compression molded polymeric material. The necessary intermediate process enhancement is the priming adhesion to polymer matrix.

- A09 / IN / 01 (biopolymer granules/powder): in this case it is proposed that this resource may originate from the processing of sub-products of the previous synergy, for the production of objects in thermoplastic polymer with fillers of different nature.

After the presentation of the results, all laboratories agreed on a further study of the synergies identified, on the basis of a more adequate knowledge of the resources and characteristics of the products.

3.6. Elaboration of potential synergies

Data received from the various companies involved in the project was compared and possible synergies have been found, in some cases providing preliminary transformations, in others considering a direct passage of the material from the manufacturer of the output to the receiver of the input. A summary table of identified synergies is proposed below; where in the three columns on the left are highlighted outputs and the three right columns lists possible inputs that can be transformed. Second and the fifth columns show the codes that have been assigned to resources, in order to preserve data confidentiality regarding products of different companies. Having found the possible synergies and processed data from laboratories, the following step was to outline and synthesize the results to make them accessible to project participants.

3.7. Synthesis and description of the results

Through collaboration of Laboratories (LEAP, Ciri Agroalimentare, Ciri Energia Ambiente, Siteia.Parma and Cipack) and ENEA, eight main flows were identified:

- agro-food scrap,
- industrial lime,
- packaging,
- building construction and demolition waste,
- textile waste,
- oil refining and natural gas purification waste,
- waste of woodworking,
- digestate.

For some synergies a preliminary processing for enhancement of the resource is required, whereas in others it can be assumed a direct recovery in the receiving. Paths towards final destination to one or more of the participating companies were provided; in addition, also others possible destinations identified by the ATECO code, i.e. through the codes of classification of economic activities, were suggested. This choice allowed leaving open more chance for participation to other companies not involved in this initial phase of the project, but also the possibility of finding other additional synergies with already participating companies.

Within these flows it is possible to classify some main flows with their main potential synergies sectors as:

Food waste: anaerobic digestion; energy recovery in biomass plants; recovery of materials for packaging; transformation for the production of pharmaceuticals and cosmetics; biopolymers.

Sludge: chemical products manufacturing; energy recovering in biomass plants; manufacture of products for farming; products for the manufacture of coke and petroleum refining.

Packaging: energy recovery from plastic packaging; anaerobic digestion.

Waste from construction and demolition: recovery of construction materials.

Textile waste: energy recovery.

Wastes from petroleum refining and natural gas purification: energy recovery.

Waste wood processing: energy recovery in biomass plants; energy recovery.

Biochar: production of compost fertilizer.

In Fig. 4 only codes representing resources and companies were used, indicating only flows and pathways between different companies. For uniformity, even for the laboratories only codes and different colors were used. The following figure shows the map legend of colors used and codes assigned to various participants. The last symbol is used to specify that, in the passage of the resource from one company to another, a valorization process is necessary, in other words an intermediate step in a plant that can convert the output for the introduction into another production cycle as an input. In Fig. 5, it is represented the general diagram built for the symbiosis project, based on the info provided by companies and labs, elaborated by ENEA adding, if possible, more synergies than those simply proposed by labs.

Arrows with colored circles represent the laboratories and indicates solutions identified by them-selves; simple arrows indicate synergies proposed by ENEA. Dashed arrows represent the solutions found according to ATECO codes, in other words possible connections found based on general industrial sectors, even if the data received from the companies did not specifically encompass that information.

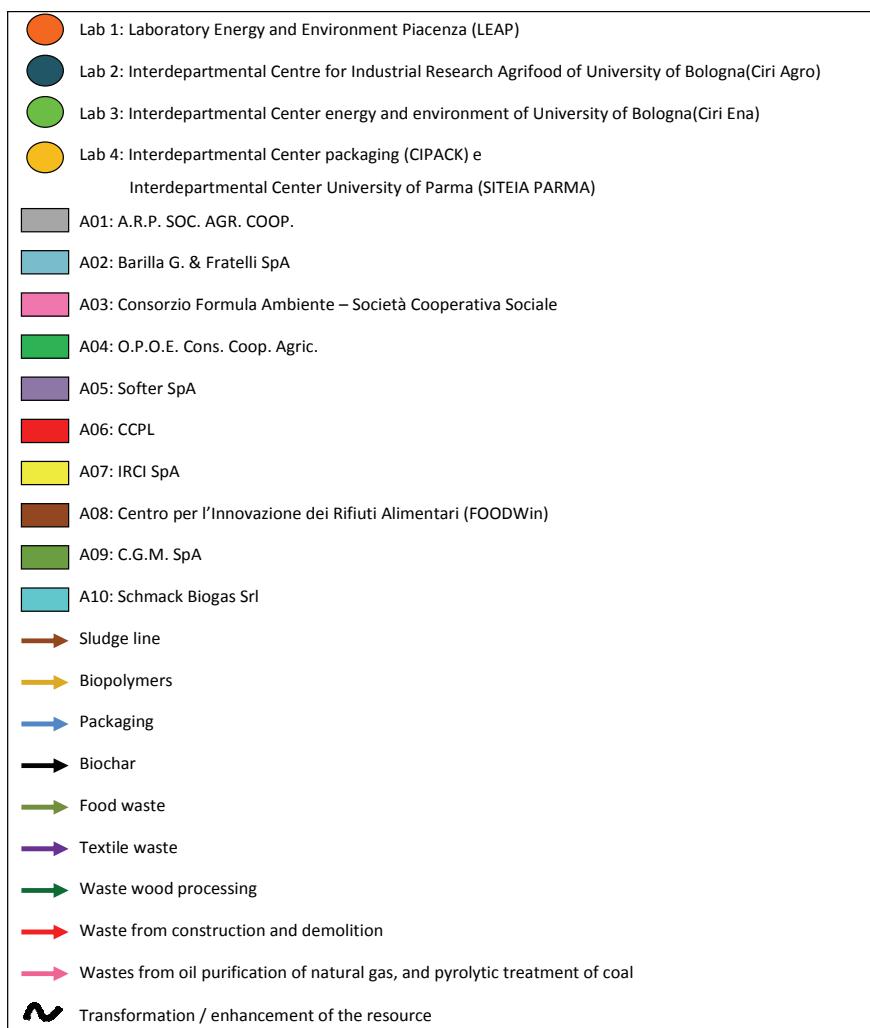


Fig. 4. Codes’ legend

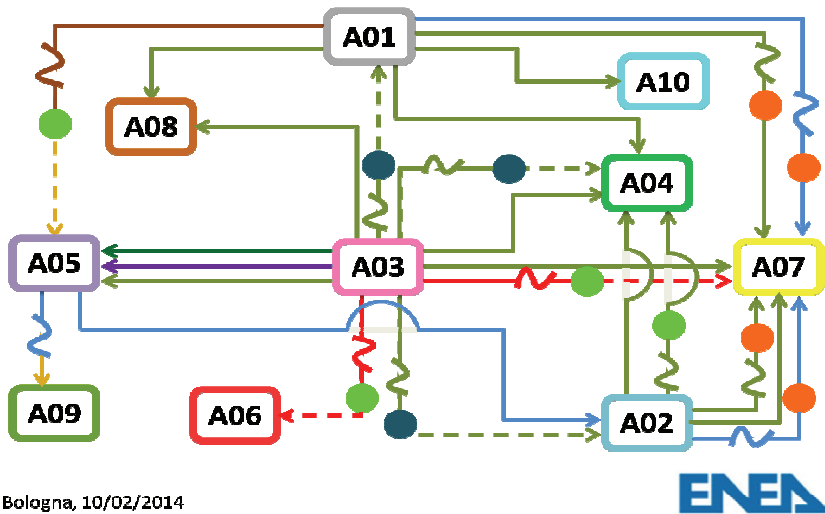


Fig. 1. Synergies network between companies participating to the project

The idea was to propose during the application of symbiosis these potential solutions, identified only by industrial sectors, in order to have them validated by companies themselves. It has to be noted that for all participating companies, at least one synergy was found. In Fig. 6 it is also shown the diagram of this potential symbiosis (matches), in order to make clear the steps followed for association between ATECO codes – and potentially receiving companies.

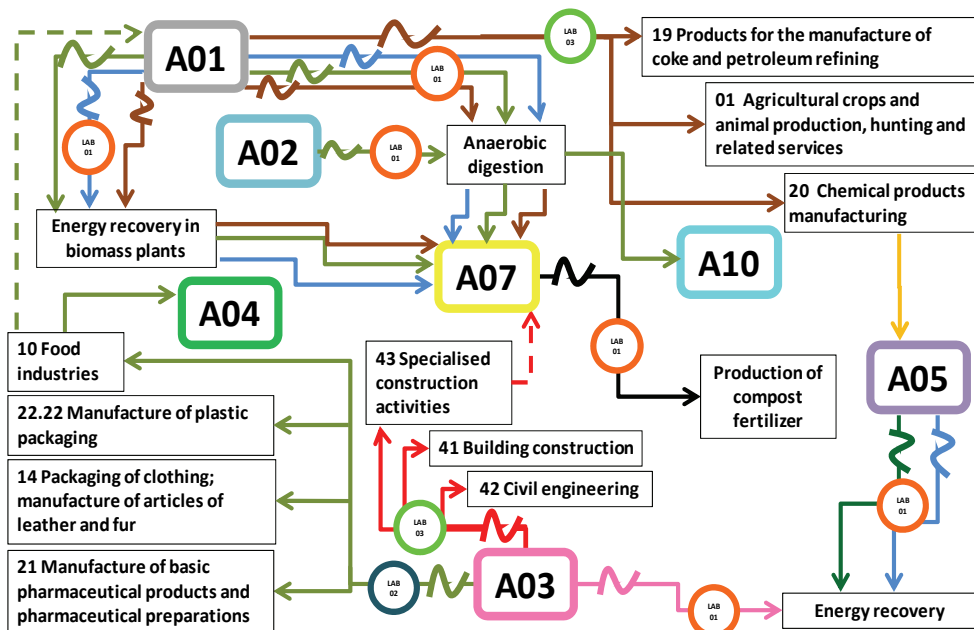


Fig. 2. Synergies network between companies participating to the project and also between companies and external potential industrial sectors

In other words, some potential synergies found by the project are between companies participating into the project, some others are between participating companies and generic potential destination sectors, named by their sector of activity (ATECO code).

This diagram also highlights other destinations not related to participating companies, but that could still be exploited by local firms interested in that type of recovery. An example would be the production of fertilizer from output A07, which could affect some agricultural cooperatives companies, very numerous in the region.

4. Organization of symbiosis application meeting

The key points set for the presentation of the results of the project were: ease of understanding, confidentiality and participation. Concerning ease of understanding, all data was presented with the help of colors and shapes in order to avoid any possible confusion. The conventions used are as simple as possible: rectangles for companies (identified by different colors), circles for the laboratories, arrows for input/output flows (dashed ones indicate hypothetical flows based only on industry ATECO codes), waves to indicate intermediate transformation process.

For confidentiality, the same method of codes already used for sending data to the laboratories was used in all documentation, although it was necessary to display companies' codes in clear during the symbiosis meeting. In order to do this, were realized labels to be delivered to the various participants to individuate its function: company or laboratory, and its identification code.

The most difficult issue was to realize meeting documentation that would help the participation of all people involved in the application meeting, depending on their roles. Laboratories were asked to check the results in order to validate the data synthesis processing. Companies were required, on the other hand, to validate and accept the proposed synergies. Specific schemes and templates to be used during the meeting were prepared for all of these objectives.

On the left column of the tables are the outputs that have been identified for synergies, in the next columns companies that could receive the resource. In the cells at the intersection between the proposed output and the receiving company are found the likely input suggested for that synergy. As an example, the output of the company A01 (A01/OUT/01), could become a possible input to the company A05, and in particular could be transformed in the input A05/IN/01 or A05/IN/02. The necessary intermediate transformation is displayed with the wave symbol and the circle indicates that a laboratory has proposed this synergy. The arrows and color codes summarize the flow of the synergy proposed.

The schemes were delivered to the participants together with the codes of their own company, so that everyone could compare the proposed symbiosis resource with the resource currently used. The availability to accept and validate a potential match was expressed with a sign on it. In the diagram following on the next page are shown some examples of outputs for which several destinations companies were proposed.

In some cases, the proposal originates from the fact that even if a company did not explicitly specify a resource as a needed input, it may still need the material according to the type of business and industrial sector. Of course, in this case the company has to validate the synergy, in a template created ad hoc for this purpose. As an example to better explain this concept, the output A01/OUT/01 could generally be reused in companies with e ATECO codes 01, 19 or 20; as company A05 has the ATECO code 20.16.0, it was asked if they would be interested in this type of material even if they did not explicitly asked for it. The aim was to engage the various participants to confirm the results, gather opinions and to have formal validation to the acceptance of flows of assigned resources.

4.1. Application meeting of Industrial Symbiosis, Bologna, February 10, 2014

After all the material to be delivered to the participants at the event was arranged as described in the previous paragraph and future scenarios have been examined, in anticipation of a possible continuation of the project, on the day of the meeting all interested parties were registered and received badges with the codes used in the preparation of the results and the corresponding names of the companies involved. Participants shown in Table 6 were present.

Irci participated and filled all data required also on behalf of Schmack. Three companies initially involved in the project did not attend the event: ARP, Formula Ambiente and CGM, however they expressed their interest in receiving the results. Note that Ciri Agroalimentare participated as a laboratory but also as a company interested in receiving waste for research purposes. After a brief introduction, results were presented in the format already described, in order to be as clear as possible for non-experts.

Table 6. Participants to the meeting held in Bologna, February 10, 2014

<i>Participants</i>	<i>Company</i>	<i>Laboratories</i>	<i>Other</i>
Barilla	X		
CCPL	X		
Cipack		X	
Ciri Agroalimentare	X	X	
Ciri Energia Ambiente		X	
Ervet			X
Irci	X		
LEAP		X	
Opoe	X		
Siteia.Parma		X	
Softer	X		

Synergy flows found based on the data collected was showed and the symbols used in the slide were explained. For each company incoming and outgoing flows were indicated. An example is given in Fig. 7.

Flows are indicated by arrows, the colors used are those already explained in the legend. Companies are represented with rectangles (the company considered in the example is the A01) in each slide the rectangle representing company of which you are dealing with is larger than the other. Circles represent laboratories that have proposed synergies. In the black boxes are reported ATECO codes of companies that could possibly receive that particular resource. Dashed arrows represent general synergies proposed from ATECO codes or from descriptions of the resources involved. They are very probable transfers, but in the end the companies have to make the choice to accept or not that synergy. Writings in bold are other possible destinations not directly provided by participating companies, but allowing the identification of a set of firms that might be interested in that type of product. The symbol “~” indicates an intermediate transformation necessary for the material in output becoming a resource input in the new production cycle.

Intermediate processing are indicated in a specific way by the laboratories and can be chemical, physical or mechanical; transformations proposed by ENEA usually provide a simple change of dimensions, so treatments are mainly of mechanical type. The synergies in which this transformation are reported have then an intermediate step consisting in the transit of resources at a treatment facility, according to the specific processing required. In designing the synergy it is necessary to take into account this factor, which provides additional steps: search for and transport to a specific plant, processing of optimal routes, transport to target final company.

In the slides showing the symbiosis results, geo-referencing of companies, inflows and outflows have been indicated: Fig. 8 shows an example.

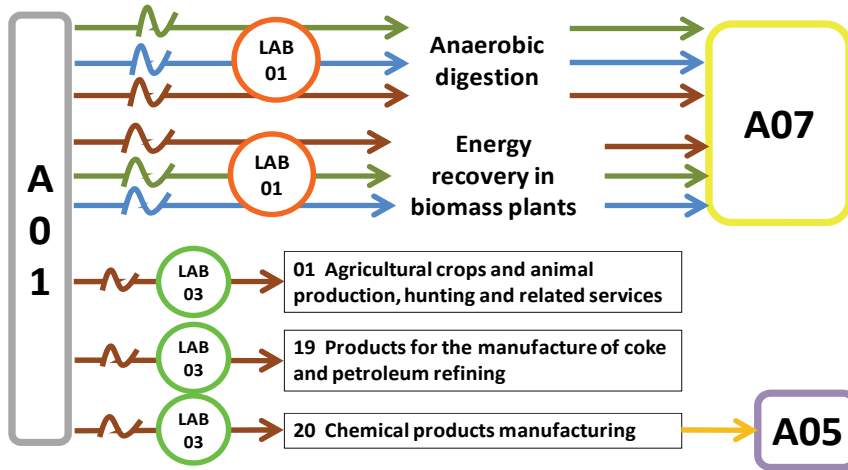


Fig. 3. Example of final results output for each company (in this case for company with code A01)

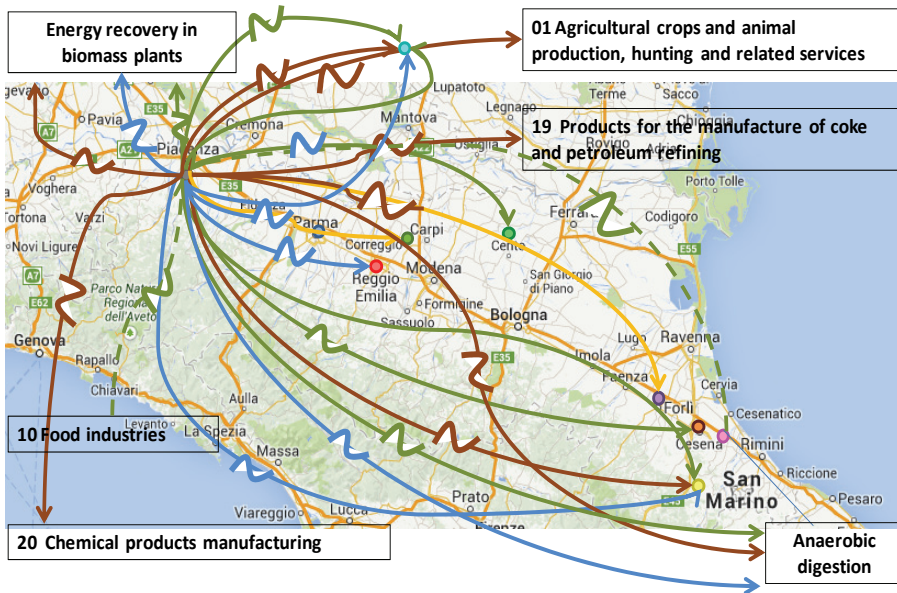


Fig. 4. Geo-referred results provided for each company (in this example for company with code A01)

The symbols used on the map are the same already explained. As before, synergies not necessarily directed to the participating companies were also included, indicating the possibility of searching for companies interested to resources outside the project, for example in the proximity of the offering firm in order to optimize transport. At the end of the meeting, each company received their own availability cards, with an indication of their codes of resources. All firms received documentation with the map legend of the symbols used and

the general outline summarizing the synergies found by ENEA and laboratories. The laboratories were asked to validate the processing identified by the solutions proposed by them. About one hour was given to control the documentation, symbiosis validation, availability and general considerations on the results. During this time experienced staff was available for clarification and to take notes about inaccuracies or particular proposals.

At the end cards were taken and every participant had the possibility to give feedback on the meeting. For this issue the representative of the Province of Rimini has shown a willingness to participate in the meetings and promote the initiative especially for experimentation, but stressed the need to engage in this activity also province's department responsible for environmental services. The Province has expressed appreciation to the project, since such activities give very important contributions towards the purpose of territorial planning.

4.2. Post meeting analysis

In the following days participating companies were asked to give consent to the publication of data for privacy and confidentiality, in order to present the results in clear text. The consent was unanimous, so the final report will be expressed in full detail, without codes. The questionnaires completed during application have been used to amend the results, symbiosis not deemed relevant by companies has been eliminated and synergies that have received confirmation have been validated. The availability was explicitly required to companies that will have to accept the sub-products, as it can be assumed that those releasing waste material should be willing to give it. Having completed the review of the results and processed the new data, a revised and amended version of the project documentation has been prepared. Since the final conference event was open not only to project participants but also to external parties interested in symbiosis and institutional representatives, it was deemed important to summarize the project phases and the methodologies used to address the various steps.

4.3. Final conference "Business opportunity from waste: experience of Industrial Symbiosis in Emilia-Romagna" - Bologna, March 7, 2014

The final meeting organized by Aster was attended by various stakeholders helping to give a complete picture of Industrial Symbiosis. Several issues were addressed: description of the practice of the symbiosis, practical implementation of some cases, legislative and administrative issues, already addressed at the end of the day the application of symbiosis.

The project Green Economy - Application of Symbiosis in Emilia-Romagna was also presented. General topics about Industrial Symbiosis and what purpose it serves were summed up. Then the application of symbiosis was presented and were recalled the milestones and the various meetings that took place from June 2013 until March 2014. It was shown the approach and methodology developed for the project and documents and materials used were presented, explaining the use of codes, colors and symbolism, with charts summarizing the results. Also geo-referencing theme was addressed, explaining the importance of this tool for decisions and organization. Finally, project data were synthesized as follows:

- 10 companies out of 13 participants in the initial focus groups have joined and participated in the project,
- 4 laboratories out of 7 participants in the initial focus groups have joined and participated in the project,
- 14 paths of Industrial Symbiosis were identified by the laboratories,
- 14 paths Industrial Symbiosis were identified by ENEA,

- 19 synergies were proposed by the laboratories,
- 50 synergies were proposed by ENEA.

The intervention was concluded by stressing that the results presented are potential synergies, but their actual realization needs further steps in economic, logistical, technical and legal – administrative areas, that are not addressed in the project.

5. Conclusions

The application of Industrial Symbiosis done within the project "Green Economy and Sustainable Development", founded and promoted by Unioncamere Emilia-Romagna and ASTER, aimed at spreading the culture of Industrial Symbiosis in the Emilia–Romagna, has been realized with the scientific and technical coordination and operational support of ENEA Environmental Technologies Technical Unit and participation of laboratories of the High Technology Network of Emilia-Romagna. Overall, the response of the participating companies was more than good and the contribution of the laboratories was significant, although greater participation might have been desirable to fully exploit the opportunities arising from the operation of Industrial Symbiosis. Moreover, the application of Industrial Symbiosis has highlighted almost 90 potential synergies both between the 10 participating companies and between these and companies located in the surrounding area.

Results of the project seem to be interesting not only for the large amount of found matches but also for the interest in Industrial Symbiosis as a tool for enhance circular economy, saving resources, a giving and maintaining opportunities in local area shown by the companies and by local authorities, directly and indirectly involved into the project (Province, Region, Chambers of commerce). The adopted methodology allowed collecting and organizing data in a very synthetic and systematic way, really appreciated by companies recognizing that some of the most import issue to solve for making Industrial Symbiosis happen is the language used and the connections created between companies.

Matches coming from this first application of Industrial Symbiosis in Emilia-Romagna need to be verified and “exploded” in order to understand the conditions at which each match can be actually finalized, with a formal agreement between companies involved. This activity is the object of a second phase of the project, which is ongoing (10.2014 – 06.2015). In this second phase following issue will be taken into account for each interesting synergy (in other words, for which companies involved have expressed explicitly their willingness to continue and collaborate):

- Budget and economical issues
- Logistics
- Technical aspects
- Legal and administrative aspects, involving local authorities and control bodies.

References

- ASTER, (2014), Project "Green – Simbiosi Industriale - Modelli di gestione integrata, sostenibile e innovativa delle aree produttive: filiere per il trattamento e la valorizzazione di biomassa da scarti agro-industriali, ASTER S. Cons. p. A., On line at: <http://www.aster.it/tiki-index.php?page=SimbiosiIndustriale>.
- CSA Project, (2014), *Community Supported Agriculture*, Provincia di Rimini, On line at: http://www.provincia.rimini.it/progetti/territorio/2005_ptcp/ptcp_2007_v_2012/2014_csa/mn_02_csa/01_origini.htm.
- Cutaia L., Sbaffoni S., Mancuso E., Barberio G., Luciano A., Scagliarino C., La Monica M., (2014), Un esempio di eco-innovazione di sistema attraverso la valorizzazione territoriale di risorse: nuovo approccio cooperativo tra mondo industriale, scientifico e istituzionale, *Energia, Ambiente e*

- Innovazione*, **5**, 76-88, On line at: <http://www.enea.it/it/produzione-scientifica/pdf-eai/5-2014/eseempioeco-innovazione.pdf>.
- ENEA, (2011-2015), "*Development and implementation of a regional platform for Industrial Symbiosis*" into the project "*Support to the development of production in the South Italy: pilot interventions for the sustainability and competitiveness of tourism and industrial areas*", funded by Italian Ministry of University and Research - MIUR), Ongoing project.
- EU Communication, (2011), *Roadmap to a Resource Efficient Europe*, COM (2011) 571, European Commission, On line at: http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm.
- Iacondini A., Mencherini U., Morselli L., Passarini F., Vassura I., (2014), Industrial symbiosis in Italy as a tool for sustainability: case study analysis and replicability, *Procedia Environmental Science, Engineering and Management*, **1**, 19-24.
- Invitalia, (2014), *La mappa delle specializzazioni tecnologiche. Il quadro regionale*, Agenzia nazionale per l'attrazione degli investimenti e lo sviluppo d'impresa SpA, On line at: https://www.researchitaly.it/uploads/7553/Mappatura%20specializzazioni_II%20quadro%20regionale_1.pdf?v=801f04a
- Laybourn P., Lombardi R.D., (2012), Industrial symbiosis in European policy. Overview of recent progress, *Journal of Industrial Ecology*, **16**, 11–12.
- OECD, (2011), Project on green growth and eco-innovation, Organization for Economic Co-operation and Development, On line at: <http://www.oecd.org/dataoecd/43/48/45169190.pdf>
- Regione Lazio, (2014), Smart Specialization Strategy (S3), On line at: http://www.regione.lazio.it/binary/rl_attivitaproduttive_rifiuti/tbl_news/S3_Regione_Lazio.pdf
- RER, (2014), *Piano Regionale di Gestione dei Rifiuti (PRG) - Regione Emilia-Romagna*, On line at: http://ambiente.regione.emilia-romagna.it/rifiuti/documenti/prgr-adottato/prgrfinale/at_download/file/PRGR%20Finale_alta%20risoluzione.pdf



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HEALTH IMPACT OF A REGIONAL PLAN FOR THE IMPROVEMENT OF PM10 AIR QUALITY*

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Abstract

An Evaluation of the Health Impact has been carried out in the context of the Strategic Environmental Evaluation belonging to the next Regional Air Quality Plan 2014-2020 (PAIR2020); this work is meant to estimate the health effects deriving from the decrease of PM10 concentration in the air.

In this purpose, it has been used a formula established by the ISPO of Florence to calculate AC (Attributable Casualties) due to PM10 action; in doing this, the ISTAT data of natural death have been taken into account, together with several parameters and values for health protection of WHO and EU, first analyzing the regional realities of 2001 and 2010, and then defining three different scenarios (BAU-TS-MFR) which will be the reference point for 2020, in relation to the average annual concentration of PM10 and according to the present available sketch of the latest PAIR2020.

The air quality scenarios has been calculated using the Emilia-Romagna Regional Emission Inventory and for neighboring regions Emilia-Romagna the National Emissions Inventory (ISPRA 2005) taking into account the national energy strategy SEN2013 (source GAINS Italy) with the RIAT+ software, that is a regional integrated assessment software tool, developed in OPERA LIFE+ Project that helps the policy makers in the selection of optimal emission reduction technologies, to improve the air quality at minimum costs. In this way, it has been possible to see the direction in which the scenarios of casualties attributable to PM10 will evolve up to 2020, obviously in relation to a reduction of the average regional concentration levels of pollutants in air.

After estimating deaths attributable for the three possible 2020 target scenarios we estimated at regional level, for the only year 2010, the separated emissions for the primary and secondary PM10, disaggregated for the 11 CORINAIR productive macro sectors sources of emissions, and then

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calculated their attributable deaths (AC) due the PM10, so you have an idea in terms of percentages, the respective responsibilities of each macro productive sector regional, highlighting the most significant.

Keywords: air quality, CORINE-AIR sectors, PM10, regional health impact

1. Introduction

The Particulate Matter PM10 (aerodynamic diameters smaller than 10 microns) represents one of the greatest problem for the air quality, and in this work will be shown the results of the epidemiological research on the evaluation of PM10 long exposure, and the related effects on human health at the different concentrations of air pollutant levels (Arduino, 2014; EC, 2014; EEA, 2013).

The following study estimates the death-rate attributable to PM10 action (AC= Attributable Cases) in the Emilia Romagna area, through the definition of three possible prospective scenarios up to 2020, applying the contents of a regional plan for the empowerment of air. The air quality scenarios has been calculated using the Emilia-Romagna Regional Emission Inventory and for neighboring regions Emilia-Romagna the National Emissions Inventory (ISPRA-SinaNet, 2005; ITA.RER, 2012) taking into account the national energy strategy SEN2013 (source GAINS Italy) with the RIAT+ software, that is a regional integrated assessment software tool, developed in OPERA LIFE+ Project that helps the policy makers in the selection of optimal emission reduction technologies, to improve the air quality at minimum costs (Battini, 2014).

To calculate the estimate of mortality, we used the formula studied in the epidemiological research on short-term effects of PM10 in the Lombardy Region area, published in 2011 (Baccini et al., 2011). Data for this work, related to Emilia Romagna Region, were selected by the Union of the Chambers of Commerce of Emilia Romagna (Union of the Chambers of Commerce of Emilia Romagna (<http://www.rer.camcom.it/studi-ricerche/banche-dati/bd/sanita/morti-per-residenza-e-causa-p-r-n/Caumorer.xls/view>) regarding the mortality data, and by ARPA's (Regional Environmental Prevention Agency of Emilia-Romagna (<http://www.arpa.emr.it>) monitoring stations regarding the concentration values of PM10 in the air.

2. Used methods and data for the calculation of the regional air quality scenarios up to 2020

2.1. The tool RIAT+

RIAT+ is a regional integrated assessment software tool, developed in OPERA LIFE+ Project that helps the policy makers in the selection of optimal emission reduction technologies, to improve the air quality at minimum costs. RIAT+ is an integrated modeling environment using tabular and geographic data, simulation and optimization models, graphical and geographical user interface, focusing on the regional scales (Fig. 1, for a scheme of RIAT+). The tool allows to identify the set of actions that need to be encouraged or introduced to effectively decrease the concentrations of secondary pollutants (PM, ozone and NO₂), minimizing the costs.

The main components of RIAT+ are represented by:

- a database of measures to reduce emissions;
- an emission inventory;
- a source/receptor function (ie. Artificial Neural Networks) obtained starting from simulations made with a CTM model (in our case NINFA, the ARPA Emilia Romagna air quality system);

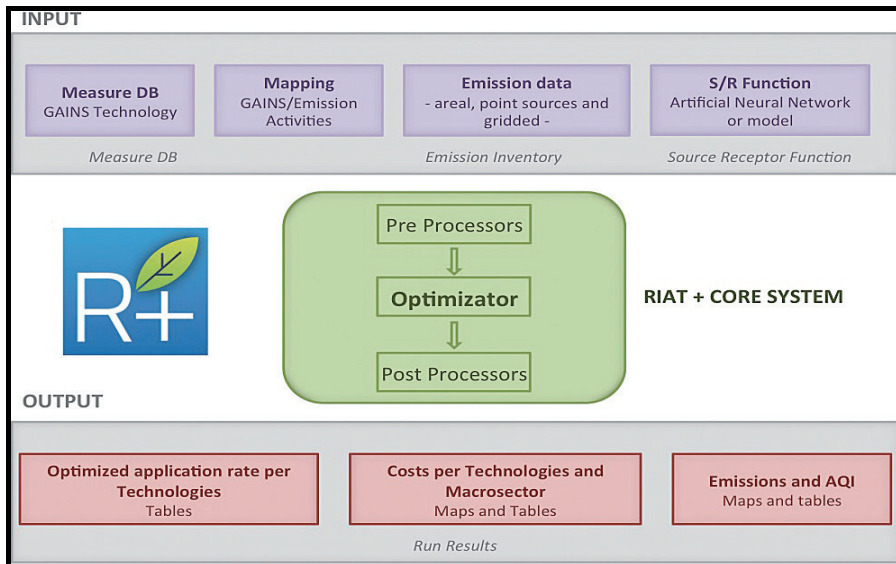


Fig. 1. RIAT+ block diagram with I/O and core system

Peculiar components of RIAT+ core system are:

- a multi-objective optimization problem solver, i.e. one or more air quality indicators (e.g. yearly PM10 average) are reduced in the policy application domain, minimizing the costs of emission reduction measures costs to obtain this concentration reduction. The solver is able to select and present to RIAT+ user the entire set of efficient abatement measures, in terms of application rates (i.e. penetration levels to be reached);
- since a CTM (Chemical Transport Model) cannot be run in real time within RIAT+ optimization procedure for its CPU time requirements, a simpler relationship between emission sources and air quality indicators at given receptor sites (S/R models) is used in RIAT+ optimization algorithm (Artificial Neural Networks – ANN in the following regional applications).

This approach compared to the traditional linear regression model (used in other systems), captures the non-linearities in the relationships between emissions and concentrations, maintaining a low CPU time.

The main outputs are provided by RIAT + are:

- Pareto curve that represent the set of solution obtained by the optimization module and shows the optimal trade-off between AQI and internal cost, considered over the CLE. It is also possible to visualize information about emissions reduction and AQI values;
- Activity details tables shows the optimization results with activity and technology detail, application rate and cost;
- Maps screens show the results (emissions, AQIs and cost) with a grid detail on cartographic basis. It is also possible visualize the maps in Google Earth.

2.2. Emission Scenarios in PAIR2020

The reference emission scenario - Adriatic Padan regional Basin - (indicated below for brevity as "APB₂₀₁₀" or "APB") has been prepared using the Emilia-Romagna Regional Emission Inventory and for neighboring regions Emilia-Romagna the National Emissions

Inventory (ISPRA-SinaNet, 2005) taking into account the national energy strategy SEN2013 (Bortone and Raffaelli, 2014; Freda, 2013).

Table 1. Emission scenarios (tons/year) and percentage variation of 2020 emission scenarios

<i>Pollutant</i>	<i>Reference scenario: PB2010 - APB -</i>	<i>Business As Usual CLE-ER 2020 (NO piano) - BAU -</i>		<i>Target Scenario plan - TS -</i>		<i>Maximum Feasible Reduction Scenario - MFR -</i>	
	Ton	Ton	%	Ton	%	Ton	%
PM10	13637	10324	-24	9531	-30	4438	-67
NOX	106745	83889	-21	59589	-44	23813	-77
NH3	51522	47085	-8	26929	-47	16745	-67
VOC	99002	81895	-17	67257	-32	31428	-68
SO2	17489	18931	+8	17067	-2	13105	-25

The emissions for the reference scenario were compared with emissions projections corresponding to different possible future developments. They were therefore considered and compared with each other the following 3 emission scenarios:

- The scenario Business As Usual CLE-ER 2020 ("Scenario NO Plan") -BAU: with regard to Emilia Romagna, in addition to using the expected development scenario SEN 2013 specifically "regionalized", takes into account the changes in emissivity due to plans regional already approved or adopted, traffic plan (PRIT), the energy plan (PER), and the Rural development plan (PSR), while the outer regions using emissions ISPRA 2005 made evolve according to the SEN2013 national scenario;
- The Target Scenario plan -TS-: estimated using the optimization tool RIAT + is an assessment of emissions in Emilia Romagna which would allow to meet the limit value of the number of exceedances daily PM10 in good part of the region. For regions outside the scenario objective of the plan coincides with Business As Usual 2020 scenario;
- The Maximum Feasible Reduction scenario -MFR- , which is also used in RIAT + is the emission scenario that you would have if in Emilia Romagna were applied at 100% all the technologies currently available, while in the outer regions MFR scenario coincides with the trend scenario 2020. Clearly, it's a theoretical limit, difficult to apply because they do not take into account the cost and practical feasibility.

3. Used methods and data for the calculation of the mortality associated to the three air quality scenarios for 2020

The sample of deaths (M=Mortality) used in this epidemiological research, was obtained from published data of the Union of the Chambers of Commerce of Emilia Romagna, and it takes into account the International Classification of Disease mortality classification ICD 9 (codes from 001 to 799) referring to the year 2001, and ICD 10 (codes from A00 to R99) referring to the year 2010; the structure of ICD codes was modified and empowered between 2001-2010, which justifies the difference of ICD codes taken in the 2001 and 2010, remembering to readers that both codes ICD 9 and ICD 10 represent the same illness groups. These ICD codes were chosen to represent the natural mortality rate in the above mentioned studio's area, and we have discarded ICD 10 from V01 to Y34, and the same was done for the pathologies of ICD 9 codes; in this way we obtained natural mortality rate for the years 2001 and 2010 (M_{2001} and M_{2010}).

To obtain data about the Particulate Matter PM10 concentration (X = air pollutant concentration, expressed in $\mu\text{g}/\text{m}^3$) we used median values recorded by the monitoring of ARPA-ER in specific urban, suburban and traffic values, keeping out the country values because monitoring were not constant in this period (Eq. 1). Thereafter we estimate a mean value thus obtaining X_{2001} and X_{2010} for the PM10 in air. To estimate the mortality rate attributable to the scenarios considered, we used the formula taken from the epidemiological research of Statistical Unit of ISPO (Institute for the Oncological Study and Prevention of Cancer of Florence) published in 2001 by Baccini et al., (2011) on the short-term effects of PM10 in Lombardy Region, according to Eq. (1), where: AC = Attributable Casualties = Number of deaths due to the air concentration of PM10; e = Number of Nepero; β = $(\log \text{RR}/10)/10$ = increase of unitary variation; $\text{RR} = 1.04$ = Relative Risk = value compared to the concentration-response function for the PM10 (WHO, 2013, Regional Office for Europe : “Health risk of air pollution in Europe - HRAPIE project Recommendations for concentration – response function for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide”); x = Annual mean concentration of pollutant; T = Limit Exposition Value (VLE) to PM10 set by WHO [$20 \mu\text{g}/\text{m}^3$] and/or by EU= [$40 \mu\text{g}/\text{m}^3$]; M = Regional appraisal of annual death-rate, due to natural factors taken by utilizing ICD codes and regional mortality data.

$$AC = \frac{e^{\beta(x-T)} - 1}{e^{\beta(x-T)}} M \quad (1)$$

The value of Relative Risk (RR) we chose among those proposed by the World Health Organization, was 1.04; even if the considered value is associated to the specific age group 1-12 years old, it was considered the most appropriated of all to realize this project.

4. Analysis of retrospective scenarios (2001 and 2010)

Values of death, attributable to PM10, are now shown as far as the citizens of Emilia Romagna are concerned, together with the mean concentration values of air pollutant annual percentage, calculated on the variable Limit Exposition Value:

- VLE proposed by WHO as $20 \mu\text{g}/\text{m}^3$ utilized in the mathematic calculation in association with the medium value of air pollutant concentration in 2001;
- VLE proposed by EU as $40 \mu\text{g}/\text{m}^3$ used in the mathematic calculation in association with the medium value of pollutant concentration in air in 2001;
- VLE proposed by WHO as $20 \mu\text{g}/\text{m}^3$ utilized in the mathematic calculation in association with the medium value of pollutant concentration in air in 2010.

The number of deaths attributable to PM10 (AC), estimated with the association of EU VLE equal to $40 \mu\text{g}/\text{m}^3$ has not been calculated for the year 2010 (and not even for the scenarios set for 2020), because this health protection value is bigger than the mean concentration value of PM10 for this year ($31.25 \mu\text{g}/\text{m}^3$). In Table 2 it is shown the relationship between the arithmetic parameters used in the formula and the values of death attributable to PM10 (AC) in the following three scenarios, called synthetically: 1) WHO-2001; 2) EU-2001; 3) WHO-2010; that identify their VLE from the following two documents listed in the bibliography: (WHO, 2005) and (ITA.DLgs, 2010). First of all, it is necessary to clarify that annual mean values of PM10 concentration recorded in the study area in 2001 ($46.75 \mu\text{g}/\text{m}^3$) and in 2010 ($31.25 \mu\text{g}/\text{m}^3$) by monitoring of ARPA-Emilia Romagna, show a very strong decrease, as $15.5 \mu\text{g}/\text{m}^3$, thanks to the efforts made by the regional policy to improve the air quality, and thanks to advantageous weather conditions that, combined with the regional policy, contributed to the pollutants dispersion. Said this, as far as 2001 is

concerned, it is possible to notice how, the use of an inferior health protection value (T) ensues a higher number of attributable cases (AC); the results show AC=4,046.4 and AC=1,061.5 respectively associated to VLE=20 µg/m³ (WHO, 2005) and VLE=40 µg/m³ (ITA.DLgs, 2010).

Table 2. Calculation of attributable deaths (AC) due to the air pollutant concentration (X) of PM10 for the 2001 and 2010 years, in association with Exposure Limit Values to the pollutant (VLE) set by WHO and UE

		<i>Unit</i>	<i>Source</i>
RR =	1.04	[1.004 – 1.09]	WHO
β =	0.003922071		ISPO
Scenario 2001 with WHO Exposition Limit Value for PM10 = [20 µg/m³]			
T =	20	µg/m ³	WHO Exposition Limit Value
M₂₀₀₁ =	40.629	deaths/year	Union of the Chambers of Commerce of Emilia Romagna, year 2001
X =	46.75	µg/m ³	Average of the concentrations for 2001
		AC =	4,046.6
Scenario 2001 with EU Exposition Limit Value for PM10 = [40 µg/m³]			
T =	40	µg/m ³	EU Exposition Limit Value
M₂₀₀₁ =	40.629	deaths/year	Union of the Chambers of Commerce of Emilia Romagna, year 2001
X =	46.75	µg/m ³	Average of the concentrations for 2001
		AC =	1,061.5
Scenario 2010 with WHO Exposition Limit Value for PM10 = [20 µg/m³]			
T =	20	µg/m ³	WHO Exposition Limit Value
M₂₀₁₀ =	45.136	deaths/year	Union of the Chambers of Commerce of Emilia Romagna, year 2010
X_{APB.2010} =	31.25	µg/m ³	Average of the concentrations for 2001
		AC =	1,948.3

It would be reasonable to argue why; having an EU-proposed VLE of 40 µg/m³, the number of deaths attributable to PM10 is lower than the one which refers to the WHO VLE of 20 µg/m³. Let's suppose that the number of deaths increases progressively as we get further from the threshold limit value: lower is the threshold value, higher is the number of death cases. Basically, the lower will be the VLE the sooner the air pollution effects shall be perceived, with a consequent increase of the death rate.

It is of the maximum importance to understand that an arithmetic increase of VLE does not imply an actual protection of human health, as already seen with the EU-proposed parameter; in fact, a lower VLE would compel public authorities to adopt stronger policies aimed at reducing the air pollutant concentration. Subsequently, aiming at a comparison with the scenarios of 2001 and 2010, we consider the data of 2001 (obtained from the calculation which displayed the WHO threshold value, showing 4,046.6 death cases attributable to the action of PM10 in the regional area) as the most appropriate term of reference.

Analyzing the 2010 data (APB₂₀₁₀), it is possible to see that the air pollutant concentration about X = 31.25 µg/m³ really decreased, if compared to the 2001 value; for this year and for the following, it was not possible to estimate the AC value compared to the VLE proposed by EU, because the VLE was lower than the air pollutant concentration as said before, and the result would have no significance. We estimate for the 2010 year, an AC result around 1,948.3 associated to the WHO VLE = 20µg/m³, that shows a reduction by 48.14% compared to AC₂₀₀₁.

5. Calculation of AC Mortality for the three prospective scenarios (BAU–TS–MFR) up to 2020

The estimation of M_{2020} , calculated as the mean of the natural deaths medium values from 2001 to 2010 in the studio area, gave us a result among 44.318 natural casualties (<http://www.saluter.it/siseeps/sanita>).

Furthermore the air pollutant concentration was estimated for (X_{2020}) 2020, according to the present available sketch of the latest PAIR2020, expressed in three different reduction percentages respectively by 9%, 17% and 31% lower than the air pollutant concentration of 2010 (X_{2010}); the pollutant percentage reductions have been associated in calculations to the three different scenarios hypothesized, shown in the Table 3 (Percentage reductions estimated and expressed in oral way during official regional dissertation about the definition of Regional Air Quality Plan PAIR2020, based on his own experience, by the authors of this article, without scientific publication) (PAIR2020, 2014; Ranzi and Giannini, 2014):

- BAU - Business as Usual Scenario: it has hypothesized that if the environmental policies about air quality were just maintained till 2020, it would be possible to see the same percentage decrease as the one occurred in 2001-2010 (9%);
- TS - Objective Scenario 2020: it is the most desirable to happen, with an estimate of pollution reduction by 17% than the concentration in 2010.

MFR - Maximum Feasible Reduction Scenario: it evaluates a pollution reduction by 31% than the concentration of 2010.

It being understood that variations in deaths attributable AC here to follow are calculated between the values of the 2001 mortality and the mortality of the three scenarios of 2020, and that instead the concentration values of the three scenarios to 2020 were estimated in percentage terms based on the 2010 concentration values X, we can come to the following endings:

- In the first Scenario (BAU - Business as Usual), the AC_{2020} data of 1442.6 is compared to the AC data of 4,046.6 casualties for 2001.

This result shows that only applying environmental policies for the empowerment of air, an important result will be obtained in the public health protection and death prevention with an air pollution reduction by 9% than the 2010 concentration;

- The second (TS - Target Scenario) shows an AC_{2020} result of 1,020.1 deaths depending on the estimated reduction of air pollution by 17% than the 2010 concentration; in this scenario, casualties would decrease by 78% than AC in 2001 (4,046.1);

- The third scenario (MFR - Maximum Feasible Reduction) considers the 31% reduction of the 2010 air pollution concentration and a percentage reduction by 93% of AC data, compared to AC in 2001 (4,046.1). Even if this scenario is unrealistic to achieve, it would represent the most virtuous direction for policy choices.

6. Data to estimate and disaggregate the primary and secondary PM10 emitted by Corine-Air productive macro sectors sources of emissions, at regional level, for the year 2010

After estimating deaths attributable for the three possible 2020 target scenarios we tried to bring the attributable deaths (AC) due the PM10 for the year 2010 to the 11 Corine-Air regional productive macro sectors sources of emissions, in function both the primary PM10 than the secondary, so to have an idea, in terms of percentages, of the respective responsibilities of each macro productive sector regional, highlighting the most significant.

Table 3. Values of attributable casualties (AC) calculated according to three scenarios of annual regional concentration of PM10 (X%) reasonably conceivable for 2020, considering the WHO’s limit value for the protection of human health for PM10: (T) = [20 µg/m³]

Scenario	Parameter	Value	Unit of measure	Source	AC results
/	RR =	1.04	[1.004 – 1.09]	WHO	/
/	β =	0.003922071	/	ISPO	/
/	T =	20	µg/m ³	WHO exposition limit value	/
/	M ₂₀₂₀ =	44.318	deaths/year	Regional Health Service of Emilia Romagna	/
APB ₂₀₁₀	X ₂₀₁₀ =	31.25	µg/m ³	ARPA Emilia Romagna	AC = 1.948.3
/	/	/	/	/	/
BAU	X _{81%} =	28.4375	µg/m ³	X ₂₀₁₀ reduced of 9%	AC = 1442.6
TS	X _{73%} =	25.9375	µg/m ³	X ₂₀₁₀ reduced of 17%	AC = 1020.1
MFR	X _{69%} =	21.5625	µg/m ³	X ₂₀₁₀ reduced of 31%	AC = 270.6

6.1. *Meteo-Pollution tool and Regional emissions inventory for the year 2010*

Through the modeling system (NINFA-E) we were able to estimate the concentration of PM10 in the zones and agglomerations of the region divided into a natural component and a component of human activity. NINFA (Northern Italy Network to Forecast Aerosol pollution) is a meteorological and pollution model based on the regional version of the CHIMERE chemical transport model (Bessagnet et al., 2004), driven by the meteorological model LAMI. The model runs daily at ARPA-SIM, and provides concentration maps of PM10, Ozone and NO2, for the previous day (hindcast) and the following 72 hours (forecast). LAMI is the Italian version of the Lokal Modell LM, developed by the Deutsche Wetterdienst. Boundary conditions are provided by the Prev’air model, emission inventories are provided by the national inventory Corinair CTN. Input data are at high resolution, using regional and urban scales (multi-level nested approach). Starting from 2006, NINFA will run daily providing hourly air quality analysis and forecasts. Before becoming operative, it has to be validated and improved.

The results of the model, performed for the reference scenario (ABP year 2010), showed that the bulk of pollution is of anthropogenic origin with a share of about 85% and the remaining 15% natural. The aforesaid anthropogenic fraction is estimated that only 25% is of primary origin, and therefore caused only to the processes of transport and diffusion of dust emitted directly from various sources of pollution, with the remainder, 75%, is believed to be due to particulate matter of secondary origin, then the product from chemical and physical processes that occur in the atmosphere from the precursors emitted by human activities.

From the above, the direct actions on emissions of PM10 can act only on a limited portion of pollution, which is the primary one. To achieve a significant reduction of the concentration in the air will be necessary to act, to a substantial degree, on precursor pollutants. It should also be pointed out that, of the total concentration of particulates in the atmosphere in Emilia-Romagna, the region is directly responsible for only a small share, equal to about 25%, while the remainder is due to pollution from neighboring regions. The regional emissions inventory, with reference to the year 2010, was updated using the database-software INEMAR (air emission inventory), an application system made to estimate the emissions of various pollutants, for different types of activities (e.g. heating, traffic, agriculture and industry) and by type of fuel, according to the classification international adopted as part of the inventory EMEP-Corinair. The methodology EMEP-CORINAIR contains the estimation methods to quantify the emissions associated with each human activity or natural (EMEP-CORINAIR, 2013). It classifies the emission sources in

three hierarchical levels: the more general class includes 11 macro sectors, which are further divided into 76 sectors and 375 activities. Each of these classes and divisions is assigned a coded reference to the common European level, called SNAP97 (Selected Nomenclature for Air Pollution 97).

Table 4. Main pollutants of the Emilia Romagna regional emissions inventory, for the year 2010, calculated with the INEMAR – EMEP CORINAIR methodology

	<i>PM₁₀</i> (t/year)	<i>COV</i> (t/year)	<i>NH₃</i> (t/year)	<i>NO_x</i> (t/year)	<i>SO₂</i> (t/year)
□ MS 01: Combustion - Energy and processing industry	87	1534	0	9482	430
□ MS 02: Combustion - not industrial	5395	28309	154	8729	1195
□ MS 03: Combustion - Industry	993	1770	0	12207	9773
□ MS 04: Production Processes	617	7645	1106	3077	4540
□ MS 05: Extraction, distribution fossil fuels / geothermal	0	5187	0	0	0
□ MS 06: Use of solvents	4	39883	1	15	2
□ MS 07: Road Transport	4593	12498	832	60675	370
□ MS 08: Other mobile sources	1524	2055	2	11300	1005
□ MS 09: Waste treatment and disposal	6	62	128	623	183
□ MS 10: Agriculture	418	59	49299	637	0
□ MS 11: Other sources of emission and Reversals	0	0	0	0	0
TOTALs	13637	99002	51522	106745	17498
TOTAL	//	274767			
TOTAL	288404				

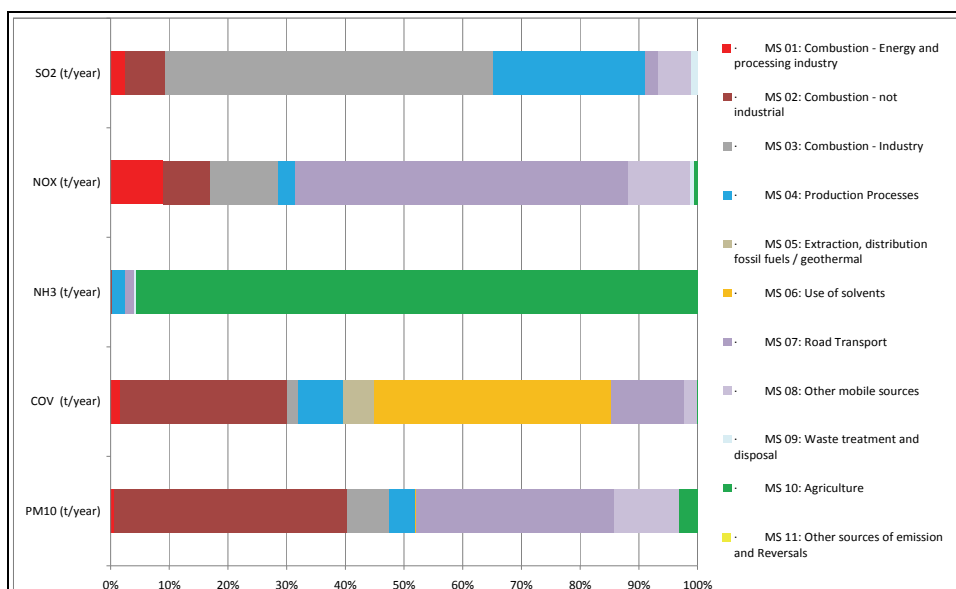


Fig. 2. Main pollutants of the Emilia Romagna regional emissions inventory, for the year 2010, calculated with the INEMAR – EMEP CORINAIR methodology (EMEP-CORINAIR, 2013)

The column of PM10, reporting direct emissions, de facto returns the primary particulate total: 13637 t/year. The other columns show the total amount issued of the main precursors of particulate matter (VOC, NH₃, NO_x, SO₂), but of these only a portion of these tons react effectively becoming secondary particulate matter.

These estimates indicate road traffic and industrial combustion (primarily heating of commercial and residential buildings) as the main sources of emissions linked to directed pollution by dust (PM10), followed by non-road transport and industry. Control policies and reduce emissions of primary particulate must therefore act primarily on these macro sectors.

Industrial emissions and the production of energy instead are the second leading cause of pollution from nitrogen oxides (NO_x), which also represent an important precursor to the formation of secondary particulate matter and ozone. It underlines that the main contribution to emissions of ammonia (NH₃), an important precursor to the formation of secondary particulate matter, resulting from agriculture, sector often overlooked in strategies to reduce dust pollution. The use of solvents in industry and civil is mainly responsible for the emission of volatile organic compounds (VOCs), the precursors together with nitrogen oxides in the formation of secondary particulate matter and ozone. The combustion in industry and manufacturing processes are rather the most important source of sulfur dioxide (SO₂) which, although present in the air a concentration far below the limit values, as seen above, is an important precursor of the formation of secondary particulate matter even at low concentrations.

7. Method to estimate the primary and secondary PM10 emitted by Corine-Air regional productive macro sectors, for the year 2010

Below are explained the steps that have led to an estimate, albeit theoretical, the number of deaths caused by the primary and secondary PM10 attributable to each productive macro-sector, on the basis of the deaths attributable to the concentration of PM10 in Emilia-Romagna for the year 2010 previously calculated.

- The fraction corresponds to 25% of the total, from which we get that the secondary is equal to about 41091 t/year. This is due to the pollutants precursors that react with each other, but being difficult to establish in what proportions, it is considered as if each contributes the same way, according to a percentage of the total weighing, and then going to calculate the t/year of each pollutant that become secondary PM10. It is possible see the derived values in the Table 5;

- Then, for each macro sector was determined the total particulate, by summing the shares of the various pollutants, and then comparing it with the total secondary PM10 (40911 t/year) were obtained a series of percentages that indicate the incidence of each sector on air pollution (Table 6) and consequently also on deaths attributable to the concentration in the air.

8. Estimation of the mortality AC for PM10 associated by CORINE-Air regional productive macro sectors, for the year 2010

Finally, the percentages thus obtained were applied to the deaths attributable with formula (1) to the base year (2010) after which that value was adjusted properly, using the percentages listed at the beginning of the chapter, in order to consider only deaths attributable to fraction and actually attributable to anthropogenic emissions of only Emilia-Romagna. With AC_{EMR} means the deaths attributable to only the responsibility of Emilia-Romagna, and these were estimated only those due to anthropogenic fraction indicated with AC_{EMRANTROPIC}.

Table 4. Main pollutants of the Emilia Romagna regional emissions inventory, for the year 2010, calculated with the INEMAR – EMEP CORINAIR methodology

	PRIMARY PM10 - (1)	SECONDARY PM10 - (2)				PM10 - TOTAL
Total Pollutants for 2010 (t/year)	1 PM10	COV	NH₃	NO_x	SO₂	PM10 - TOTAL
	//	99002	51522	106745	17498	274767
%	//	36.03%	18.75%	38.85%	6.37%	100%
%	25%	75%				100%
Weighted estimates for 1 and 2 PM10 (t/year)	13637	41091				54548
	13637	14806	7705	15964	2617	54548

Table 5. Estimates and percentages that indicate the incidence of each sector on air pollution for each pollutant

<i>Weighted estimates for 1 and 2 PM10 - (t/year)</i>	13637			14714		7671		15894		2605	<i>1+2 PM10 (t/year)</i>	%
Macro Sector	1 PM10	1 PM10 %	COV %	PM10 from COV	NH₃ %	PM10 from NH₃	NO_x %	PM10 from NO_x	SO₂ %	PM10 from SO₂		
MS 01: Combustion - Energy and processing industry	87	1	2	228	0	0	9	1412	2	64	1791	3.3
MS 02: Combustion - not industrial	5395	40	29	4215	0	23	8	1300	7	178	11111	20.4
MS 03: Combustion - Industry	993	7	2	264	0	0	11	1818	56	1455	4529	8.3
MS 04: Production Processes	617	5	8	1138	2	165	3	458	26	676	3054	5.6
MS 05: Extraction, distribution fossil fuels / geothermal	0	0	5	772	0	0	0	0	0	0	772	1.4
MS 06: Use of solvents	4	0	40	5938	0	0	0	2	0	0	5945	10.9
MS 07: Road Transport	4593	34	13	1861	2	124	57	9034	2	55	15667	28.7
MS 08: Other mobile sources	1524	11	2	306	0	0	11	1682	6	150	3662	6.7
MS 09: Waste treatment and disposal	6	0	0	9	0	19	1	93	1	27	154	0.3

MS 10: Agriculture	418	3	0	9	96	7340	1	95	0	0	7862	14.4
MS 11: Other sources of emission and Reversals	0	0	0	0	0	0	0	0	0	0	0	0.0
TOTAL	13637	100	100	14741	100	7671	100	15894	100	2605	54548	100

From Table 7 we see that the highest value comes from road transport (M7), followed by non-industrial combustion (M2) and agriculture (M10). The latter, as already mentioned, it emits a quantity of primary PM10 much lower than the other two, (418 t/year against 4593 t/year from road transport and 5395 t/year from industrial combustion), but at the same time is responsible for 96% of all the NH₃ emitted in the region and thus will have a high impact on the secondary particles.

Table 6. Estimates and percentages that indicate the incidence of each sector on air pollution for each pollutant

<i>AC caused by all the Padan basin sources of PM10 (100%)</i>	<i>AC caused ONLY by Emilia-Romagna regional sources of PM10 (25%)</i>		
AC ₂₀₁₀	AC _{EMR}	AC _{EMR} ANTROPIC (85%)	AC _{EMR} NATURAL (15%)
1948	487	414	73

Table 7. AC deaths for year 2010 disaggregated per single macro-sector, attributable to anthropogenic fraction and actually attributable to emissions of only Emilia-Romagna region

<i>Macro Sector</i>	<i>%</i>	<i>AC</i>
MS 01: Combustion - Energy and processing industry	3	12
MS 02: Combustion - not industrial	20	83
MS 03: Combustion - Industry	8	33
MS 04: Production Processes	6	25
MS 05: Extraction, distribution fossil fuels / geothermal	1	4
MS 06: Use of solvents	11	46
MS 07: Road Transport	29	120
MS 08: Other mobile sources	7	29
MS 09: Waste treatment and disposal	0	0
MS 10: Agriculture	15	62
MS 11: Other sources of emission and Reversals	0	0

9. Conclusions

The represented scenarios show a constant reduction of the air pollutant concentration PM10 and AC data. The environmental policies need to aim at evolution, leading, as a result of the policy choices, to a lower number of AC deaths: casualties in 2001 were in fact 4,047, while in 2010 they decreased to 1,948. Thereafter it was possible to expose the three AC results of the hypothesized air pollution concentration reduction scenarios for 2020, in function of the actuation of the PAIR2020 Regional Air Quality Plan 2014-2020. In the first scenario BAU Business as usual we estimated an air pollution reduction by 9% than the 2010 air pollution concentration, obtaining an AC result of 1,443 casualties; in the second, the TS Target Scenario, we estimated a reduction by 17% than 2010 concentration, obtaining a new

decrease to 1,020 casualties; in the last scenario, MFR Maximum Feasible Reduction, we estimated a reduction by 31% than 2010 concentration obtaining 271 casualties, which represents a reduction by 93% than 2001 casualties data (Francia, 2014).

The importance of prospective scenarios represents a significant way to predict socio-economic and environmental agreements, in order to employ the best policies for a better future. Then, for the only year 2010, we attributed to each INEMAR-CORINAIR regional productive macro-sector the own responsibility (in terms of AC deaths attributable) always referred to as the only PM10, and it is noted that "in the head" we find the road transport sector M7, followed by industrial combustion M3, and at the third place the agricultural sector M10 responsible for as much as 96% of ammonia emitted in the region, from which it derives a marked incidence with respect to the secondary PM10 and therefore to the number of deaths caused by this.

The policies of air quality management, in order to achieve the limit values, have to act simultaneously on different levels and with different temporal and spatial scales. At regional scale, and in the long run you have to identify measures that act both on direct emissions that precursors of dust pollution. Each macro sector provides a specific contribution on which you will have to take action in a more or less marked, even according to the calculations and estimates reported here.

From these results we can then detect, in conclusion, the importance and role that the preparation and calculation of forecast scenarios should have within evaluations of the regional and national programs, in order to enable Public Institutions to establish appropriate and corrected socio-economic, territorial and environmental planning.

References

- Arduino G., (2014), New policies for cleaner air for Europe (Nuove politiche per un'aria più pulita in Europa), *Ecoscienza*, On line at: http://www.arpa.emr.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2014_1/arduino_ecoscienza_2014_1.pdf.
- Baccini M., Biggeri A., Grillo P., Consonni D., Bertazzi P.A., (2011), Health impact assessment of fine particle pollution at the regional level, *American Journal of Epidemiology Advance Access*, **5**.
- Battini B., (2014), *Estimation of the health impact of PM10 in Emilia Romagna due to different macro-industrial sectors present in the region* (in Italian: *Stima dell'impatto sanitario da PM10 in Emilia Romagna dovuto ai diversi macrosettori industriali presenti in regione*), Graduation Thesis, University Alma Mater Studiorum of Bologna, Italy.
- Bessagnet B., Hodzic A., Vautard R., Beekmann M., Cheinet S., Honoré C., Liousse C., Rouil L., (2004), Aerosol modeling with CHIMERE - preliminary evaluation at the continental scale, *Atmospheric Environment*, **38**, 2803-2817.
- Bortone G., Raffaelli K., (2014), An agreement to improve the area of the basin Padano (In Italian: Un accordo per migliorare l'aria del bacino padano), *Ecoscienza*, On line at: http://www.arpa.emr.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2014_1/bortone_raffaelli_ecoscienza_2014_1.pdf.
- EC, (2014), Air Quality Standards, European Commission - Environment - Air - Air quality: On line at: <http://ec.europa.eu/environment/air/quality/standards.htm>
- EMEP-CORINAIR, (2013), Atmospheric Emission Inventory: On line at: <http://www.eea.europa.eu/publications/emep-eea-guidebook-2013>.
- EEA, (2013), Air quality in Europe - 2013 report, European Environment Agency EEA Report, On line at: www.eea.europa.eu/publications/air-quality-in-europe-2013/download.
- Francia R., (2014), *Estimation of the health impact of the Regional Plan for Quality in Emilia Romagna (PAIR2020)* (in Italian: *Stima dell'impatto sanitario del Piano Regionale per la Qualità dell'aria in Emilia Romagna (PAIR2020)*), Graduation Thesis, University Alma Mater Studiorum of Bologna, Italy.

- Freda S., (2013), The Emilia-Romagna to the plan of integrated area (in Italian: L'Emilia-Romagna verso il piano aria integrato), *Ecoscienza*, INEMAR (air emission inventory): On line at: http://www.arpa.emr.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2013_3/freda_es3_13.pdf.
- ISPRA-SinaNet, (2005), Disaggregation of National Emissions Inventory 2005, Institute for the Environmental Protection and Research (ISPRA), National Environmental Information System, Rome, Italy, On line at: <http://www.sinanet.isprambiente.it/it/sia-ispra/inventaria>.
- ITA.DLgs, (2010), Legislative Decree of 13 August 2010, 155: Implementation of Directive 2008/50/EC on ambient air quality and cleaner air for Europe, (in Italian), Official Journal, No. 216/15.09.2010, 45-46, On line at: <http://www.camera.it/parlam/leggi/deleghe/10155dl.htm>.
- ITA.RER, (2012), Proposal of the Regional Council of Emilia Romagna, GPG/2012/2187: Guidelines for the development of a regional integrated air quality (PRIQA) (in Italian: Indirizzi per l'elaborazione del piano regionale integrato di qualità dell'aria (PRIQA) 28/12/2012, On line at: <http://bur.regione.emilia-romagna.it/dettaglio-inserzione?i=1bc5e06daf4a6320bee8083faef6ce86>.
- PAIR2020, (2014), Regional Air Quality Plan 2014-2020 for Emilia-Romagna, On line at: <http://ambiente.regione.emilia-romagna.it/aria-rumore-elettrosmog/temi/pair2020>.
- Ranzi A., Giannini S., (2014), La valutazione dell'impatto sulla salute, rivista *EcoScienza* numero 1, marzo 2014: On line at: http://issuu.com/ecoscienza/docs/ecoscienza2014_1.
- WHO, (2005), WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005 Summary of risk assessment, World Health Organization, On line at: http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf?ua=1
- WHO, (2013), Health risks of pollution in Europe - HRAPIE project 2010, World Health Organization, On line at: http://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health-risks-of-air-pollution-in-Europe-HRAPIE-project,-Recommendations-for-concentration-response-functions-for-costbenefit-analysis-of-particulate-matter,-ozone-and-nitrogen-dioxide.pdf.

Websites:

- http://www.arpa.emr.it/dettaglio_documento.asp?id=433&idlivello=64
http://www.arpa.emr.it/dettaglio_documento.asp?id=434&idlivello=64,
http://www.arpa.emr.it/cms3/documenti/_cerca_doc/meteo/ambiente/descrizione_ninfa_gb.pdf
<http://www.reteclima.it/piano-20-20-20-il-pacchetto-clima-energia-20-20-20/>
<http://www.operatool.eu/html/eng/documentation.html>.
<http://www.lmd.polytechnique.fr/chimere/>
<http://www.rer.camcom.it/studi-ricerche/banche-dati/bd/sanita/morti-per-residenza-e-causa-p-r-n/Caumorer.xls/view>
<http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009>
http://www.arpa.emr.it/cms3/documenti/_cerca_doc/meteo/ambiente/inventario_gas_serra_2007.pdf
<http://www.arpa.veneto.it/temi-ambientali/aria/emissioni-di-inquinanti/metodologia-EMEP-CORINAIR>.
http://www.arpa.emr.it/cms3/documenti/_cerca_doc/aria/inventario_emissioni_2010.pdf.



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MEASURING PERFORMANCE OF MUNICIPAL SOLID WASTE COLLECTION SERVICES*

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Abstract

Like other public services (water, energy and gas), Municipal Solid Waste (MSW) has been studied to observe the determinants of cost variations among environmental and operational variables. The current paper studies the determinants of efficiency in waste collection, observing 40 municipalities in the north-west of Verona province. Economic efficiency was measured using the ratio of costs to tons of waste collected per year, which was then related to eight operational and environmental variables that according to the literature could affect it. The quality of services was measured with waste separation percentage. The independent variables chosen reflect socio-demographic conditions and organizational choices. A key finding was that efficiency and quality of services increase when high density populated areas are served. Efficiency also increases with household density. Finally, curbside collection is more expensive than street bins, but the waste separation percentage achieved is higher and is positively affected by economies of experience.

Keywords: efficiency, Italy, operational environment, partial frontier nonparametric methods, waste collection services

1. Introduction

In the last 20 years, the importance of Municipal Solid Waste (MSW) services has increased sharply in developed countries. In Italy the annual per capita weight of waste produced increased by 22% in the ten years from 1995 to 2006, rising from 449 to 552 kg (Italian Institute of Statistics – ISTAT). This rapid growth required a series of reforms to improve efficiency and effectiveness of MSW management. Law 22/97 (“Ronchi Law”)

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stipulates that waste handling, collection, recycling, disposal and energy generation in a specific area be provided by only one firm, selected by public tender, in order to exploit economies of scale, scope and vertical integration (D.lgs. 22/97 “Ronchi Law”, <http://www.camera.it/parlam/leggi/deleghe/97022dl.htm>)

To achieve efficiency, public utilities have various options, including technological innovations, job training, improved procurement policies and development of internal control systems aimed at effective and efficient corporate processes. Other options, such as firm size, investment diversification, vertical integration and population density, usually depend on the context in which the utility operates, so that they cannot be fully controlled by the managers and owners of the firm (Berg and Marques (2011) for water utilities; Kumbhakar and Hjalmarsson (1998) for electric retail services; Hollas et al. (2002) for gas distribution).

Like other public services (water, energy and gas), MSW has been studied to observe the determinants of cost variations among environmental and operational variables (Carvalho and Marques, 2010; De Jaeger et al., 2011; Jacobsen et al., 2013; Simões et al., 2010; 2012). Unlike the water sector, literature on MSW is fragmented (extensive analysis of the literature can be found in Simões and Marques, 2012). Although many authors have studied the effects of different variables on efficiency, the only factor extensively studied has been the ownership structure of waste utilities. The literature on MSW offers abundant evidence on the advantages and disadvantages of privatized waste utilities, however, as in other public sectors, the findings are not unanimous (Simões et al., 2012). Some authors report that private participation in waste management services is beneficial, as utilities are no longer under the control of politicians and use incentive mechanisms, such as performance evaluation, internal auditing and human resource management to improve efficiency (Berenyi and Stevens, 1988; Cubbin et al., 1987; Domberger et al., 1986; Jacobsen et al., 2013; McDavid, 1985; Savas, 1974; Szymanski and Wilkins, 1993; Szymanski, 1996). Other studies are inconclusive (Callan and Thomas, 2001; Collins and Downes, 1977; Garcia-Sánchez, 2008; Hirsh, 1965; Simões et al., 2012) or support public ownership as a determinant of lower costs (Benito et al., 2010; Ohlsson, 2003; Pier et al., 1974). Studies focusing on other operational and environmental variables provide discordant results. Population density (population per square kilometer of area served), for instance, is a major environmental variable affecting waste utility performance. In a certain range, the higher the density, the greater the saving in costs, since a greater weight is collected at each pick-up point (Callan and Thomas, 2001; Carroll, 1995; Dubin and Navarro, 1988; Koushki et al., 2004). Other authors have demonstrated that this variable actually damages efficiency in certain situations (Benito et al., 2010; Benito et al., 2011; De Jaeger et al., 2011; Vishwakarma et al., 2012; Worthington and Dollery, 2001), since narrow densely populated streets may reduce the possibility of using large specialized equipment and must rely on less productive manual activities; moreover, the effect of traffic congestion may offset any cost saving gained covering shorter distances between pick-up points. According to Passarini et al. (2011) these characteristics also seem to have a negative effect on waste separation percentage, which is higher for example in the rural areas of Emilia Romagna (low population density) than elsewhere in the Region. Finally, Simões et al. (2012) recently demonstrated that cost efficiency was lower in sparsely populated rural areas as well as in densely populated towns.

Economies of scale and economies of scope are other variables that may influence the efficiency of waste utilities. Economies of scale exist when a unit increase in outputs results from a less than proportional increase in inputs (Silvestre, 1987). Dubin and Navarro (1988) found economies of scale in municipalities with populations of less than 20,000 persons. Callan and Thomas (2001) found product-specific scale economies for recycling services, while disposal activities showed constant returns to scale. As regards collection services, high cost savings have been reported for firms operating in large areas (Carvalho and

Marques, 2014; Vishwakarma et al., 2012; Worthington and Dollery, 2002). Thus larger municipalities exhibit better efficiencies, possibly implying better management and governance. Similarly, firms that are members of waste collection joint ventures collect and process MSW more efficiently than other firms (De Jaeger et al., 2011; Zamorano et al., 2011). On the other side, Carroll (1995) proved that recycling costs are not affected by the firm's scale of operations. The same conclusion was reached by Marques et al. (2012). Similarly, García-Sánchez (2008) found that municipal population does not affect efficiency in Spanish municipalities with populations over 50,000.

Economies of scope occur when the average unit cost of producing two or more goods or services is lower than when they are produced or provided by separate entities (Panzar and Willig, 1981). For MSW these economies could arise when a single firm provides more than one service (e.g. collection, disposal and recycling). To the best of our knowledge, only Callan and Thomas (2001) and Simões et al. (2013) have researched economies of scope in the MSW sector. Callan and Thomas (2001) demonstrated that MSW shows economies of scope when disposal and recycling activities are carried out by the same firm: disposal services lower the marginal cost of recycling services and vice versa. Simões et al. (2013) found strong diseconomies of scope in combined waste, water and wastewater services in Portugal.

Two recent studies broadly explained the determinants of waste collection efficiency, expanding the set of observed variables (Benito et al., 2011; De Jaeger et al., 2011). The first authors showed a relationship between efficiency and per capita income, urban population density, an index of tourism and economic activity and the political orientation of the governing party. Adopting a robust nonparametric technique (Data Envelopment Analysis – DEA – double bootstrapped), this study demonstrated that high per capita income does not promote firm efficiency because greater taxation revenues can cover some inefficiencies. Furthermore, well-developed tourism and economic activities induce politicians and firm managers to maintain the municipal image, keeping the streets clean and avoiding any waste of resources: heaps of waste on the street seriously undermines such activities. However, this result is not consistent with prior studies: Bosch et al. (2000) and García-Sánchez (2008) backed the hypothesis that tourist flow has a negative effect on the ease of providing collection services. Benito et al. (2011) showed that municipalities governed by left-wing parties save more costs. These findings are confirmed by De Jaeger et al. (2011) who showed that changes in efficiency can also be due to socio-demographic conditions (such as the proportion of elderly and young households served). The study also examined the effect of pick-up frequency: unlike prior studies (Callan and Thomas, 2001; Distexhe, 1993; Hirsh, 1965), it did not confirm an adverse effect of this variable on efficiency.

This state of the art reveals the need to examine whether a wider set of operational and environmental variables might affect the efficiency of MSW collection services, confirming previous findings. The most appropriate methods (in particular nonparametric methods) have not always been used to investigate the influence of exogenous variables on the efficiency of Decision Making Units (DMU). We therefore applied a robust and more suitable nonparametric method to identify the influence of some major environmental variables on the efficiency of the 40 waste collection municipalities in the north-west of Verona province. The method consisted in estimating unconditional and conditional efficiency scores (on the environmental variables) and comparing them by smoothed nonparametric regression (Daraio and Simar, 2005).

Framework of the Italian waste sector. The method used to estimate efficiency and its determinants is illustrated in Section 3, followed by a description of the main characteristics of the municipalities. The paper is organized as follows. Section 2 describes the market structure and regulatory in question. Section 4 presents the main results and Section 5 discusses the results and offers concluding remarks.

2. Data and method specification

2.1. The case studied

The dataset analyzed includes data on the solid waste collection services for 40 Italian municipalities in the region of Verona (all members of the consortium “Consorzio di Bacino Verona 2”) over a period of five years (2008-2012). The consortium was founded in 1997 by the municipalities of the western part of Verona Province, and its main aims are: organizing the collection, disposal and recycling of MSW; entrusting these activities to a separate legal entity; drafting a plan of the main future investments; controlling the municipalities by periodic analysis of collection and disposal costs, the quantity of waste “produced” and waste separation percentage.

MSW collection is entrusted to a single utility (SER.I.T s.r.l.) which provides its services to all members of the consortium. SER.I.T. s.r.l. is a fully publicly owned utility controlled by AGSM S.p.A., the energy and gas provider of Verona municipality. SER.I.T. s.r.l. stipulated a main agreement with Consorzio di Bacino Verona 2, but applies different rates to the various municipalities on the basis of their operational and environmental characteristics, namely collection method (curbside or street bins), waste collection frequency, population density and number of tourists per year. A higher rate is usually paid for frequent curbside collection in municipalities with low population density and high tourist flows. Fig. 1 provides a framework of the governance of MSW collection services in Verona province. The 40 municipalities differ in their geographic and demographic features and economic activities.

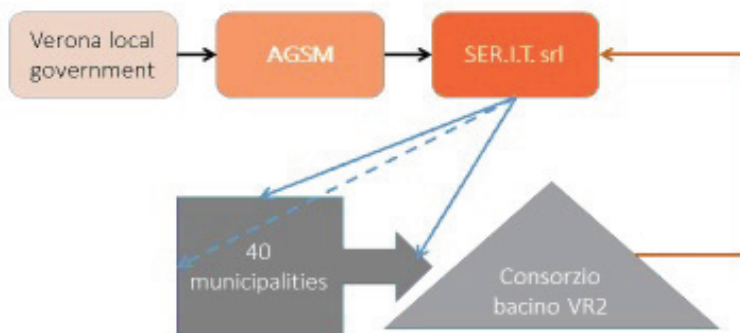


Fig.1. The governance of municipal solid waste collection in Verona

Fig. 2 shows their location in Verona Province. A first group is on the east coast of Lake Garda and has low population density and high tourist flows (e.g. Lazise); a second group includes municipalities in the Verona hinterland with high population density and low tourist flows (e.g. Castel d’Azzano); a third group consists of small and sparsely populated rural villages in hilly and mountain areas that attract few visitors. For efficiency estimation, the model that best characterizes the activity of waste utilities was adopted.

The model has total costs of collection (in Euro) as input and the quantity of unrecyclable and recycled household waste collected (in tons) as outputs. Table 1 provides some statistics for these variables. Collection costs include expenditure for internal manpower, external services, amortization, depreciation and maintenance of vehicles, fuel and materials, and overheads. Concerning the outputs, unrecyclable waste is what goes to landfills or incinerators, while recycled waste is quantified by summing the tons of paper,

plastic, metal, glass and organic waste collected. We used an input orientation, minimizing Decision Making Units (DMUs) (in this case, costs) with respect to outputs (recycled and unsorted waste collected) (Eurostat, 2012).

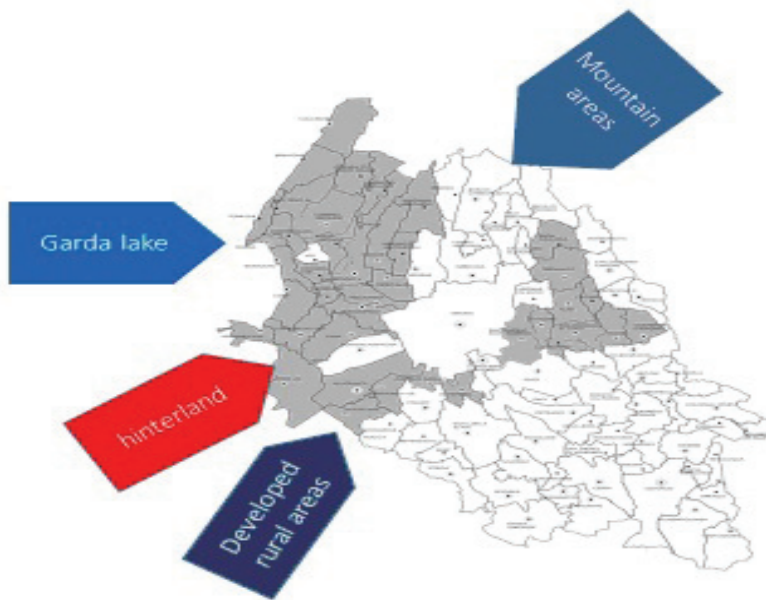


Fig. 2. Verona province (Italy) and the municipalities studied (grey)

In analyzing the influence of operational environment on the production process, a range of environmental variables, known from the literature and empirical world as the main variables with a significant effect on the activity of waste utilities, were considered. The variables are shown in Table 2 which also summarizes the measures used to quantify them, while Table 3 provides some descriptive statistics.

During the observation period all variables increased: the increases in population, area served, tons of waste collected and total costs are explained by the increase in the number of municipalities from 23 in 2008 to about 40. Other variables, such as index of economic activity and population density, increased because other municipalities also in the Verona hinterland, with high population density and industries, became customers of SER.I.T. Finally, changes in unit cost per ton and waste separation percentage represented pure performance that depends on ability to provide collection services in the different areas and on the effects of the abovementioned operational and environmental variables.

Table 1. Statistics of costs, tons of waste collected, unit costs and waste separation percentage

	<i>Collection costs (€)</i>	<i>Unsorted waste (tons)</i>	<i>Recyclable waste (tons)</i>	<i>Total waste (tons)</i>	<i>Collection cost per ton of total waste (€/ton)</i>	<i>Waste separation (%)</i>
Mean	359,931	1,166.49	1,755.08	2,921.57	137.08	62.3
Max	1,607,558	5,876.56	7,488.35	12,687.08	228.34	80.1
Min	36,661	108.32	8.2	203.95	58.20	4.0
SD	256,037	1,147.98	1,276.88	2,278.04	33.82	15.0

Table 2. Environmental, operational and performance variables

<i>Variable</i>	<i>Acronym</i>	<i>Measure</i>
Population served	POPS	Municipal population
Index of economic activities in the area served	ECACT	Non domestic customers/Total customers
Population density	POPD	population/area of municipality in km ²
Household density	HOUSD	population/number of households
Annual tourist flow	TOUF	Number of tourists per year
Collection method	COLM	Street bins or curbside collection
Frequency of pick-ups	NUMPI	Number of pick-ups per year
Weight of waste collected per pick-up	TONSP	Total weight of waste collected (in tons)/no. pick-ups
Years of experience with curbside collection	YCURB	Years of experience with curbside collection
Cost for type of waste collected	COST	Total cost in euro
Total quantity of waste collected	TONS	Total quantity collected for each kind of waste (in tons)
Waste separation percentage	WSP	Percentage of recyclable waste to unrecyclable waste

Table 3. Statistics of environmental variables

<i>Year</i>	<i>Population served</i>	<i>Index of economic activities (%)</i>	<i>Area served (km²)</i>	<i>Population density (persons/km²)</i>	<i>Quantity of waste collected (tons)</i>	<i>Total cost (€)</i>	<i>Unit cost per ton (€/ton)</i>	<i>Waste separation (%)</i>
2008	169,501	2.66	700	309	70,497	7,493,237	123	58
2009	178,406	2.98	777	303	74,674	8,359,299	127	60
2010	239,891	4.11	973	320	92,158	10,840,561	130	62
2011	288,932	4.02	1,099	328	108,872	13,136,220	132	64
2012	316,303	4.30	1,182	329	112,486	14,398,950	140	65

2.2. Method specification

We adopted two general panel data regression models under two different assumptions: fixed and random effects (Eqs. 1-2).

$$\text{COSTON} = f(\text{POPS}; \text{ECACT}; \text{POPD}; \text{HOUSD}; \text{TOUF}; \text{COLM}; \text{TONSP}; \text{YCURB}) \quad (1)$$

$$\text{WSP} = f(\text{POPS}; \text{ECACT}; \text{POPD}; \text{HOUSD}; \text{TOUF}; \text{COLM}; \text{TONSP}; \text{YCURB}) \quad (2)$$

Eq. (1) relates the unit cost of waste collection to environmental and operational variables to determine whether efficiency is affected by population features, wealth and the way the waste collection service is organized. Eq. (2) attempts to explain variations in waste separation percentage using the same variables. POPS measures the effect of size and is useful to identify scale economies on unit costs and waste separation percentage when an increase in POPS causes a decrease in unit costs and a higher WSP. The intensity of economic activity is measured by ECACT, the ratio of non-domestic customers, such as factories, restaurants, hotels and other services providers, to total customers. A change in this variable affects the quantity and quality of waste collected and may therefore affect efficiency and waste separation percentage. Two further environmental variables that could potentially affect performance of waste collection are population density (POPD) and

household density (HOUSD) in a given area. Ideally, the higher the density, the greater the quantity of waste collected per km² and per building: this should improve efficiency, while no clear effects are predictable for waste separation percentage. The last demographic variable is annual tourist flow (TOUF), which can damage the performance of waste utilities if the storage of waste generated by tourism (hotels, restaurants, bars, camping areas, tourist attractions and holiday accommodation) is not properly organized by a municipality. In these cases, the quantity of waste is seasonal and waste is inadequately separated into the different materials. Finally, three operational items were included in both models to represent the way the service is organized: the collection method (COLM), distinguishing between curbside and street bin collection, quantity collected per pick-up (TONSP), a productivity index for each area monitored, and the number of years curbside collection had been operating (YCURB), measuring a municipality's experience with this method.

General panel data regression models help check for specific effects that are not measured by the explanatory variables and concern specific features of single firms and years. Two common assumptions (random-effects and fixed-effects assumptions) are made about specific effects. The random-effects assumption is that specific effects are unrelated to the independent variables. The fixed-effect assumption is that specific effects are related to the independent variables. If the random-effects assumption holds, the random-effects model is more efficient than the fixed-effects model. However, if this assumption does not hold, the random-effects model is not consistent. The Hausman test was used to determine whether to use the fixed-effects assumption (predicting different coefficients for each firm in the data set) or the random-effects assumption (predicting different coefficients for each firm in the dataset in a random manner) for datasets that included short time periods or had similar properties. The Hausman test assesses the following hypotheses:

H0: fixed-effect estimates and random-effect estimates are equal;

H1: fixed-effect estimates and random-effect estimates are different from each other.

If H0 is rejected, the random-effect model is inconsistent and a fixed - effect model must be applied; conversely, when H0 is accepted the former is consistent and efficient, while the latter is consistent but inefficient: in this case the random-effect assumption should be applied. A simple function of the panel data with a fixed effect is given by Eq. (3), where *i* are the individuals observed and *t* is time.

$$Y_{it} = \alpha_i + \beta_{1it} * X_{1it} + \dots + \beta_{kit} * X_{kit} + e_{it}, \quad i=1, 2, 3, \dots, N; \quad t=1, 2, \dots, T \quad (3)$$

The specific effects are fixed and are included among the independent variables as a specific constant (α_i). In contrast, in the random-effects model the specific effects are considered a component of the error term (Eq. 4).

$$Y_{it} = \beta_{1it} * X_{1it} + \dots + \beta_{kit} * X_{kit} + e_{it}, \quad i=1, 2, 3, \dots, N; \quad t=1, 2, \dots, T \quad (4)$$

3. Results and discussion

In this section we present and discuss the results obtained with a random-effects model, since H0 of Hausman test was accepted for both models (Prob>chi2 > 0.05). Environmental variables POPD and HOUSD negatively affected costs, with a significance level greater than 95%. The significance of the squared variables and the positive sign of both estimators showed that unit cost per ton of waste formed a U-shaped curve when POPD and HOUSD were observed (Figs. 3 and 4).

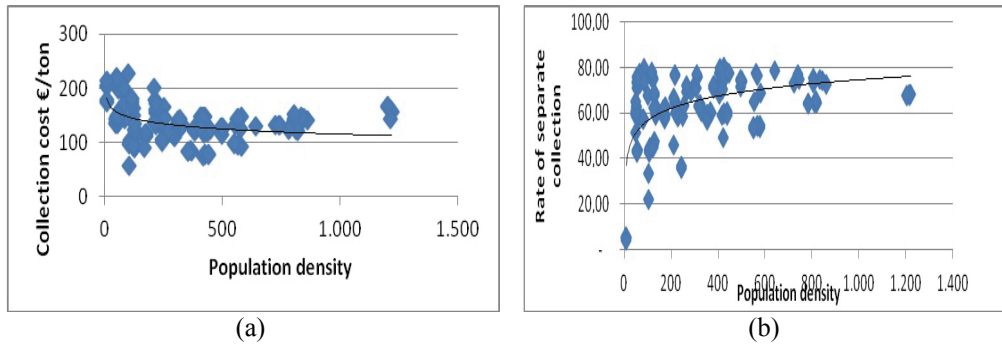


Fig. 3. Cost (a) and waste separation percentage (b) curves in relation to population density

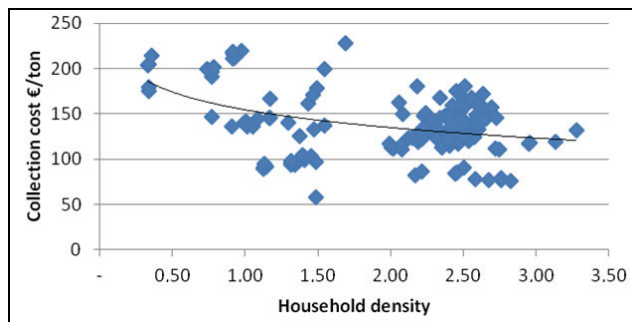


Fig. 4. Cost curve in relation to household density

Table 4. Estimators and significance level of explanatory variables

<i>Cost per ton of waste collected</i>	<i>Estimator</i>	<i>Waste separation percentage</i>	<i>Estimator</i>
Population served	0.004	Population served	0.000
Index of economic activity	-54.96	Index of economic activity	14.22
Population density	-0.109**	Population density	0.041**
Household density	-58.98**	Household density	12.58
Collection method (curbside)	66.200***	Collection method (curbside)	29.56***
Tons per pick-up	-7.26***	Tons per pick-up	-1.75
Years of adoption of curbside collection	-1.11	Years of adoption of curbside collection	0.74*
Tourist flows	-0.000	Tourist flows	0.000
Population served ²	0.000	Population served ²	0.000
Index of economic activity ²	85.28	Index of economic activity ²	-24.76
Population density ²	0.000***	Population density ²	-0.000**
Household density ²	11.39**	Household density ²	-1.96
Tons per pick-up ²	0.068*	Tons per pick-up ²	0.000
Years of adoption of curbside collection ²	0.021	Years of adoption of curbside collection ²	-0.03
Tourist flows ²	0.000	Tourist flows ²	-0.000

Operational variables, such as curbside collection and TONSP, had opposite effects on costs: the former increased costs, while higher productivity lowered costs. Both results were robust, since their significance exceeded 99%. When the squared variable was analysed, even TONSP generated a U-shaped cost curve (Fig. 5).

For the WSP function, only three variables were significant. POPD improved the quality of waste collection. Study of the squared variable showed that POPD generated a reversed U-shaped curve when related to costs (Fig. 3). The same positive effects on WSP occurred for curbside collection, but with a greater significance (>99%). No effects of the squared variable were observed. Finally, experience had a weak impact on WSP (significance 90-95%), since YCURB was positively related to this dependent variable.

It is worth discussing the results in terms of the effects of the different operational and environmental variables on costs and quality of waste collection. As regards the results obtained for population density, collection proved to be cheaper in major towns and high density areas than in rural and sparsely populated areas. These results depend on smaller distances travelled per ton of waste collected, leading to fewer man-hours and lower fuel consumption, truck depreciation and maintenance. The greatest economies were achieved at population densities over 500 persons per km²: below this threshold the marginal cost per ton of waste collected increased rapidly; above it, the savings generated by POPD were greater.

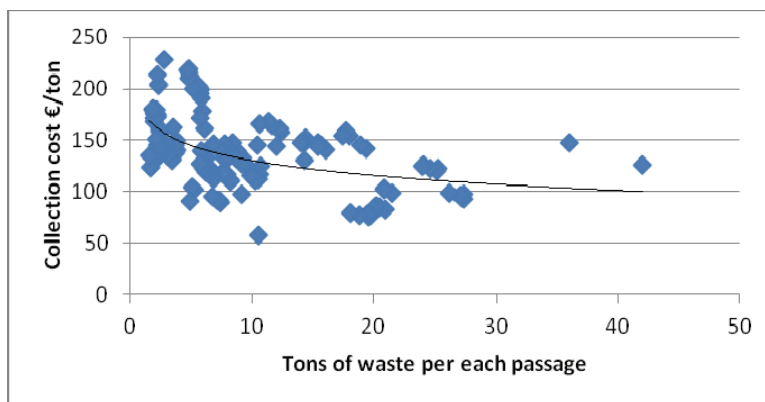


Fig. 5. Cost curve in relation to weight per each passage

A similar effect was observed for waste separation percentage: cities and highly populated municipalities seemed to be the best places for organizing separate collection of wastes: the high volume of waste collected per km² seemed to induce local government to improve the quality of collection through more effective methods. The results obtained for POPD demonstrated that good waste separation mainly occurred in areas where productivity was high. HOUSD also negatively affected unit collection costs: this implies that collection is more efficient in residential areas where families live. By contrast, waste collection in tourist areas and depopulated municipalities was very expensive. In the first case, large seasonal variations in the total weight of waste produced caused inefficiency in the low season, when waste production was quite low: this issue especially concerns municipalities on the eastern shore of Lake Garda, where second houses and holiday accommodation are common. Secondly, mountain municipalities include many small depopulated villages with many empty houses. These areas have the problems associated with low POPD: the collection trucks have to travel long distances to collect a limited quantity of waste.

This effect of low productivity is reflected by the negative relation between TONSP and unit costs. The finding is intuitive: the greater the quantity per pick-up, the lower the unit cost. A waste utility therefore has to carefully plan the itinerary of every truck in order to maximize the quantity collected per pick-up and improve truck productivity. The unit cost drops sharply when the amount of waste collected per pick-up increases from 1 to 10 tons.

The last effect on unit cost of waste collected is the negative one related to curbside collection. A transition from street bins to curbside collection, which is widespread in

Veneto Region, generates a significant increase in unit cost. The average cost for curbside collection was €138 compared to €130 for street bins. The extra-costs incurred with curbside collection are compensated by a higher waste separation percentage. The method actually enabled an increase in collection productivity for both recyclable and unrecyclable waste. To evaluate the total costs and benefits of curbside collection it would be useful to estimate the value of the extra volume of recyclable waste gathered with respect to street bins, and compare it with the €8 difference in collection cost. Finally, another variable affecting waste separation percentage is YCURB: while costs are not affected by the experience gained with curbside collection, the waste separation percentage improves: this demonstrates that citizens and municipalities need to learn by doing and this could be expedited by effective information campaigns on how to correctly separate the different types of waste, with intensive control, especially in the first years of adoption, associated with severe penalties.

4. Conclusions

In studying the determinants of waste collection efficiency for 40 municipalities in the north-west of Verona province we measured economic efficiency in terms of cost per ton of waste collected on a yearly basis and analyzed this cost in relation to eight operational and environmental variables. Efficiency, in terms of the quality of services provided, was measured in terms of waste separation percentage. The independent variables chosen reflect socio-demographic conditions and organizational choices. The method used was a general panel data regression model under the assumptions of fixed and random effects, verified by the Hausman test.

Unit collection costs were affected by population density, household density, weight of waste collected per pick-up and collection method, while the waste separation percentage depended on population density, collection method and period of experience with curbside collection. The results suggest that the logistics of waste collection can be improved, especially in disadvantaged areas, such as rural areas, small villages and tourist destinations. In municipalities on Lake Garda, pick-up frequency could be varied according to season (frequent in summer, less frequent in winter) and in the low season wastes could be collected with skips placed in convenient locations or by creating huts where bins are located. These solutions enable collection itineraries to be planned efficiently, reducing pick-up frequencies in the low season. They could also be adopted in sparsely settled areas, such as mountain municipalities. This optimization of the logistics of waste collection would make it possible to maximize the quantity of waste per pick-up, keeping costs low and achieving high productivity and waste separation percentage.

With reference to collection method, some interesting insights emerge for curbside collection: firstly, further study could estimate the real costs and benefits of this collection method, considering not only the collection step, but also disposal and recycling; secondly, economies of experience associated with separate collection demonstrate the utility of training and information campaigns for citizens and for the staff of municipalities embarking on curbside collection for the first time.

References

- Benito B., Bastida F., Garcia J., (2010), Explaining differences in efficiency: an application to Spanish municipalities, *Applied Economics*, **42**, 515-528.
- Benito B., del Rocio Moreno M., Solana J., (2011), Determinants of efficiency in the provision of municipal street-cleaning and refuse collection services, *Waste Management*, **31**, 1099-1108.
- Berenyi E.B., Stevens B.J., (1988), Does privatization work? A study of the delivery of eight local services, *State Local Government Review*, **20**, 11-19.

- Berg S.V., Marques R.C., (2011), Quantitative studies of water and sanitation utilities: a literature survey, *Water Policy*, **13**, 591–606.
- Bosch N., Pedraja F., Suaréz-Pandiello J., (2000), Measuring the efficiency in Spanish municipal refuse collection services, *Local Government Studies*, **26**, 71–90.
- Callan S.J., Thomas J.M., (2001), Economies of scale and scope: a cost analysis of municipal solid waste services, *Landscape Economies*, **77**, 548–560.
- Carroll W., (1995), The organization and efficiency of residential recycling services, *Eastern Economic Journal*, **21**, 215–225.
- Carvalho P., Marques R., (2010), The influence of the operational environment on the efficiency of water utilities, *Journal of Environmental Management*, **92**, 2698–2707.
- Carvalho P., Marques R., (2014), Economies of size and density in municipal solid waste recycling in Portugal, *Waste Management*, **34**, 12–20.
- Collins J.N., Downes B.T., (1977), The effects of size on the provision of public services: The case of solid waste collection in smaller cities, *Urban Affairs Quarterly*, **12**, 333–347.
- Cubbin J., Domberger S., Meadowcroft S., (1987), Competitive tendering and efficiency: The case of hospital cleaning, *Fiscal Studies*, **8**, 49–58.
- Daraio C., Simar L., (2005), Introducing environmental variables in nonparametric frontier models: a probabilistic approach, *Journal Productivity Analysis*, **24**, 93–121.
- De Jaeger S., Eyckmans J., Rogge N., Van Puyenbroeck T., (2011), Wasteful waste-reducing policies? The impact of waste reduction policy instruments on collection and processing costs of municipal solid waste, *Waste Management*, **31**, 1429–1440.
- Distexhe V., (1993), Productive efficiency from refuse collection and disposal services in Wallonia (L'Efficacité productive des services d'enlèvement des immondices en Wallonie), *Cahiers Economiques de Bruxelles*, **137**, 119–138.
- Domberger S., Meadowcroft S., Thompson D., (1986), Competitive tendering and efficiency: the case of refuse collection, *Fiscal Studies*, **7**, 69–87.
- Dubin J.A., Navarro P., (1988), How markets for impure public goods organize: the case of household refuse collection, *Journal of Law Economic Organization*, **4**, 217–241.
- Eurostat, (2012), Waste database municipal waste, On line at: <http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/database>.
- García-Sánchez I.M., (2008), The performance of Spanish solid waste collection, *Waste Management Resources*, **26**, 327–336.
- Hollas D.R., Macleod K.R., Stansell S.R., (2002), A data envelopment analysis of gas utilities' efficiency, *Journal of Economics and Finance*, **26**, 123–137.
- Jacobsen R., Buysse J., Gellynck X., (2013), Cost comparison between private and public collection of residual household waste: Multiple case studies in the Flemish region of Belgium, *Waste Management*, **33**, 3–11.
- Koushki P., Al-Duaij U., Al-Ghimlas W., (2004), Collection and transportation cost of household solid waste in Kuwait, *Waste Management*, **24**, 957–964.
- Kumbhakar S., Hjalmarrsson L., (1998), Relative performance of public and private ownership under yardstick competition: Swedish electricity retail distribution, 1970–1990, *European Economic Review*, **42**, 97–122.
- Marques R.C., da Cruz N.F., Carvalho P., (2012), Assessing and exploring (in) efficiency in Portuguese recycling systems using non-parametric methods, *Resources, Conservation and Recycling*, **67**, 34–43.
- McDavid J.C., (1985), The Canadian experience with privatizing residential solid waste collection services, *Public Administration Review*, **45**, 602–608.
- Ohlsson H., (2003), Ownership and production costs. Choosing between public production and contracting-out in the case of Swedish refuse collection, *Fiscal Studies*, **24**, 451–476.
- Panzar J.C., Willig R.D., (1981), Economies of Scope, *American Economic Review*, **71**, 268–272.
- Passarini F., Vassura I., Monti F., Morselli L., Villani B., (2011), Indicators of waste management efficiency related to different territorial conditions, *Waste Management*, **31**, 785–792.
- Pier W.J., Vernon R.B., Wicks J.H., (1974), An empirical comparison of government and private production efficiency, *National Taxation Journal*, **27**, 653–656.
- Savas E.S., (1974), *Municipal Monopolies vs. Competition in Delivering Urban Services*, In: *Improving the Quality of Urban Management*, Howley W., Rogers D. (Eds.), Sage Publications, Beverly Hills, 437–500.

- Silvestre J., (1987), *Economies and diseconomies of scale*, In: *The new Palgrave: A Dictionary of economics*, Eatwell J., Milgate M., Newman P., (Eds.), Palgrave Macmillan, London, On line at: <http://www.palgraveconnect.com/pc/doi/10.1057/9780230279803.0541>.
- Simões P., De Witte K., Marques R.C., (2010), Regulatory structures and operational environment in the Portuguese waste sector, *Waste Management*, **30**, 1130-1137.
- Simões P., Cruz N.F., Marques R.C., (2012), The performance of private partners in the waste sector, *Journal of Cleaner Production*, **29–30**, 214-221.
- Simões P., Marques R.C., (2012), On the economic performance of the waste sector. A literature review, *Journal of Environmental Management*, **106**, 40-47.
- Simões P., Carvalho P., Marques R.C., (2013), The market structure of urban solid waste services: how different models lead to different results, *Local Government Studies*, **39**, 396–413.
- Szymanski S., Wilkins S., (1993), Cheap rubbish? Refuse collection costs and collective tendering 1984-88, *Fiscal Studies*, **14**, 109-31.
- Szymanski S., (1996), The impact of compulsory competitive tendering on refuse collection services, *Fiscal Studies*, **17**, 1-19.
- Vishwakarma A., Kulshrestha M., Kulshrestha M., (2012), Efficiency evaluation of municipal solid waste management utilities in the urban cities of the state of Madhya Pradesh, India, using stochastic frontier analysis, *Benchmarking: International Journal*, **19**, 340-357.
- Worthington A.C., Dollery B.E., (2001), Measuring efficiency in local government: an analysis of New South Wales Municipalities domestic waste management function, *Journal of Policy Studies*, **29**, 4–24.
- Worthington A., Dollery B., (2002), Incorporating contextual information in public sector efficiency analyses: a comparative study of NSW local government, *Applied Economics*, **34**, 453-464.
- Zamorano M., Grindlay A., Molero E., Rodriguez M.I., (2011), Diagnosis and proposals for waste management in industrial areas in the service sector: Case study in the metropolitan area of Granada, (in Spanish), *Journal of Cleaner Production*, **19**, 1946-1955.



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BONIFICA 2.0 – A SUSTAINABLE MOBILITY NETWORK BASED ON THE AGRO PONTINO LAND RECLAMATION WATERWAYS*

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Abstract

The main objective of this paper is to illustrate how the *Bonifica 2.0* initiative aims to fulfil a sustainable development vision by proposing a new way of experiencing the Pontine territory. *Bonifica 2.0* consist of a sustainable mobility network composed by full-electric vehicles and mini smart grids and involves a rehabilitation of the entire land reclamation channels system of the local area *Agro Pontino*. *Agro Pontino* is a large natural landscape (former marshland) in the Lazio region, south of Rome, where 350.000 inhabitants are settled. The area stretches over 700 km², with drainage channels and waterways extended for about 300 km. The territory is characterized by a rich and diverse environment (it was object of land reclamation between 1926 and 1937) and holds a great potential for tourism.

The project *Bonifica 2.0* aims at exploring the potential for tourist exploitation for a wide area in the “Agro Pontino”. To this end, various goals have been set, such as the creation of mixed routes that try to connect water channels with bicycle- and pedestrians paths. The concept is based on the philosophy of a sustainable mobility of waterways and coastal lakes that characterize the land.

Another important goal is the restoration and revaluation of the archeological historical and cultural aspects of the area in a different and innovative way, based on the use of new environmentally sustainable means of transportation. An integrated system, along with the implementation of network infrastructures, will regulate connections with the mainland.

Keywords: green economy, green energy, sustainable development, sustainable tourism

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1. Introduction

Technological progress and dissemination of innovative solutions are crucial aspects of sustainable development. Innovations need to be tailored to the specific characteristics of a territory and hence able both to address its weakness and release its potential through a local and holistic approach.

When it comes to sustainable development discourses, the relevance of innovation in the transport sector is clear, not the least considering that the sector produced 7.0 GtCO₂eq of direct Green House Gas (GHG) emissions (including non-CO₂ gases) in 2010 and hence was responsible for approximately 23% of total energy-related CO₂ emissions (6.7 GtCO₂) (Edenhofer et al., 2014). In the last report of the International Panel for Climate Change (IPCC) it is stated that without aggressive and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors and reach around 12 GtCO₂eq/yr by 2050.

Since transport demand per capita in developing and emerging economies is expected to grow due to rising incomes and infrastructure development, effective GHGs mitigation policies will need to be implemented using a multi-sectorial approach and combine different strategies, such as: (i) avoided journeys and modal shifts due to behavioral change, (ii) uptake of improved vehicle and engine performance technologies, (iii) low-carbon fuels, (iv) investments in related infrastructure, (v) and changes in the built environment (IPCC, 2014). Nevertheless, the impact of transport on sustainability does not end with GHGs emissions: different impacts found in the literature, structured according the three pillars of sustainable development are shown in Fig. 1 (Black, 2010; Jones and Boujenko, 2011; Jones and Lucas, 2012; Power, 2012; Ribeiro et al., 2007; Sterrett et al., 2012).

Environmental impacts	Social impacts	Economical impacts
<ul style="list-style-type: none"> • Energy use • GHGs Emissions • Climate change • Air quality • Water & soil quality • Biodiversity • Animal migration Routes • Land use 	<ul style="list-style-type: none"> • Equity • Accessibility • social inclusion • Community cohesion • Participation • Safety • Segregation • Gentrification 	<ul style="list-style-type: none"> • Personal income • Purchasing power • Prices • Employment possibilities • Productivity • Public health • GDP • External costs

Fig. 1. Impacts of transport on the sustainability

The relevance of a well-functioning sustainable mobility scheme in the alternative tourism sector has been stated by various authors and has been identified as a function responding to market demand and competitive challenges (Hassan, 2000). Access results to

be a decisive factor for the selection of travel destinations, both at macro- and micro level, beating indicators like availability of infrastructures and facilities (Ritchie and Crouch, 2003).

Some studies have even been considering a broader concept of mobility, not only as usage of low emission means of transport but also as reduced level of mobility, as the only indicator of sustainable tourism (Høyer, 2008). In addition to this, conscious mobility practices have been identified as relevant tool to mobilize citizen-consumers as change-agents in relation to the local context (Verbeek and Mommaas, 2008). As mentioned above, mobility is a site-specific matter.

Transportation and individual choices are driven by economic factors, such as willingness to pay for transport (Huang et al., 1997), social factors, including location selection and gentrification processes (Glaeser et al., 2008) and cultural factors, like the recognition of private means of transportation as status symbol (Banerjee et al., 2010). These factors vary remarkably according the study area. While mobility choices made by individuals, local government interventions and national or regional networks planning may have global consequences, relevant solutions to mobility problem can only be found on a local scale (Amekudzi et al., 2011).

The *Bonifica 2.0* initiative, conceived by the research pole for Sustainable Mobility of Sapienza University of Rome, *Polo per la Mobilità Sostenibile – POMOS*, aims at developing tools and methods designed to facilitate a local sustainable tourism in order to activate a virtuous circle able to empower the territory. In its pilot phase, *Bonifica 2.0* aims to find local solutions that can be used as reference point for other local contexts, as well as able to connect the Pontine territory with the “supra-local” scale (the entire mobility network of Lazio Region). The problem is complex because although the local context is the application scale, integration with the supra-local context is a necessity when it comes to infrastructural network planning, fare and pricing policies, and multi-modal approach. Moreover, the risk of “localism” exists (Sassen, 1996).

The idea behind developing the *Bonifica 2.0* mobility scheme for touristic purposes stems from the specificity of the context. The Agro Pontino is a scarcely populated area dominated by an agricultural landscape, which due to the fertility of the area and the mild climate has led to the emergence and spread of several plant species typical for the area. The wild areas are mostly forests, composed of tall trees, such as oaks, poplars, pines and eucalyptus, introduced during the land reclamation because of its extraordinary ability to absorb water, as well as used for the creation of bands windbreak.

There are several touristic spots in Agro Pontino: the inland mountain are characterized by the presence of medieval hamlets, including Sermontena, Bassiano, Norma and Sezza; The “Garden of Ninfa” lies at the foothill of Lepini Mountains; while the coastline is dominated by the Natural reserve of Circeo which includes the lake of Fogliano, Caprolace and Sabaudia, the “Circe’s forest”, the dunes of Sabaudia and the Mount Circeo where the village of San Felice is located. The main touristic poles are shown in Fig. 2.

The poor communication and mobility system of the whole area has caused isolation of a number of these tourist attractions, mostly of the hinterland areas and villages, only marginally involved in existing tourism flows. *Bonifica 2.0* aims at stimulating the demand for tourist activities and drive it toward scarcely promoted and visited cultural and natural resources and alternative tourism.



Fig. 2. Main point of interest of Agro Pontino

This will be achieved by increasing the number of environmentally friendly facilities for mobility, in order to connect a network of typical agro-foods products and handcraft, organized guided tours and educational courses on environmental issues along with sport activities. *Bonifica 2.0* will combine innovative solutions, like zero emission vehicle prototypes, mini smart grids associated to renewable energy sources and monitoring of the territory using remote sensing, together with sustainable management of the territory with a bottom-up approach in order to release the potential of Agro Pontino territory. From a technological point of view, the program, foresees the realization of three types of sustainable infrastructures (green infrastructures), both logically and structurally interrelated, and a series of activities aimed at explaining the nature and philosophy of the whole program, for educational and cultural communication purposes. In particular, it is provided for the realization of the following points:

1. An experimental system of sustainable intermodal mobility: small fleets of electric propulsion vehicles and boats;
 - a) An advanced ICT infrastructure (inspired from the paradigm of Open Data and the Internet of Things) aimed at: a) Control of the fleets; application management; security; b) Collecting environmental data through a sensor network: fixed sensors to be installed in the infrastructure, mobile sensors to be placed in the vehicles, considering also the use of drones; c) GIS platform for a physical-mathematical representation of the territory able to accommodate the data flow from the sensor network and to feed proper models of evaluation, planning and monitoring - not only monitoring of the area but also of the experimentation itself.
2. An energy infrastructure, designed according to the structure of the micro smart grids, able to draw energy from small production systems by renewable sources and meet the energy demands – primarily those from the vehicle fleets – through innovative “double-front” quick charging systems (for both water and land vehicles);
3. One or more exhibition halls of the entire program, which emphasize the cultural value, equipped with the following features: models, dioramas, rendering 3D model and augmented reality systems, all designed with technical and scientific exactness (making them direct reference to the collected data, available through the GIS platform). There are indeed provided training activities, technical and managerial, historical and cultural, in close connection with the forms of exhibits described above. A schematic representation of the main activities related to *Bonifica 2.0* program is depicted in Fig. 3.

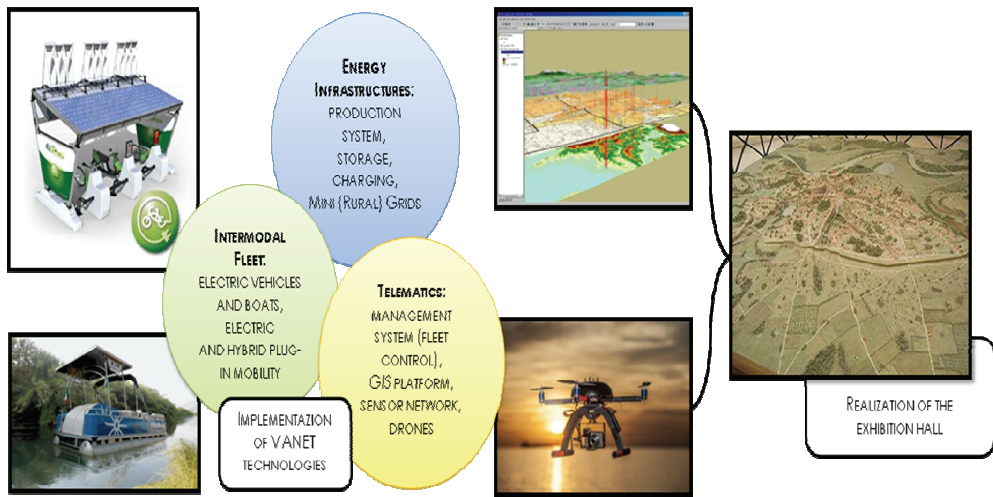


Fig. 3. Schematic representation of *Bonifica 2.0* program main activities

Alongside technological and implementation-oriented goals, the experimentation of program *Bonifica 2.0* extends to the achievement of the following results:

- the use of a method of universal design within the technological choices, which underlines important criteria of sustainability, accessibility and social inclusion;
- the introduction of project management activities inspired by the best practices generally used in the international context, considering in an original manner the characteristics of the local land;
- the emergence of a system of enterprises, especially SMEs with a strong innovation side, even with the rise of qualified Spin Off - Start Up that can find in the program *Bonifica 2.0* a proper development for their goals;
- encouraging the sharing of intentions among stakeholders (institutions and individuals) for a wide and balanced territorial development.

2. Material and methods

In order to develop the *Bonifica 2.0* program methodology, POMOS working group has analyzed and adapted the SLoT model (Dematteis and Governa, 2005), considered a relevant starting point for the analysis of the territory and its stakeholders. This model is based on the assumption that local development stems from the relationship that links a society and a territory in a long-standing interactive process. It follows that the programs and measures that succeed in taking part in these co-evolutive dynamics and access their potential can generate added value in terms of sustainability, effectiveness and legitimacy. This value springs from the territorialized and territorializing action of local actors who, interacting with the supra-local levels, are able to “grasp” the components of the local “milieu”, activating their specific potential, using and reproducing them to help build new territorialities both locally and at higher levels (Sommella and Viganoni, 2003). POMOS in the definition of *Bonifica 2.0* methodology is using the SLoT model to describe the relationships between social interaction, the potential of the local territory, governance and development.

The local system is considered as consisting of two sets of components and three sets of relationships. The components are the local networks of actors and the local territorial milieu. The relationships are those among the local players, those between the local players

and the territorial milieu, and those between the local components and the levels on the supra-local scale. These assumptions have been used to develop a Program Matrix (Fig. 4).

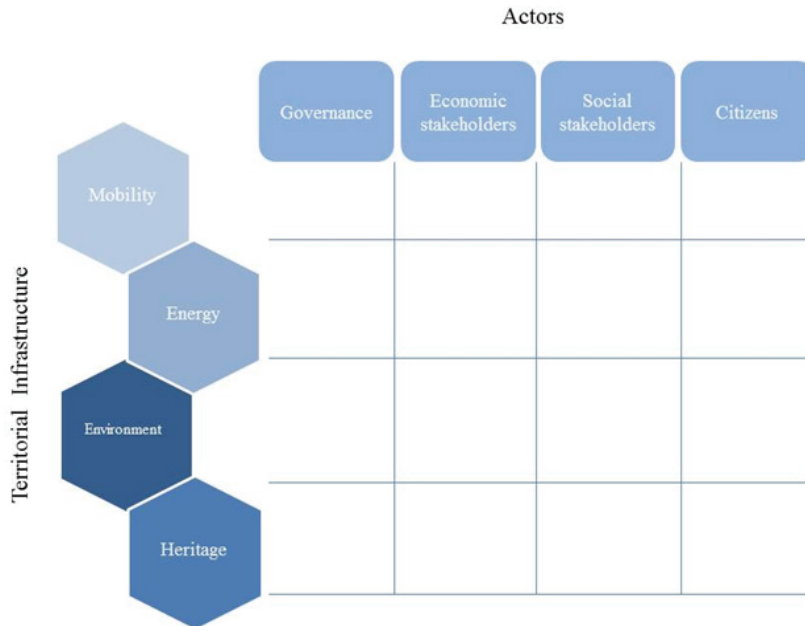


Fig. 4. The methodological matrix of *Bonifica 2.0*

The *matrix* in current in use to:

- Identify the status of the relationships between territory, players and actions with a view to activating a local system and a collective actor;
- Perform *ex ante* evaluations of the potential for implementing *Bonifica 2.0* development processes, and *ex post* evaluations of the territorial added value they produce;
- Suggest the architectures which are most appropriate in each individual instance on the program for building an effective governance system and for implementing actions in a trans-scalar, multilevel perspective;
- Identify networks of local systems that can serve as the basic structures for regional development;
- Evaluate the territorial sustainability of development, in the sense of the ability to reproduce and enrich local territorial capital without depleting that of other territories.

Regarding the technical and scientific aspects of the experimentation of the program, POMOS working group approved the following methodological approach with the constraints dictated by the economic and human resources that can be used according to the implementation timeline:

- Definition of the technical specification of the systems and devices involved in the experimentation, according to the criteria of the maximum qualitative coverage alongside the minimum quantitative coverage (specifically, the experimentation must have control of all the technological specificities involved in testing in order to evaluate effectiveness, with the minimum number of elements necessary so that such assessment would be credible, but so as not to indiscriminately increase the resource requirements);
- Definition of morphological and functional specifications of the land suitable for hosting the experimental demonstrator, considering the same philosophy adopted for the previous point. The territory must contain accessible parts for both terrestrial and nautical

paths and must be sufficiently limited in size, in order to restrict the number of elements to realize.

In the determination of the area of experimentation the following requirements apply:

- easy accessibility (which does not require demanding civil works);
- safety for people and property infrastructure;
- attractiveness;
- presence of primary stakeholders.

The choice of technological systems and areas of experimentation follows the basic philosophy of the reproducibility of demonstrator, with the standards so-called "patchy". This implies that during the experimental phase, in addition to evaluate the strengths and weaknesses of the demonstrator, it also determines a selection - regarding priorities - of the following areas in which is planned to extend the program, taking advantage from the data acquisition system, the GIS and valuation parameters.

The experimentation will give information on future moves to be made for the performance of the entire program, each time by correcting the problems that are found - and emphasizing the strengths - with a progressive refinement approach, which makes the whole program robust while practicable in reference to the resource requirements. From the testing phase, the program will be able to accommodate the needs of the territory in terms of projects and skills.

3. Case study presentation

The pilot phase of the project consists in the implementation of a small-scale demonstrator of the project. It consists on the creation of a micro grid equipped with a recharge station, powered by a mini-wind generator and equipped with an energy storage system. Moreover a few prototypes of electric vehicles have been developed to test the system.

In the following a brief description of the micro-grid and of the electric boat will be given. More precisely, the implemented micro-grid is constituted by a DC high power fast recharge station powered by a mini-wind innovative vertical axis generator capable to produce from 6 to 30 kW with a wind speed higher than 2m/s. The generator is interconnected by means a power converter to an energy storage system capable to supply the recharge dock independently by the power generated by the wind generator.

The fast recharge dock implements the Yazaki/CHAdeMO protocol, the main characteristics of the developed CHAdeMO station are listed below:

- Power max 50 kW;
- Voltage max 400 V;
- Current max 125 A.

The recharge dock is made of two main sub-components. The first one is the power unit used to manage the power flow. It is capable to manage charge ramps, temperature limitations, power limitations and internal faults or warnings. The second component is the control unit used to manage Yazaki/CHAdeMO signals in order to realize the communication between the vehicle and the station. More precisely, it uses the signals read from the Battery Management System (BMS) installed on the vehicle to drive the power unit by means of a suitable control signal used to adjust the level of the recharge current. In order to facilitate the use of the dock a GUI showing the status of the recharging procedure has been developed. This GUI allows the user to monitor all the signals exchanged during the recharge procedure such as the level of current flowing in the battery pack and the level of the achieved charge of the vehicle instant by instant. Moreover, the station is capable to record the acquired information (Paschero et al., 2013).

A prototype of an eco-friendly, photovoltaic roof boat made of recyclable materials and powered by an electric motor with high efficiency connected to a paddle wheel has already been developed by POMOS (Fig. 5).

The structure of the boat was projected considering ergonomic and accessibility problems. The boat space is 30 meter square and provides 32 seats. The benches can be folded in case of need allowing access on the vehicle for people with disabilities. Most of the material used for the boat, such as the accumulators and vessel structure, are recyclable. Attention was given to the safeguard of the flora and fauna of the land.



Fig. 5. Electric boat

The propulsion elements are designed to protect aquatic species, whether animal or vegetable. Furthermore, the rotor blades are able to work in total silence. The use of innovative and specific rotor blades allows the boat to navigate any kind of channel, lake and water paths with the focus on preserving the landscape without affecting the local flora and fauna. The boat is as well able to go over the water paths where the presence of algae would cause problems to navigation through the innovative rotor blades described.

The boat is equipped with a custom embedded system in order to monitor and manage all the parameters and functions collected from the sensors. The control board system works on the microcontroller Arduino Mega. The data collected during the navigation can be shown thanks to the implementation of a GUI (graphic user interface) on a touch screen video. The GUI allows showing the current speed of the boat, instantaneous current output, battery percentage charge, battery voltage and expected charge time on the display. Various sensors are located on the boat providing accurate data.

An accelerometer to test and monitor the boat acceleration has been implemented, along with temperature sensors. Various parameters can be collected and saved in the database during the navigation such as the current supplied to the motor at the moment, the voltage of the battery pack and the energy produced by the photovoltaic panels. Controllers have been added to the vehicle in order to handle and manage events in dangerous cases like too low voltage, too high voltage temperature over range and discharging current over range.

An innovative fast charging system is provided for the boat, in case of night navigation or insufficient self-production from photovoltaic panels. The battery charging can be expired in just a few minutes when the boat is stationary docked. The system constantly

administrates the charging process checking that it meets the design parameters of the batteries. A battery charge manager is able to currently collect data and set a balance between the energy spent for the motor and the energy produced by the photovoltaic panels. The battery charge manager has been projected and designed considering the CHAdeMO protocol, ensuring a hardware/software information redundancy to provide a high security level. The system is accurate and optimal, and is able to work allowing the chargers to provide DC current as directed by commands transmitted from the on-board ECU as it decides the best charging current matched to the battery status so that energy is assured for any kind of vehicle. The controller accepts receives inputs though a CAN bus and charger sets the current in order to feed the command values of the vehicle. A GPRS module enables the system to be steadily monitored. All the collected data are stored in a central server that can easily queried. The system is designed and projected regarding the hardware and software infrastructures, so that many interfaces can be expanded and upgraded, leaving ports free. It allows adding power and energy to the environmental sensors. The boat is able to provide 10 hours of navigation at a cruising speed of 3.5-4 marine knots.

4. Conclusions

Bonifica 2.0 is a complex program which aims at modelling the development of the entire *Agro Pontino* in the next future. The program vision goes in the direction of sustainability considered as a paradigm of participation, social integration, economic feasibility and legitimacy of the governance. This vision, in the planning phase of the program, has been tailored on the specificity of the territory, using a local approach to address its weakness and release its potential. Moving from the results of the preliminary analysis of the context it has been chosen, together with all the stakeholders involved in the process, to focus the program on the promotion of sustainable tourism through the creation of a carbon free mobility scheme based on the *Agro Pontino* land reclamation waterways.

The implementation of the program has officially started on the 03-10-2014 with the first meeting of the “technical table” created ad hoc by the Regional Ministry of Infrastructure and Environment of Lazio Region. This “technical table” composed by POMOS, all the governance structure of the *Agro Pontino*, and open to the participation of the corporations and association of the area, is currently mapping and analyzing the relationship between the local stakeholders that have shown interest in the Initiative and the territory. The expected output of the table, within the first six months of 2015, is the individuation of the portion of the territory where the experimentation of the mobility network will be implemented.

In the meanwhile, the technical aspects of the program have been developed by POMOS working group. Three prototypes have been realized and are currently undertaking the testing phase: a four-wheel light off-road vehicle powered by human force (pedaling) assisted by two eclectic motors; a four-wheel heavy vehicle for paved roads powered by a full-electric motor; a photovoltaic roof eco-friendly boat powered by an electric motor. In addition to this also a prototype of a micro-grid has been realized, constituted by a DC high power fast recharge station powered by a mini-wind innovative vertical axis generator and a control unit used to manage Yazaki/CHAdeMO signals in order to realize the communication between the vehicle and the station.

In the second half of the 2015, with the conclusion of the testing phase and the release of the output of “technical table” concentration, the experimental phase of *Bonifica 2.0* will get to its crucial point as the planning realized by the stakeholders will have to merge and interconnect with the technical implementation. This will be a great challenge and from its success will depend the future scale up of the initiative.

References

- Banerjee I., Walker J.L., Deakin E.A., Kanafani A., (2010), *New Vehicle Choice in India: Household Choice among Motorized Vehicle Segments*, 12th World Conference on Transport Research Society (WCTR), Lisbon, Portugal.
- Black W.R., (2010), *Sustainable Transportation: Problems and Solutions*, The Guilford Press, New York.
- Edenhofer O., Pichs-Madruga R., Sokona Y., Farahani E., Kadner S., Seyboth K., (2014), *Climate change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, USA, 511-597.
- Glaeser E.L., Kahn M.E., Rappaport J., (2008), Why do the poor live in cities? The role of public transportation, *Journal of Urban Economics*, **63**, 1-24.
- Hassan S.S., (2000), Determinants of market competitiveness in an environmentally sustainable tourism industry, *Journal of Travel Research*, **38**, 239-245.
- Høyer G.K., (2000), Sustainable tourism or sustainable mobility? The Norwegian case, *Journal of Sustainable Tourism*, **8**, 147-160.
- Huang J.C., Haa T.C., Whitehead J.C., (1997), Willingness to pay for quality improvements: should revealed and stated preference data be combined?, *Journal of environmental economics and management*, **34**, 240-255.
- Jones P., Boujenko N., (2011), *Rethinking Transport and Connectivity for a Shared City*, Northern Ireland Community Relations Council, Belfast, Ireland.
- Jones P., Lucas K., (2012), The social consequences of transport decision-making: clarifying concepts, synthesizing knowledge and assessing implications, *Journal of Transport Geography*, **21**, 4-16.
- Paschero M., Anniballi L., Del Vescovo G., Fabbri G., Frattale Mascioli F.M. (2013), *Design and implementation of a fast recharge station for electric vehicles*, In: *IEEE International Symposium on Industrial Electronics (ISIE)*, 1-6.
- Power A., (2012), Social inequality, disadvantaged neighborhoods and transport deprivation: an assessment of the historical influence of housing policies, *Journal of Transport Geography*, **21**, 39-48.
- Ribeiro K., Kobayashi S.S., Beuthe M., Gasca J., Greene D., Lee D.S., Muromachi Y., Newton P. J., Plotkin S., Sperling D., Wit R., Zhou P.J., (2007), *Transport and its infrastructure*, In: *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Cambridge University Press, Cambridge, UK.
- Ritchie J.R.B., Crouch I.G., (2003), *The Competitive Destination - A Sustainable Tourism Perspective*, CABI Publishing, London, UK.
- Sterrett K., Hackett M., Hill D., (2012), The social consequences of broken urban structures: a case study of Belfast, *Journal of Transport Geography*, **21**, 49-61.
- Verbeek D.H.P., Mommaas J.T., (2008), Transitions to sustainable tourism mobility: the social practices approach, *Journal of Sustainable Tourism*, **16**, 629-644.



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IMPLEMENTATION OF GUIDELINES FOR ECO-LABELLING IN THE AGRI-FOOD SMES: THE SICILIAN PISTACHIO SECTOR*

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Abstract

This paper represents the practical implementation of some guidelines developed in the context of a published book entitled “*Product-Oriented Environmental Management System (POEMS). Improving Sustainability and Competitiveness in the Agri-Food Chain with Innovative Environmental Management Tools*”.

Nowadays, companies show growing interest in the most suitable instrument of environmental communication for the characteristics of their products (and the related sector) could be. This aspect becomes particularly important in the agri-food compartment where the products features are the result of the interaction among very different subsystems, from the farming to the transformation and marketing processes. Over time, in this sector, a huge number of voluntary environmental labelling schemes systems, used as instruments of environmental communication, have sprung up. Consequently it becomes extremely difficult for the operators to choose the most suitable label for their needs.

In this context these guidelines were established with the aim of representing an innovative tool which, through the evaluation of key aspects of the environmental impacts of a product, can support the Small and Medium sizes enterprises (SMEs) in their choice of the most suitable environmental label for their own product; they can also enhance their communication strategies and their visibility in the market.

The company chosen for carrying out the implementation of these guidelines belongs to the Sicilian pistachio industrial sector and it is typical for its size and market within the Sicilian economic system. About 90% of the total Italian Pistachio area is concentrated in a few territories of Eastern Sicily, mainly located in the province of Catania (Bronte and Adrano).

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1. Introduction

Nowadays it has become clear that the purchase decisions taken by consumers for satisfying their needs can have a strong impact on the environment. In particular the choice of more sustainable products, in other words products providing environmental, social, and economic benefits while protecting public health and environment over their whole life cycle (from the extraction of the raw materials until the final disposal), can certainly be decisive in terms of impacts reduction.

At the same time, from the companies' perspective, the consumers' orientation toward more eco- friendly products is a powerful incentive. Companies are, in fact, motivated to find more sustainable ways of production for improving products' performance throughout their life cycle and to intensify efforts at environmental management level (Udo de Haes and de Snoo, 2010). All that considered, it is important to give consumers the suitable tools for making correct purchase choices such as, for example, accessible, understandable, relevant, and credible information on the environmental quality and performance of the products. In this context, along the decades, the European action lines within the Sustainable Production and Consumption (SPC) strategy have been based on innovative tools able to develop the capability of producers and consumers to make "sustainable" choices and to influence each other. These tools refer to Life Cycle Assessment (LCA) which represents not only one of the fundamental methods for the Integrated Product Policy (IPP) realization but also the main operative instrument of the Life Cycle Thinking (LCT). Among these instruments, as also suggested by the Agenda 21, eco-labels can be considered as a mean for achieving this goal. In the last decades environmental labels and declarations gained attention at international level as a means for implementing a policy which can encourage producers to improving products' environmental performances (Clasadonte et al., 2013); at the same time, as reported by Hale (1996) and Wojnarowska (2014) the implementation of eco-labelling tools could lead to a change in the consumer's behavior connected to an increased ecological awareness. This awareness could be stimulated by the fair and reliable information regarding the product's environmental performances along its life cycle as an additional criterion to price and quality.

According to the ISO Standard 14020:2000 (ISO 14020, 2000), voluntary environmental labels and declarations aim at "encouraging the supply and demand for those products and services able to cause low damage to the environment so that it will stimulate a continuous environmental improvement process managed by the market". This standard identified three types of environmental labels and declarations: Type I (ISO 14024, 1999), for example the EU Ecolabel, the most widespread and well-known Type I label; Type II (ISO 14021, 1999), for example the "Mobius Cycle", related to the percentage of recycled material in a product; and Type III (ISO 14025, 2006), for example the International EPD® system, the most widespread and well-known Type III declaration; there is also another category, not regulated by ISO standards, which has been defined as "environmental labels of Type IV", for example the Forest Stewardship Council (FSC), Dolphin Safe, and Fair-trade Global labels.

Nowadays there is a growing interest from the companies on which the most incisive instrument of environmental communication suitable for the characteristics of their products (and the related sector) could be. This aspect becomes particularly important in the agri-food compartment where the products features are the result of the interaction among very different subsystems, from the farming to the transformation and marketing processes. Over time, in this sector a huge number of voluntary environmental labelling schemes systems

used as instruments of environmental communication sprung up. Consequently it becomes extremely difficult for the operators to choose the more effective label suitable for their needs. Hence it follows the need to realize some guidelines which, considering the peculiarities of the soil, the specificity of the products, the characteristics of the supply chain, of the company operative context, and of the final reference markets, can be of some help in giving the firm a way to choose the more adequate environmental label for their agricultural and food products and which allow to bring out its communication strategies and the visibility on the market.

The development of this paper arises just from these considerations and it represents the practical implementation of some guidelines developed in the context of a published book entitled “*Product-Oriented Environmental Management System (POEMS). Improving Sustainability and Competitiveness in the Agri-Food Chain with Innovative Environmental Management Tools*”.

In this case, the company chosen for carrying out the implementation of these guidelines belongs to the Sicilian pistachio industrial sector and it is typical for its size and market within the Sicilian economic system.

It is important to underline that about 90% of the total Italian Pistachio area is concentrated in a few territories of Eastern Sicily, mainly located in the province of Catania (Bronte and Adrano). Recently the production of the Sicilian pistachio has had a re-launching in terms both of an increase in the number of companies, as well as an increase in the number of companies involved in transformation, with an increasingly concentrated specialisation, of the latter, besides the diffusion of associations between producers of semi-finished products. Besides, the demand for pistachio nuts has undergone, moreover, a significant increase, pushing many countries to invest in the production of this fruit and in its cultivation. The result is that the Bronte pistachio, for its special qualities, has acquired the protected designation of origin (PDO) “Green Pistachio of Bronte”, reserved only for the quality of pistachios that comply with the conditions and the European community’s established requirements of the Council Regulation (EC) No. 510/2006 (Council Regulation, 2006), which has recognized it as PDO.

2. The production chain of the Bronte Pistachio and its characteristics

Pistachio, from the Greek word *Pistàkion*, is a plant that is found in the Mediterranean area and its seeds are used for very different purposes: direct consumption or they are sought after by confectioners or for flavouring cold cuts (Woodroof, 1967). Grown first by the ancient Jews, who believed the fruit to be precious, the pistachio nut quickly spread to Eastern populations as a plant with medicinal properties, a strong aphrodisiac and an antidote for poisoning; around 77 BC its cultivation spread in Italy, in particular to Liguria, Apulia, Campaniam, and Sicily.

Starting from 900 BC, the Arabs, who landed in Marsala (Sicily), began growing it (Fabbri and Valenti, 1997; Insero, 2014). They found the soil more fertile and in particular on the slopes of Mt. Etna, in the territory of Bronte where the plant grown in the lava ground was constantly fertilised by volcanic ash, and gave origin to a special fruit for its taste and smell, of a clearly superior quality (also from a functional point of view) to the rest of production worldwide.

Pistachio nuts are known to have a high content of polyphenols, e.g. anthocyanins, flavonols, proanthocyanidins, isoflavones etc., that are all potent antioxidants and that may have protective effects against diseases related to free radical overproduction, such as cardiovascular diseases and cancer (Bonina et al., 2000; Briamonte, 2005; Hou et al., 2004; Hu and Willett, 2002; Lo Giudice et al., 2011; Ros, 2009; Seeram et al., 2006; Tomaino et al., 2010; Zafra-Stone et al., 2007; Wang and Stoner, 2008; Yang et al., 2009). Some studies had

underlines that there are some particular characteristics of Bronte pistachios, such as the presence of a number of bioactive compounds never identified in pistachios until today; furthermore the peculiar antioxidant power of pistachio skins has been clearly shown. There is much evidence that polyphenolic antioxidants from fruits and vegetables play an important role in the prevention of cancer, inflammatory activities and cardiovascular disease. In this context, introduction of pistachios in daily diet may be of undoubted utility in the protection of human health and well-being. Other studies evidence that the beneficial effects of this food might be optimized by consumption of the unpeeled nuts; on the other hand they suggest that pistachio skins, as a significant by-product of pistachio industrial processing, could be successfully employed in food, cosmetic and pharmaceutical industry (Bellomo and Fallico, 2007; Gentile et al., 2007; Tomaino et al., 2010).

Chemical studies on pistachio kernels mainly regarded the fatty acids and sterols content (Arena et al., 2007; Okay, 2002; Venkatachalam and Sathe, 2006); other studies concern the kernel pigments characterisation (Bellomo and Fallico, 2007; Giuffrida et al., 2006), the resveratrol recovery in seeds (Gentile et al., 2007; Grippi et al., 2008; Tokusoglu et al., 2005) and the presence of anacardic acids in the outer green shell (Saitta et al. 2009; Yalpani and Tyman, 1983).

The typicalness of this production with unique characteristics in the world – not incidentally “green-gold” is spoken of – has allowed the companies of transformation to distribute their derived products to all markets, national and international. Nowadays, consumers in the most advanced countries have increased their consumption of pistachio nuts, increasing demand both for the fruit itself as well as its side products (Bellia et al., 1988).

The territory of Bronte is home to 80% of the land surfaces investing in pistachio nuts in the province of Catania with 2,650 hectares of pistachio groves, of which 2,400 hectares of main cultivation. In this town a decrease has been noted in comparison to 1995, equal to 150 hectares, above all in the surface areas of the subsidiary companies (-37%) (Caruso and Motisi, 1996; Caruso et al., 2003).

From the analysis of the provincial data it is evident that in Sicily the largest contribution is given by the province of Catania which with 1,093 tonnes in the period 2002/2005, holds more than 85% of regional production; even so it should be pointed out that there is a noticeable drop in production, in comparison to the previous four year period during which more than 1,800 tonnes of pistachio nuts were produced, equal to 91% of the total for the Island. Today the quota of sales of transformed pistachio nuts absorbs 60% of production and a good 4,000 hectares of lava ground of the 25,000 hectares of the territory of Bronte are dedicated to pistachio groves (Buffa et al., 2007). As far as the varieties produced are concerned, the Sicilian pistachio cultivation is centred solely on the “Napoletana or Bianca” variety, which represents 96-98% of the companies and their related production; it is the only cultivar widely utilized both in the “natural” or in the regular plantations and Terebinth is the only rootstock (Barone et al., 1997), Bianca tree can be defined of low-intermediate vigour. Growth habit is spreading; branching habit is intermediate. The harvesting of the Bronte pistachio is biennial and is done in odd numbered years, between the end of August and the beginning of September and every plant produces from 10 to 30 kilograms of fruit.

The picking is done totally by hand directly from the trees, making the fruit simply fall into a container carried on the picker’s shoulder or by shaking the branches of the trees to collect the fruit on sheets spread at the feet of the trees or, in some cases, also by using an upside down umbrella. After the fruit is harvested it is hulled, or rather separated from its hull, the leathery wrapping which covers it, by a mechanical scrubbing and, afterwards, dried for 3-4 days in the sun in large open spaces. In this way, the pistachio nut in its shell is obtained, locally called the “Tignosella”, which is stored by the producers in dark dry places,

awaiting to be sold. The shelling, or rather the removal of the woody shell, is the next step; the cooperatives or local tradesmen who buy the product deal with this operation (Leone, 1969).

The peeling, or rather the removal of the endocarp (thin layer of purpley-red coloured skin which covers the fruit) is done by a highly technological process, after a brief steaming of the fruit at high temperatures which causes the endocarp to detach itself from the fruit. By the rubbing on the rollers of the peeling machine, at varied speeds, the detached film is removed. Then, the pistachio nuts pass through a complex circuit of desiccation at low speeds and from this to the electronic selectioning machine that eliminates possible nuts that are not dark green; the dried product is, then, packaged in wrappings of various materials (La Russa et al., 2006; La Russa et al., 2007).

Despite of the increase in demand, the production chain of pistachio nuts in Sicily does not have a solid basis, given that the pistachio nut growers continue to keep production prices high and sale prices are not very profitable; all this means low profit margins for the farming companies.

In recent years, the institutions have given financial aid to the producing companies (PAC, biological). The first step in this direction was made on 3rd November 2004 when 30 producers and businesspeople set up the “Safeguarding Consortium” also having the function to exploit a product which has special features closely linked to the geographic area of origin and that seems threatened by the importing of lower quality pistachio nuts (in March 2004 the Ministry of Agricultural Policies and Forestry published a law that included the “the provisional agreement of Protection on a national level for the designation of “the Green Pistachio of Bronte”).

In particular, the Protected Designation of Origin (PDO) “the Green Pistachio of Bronte” is reserved for the pistachio nut that complies with the conditions and requirements established by the Council Regulation (EC) No. 510/2006; it deals with the “*product, shelled, unshelled or peeled, of the botanical plant species “Pistacia vera”, cultivar “Napoletana”, also called “Bianca” or “Nostrale”, grafted on “Pistacia terebinthus”* the Green Pistachio of Bronte” PDO.

In this context, every stage of the production process is monitored and documented, and the cadastre lots where production takes place are registered in lists provided for the purpose, run by the controlling structure and, in this way, the traceability of the product is guaranteed. In particular, the registration in the list of producers implies the allocation of an identifying code by which both the manager and the related pistachio grove can be identified (Production ruling “Green Pistachio of Bronte” Protected Designation of Origin). All the people, physically or legally, registered in the relative lists, are subjected to the “Green Pistachio of Bronte” PDO (in Fig. 1 the logo is reported), which in order to be eligible for marketing must have, besides the normal requites of quality, other special physical and organoleptic features: dark green colour of the cotyledons, ratio of chlorophyll a/b between 1.3 and 1.5; strong aromatic taste, without any hint of mould or strange flavours; humidity content between 4% and 6%; ratio of length/width of the nut between 1.5 and 1.9; high content of monounsaturated fats in the fruit (Barone and Marra 2008).

The production area falls in the territory of the towns of Bronte, Adriano, Biancavilla and is characterised by land of volcanic origin and by a subtropical, semi-dry Mediterranean climate with long, arid summers, rainfall concentrated in the autumn and winter periods and significant temperature ranges between day and night. The ground comes from lava formations, having a good fertility and neutral pH, which are suitable for the vegetative development of the pistachio nut, as are the surrounding areas of a autochthonous nature (Barilaro, 2006).



Fig. 1. The logo of Protected Designation of Origin PDO

The pedo-climatic peculiarity and the techniques of de-gemination used in the area of production, permit the natural rotation of the species to be emphasized, and to get advantages from the plants' protection (Barilaro, 2007; Pellegrino Faro, 2007). These pedo-climatic factors give the fruit particular characteristics of quality (the dark green colour typical of the territory, the elongated shape, aromatic flavour and high content in monounsaturated fatty acids of the fruit) that identify the "Green Pistachio of Bronte" PDO from the other pistachio nuts that come from other geographical areas (Maccarone, 2007). In particular the boundaries are identified in the territory of Bronte, to the West along the River Simeto, Adrano and Biancavilla.

3. The implementation of the guidelines for environmental labels in agri-food SMEs

In order to test the implementation of the guidelines for environmental labels and declarations in agri-food SMEs, a firm which operates in the pistachios chain was chosen as it was considered representative of the Sicilian economic system. After a brief description of the sector and the pilot firm, the path followed by the firm towards the choice of a voluntary environmental labelling system which suited its peculiarities will be reported.

The company has drawn up the check lists reported the guidelines (Clasadonte et al., 2013), with the aim of furthering its knowledge and the sensitivity of the organization to environmental issues and of identifying the environmental impacts produced during the various phases of the productive process. In the following box there is a brief description of the pilot firm, subject of the study case.

MARULLO S.P.A.

The Marullo trademark was born in 1960. The present state of this enterprise is the result of experience and tradition which have been handed down from generation to generation for over 50 years. Marullo have always marked dried fruit, in particular pistachios fruit. The plant is located in Bronte, in East of Sicily and covers an area of about 10,000 m², 3,000 m² of which is covered. Today the farmhold is managed by the third generation and the traditional methods adopted by the grandfather have been improved by new productive systems which respect both the environment and the consumer. The Marullo is today a modern and avant-garde for the selection and processing dried fruit, has long established itself in Italy and abroad the export of finished and semi-finished products sweet confectionery. Each product may also be packaged and 'custom' tailored customer needs.

The productive chain meets all the law requirements, respects all health and hygiene standards including the internal control standards for food companies (HACCP) and the recent standard relating to chain traceability; moreover it has quality voluntary certification as international laws ISO 9000:2008. In these last years, thanks to the Marullo trademark, the farmhold has consolidated the Sicilian market and it has been planning to expand abroad, looking at the international market.

Products

- Crumbles
- Dried fruit
- Pistachio natural colored paste
- Pistachio natural pure paste
- Hazelnut clear pasta
- Pine clear pasta

Marullo factory has the following certifications:

- BRC (British Retail Consortium)
- Green Pistachio of Bronte Protected Designation of Origin (PDO)
- FS (International Food Standard)
- HALAL

The company has drawn up the check lists reported in the guidelines, “Starting evaluation of the firm”, with the aim of furthering their knowledge and the sensitivity of the organization to environmental issues and of identifying the environmental impacts produced during the various phases of the productive process. In particular Table 1 reports on the main information collected by the firm.

Table 1. Company check list process

<i>Data</i>	<i>Answers</i>	<i>Data</i>	<i>Answers</i>
Name	Marullo s.p.a.	Label	In accordance with the law
Legal form	Limited Company	Distribution net	wholesalers (other)
Sector	Dried fruit	Types of packages	PP Carton
Site	Bronte (CT), Italy	Difficulties to carry out the legally binding standard in the agri- food sector	NO
Employees	10	LCA study	NO
R&S in QES	YES	Voluntary certifications	BRC IFS ISO 9000 PDO HALAL
Request for certified products	YES	Knowledge of voluntary environmental labels	Type I, II, III, IV
Customers' environmental sensitivity	YES	Renewable energy sources	YES- solar panels
Steps of the productive cycle (internal)	harvesting; hulling; shelling pelling drying process; packaging; storage ; distribution;	Steps of the productive cycle (external)	First activity: conventional
Main environmental impacts	material waste packaging energy consumption		

As far as the environmental policy of the firm is concerned, from discussions with the management, it emerged that Marullo should have an environmental policy coherent with ISO 14020 (2000) and the ISO 14063 (2010) set of standards which, in the literature, are the reference international regulations. the foremost objectives of the company should be: to encourage suppliers to adopt more sustainable farming production systems; to enrich the knowledge of its consumers regarding eco-compatible reduction; to prevent and reduce environmental impacts connected with the company productive cycle; to implement a system of integrated medium-term management, to use high quality raw materials, internal audit to measure environmental performance, continuous improvement in customer satisfaction, to improve green marketing through consumers very sensitive to environmental issues, finally training allows workers to learn the proper use of equipment, machinery and plant.

Regarding the environmental communication policy, the management has decided to control periodically the procedures and the results of the company's environmental performance in accordance with the legally binding requisites; it has also decided to make all the necessary improvements in order to reach the environmental aims described above, thus ensuring the continuous improvement of the company at large, and to communicate its commitment to consumers and stakeholders.

Moreover, to promote this policy, the management pointed out the appropriate financial, human, technical and structural resources with a view to putting into practice programmes of technological development within the company and monitoring the effectiveness of the communication system set up. The management decided that the company strategy of environmental communication had to include the identification and quantification of the different environmental impacts connected with the different steps of the productive process; moreover, from the analysis of the specially carried out market research, it emerged that the reference target group for the company seemed to be mainly composed of the current end-consumers, who were more or less sensitive to environmental issues, distribution operators of the pasta product and other consumers, including foreign ones, who would remain loyal to the firm if it adopted proper environmental communication systems (Salomone et al., 2011; Salomone et al., 2012).

The main company environmental impacts have been not pointed out, Through analyzing the life cycle Analysis of the entire productive chain (from the farming to the final consumption by the end-user and the disposal of the packages), and it is necessary to detect besides the high energy and thermal consumption during the entire production process and to quantify the most important indicators of the environmental performance detected during the company's environmental evaluation.

The information collected by the firm, subject of this case study, was integrated with the decision support tables given in the Guidelines: it emerged that the voluntary labelling system most in line with the organizational, environmental and economic characteristics of the company was Type I "LCA Eco-labels (ISO 14024)": these labels are generally voluntary, multi-criteria based, third-party verified schemes that award a licence to use the scheme label/logo for specific products or services that meet prescribed standards based on a life cycle assessment approach including, for example, energy and water consumption, emissions, disposal, etc. The standards and scheme criteria are usually developed through the involvement of stakeholders and awarded after an independent process of verification.

4. Conclusions

The experience resulting from the application of the guidelines proposed to the firm has shown how it is possible to choose the voluntary communication system, closer to the business reality, by starting from the analysis of the company activities and of the

expectations of the management, the stakeholders and their environmental awareness. The guidelines take into account the peculiarities of the soil, the specific quality of the products, the characteristics of the supply chain and of the company operative context and the final reference markets. They are derived from objective environmental assessments, so during the application phase they could make the management more aware of a higher control of the productive processes and of a more responsible management of all the company activities thus making sure production improves continuously in terms of environmental performance.

Following the iterative procedural steps and making use of decision support instruments, the organization has achieved the aim of giving to its distributors and consumers the necessary information for a conscious choice of eco-compatible products; it has also given the relevant information connected with the phases of the productive process, the product itself and the performance in terms of environmental impact. By choosing the most suitable environmental label, the pilot firm can improve its production chain drive within the limits of sustainability, also because the success of any environmental label mostly depends on the level of consumer awareness.

The firm has decided the environmental communication goals with own environmental communication policy which an organization sets up as part of its environmental communication strategy, such as helping organization framework for implementing its environmental communication policy and for the setting of environmental communication objectives and targets. The label could improve also the green marketing, instruments based on strategic incentive and on competitiveness, which are extremely important for the firms which base their communications on the strong and concrete improvement of their own environmental performances and which try to meet the increasing sensitivity of the consumer to environmental defence.

References

- Arena E., Campisi S., Fallico, B., Maccarone, E., (2007), Distribution of fatty acids and phytosterols as a criterion to discriminate geographic origin of pistachio seeds, *Food Chemistry*, **104**, 403–408.
- Barilaro C., (2006), *Pistachio, the "Green Gold" of Etna. A Symbiosis between Nature and Culture (Il pistacchio, "oro verde" dell'Etna. Una simbiosi tra natura e cultura)*, In: *Landscapes, Values and Flavours (Paesaggi, valori e sapori)*, Grillotti M.G., Borghese A., Esposito G., Lodi M., Mastrobernardino L., (eds.). WIP Edizioni, Rome, Italy.
- Barilaro C., (2007), *The "Emerald" Etna between Local Identity and Global Challenges (Lo "Smeraldo" dell'Etna tra Identità locale e Sfide Globali)*, in: *The Future of Geography: Environment, Culture, Economy (Il futuro della geografia: ambiente, culture, economia)*, Di Blasi A. (Ed.), vol.I, Patron Editore, Bologna, 219-226.
- Barone E., Padulosi S., Van Mele P., (1997), *Descriptors for Pistachio (Pistacia vera L.)*, International Plant Genetic Resources Institute, Rome, Italy.
- Barone E., Marra F., (2008), *The Pistachio Industry in Italy: Current Situation and perspectives*, World Edible Nuts Economy, Concept Publishing Co.
- Bellia F., Maugeri G., (1988), *Economic Aspects of the Production and Market of Pistachio (Aspetti economici della produzione e del mercato del pistacchio)*, Proc. of the conference *Current and prospects of pistacchicoltura* (Atti del convegno Attualità e prospettive della pistacchicoltura), September 6th-8th, Bronte (Italy), University of Catania, Italy.
- Bellomo M.G., Fallico B., (2007), Anthocyanins, chlorophylls and xanthophylls in pistachio nuts (*Pistacia vera*) of different geographic origin, *Journal of Food Composition and Analysis*, **20**, 352–359.
- Bonina F., Puglia C., Tomaino A., Saija A., Mulinacci N., Romani A., Vincieri FF., (2000), In vitro antioxidant and in vivo photoprotective effect of three lyophilized extracts of *Sedum telephium* L leaves, *Journal of Pharmacy and Pharmacology*, **52**, 1279–1285.
- Briamonte L. (ed.), (2005), *The sector of nuts in Italy (Il comparto della frutta in guscio in Italia)*, INEA, Roma.

- Buffa R., La Mantia M., Marra F. P., Cutuli M., Caruso T., Spata P., (2007), Rese dei pistacchietti etnei a rischio per il poco polline, *L'Informatore Agrario*, **39**, 26.
- Caruso T., Motisi A., (1996), Development opportunities in the South of pistacchicoltura: technical and production guidelines (Possibilità di sviluppo della pistacchicoltura nel Mezzogiorno: indirizzi tecnici e produttivi), *Magazine of fruit and vegetable producers (Rivista di frutticoltura e di ortofloricoltura)*, **1**, 9-17.
- Caruso T., Barone E., Marra F.P., Sottile F., La Mantia M., De Pasquale C., (2003), *Effect of rootstock on growth, yield and fruit characteristics in cv. Bianca Pistachio (Pistacia vera L.) trees*, Proc. XIII GREMPA Meeting on Almonds and Pistachios, Mirandela, Portugal.
- Clasadonte M.T., Lo Giudice A., Matarazzo A., (2013), *Environmental Labels and Declarations in the Agri-Food Sector*, In: *Product-Oriented Environmental Management Systems (Poems): Improving Sustainability and Competitiveness in the Agri-Food Chain with Innovative Environmental Management Tools*, Salomone, R., Clasadonte, M.T., Proto, M., Raggi, A. (Eds.), Springer, The Netherlands, 177-201.
- Council Regulation, (2006), European Council Regulation No. 510/2006 of 20 March 2006 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs, *Official Journal*, No. 93 of the 31st March 2006.
- Fabbri A., Valenti C., (1997), The Sicilian Pistachio industry: an overview, *Acta Horticulturae*, **470**, 43- 49.
- Gentile C., Tesoriere L., Butera D., Fazzari M., Monastero M., Allegra M., Livrea M.A., (2007), Antioxidant activity of Sicilian pistachio (*Pistacia vera L. var. Bronte*) nut extract and its bioactive components, *Journal of Agriculture and Food Chemistry*, **55**, 643-648.
- Giuffrida D., Saitta M., La Torre L., Bombaci L., Dugo G., (2006), Carotenoid, chlorophyll and chlorophyll-derived compounds in pistachio kernels (*Pistacia vera L.*) from Sicily, *Italian Journal of Food Science*, **18**, 309–316.
- Grippi F., Crosta L., Aiello G., Tolomeo M., Oliveri F., Gebbia N., (2008), Determination of stilbenes in Sicilian pistachio by high-performance liquid chromatographic diode array (HPLC-DAD/FLD) and evaluation of eventually mycotoxin contamination, *Food Chemistry*, **107**, 483–488.
- Hale M., (1996), Ecolabelling and cleaner production: principles, problems, education and training in relation to the adoption of environmentally sound production processes, *Journal of Cleaner Production*, **4**, 85-95.
- Hou D., Kai K., Li J., Lin S., Terahara, Wakamatsu M., Fujii M., Young M.R., Colburn N., (2004), Anthocyanins inhibit activator protein N.1 activity and cell transformation: structure-activity relationship and molecular mechanisms, *Carcinogenesis*, **25**, 29-36.
- Hu F.B., Willett W.C., (2002), Optimal diets for prevention of coronary heart disease, *Journal of American Medical Association*, **288**, 2569-2578.
- Insero O., (2014), Pistachio, long-lived tree that requires hot climates (Pistacchio, albero longevo che esige climi caldi), *Agrarian Informer (L'informatore agrario)*, **07-08**, 30.
- ISO 14020 (2000), Environmental labels and declarations - General principles, Technical Committee ISO/TC 207, Environmental management, Subcommittee SC 3, Environmental labelling, On line at: http://www.iso.org/iso/catalogue_detail?csnumber=34425.
- ISO 14021, (1999), Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling), On line at: http://www.iso.org/iso/catalogue_detail.htm?csnumber=66652.
- ISO 14024, (1999), Environmental labels and declarations. Type I environmental labelling. Principles and procedures, On line at: http://www.iso.org/iso/catalogue_detail?csnumber=23145.
- ISO 14025, (2006), Environmental labels and declarations. Environmental labels and declarations -- Type III environmental declarations - Principles and procedures, On line at: http://www.iso.org/iso/catalogue_detail?csnumber=38131.
- La Russa E., Barone E., Marra F. P., Caruso T., Finoli C., Mineo V., (2006), Seafood pistachio compared in storage phase (Frutti di pistacchio a confronto in fase di conservazione), *Agrarian Informer (L'Informatore Agrario)*, **27**, 25-29.
- La Russa E., Marra F. P., Caruso T., Finoli C., Mineo V., Pulvirenti G., (2007), The automated drying maintains the quality of pistachio (L' essiccazione automatizzata mantiene la qualità del pistacchio), *L'Informatore Agrario (Agrarian Informer)*, 22-25, On line at: http://www.agrinnovalazione.regione.sicilia.it/rassegna_stampa/frutta_secca/file/l_essiccazione_automatizzata_mantiene_la_qualita_del_pistacchio.pdf.

- Leone G., (1969), *The cultivation of pistachios (La coltivazione del pistacchio)*, Paruzzo, Caltanissetta, Italy.
- Lo Giudice A., Clasadonte MT., Matarazzo A., (2011), LCI preliminary results in the sicilian durum wheat pasta chain production, *Journal of Commodity Science, Technology and Quality*, **50**, 65-79.
- Maccarone E., (2007), Improvement and development of fruit production of Etna (Miglioramento e valorizzazione delle produzioni frutticole etnee), *Agrarian Informer (L'Informatore Agrario)*, Supplement of Sicily - Innovation Agribusiness (Supplemento Sicilia - Innovazione agroalimentare), **27**, 40-46.
- Okay Y., (2002), The comparison of some pistachio cultivars regarding their fat, fatty acids and protein content, *horticultural Science (Gartenbauwissenschaft)*, **67**, 107-113.
- Pellegrino Faro I., (2007), *L'oro verde di Sicilia: percorsi storico-gastronomici sul Pistacchio*, Il lunario Enna, Italy.
- Ros E., (2009) Nuts and novel biomarkers of cardiovascular disease, *American Journal Clinical Nutrition*, **89**, 1649-1950.
- Saitta M., Giuffrida D., La Torre G., Potorti A. G., Dugo G., (2009), Characterisation of alkylphenols in pistachio (*Pistacia vera* L.) kernels, *Food Chemistry*, **117**, 451-455.
- Salomone R., Clasadonte M T., Proto M., Raggi A., Arzoumanidis I., Ioppolo G., Lo Giudice A., Malandrino O., Matarazzo A., Petti L., Saija G., Supino S., Zamagni A., (2011), *Product-Oriented Environmental Management Systems (POEMS): Improving Sustainability and Competitiveness in the Agri-Food Chain with Innovative Environmental Management Tools (Proposta di un Modello di Product-Oriented Environmental Management System (POEMS) per l'industria Agro-Alimentare: Risultati Preliminari)*, Proc. 25th Italian Congress on Commodity Science: *The contribution of Science Merchandise for a Sustainable World (Il contributo delle scienze merceologiche per un mondo sostenibile)*, Campisi B., Novelli V. (eds), FORUM Edizioni, Udine, Italy.
- Salomone R., Clasadonte MT., Proto M., Raggi A., Arzoumanidis I., Ioppolo G., Lo Giudice A., Malandrino O., Matarazzo A., Petti L., Saija G., Supino S., Zamagni A., (2012), *Improving Life Cycle Management (LCM) tools for the food industry: a framework of Product-Oriented Environmental Management System (POEMS)*, Abstract book of the 6th SETAC World Congress, Berlin, Germany.
- Seeram N.P., Zhang Y., Henning S.M., Lee R., Niu Y., Lin G., Heber D., (2006), Pistachio skin phenolics are destroyed by bleaching resulting in reduced antioxidative capacities, *Journal of Agriculture and Food Chemistry*, **54**, 7036-7040.
- Tokusoglu O., Unal M.K., Yemis, F., (2005), Determination of the phytoalexin resveratrol (3,5,40-trihydroxystilbene) in peanuts and pistachios by high performance liquid chromatography diode array (HPLC-DAD) and gas chromatography-mass spectrometry (GC-MS), *Journal of Agriculture and Food Chemistry*, **53**, 5003-5009.
- Tomaino A, Martorana M, Arcoraci T, Monteleone D, Giovinazzo C, Saija A. (2010), Antioxidant activity and phenolic profile of pistacchio (*Pistacia vera* L., variety Bronte) seeds and skins, *Biochimie*, **92**, 1115-1122.
- Udo de Haes H.A., de Snoo G.R. (2012), *Eco-labelling of Agricultural Food Products*, In: *Environmental assessment and management in the Food Industry. Life Cycle Assessment and Related Approaches*, Sonesson U., Beril J., Ziegler F. (Eds.), Woodhead Publishing Limited, 374-397.
- Venkatachalam M., Sathe S.K., (2006), Chemical composition of selected edible nut seeds, *Journal of Agriculture and Food Chemistry*, **54**, 4705-4710.
- Wang L.S., Stoner G.D., (2008), Anthocyanins and their role in cancer prevention, *Cancer Letterature*, **269**, 281-290.
- Wojnarowska M., (2014), *On Possible Application of the Product Life Cycle Analysis (LCA) in Environmental Labelling*, In: *Commodity Science in Research and Practice - Towards Sustainable Development*, Adamczyk, W. (Ed.), Foundation of the Cracow University of Economics, Cracow, 199-210.
- Woodroof J.G., (1967). *Pistachio nuts*, In: *Tree nuts: Production, Processing, Products*, AVI Publishing, Westport, Conn, 261-287.
- Yalpani M., Tyman J.H.P. (1983), The phenolic acids of *Pistachia vera*, *Phytochemistry*, **22**, 2263-2266.

- Yang J., Liu R.H., Halim L., (2009), Antioxidant and antiproliferative activities of common edible nut seeds, *LWT-Food Science Technology*, **42**, 1-8.
- Zafra-Stone S., Yasmin T., Bagchi M., Chatterjee A., Vinson J.A., Bagchi D., (2007), Berry anthocyanins as novel antioxidants in human health and disease prevention, *Molecular Nutritional Food Researches*, **51**, 675- 683.



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A WIN-WIN-WIN STRATEGY FOR THE BUILDING SECTOR: THE CASE OF THE RESIDENTIAL COMPLEX PALAGIO ANZIO*

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Abstract

Metodo Palagio is an innovative building method which combines high standard environmental quality with building construction, maintenance and management costs control. The premise is that the house has to be conceived according to the value, both emotional and financial, it represents for a family and to its needs. Process innovation in Palagio-Anzio, inspired by Life Cycle Thinking approach, has affected planning, building site management, materials selection, staff training, etc. The result is a methodology which makes green building "aware" of customer needs, as well as local and social context, and "sustainable" for household economy and in terms of quality of life. "Metodo Palagio" implements a *win-win-win strategy* a business approach which simultaneously benefits the company, its customers (families) and the environment through a sustainable development. This way, Metodo Palagio is able to renovate the traditional way the small businesses (the majority in the business sector) operate. Despite green buildings are usually more expensive than traditional ones and often lacking any external audit guarantee, Palagio-Anzio is going to enter the real estate market with a product offering high quality at a competitive price.

Keywords: eco-innovation, energy efficiency, family friendly, green building

1. Introduction

The project is aimed at making certified green buildings financially convenient for the typical Italian building enterprise, through process innovations not increasing production

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costs. The challenge is realizing a small scale residential building with high environmental and energy performance, certified by a third party, and at the same time keeping selling price within the average market price. As a first step, research and benchmarking activities have been realized to get a set of procedures aimed at deeply restoring traditional construction process. “Metodo Palagio” integrates new topics, especially for small enterprises in the building sector, as Integrated Design Process, Life Cycle Thinking, construction site sustainable management, green procurement. These are all combined in Palagio strategy. The strategy, according to the affirmation that “true sustainability requires industries to pay attention to the entire life cycle of products and to the specific needs of customers” (Elkington, 1994), consists in realizing green buildings which are economically sustainable, as maintenance and management costs are reduced, and sustainable in terms of quality of life, as it takes into account family and kids’ needs as well as accessibility rules.

Research work has focused on the analysis of some peculiarity of the modern real estate industry and of construction enterprises operating in domestic market. Construction sector in Italy is mainly formed by small enterprises (Gregori, 2007); the analysis has examined the implication of size on the sector delay in introducing technological innovations to replace traditional techniques and in the adoption, even on voluntary basis, of protocols related to environmental topics. Further element considered is the shortage of pathways for training to make production process more efficient in a sector whose main input is labour.

Also, aspects related to the demand side have been investigated. As costumers, in economic cycles of oversupply, refine their real estate selection (Petracca and Ielasi, 2012), the analysis has examined the effects of price raise due to the introduction of construction technologies to improve buildings eco-efficiency. Unfortunately, poor transparency due to the agreements private nature (Casertano, 2011) and the very little number of certified buildings (in June 2014, when Palagio Anzio started, 9 residential buildings where registered under GBC Home protocol, and very little were the numbers for protocols like ITACA and Casaclima in center and south of Italy) have limited the analysis work. However it can be stated that there is elasticity of demand on the market since as green buildings price raises there is a larger decrease in demand. So buildings with verified characteristics of eco-efficiency represent a very little market niche in real estate sector, while market share for new built houses classified in energy efficiency classes A or B is definitely greater. In Italy the approach is almost exclusively concentrated on energy saving; poor attention has been given to water saving, emissions, indoor air quality, materials and products selection, building site sustainable management, and so on. This, despite various studies state that about 36% of green house gas emissions come from the building sector and that it takes 40% of energy production in Europe (http://ec.europa.eu/research/industrial_technologies/energy-efficient-buildings_en.html). Also, it is responsible for natural resources consumption and production of huge quantities of waste. It is indeed a sector in which it is complicated to intervene, because of intense urbanization of the last 60 years and the buildings poor quality: it is therefore clear the urgency to spread green building practices. By the joint analysis of construction industry and real estate market, the team opted for interventions which could give a substantial contribution to the achievement of the certification without increasing the costs, in order not to weaken the enterprise positioning on the market.

2. Case study presentation

2.1. Palagio method (Metodo Palagio)

“Metodo Palagio” aim is to codify in formal procedures a complete renewal path about the building process which, by integrating diverse expertise, involves the whole “house-product” life cycle, from the planning to the operational and maintenance stage.

The “Metodo Palagio” developer has started a planning path, consistent with the current economic circumstances, in order to balance targets of eco-efficiency and low consumer-price, in a “small construction and real estate market” framework. The preliminary benchmarking analysis has shown unstable, poor – and locally uneven - growth trend of the number of the certification protocols attesting energetic and environmental efficiency parameters, despite the high potential improvement of technical and qualitative aspects of the house-product. The analysis has underlined some decisive factors of the situation in object:

- national normative framework;
- small business size of the players in the system;
- no Integrated Design Process approach;
- final user low awareness.

On the basis of the analysis result, the company has adopted the following strategy:

- Integrated Design Process approach with multidisciplinary expertise involvement;
- definition of company procedures compatible with quality and environmental management system, applicable to all the building chain (hence to all subcontractors);
- workforce training on environmental topics;
- partnership creation with suppliers of products, materials and services aimed at removing an intermediate commercial stage.

Great attention has been given to innovations to the production process and product, in order to achieve high eco-efficiency and house-quality standards. Palagio is based on an Integrated Design Process, which allows renewing the traditional working method. It’s been considered that realizing a not industrialized house-product, integrating diverse expertise and applying the Life Cycle Thinking approach, would bring great results in terms of eco-efficiency. This would be achieved also by focusing on the house-product life cycle in the planning stage: from the building site management, the materials selection, to the final user usability. Metodo Palagio provides guidelines for an “aware” and “sustainable” green building.

- **Aware** of the necessity to use the highest performance levels building techniques and materials and, at the same time, to adjust them according to local environment and end users needs.

- **Sustainable for the environment** (Net Zero Energy Building, sustainable building site management).

- **Economically sustainable** since it reduces management and maintenance costs;

- **Sustainable in terms of quality of life**, since it takes account of household and children needs and is liable to security regulations.

2.2. Applied certification programs: LEED – GBC Home

We chose to certify the energy and environmental sustainability of the project by the application of the rating system GBC Home, which is the Italian LEED rating system for small houses. GBC Home is a voluntary rating system based on six environmental areas: sustainable sites, Water efficiency, Energy and atmosphere, Materials and resources, Indoor environmental quality, Innovation in design.

Each category has mandatory prerequisites and credits giving a score for the certification. GBC Home has 4 certification levels: Certified, Silver, Gold and Platinum which is the higher certification level. The certification target of Palagio Anzio is Gold level.

2.3. The project “Palagio – Anzio”

“Palagio – Anzio” is the first “pilot” application of Metodo Palagio; it is considered experimental especially with reference to the site work for the innovative procedures

foreseen and the need to test them in practice. Main areas of activity involved in process innovation are: design, training, contracts, building site management, procurement. Metodo Palagio intervenes on errors in the process with the aim to make convenient certified green building interventions for small businesses. As regarding design, Integrated Design has been introduced and has affected not only the methodology, but even the introduction of new competences (illuminating engineering, gardening, safety and security, family needs etc.). The establishment of a multidisciplinary team has allowed a broad view and the sharing of different points of view so to integrate knowledge and experiences. With regard to training, a new figure has been introduced: the “building site tutor”.

As the supply chain is made up of small enterprises, subcontractors and artisans, whose training is mainly realized on the job through *learning by doing*. As a tutor has been chosen a figure (section engineer or surveyor) who can give immediate and daily instructions to workforce and artisans. As for contracts the team has worked to solve the problem of disagreement between parties (building owner, contractor, subcontractor, suppliers). As for the training, in fact, small businesses disregard the importance of contracts, but the introduction of innovative products and materials could increase controversy if standard contracts are not provided.

2.4. The environmental management of the construction site

During the preliminary phases of Palagio Anzio design an analysis of the best practices for construction waste has been conducted; then it was established a Construction Waste Management Plan. The plan established great attention toward communication and education of all the workmen on the requirements of the construction waste management plan and the collection of the construction waste. The designer of the plan conducted on site meetings with the construction surveyor, the construction responsible and all the key field personnel of the contractor, with the purpose to communicate the project goals and requirements about construction waste, and to illustrate the Construction Waste Management Plan.

The general contractor identified a responsible for construction waste management with the task to control the workmen about the separately collection of construction waste and the respect of all the environmental measures of the work site. The sorting and separation of construction waste is done on site by the responsible of the general contractor, in order to make a more correct collection of waste and also to increase the percentage of recycled waste. The project goal is to recover 95% of construction waste. An area for the collection of the construction waste has been identified on site, with big bags containing different typologies of waste: brick, concrete, metal, plastics, wood etc. (Fig. 1); the area is isolated from the soil in order to prevent pollution. Communication panels were located all over the construction site to identify the different measures for the environmental management of the site.

Actually the percentage of recovery of the construction waste is of the 100%. The main problem occurred is the deficiency of infrastructures for the recovery of construction waste near the site, and, in particular, the complete absence of infrastructures for the recovery of polystyrene all over Lazio region. The presence of the responsible for waste management on the construction site contributed to solve these problems. On the other side, the recovery of brick, concrete, metal was simpler.

An Erosion and sediment control plan has been implemented in order to prevent stormwater pollution during the construction of Palagio Anzio by using best management practices. The plan established the construction of a silt fence consisting of a geotextile attached to the existing fence aimed to retain sediment that has been dislodged by stormwater.



Fig. 1. Construction waste management area

The construction site has a stabilized construction exit using a geotextile fabric under a layer of aggregates, in order to prevent that vehicles entering and leaving the site track significant amounts of sediment onto streets. On South-West perimeter it has been realized an embankment to keep rain far from the construction site. Areas not under construction have been temporary stabilized through seeding measures to control erosion. The plan establishes weekly regular inspections of the measures and also during or after storm events to ensure that controls are working effectively.

The plan also includes other measures to prevent pollution. Building materials, especially those that are hazardous or toxic, are stored under a covered area with a secondary containment in order to prevent soil and water pollution. Nearest to the construction site exit a washout area (Fig. 2) has been designated in order to wash only the canal through which concrete exits. In fact concrete contractors are obliged to wash concrete trucks in their own plants and not in the construction site, where it is possible only to wash the canal. The washout area is made of a excavated basin with a geotextile fabric under a layer of aggregates to filtrate the wash water. The plan also established the training of the site staff on erosion and sediment control measures and on pollution prevention measures.

2.5. The choice of construction materials and products

Palagio Anzio has an integrative approach to the choice of materials both in design and construction phases, aimed to reducing the waste production and the environmental impact of materials. For example the floors are made of prefabricated materials in order to have an high quality and energy performance also by reducing the production of construction waste. All the used construction materials are of high quality in order to give the best performance to the building, and they also have the less lifecycle impact according to the GBC Home requirements. At least 10% of the total of materials used in the project has a recycled content, both post-consumer and pre-consumer content, according to the GBC home requirements, in order to reduce impacts resulting from extraction and processing of virgin materials. A minimum of 10% of the total of materials used in the project have been extracted, harvested or recovered, as well as manufactured, within 350 km of distance of the project site in order to reduce the environmental impacts resulting from transportation.



Fig. 2. The washout area

The design and construction of Palagio Anzio give high importance to the indoor air quality, so that all the used indoor materials will be VOC free, according to the requirements of GBC Home rating system, especially referring to paints, adhesives, sealants, floor systems. The green procurement is a very important aspect in building design and construction, and small and medium - sized enterprises are often disorganized about purchases planning, aimed to realize eco innovative buildings. During the design and construction process of Palagio Anzio it has been necessary to identify a specific consultant for materials in order to choose the best performance materials having the same costs of traditional materials. The materials consultant made a list of principal materials and of the necessary environmental and quality certifications in according to GBC Home. Each producer or dealer has to subscribe a declaration of the main performances of the product, referring to the percentage of recycled content, the site of production and the VOC emissions, in order to give the consultant the possibility to compare different product and choose the product with the best relation between costs and performances.

2.6. Energy and water efficiency

Palagio Anzio design establishes an high level of energy performance especially due to the use of renewable energy by means of photovoltaic panels on the roof. The use of an high energy efficient enclosure (Fig. 3) and of high performing heating and conditioning systems give to the building the possibility of achieving an improvement of about 89% in the energy performance rating compared with a baseline building performance rating. Palagio Anzio will be totally unplugged from the local gas network and it will be only powered by renewable energy.

Palagio Anzio has also high performances in water use reduction. The design establishes the use of high efficiency fixtures to reduce potable water demand (toilets, bathroom and kitchen faucets, showerheads). Palagio Anzio also limits the use of potable water for landscape irrigation, through the use of rainwater captured from the roof and of plant species with low irrigation requirements. According to the requirements of GBC Home, Palagio Anzio employs strategies that, in aggregate, use about 38% less water than the water use calculated for a baseline building.



Fig. 1. Insulation of heat bridges

2.7. An “house for all”

At the attention for eco-efficiency and the realization of a high performing product, Metodo Palagio has efficiently associated the introduction of security and accessibility (SIA 500 rules) measures and especially to make the house “family friendly“. Spaces, in fact, are designed to result accessible for people with disabilities and to guarantee adequate spaces for children. Also, the project is aimed at satisfying children’s necessities (kid’s friendly garden, exclusion of dangers; suitability of spaces).

The most “attractive” innovation for somebody could be the kid’s friendly garden. That project has been made by an expert of gardening, who selected every single tree and bush. The garden design has considered the right to play, to the contact with nature, to discovery, typical of kids. The garden has been designed to limit the dangers in case of falls. A part of the garden back yard, for example, will be covered with a special no slipping floor, composed by 65% recycled materials for security kids’ playing.

3. Results and discussion

The Palagio Anzio complex is actually under construction. On the 15th of December we had the first visit on the construction site by the inspection body for certification, in order to verify the respect of the GBC Home requirements. Actually the percentage of the recovery of the construction waste is of the 100% even if the target value is of 95%; the inspector also verified the correct implementation of the measures for the control of the erosion and sedimentation, and for the energy efficiency. The selling price fixed by the investor is the standard price for traditional homes in Lazio. Until now the construction costs are similar to those for traditional constructions.

The main way to gain the objective is the integrated design and construction; investor and the construction enterprise have to work together with the environmental consultant and with all the designers in order to reach all the established objectives. The working group makes at least two monthly meetings in order to solve problems and to take decisions together. The main problem engaged is to persuade the staff of workmen to make the separately collection of construction waste and to respect all the environmental measures of the work site. They have the habit of discarding construction waste everywhere on the site without making separately collection; they don’t care about the soil pollution. So, the most

expensive activity is the surveillance of workmen and of the correct collection of wastes and the respect of the environmental measures.

The second problem is the choice of the construction materials; they must have a great recycled content and also they must come from local manufacturers. The interior materials have also to be VOC free for the indoor environmental quality. Materials must have specific certifications and respect specific regulations; often manufacturers and dealers don't know anything about their materials characteristic, so that it is necessary to have a material consultant having the function to search materials and verify their characteristics, asking the producers to certificate the recycled content and the origin of materials. The consultant must also have the function to analyze the costs and choose materials with the main relation between quality and price.

4. Conclusions

Up to the current working stage, Metodo Palagio has proven that building houses in a sustainable and profitable way is possible. It requires hard work of course and a big change for the whole process, from the design stage to the costumes of people operating in the construction site. But the result of this first pilot project has fulfilled the expectations. Suppliers and other stakeholders feedback is proving this is the course to follow to remain in the market, benefit the environment and improve our quality of living.

References

- Casertano G., (2011), *The Real Estate Market: General Profiles*, In: *Finance Real Estate: The Market, The Instruments, Investment Products (Il mercato immobiliare: profili generali, In: Finanza real estate: il mercato, gli strumenti, i prodotti d'investimento)*, Casertano G. (Ed.), CEDAM, Milan, Italy.
- Elkington J., (1994), Towards the sustainable corporation: win-win-win business strategies for sustainable development, *California Management Review*, **36**, 90-100.
- Gregori T., (2007), *The Role of the Construction Sector in the Italian Economy*, In: *The Buildings and Small Business (Il ruolo del settore delle costruzioni nell'economia italiana, In: Le costruzioni e la piccola impresa)*, Gregori T., Neri F., Benedetti G. (Eds.) FrancoAngeli, Milan, Italy.
- Petracca A., Ielasi F., (2012), *Developmental Profiles of Real Estate Marketing*, in: *Real Estate (Profili evolutivi del marketing immobiliare, In: Real estate, Cacciamani C. (Ed.), Egea, Milan, Italy.*



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COMPARATIVE ENVIRONMENTAL ASSESSMENT OF NANOFLUID APPLICATION IN REFRIGERATION OF POWER ELECTRONIC TRACTION SYSTEMS*

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Abstract

In Power Electronic Traction (PET) applications one of the central problems is the effective temperature management, since power demand and reliability requirement grow and devices become increasingly miniaturized. This paper presents a comparative Life Cycle Assessment (LCA) study among three systems: 1. Baseline Cooling System (BCS) that uses as refrigerant a mixture 50wt% of water and glycol; 2. Nanofluid Cooling System single stage (NCS_{single}) that uses alumina nanofluid as refrigerant produced with the single stage process; 3. Nanofluid Cooling System two stage (NCS_{two}) that uses alumina nanofluid produced with the two stage process. The functional unit is a liquid cooling system for Insulated Gate Bipolar Transistor (IGBT) in PET system for train with a lifetime of 30 years. The system boundary is from cradle to grave. Both NCS_{single} and NCS_{two} show lower potential environmental impacts than the BCS for all impact categories, due to better energy efficiency and increased lifetime of the IGBT. The latter is possible thanks to the lower service temperature. NCS_{two} has lowest potential impacts for all categories, due to the less energy consumption in the alumina nanofluids two stage production. A sensitivity analysis using several IGBT lifetime shows that the longer is the lifetime the more potential environmental advantages arise for all impact categories, due to a more efficient use of materials. Anyway, nanofluid application requires further development in terms of improvements of nanofluid stability and a new design of the cooling system.

Keywords: cooling system, IGBT, LCA, nanoalumina

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1. Introduction

The transport is a critical sector in European Community. In 2010 it accounts for about 4.9% of EU-27 gross value added (GVA) and for around 5% of employment (EC statistical pocketbook, 2013). The railway plays a key role in addressing rising traffic demand, congestion, fuel security and decarbonization. The European Commission presented a comprehensive package of measures to deliver better quality and more choice in railway services in Europe (EC, 2013). The energy saving in the railway sector is increasing. The sector is in continuing development, in particularly the High Speed Rail (HSR). For controlling the output power of the engine of the train, Insulated Gate Bipolar Transistor (IGBT) Modules are widely used (Gelman, 2014; Uzuka and Masada, 2014). The IGBT (Fig. 1) represents the last generation of power semiconductors. The IGBT are capable of switching high currents (~kA) and high voltages (~kV), which lead to electric powers in the MW range. The switching works very efficiently but there are still heat losses of some kW.

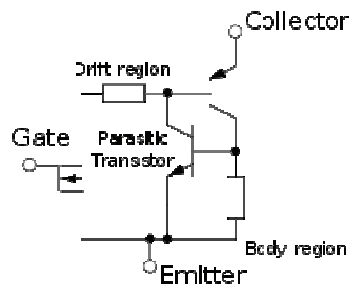


Fig. 1. Equivalent circuit for IGBTs

Therefore, for this power electronics traction (PET) application one of the central problems is the effective temperature management, since power demand and reliability requirements grow and devices become increasingly miniaturized. The thermal management limits the switching power of converters based on IGBT modules and it has a strong impact on converter reliability. The efficiency of thermal management is substantially defined by the cooling system. Liquid cooling systems are suitable for applications with high power (Kang, 2012; Wang et al., 2014). These cooling systems consist mainly of a cold-plate, which is directly placed on the IGBT surface, a pump to circulate the cooling fluid, a heat exchanger to remove the heat from the system, and a reservoir to fill in the fluid and to allow thermal expansion of the fluid.

Further improvements of this system are being investigated by new designs integrating liquid cooling structures in IGBT modules for Hybrid and Electric Vehicles (Wang et al., 2014) or by adaptation of microgroove structures in the design of the internal flow passage of the cooling system (Zhang et al., 2013). Instead, the NanoHex project (<http://www.nanohex.org/the-project>), financed by the 7th Framework Program, and focused on the use of new cooling fluids to improve thermal management limits. In particular, alumina (Al_2O_3) nanofluid was investigated as a new refrigerant for the power electronics traction system. The production of alumina nanofluid with two different pilot lines, “single-stage” and “two-stage” was also compared.

A comparative Life Cycle Assessment (LCA) study, from cradle to grave, assessed the environmental performance of this new coolant compared with the traditional coolant, in order to better understand the main environmental aspects of the system and to derive recommendations to improve it. The paper, after a short description of the analysed system

and how its functioning has been tested, describes the LCA study and its main results, providing some recommendations for the industrial implementation.

2. Material and methods

2.1. Cooling system: description and tests

The analysed product is a liquid cooling system of the Insulated Gate Bipolar Transistor (IGBT) power semiconductor with integrated Pulse Width Modulation (PWM) inverters. The main components of liquid cooling systems of IGBT are the cold plate, the circulation pump and the heat exchanger. A mixture of water and glycol is used as coolant fluid, to have high thermal exchange performance. A demonstrator was developed to simulate the heat management for applications like electrically driven trains. All components of the Demonstrator were assembled as shown in Fig. 1.

In the tests it is assumed that the IGBT works at 70% of the nominal current 1200A with an average efficiency of 98%. The tests show that, using the two alumina nanofluids, the cold plate and IGBT chip temperature is 3K lower than when using water and glycol, thanks to an increase of about 20% of the thermal heat exchange performance of the nanofluid.

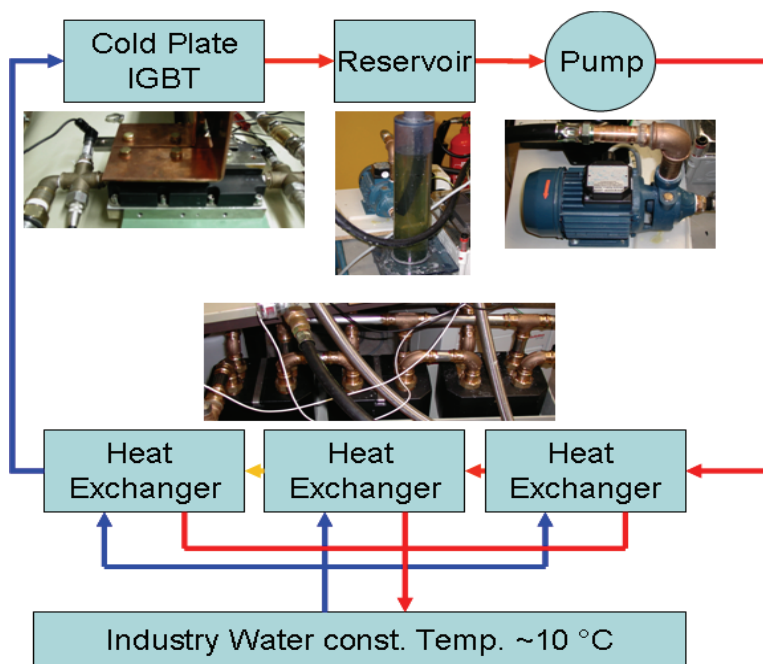


Fig. 1. Demonstrator Assembly (NanoHex, 2013)

The IGBT chip temperature influences the conduction and switching losses, where the reduction of temperature leads to reduced electrical losses. These losses reduction depend on the load cycle of the IGBT, in turns, depending on how the drive cycles of the train is. Anyway, a temperature reduction of about 3 K in the IGBT leads to about 2% reduction in the energy losses of the IGBT. Even though compared to the energy consumption of a train in its life time is a very small percentage, in absolute value in 30 years, a total amount of about 63 MWh could be saved in the use of a train with about 1 MW power.

Moreover, the reduction in temperature during the use increases the PET lifetime. In the study we assumed, based on expert judgement, an increase from 30 to 37 years using nanofluid coolant. The effects of this assumption have been checked in the sensitivity analysis, described in section 0.

2.2. Production of alumina nanofluid

The NanoHex project developed two pilot lines to produce nanofluid of alumina, named “single-stage” and “two-stage”. The “single-stage” incorporates the complete production of the nanofluid from particle formation to stable dispersion in one production line. Depending on the formulation, this process can vary a lot already for the particle formation step. In case of alumina nanofluid (with a concentration in mass of 9wt%), an aqueous solution (50%) of $\text{Al}(\text{OH})_n\text{Cl}_{6-n}$ and alumina comes under calcination at 1000C° in oven. In this phase, the nanoparticles are produced. Ethanol is after added to produce a suspension at 20wt%, that is milled, breaking agglomerations and producing surface modification. At the end, the solution is distilled in a rotary vacuum evaporator to remove the ethanol. In the “two-stage” production line, the pre-produced nanoparticle powder is added to a carrier fluid (water). To produce alumina nanofluid (9wt%), in the first stage a suspension with carrier fluid, nanoparticle of alumina 20wt% and ethanol is prepared and in the second stage the suspension is milled, breaking agglomerations and producing surface modification. At the end, the solution is diluted to 9wt% alumina and is distilled in a rotary vacuum evaporator to remove the ethanol. The main differences in the two pilot lines are that the “single-stage” production is far more versatile, while “two-stage” production is faster and more cost effective (Barberio et al., 2014).

The end-of-life treatment of nanofluids depends on their composition. There is no general rule, however, NanoHex partners proposed some guidelines for different nanofluids: Nanofluids with water as base fluid and particles of a material with toxic properties: measure pH value; dispose as hazardous liquid waste, after process of neutralization if pH is <7.2 or >7.9

- Nanofluids with water as base fluid and particles of a material with no toxic properties: evaporate water (at a temperature of 90°C); avoid formation of fine dust; if the composition of the nanofluid does not automatically leave large agglomerates after water removal, it is best to add a binding agent before vaporization; dispose of dried solids with normal household or industrial waste
- Nanofluids with water/ethylene glycol as base fluid: dispose as hazardous waste containing organic solvents.

In literature no data on toxicity of alumina nanofluid was found. However, alumina nanopowder is less toxic than Al nanopowder. Al_2O_3 nanoparticles exhibited mild toxicity toward microorganisms in the environment (Sadiq et al., 2009) and showed the ability to induce genotoxicity and cytotoxicity in vitro test (Di Virgilio et al., 2010); otherwise Zhu et al. (2008) showed that Al_2O_3 nanoparticles produced effects on zebrafish embryos and larvae not different from the effects caused by exposing to its bulk counterparts, that is considered non toxic. These data are conflicting and too poor to identify with sufficient confidence the toxicity of nanoalumina. Indeed, adopting the precautionary approach to risk management, the study assumed as end-of-life treatment that recommended for nanofluids with water as base fluid and particles with toxic properties, without a process of neutralization because the measured pH is between 7.3 and 7.8

2.3. LCA goal and scope

The goal of the study is twofold:

1) Identifying the main parameters (process, materials, energy consumption, elementary flows), that contribute more to the potential environmental impacts in the life cycle of the cooling system for power electrical traction system for a train

2) Identifying eco-design recommendations for the industrial scale up of the nanofluid cooling system.

To reach these goals, an LCA study was performed to compare the environmental performance of alumina nanofluid systems with respect to the present conventional technology. Therefore, only differences between the systems are modelled. The nanofluid refrigerant technology, developed by NanoHex, is the basis for the comparison. The three systems are:

1. Baseline Cooling System (BCS) that uses as refrigerant a mixture of water (50wt%) and glycol (50wt%);

2. Nanofluid Cooling System single stage (NCS_{single}) that uses as refrigerant alumina nanofluid produced with the single stage process;

3. Nanofluid Cooling System two stage (NCS_{two}) that uses as refrigerant alumina nanofluid produced with the two stage process.

The common function of the three systems is the heat removal from IGBT to improve performances and lifetime of trains. The functional unit is a liquid cooling system for IGBT in power electronic traction system for train with a lifetime of 30 years. The system boundary is from cradle to grave (Fig. 3)

BCS and NCSs has different expected lifetime for the power electronic traction system (30 and 37 year, respectively). That has been accounted for considering the material composition (copper, steel, aluminum, plastics etc.) of the PET (cooling system, IGBT and integrated PWM inverters) systems and the end of life of these materials. The energy for assembly and disassembly is neglected because assumed equal in both systems. In BCS we considered the production and the end of life of one system. In NCSs we considered the production and the end of life of 30/37 of the system. The main components of PET included in the analysis are:

- power electronic IGBT modules with integrated Pulse Width Modulation (PWM) inverters;
- cold plates in Aluminum;
- heat exchangers;
- electrical blowers and passive heatsinks in Aluminum;
- pumps;
- coolant (water/ethylenglycol and alumina nanofluid produced with single and two stage system);
- electrical circuit boards.

2.4. Life Cycle Inventory

The data collected comprehend:

- Primary data from NanoHex partners on production, use and end of life of nanoparticle (NPs), nanofluid, cooling system and on IGBT and cold plate composition in terms of component and materials. The data were collected throughout a questionnaire and a spread-sheet, sent to NanoHex partners.
- Secondary data from commercial databases Ecoinvent 2.2 and from literature.

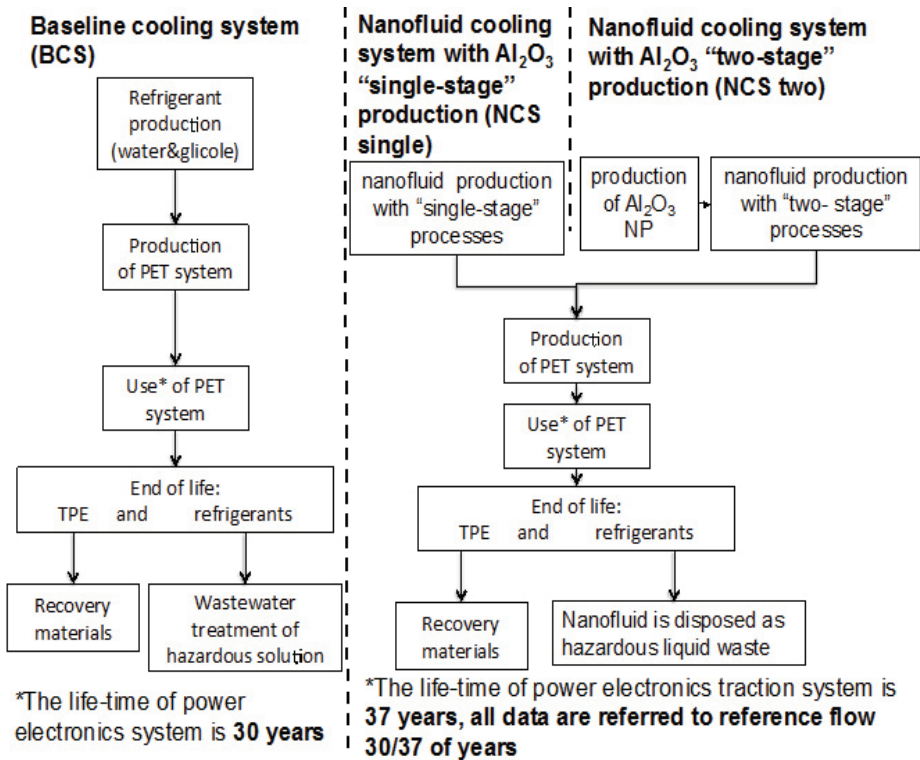


Fig. 3. System boundaries of BCS and NCS

2.4.1. BCS system

Table 1 shows the process considered in the BCS system and their amount for all life cycle, considering a life time of 30 years.

Typically an amount of 30-50 L of *refrigerant* (50wt% water and 50wt% glycol) is used for a power electronic converter, and in this study a value of 30 l is used as suggested by NanoHex partners. During maintenance the fluid level is controlled and refilled if necessary. It is assumed that only one complete refill of baseline refrigerant is necessary during the lifetime, total 60 L. Moreover, the water and glycol mixture is classified as hazardous waste (CER 07.07.04) so it is assumed that is treated in a wastewater treatment plant for hazardous waste.

2.4.1.1. Energy consumption

To calculate the energy consumption in use phase of BCS, data from demonstrator tests are used. Train characteristics, in term of power, energy losses and use of train in its lifetime had been proposed by NanoHex partners. The power of the train (P_t) is equal to 1MW, the total energy losses in the IGBT are 2% and the train is used for about 60% of a year, the calculation for energy losses in 30 year gives is 3513.6 MWh (Eq.1).

$$E_{\text{loss}(30y)} = 0.02 * 1\text{MW} * 365\text{days} * 30\text{years} * 0.6 = 3513.6 \text{ MWh} \quad (1)$$

The *electricity* considered in the study is only the difference in the energy consumption between BCS and NCSs. Considering that the reduction of IGBT losses using nanofluid is 2%, the energy saving is 63.07 MWh (Eq. 2).

$$E_{\text{saving}(30\text{y})} = 0.02 * E_{\text{loss}(30\text{y})} = 63.07 \text{ MWh} \quad (2)$$

The electricity module is taken from Ecoinvent database 2.2 and includes the electricity production in Europe, the transmission network and direct SF6-emissions to air. Electricity losses during medium-voltage transmission and transformation from high-voltage are accounted for. The production energy considers 29.2% of nuclear energy, 14.4% of hydro energy, 1.1% of hydropower energy, 50.7% of fossil fuel, 3.3% of renewable energy, 1.2% of energy from waste.

Table 1. Inventory data for BCS system

Process	Amount	Unit	Process in database
<i>BCS refrigerant: Water (50wt%) and glycol (50wt%)</i>	31.6	kg	CH: water, deionised, at plant
	31.6	kg	RER: ethylene glycol, at plant
<i>Production of IGBT-cold plate (materials only):</i>	1	pcs	
Aluminium	660	kg	aluminium, primary, at plant
Copper	870	kg	copper, at regional storage
Steel	630	kg	steel, converter, unalloyed, at plant
Solder	2	kg	solder, bar, Sn95.5Ag3.9Cu0.6, for electronics industry, at plant
Ceramic	8	kg	ceramic tiles, at regional storage
Plastic	160	kg	polyvinylchloride, at regional storage
Silicon Gel	8	kg	silicon, solar grade, modified Siemens process, at plant
Printed wiring boards	11	kg	printed wiring board, power supply unit desktop PC, Pb containing, at plant
<i>electricity</i>	63	MWh	electricity, low voltage, production RER, at grid
<i>end of life IGBT-cold plate:</i>	1	pcs	
Aluminium	660	kg	Recycling; aluminium secondary, from old scrap, at plant
Copper	870	kg	Recycling; copper, secondary, at refinery
Steel	630	kg	Recycling; steel, electric, un- and low-alloyed, at plant
Aluminium	669	kg	Avoided product: aluminium primary, at plant
Copper	641	kg	Avoided product: copper primary, at plant
Steel	573	kg	Avoided product: steel, converter, low-alloyed, at plant
Solder	2	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Ceramic	8	kg	disposal, inert waste, 5% water, to inert material landfill
Plastic	160	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Silicon Gel	8	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Printed wiring boards	11	kg	disposal, treatment of printed wiring boards
<i>end of life refrigerants</i>	60	L	treatment, heat carrier liquid, 40% C ₃ H ₈ O ₂ , to wastewater treatment, class 2

2.4.1.2. End of life power electronic traction system

The end of life of these components is regulated by the European Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) (EC Directive, 2012). The end of life scenario takes in to account the separation of metals and their recovery. The IGBT and the cold plate are removed manually. Table 1 and Table 2 show the end of life treatment of each component and material for BCs and NCSs respectively. The substitution approach has been applied. This approach considers that the materials derived from the recycling process are accounted as credit, avoiding the production of the same quantity of primary metals. This approach is particularly efficient for the metals as reported in the Declaration by the Metals Industry on Recycling Principles (Atherton, 2007) and suggested by the PE International (2014) and WSA (2011). The yield of recycling is different for each material. The yield of secondary metals depends on the phase of disassembly, the recyclability of each metals and the rate of production for the secondary production.

After the disassembly, all metals used in the production of the system are assumed to be recycled. Copper (CDA, 2014), aluminum (EAA, 2013) and steel (WSA, 2011) are 100% recyclable. The amount of secondary metals production is calculate considering that:

- Copper: to produce 1 kg of the secondary copper, the Ecoinvent process uses 1.3kg of scrap, so from 870kg of recovery copper about 669kg (870kg/1.3kg) of secondary copper from old scraps are produced. This avoids the production of the same amount of primary copper;
- Aluminum: to produce 1kg of secondary aluminum, Ecoinvent process uses 1.03 scraps of aluminum, so from 660 of recovered aluminum about 641kg (660kg/1.03kg) of secondary aluminum from old scraps (ingots) are produced. This avoids the production of the same amount of primary aluminum;
- Steel: to produce 1 kg of steel, electric, un- and low-alloyed, the Ecoinvent process uses 1.1 kg of steel scrap, so from 630kg of recovered steel, 573kg (630/1.1kg) of steel, electric, un- and low-alloyed are produced. This avoids the production of the same amount of steel.

2.4.2. The NCSs systems

The main differences are the refrigerant, the energy saving and the lifetime of the PET, 37 years instead of 30 years (Table 2). In NCS_{single} and NCS_{two} the refrigerant is alumina nanofluid and it is assumed that is totally refilled every 5 years. In total 210 L are used in the all life of PET system.

The production and refrigerant end of life are described in section 0. For material recycling, please refer to section 2.4.1.

3. Results

The characterization method adopted to evaluate the environmental impacts is IMPACT 2002 + (Jolliet et al., 2003). It is important to highlight that the scientist community is developing the standards test and metric to measure the humans and eco toxicity of nanomaterials (OECD 2013; SCENIHR, 2007), but the present information on nanoalumina is not sufficient, as mentioned in the chapter 2.2, to develop characterization factors for LCA impact categories, so all information on aquatic and terrestrial ecotoxicity, presented in the results, are referred at the bulk chemicals.

The NCSs show lower potential environmental impacts than the BCS for all impact categories. In particular, results show that NCS_{two} has lowest potential impacts for all categories, due to the less energy consumption in the alumina nanofluid two stage production. NCS_{two} shows impacts ranging between 13% (Nonrenewable energy) and 77% (Mineral extractions) of those of BCS (Table 3).

Table 2. System descriptions and data for NCS single and two systems

<i>Process</i>	<i>Amount</i>	<i>Unit</i>	<i>Process in database/Reference</i>
<i>refrigerant consumed:</i> alumina nanofluid 9 wt%	210	L	Barberio et al., 2014
<i>Production of IGBT-cold plate (materials only)</i>	0.81	pcs	
Aluminium	534.6	kg	aluminium, primary, at plant
Copper	704.7	kg	copper, at regional storage
Steel	510.3	kg	steel, converter, unalloyed, at plant
Solder	1.6	kg	solder, bar, Sn95.5Ag3.9Cu0.6, for electronics industry, at plant
Ceramic	6.5	kg	ceramic tiles, at regional storage
Plastic	129.6	kg	polyvinylchloride, at regional storage
Silicon Gel	6.5	kg	RER: silicon, solar grade, modified Siemens process, at plant
Printed wiring boards	8.9	kg	GLO: printed wiring board, power supply unit desktop PC, Pb containing, at plant
<i>electricity</i>	63	MWh	“RER: electricity, low voltage, production RER, at grid
<i>end of life IGBT-cold plate:</i>	0.81	pcs	
Aluminium	534.6	kg	Recycling; aluminium secondary, from old scrap, at plant
Copper	704.7	kg	Recycling; copper, secondary, at refinery
Steel	510.3	kg	Recycling; steel, electric, un- and low-alloyed, at plant
Aluminium	519.0	kg	Avoided product: aluminium primary, at plant
Copper	542.1	kg	Avoided product: copper primary, at plant
Steel	463.9	kg	Avoided product: steel, converter, low-alloyed, at plant
Solder	2	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Ceramic	8	kg	disposal, inert waste, 5% water, to inert material landfill
Plastic	160	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Silicon Gel	8	kg	disposal, plastics, mixture, 15.3% water, to municipal incineration
Printed wiring boards	11	kg	disposal, treatment of printed wiring boards
<i>end of life refrigerants</i>	60	L	CH: treatment, heat carrier liquid, 40% C ₃ H ₈ O ₂ , to wastewater treatment, class 2

3.1. Contribution analysis

In order to identify the main parameters (process, materials, energy consumption, elementary flows), that contribute more to the potential environmental impacts in the life cycle of PET, a deep analysis was performed for the categories of the mineral extraction, which refer to the depletion of metals ores (e.g. copper and bauxite) and the global warming potential, in line with the strategy of Europe 2020 a resource-efficient Europe - Flagship initiative of the Europe 2020 Strategy (EC, 2011) and the “European Climate Change Program” (EU, 2003).

As regards of mineral extraction category, the characterization analysis shows that production of power electronic gives the main contribute, these for all systems (Fig. 4). This impact is due to the use of metal in the construction of PET system. In particular the main impact is due to depletion of copper for about 88% in the BCS and 89% in NCS_{single} and NCS_{two}, followed by nickel with the contribute of 6% (BCS), 4% (NCS_{single} and NCS_{two}) respectively.

Table 3. Impact characterization (in absolute value and in percentage respect to BCS)

<i>Impact categories</i>	<i>Unit</i>	<i>BCS</i>		<i>NCS_{single}</i>		<i>NCS_{two}</i>	
Aquatic acidification	kg SO ₂ -eq	4.5E+02	100%	2.8E+02	63%	2.7E+02	61%
Aquatic ecotoxicity	kg TEG-EQ	1.6E+08	100%	4.1E+07	26%	3.0E+07	19%
Aquatic eutrophication	kg PO ₄ eq	1.0E+00	100%	5.4E-01	52%	4.6E-01	45%
Carcinogens	kg C ₂ H ₃ Cl eq to air	1.1E+03	100%	8.2E+02	76%	8.2E+02	76%
Global warming 500yr	kg CO ₂ eq	4.0E+04	100%	8.5E+03	21%	6.3E+03	16%
Ionizing radiation	Bq-C14	3.9E+06	100%	1.0E+06	27%	8.5E+05	22%
Mineral extraction	MJ surplus	3.2E+04	100%	2.5E+04	77%	2.5E+04	77%
Non Carcinogens	kg C ₂ H ₃ Cl eq to air	1.0E+04	100%	7.8E+03	77%	7.8E+03	76%
Non-renewable energy	MJ surplus	8.5E+05	100%	1.6E+05	19%	1.1E+05	13%
Ozone layer depletion	kg CFC-11 eq	2.1E-03	100%	5.1E-04	25%	4.0E-04	19%
Photochemical oxidation	kg C ₂ H ₄ eq	9.1E+00	100%	5.0E+00	55%	4.8E+00	52%
Respiratory effects	PM2.5 eq	8.6E+01	100%	5.1E+01	60%	5.0E+01	58%
Terrestrial acidification/nitrification	kg SO ₂ -eq	1.1E+03	100%	5.6E+02	52%	5.3E+02	49%
Terrestrial ecotoxicity	kg TEG- EQ soil	5.2E+06	100%	3.8E+06	74%	3.8E+06	74%

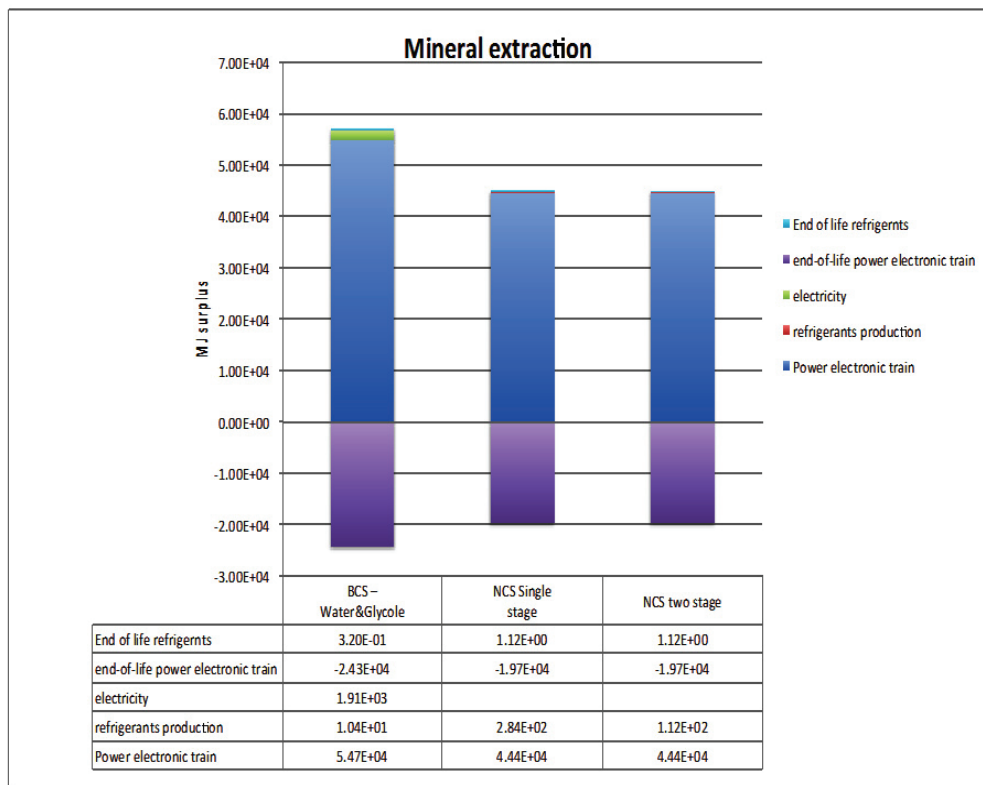


Fig. 4. Mineral extraction potential results for each system and for each process

The recovery of metals at the end of life of IGBT is considered as “avoided product”. These impacts are represented as negative contribution to the overall impacts of the systems and reduce the total positive impacts for about 42% (BCS) and 44% for (NCS_{single} and NCS_{two}).

The most relevant elementary flows for the GWP 500 years are the emissions into air of CO₂, contributing for 97% in BCS, 96 % in the NCS_{two} and 95% in NCS_{single}. The CO₂ emissions are due to the large contribution of fossil fuels to the production of electricity and metals. The recovery of metals in the end of life of power electronic traction system reduces the total impacts of each system for about 16% in BCS, 42% in NCS_{single} and 49% for NCS_{two} (Fig. 5).

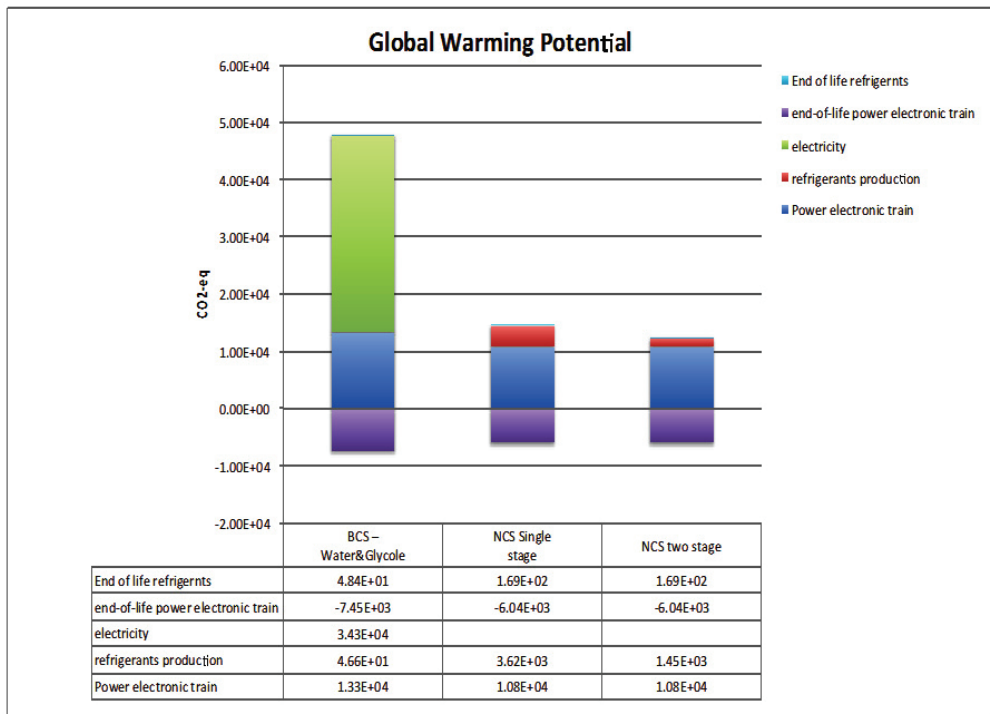


Fig. 5. Global Warming Potential results for each system and for each process

3.2. Sensitivity analysis

A sensitivity analysis was performed with the aim to verify the influence on results of key data and assumptions in modelling. In the study, the main assumption is the increase of lifetime of electronic traction power system from 30 to 37 years when using nanofluid coolant, justified by the lower working temperature. Three additional life time hypotheses are checked for NCS_{single}, selected being the worse case between the two NCS systems: 1) The life time doesn't increase and remains 30 years, (NCS_{single}30); 2) The life time increases to 34 years, (NCS_{single} 34); 3) The life time increases to 41 years, (NCS_{single} 41).

The results show that the Nanofluid cooling systems have less potential impact than BCS for all lifetime scenarios. The potential environmental advantages of NCSs systems are due to less use of materials and this increases with longer lifetime (Table 4).

Table 4. Potential impacts for the several lifetime scenarios in percentage respect to BSC (set equal to 100%), in grey the best scenario

	<i>BSC, %</i>	<i>NCS_{single} 37, %</i>	<i>NCS_{single} 30, %</i>	<i>NCS_{single} 34, %</i>	<i>NCS_{single} 41, %</i>
Aquatic acidification	100	63	68	77	57
Aquatic ecotoxicity	100	26	27	30	24
Aquatic eutrophication	100	52	55	59	48
Carcinogens	100	77	83	94	69
Global warming 500yr	100	21	22	23	20
Ionizing radiation	100	27	28	31	25
Mineral extraction	100	77	84	95	70
Non Carcinogens	100	77	84	95	70
Non-renewable energy	100	19	19	21	18
Ozone layer depletion	100	25	26	28	23
Photochemical oxidation	100	55	59	66	50
Respiratory effects	100	60	65	73	54
Terrestrial acidification/ nitrification	100	52	56	63	47
Terrestrial ecotoxicity	100	74	81	91	67

4. Conclusions and recommendations

The analysis was based on differences existing among the three analysed PET systems. Common parts and processes were not modelled. This approach allows for highlighting the differences in environmental performances, otherwise overwhelmed by the energy consumption in train use. The results show that nanofluid-based cooling systems could have environmental advantages in applications of power electronics traction. The detailed analysis of the life cycle of the cooling system shows how the abiotic depletion and the substitution of scarce resources are important issues. Mineral extraction is a relevant impact and it is mainly originated by the use of copper in construction of power electronic traction system, followed by nickel.

Moreover, the contribution analysis shows that production of alumina nanofluid has negligible contribution (less of 1%) for the abiotic depletion but about 25% in NCS_{single} and 12% in NCS_{two} for the Global warming potential. This impact is due to the need of replacing the nanofluid during the lifetime of the train. Further efforts should be devoted to increase the stability of the nanofluids, reducing the need of replacement. The alumina nanofluid end of life, precautionally considered as hazardous waste, has a negligible effect on all impact categories. Anyway, it is necessary to stress again that these results do not include the toxicity of nanofluid and nanoalumina, because the characterization factors of nanomaterials for toxic categories are not available, so all information on Eco-toxicity are referred at the bulk chemicals.

Recommendations for the industrial scale up should take into account the possibility to use less material and substitute copper and nickel with more abundant resources. The energy saving is another key issue. It deserves further development: the results of experimental tests in NanoHex project have shown that the SiC nanofluid has better conductive performance than alumina nanofluid. However, it produces problems of corrosion and erosion on the cold plate. So a re-design of the cold plate with different materials is necessary in order to use SiC nanofluids. Moreover, the use of nanofluid could be very interesting if they increase the lifetime of the PET, as shown in the sensitivity analysis.

Therefore, more technical tests are recommended.

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References

- Atherton J., (2007), Declaration by the metal industry on recycling principles, *The International Journal of Life Cycle Assessment*, **12**, 59-60.
- Barberio G., Scalbi S., Buttol P., Masoni P., Righi S., (2014), Combining life cycle assessment and qualitative risk assessment: The case study of alumina nanofluid production, *Science of the Total Environment*, **496**, 122–131.
- CDA, (2014), Copper Development Association, INC, On line at: http://www.copper.org/environment/green/sustainable_material.html.
- Celata G.P., D'Annibale F., Mariani A., Saraceno L., D'Amato R., Bubbico R., (2013), Heat transfer in water-based SiC and TiO₂ nanofluids, *Heat Transfer Engineering*, **34**, 1060-1072.
- Di Virgilio A.L., Reigosa M., Arnal P.M., de Melea M.F.L., (2010), Comparative study of the cytotoxic and genotoxic effects of titanium oxide and aluminium oxide nanoparticles in Chinese hamster ovary (CHO-K1) cells, *Journal of Hazardous Materials*, **177**, 711–718.
- EAA, (2013), European Aluminium Association, Contributing to a competitive Europe, report activity 2013, On line at: <http://www.alueurope.eu/wp-content/activity-report/2013/EAA%20AR%2013.pdf>.
- EC Directive, (2012), Directive 2012/19/EU of The European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), *Official Journal of the European Union*, **L197**, 38-71.
- EC, (2011), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, European Commission, COM(2011) 21 Brussels, On line at http://ec.europa.eu/resource-efficient-europe/pdf/resource_efficient_europe_en.pdf
- EC, (2013), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The fourth railway package – completing the single European railway area to foster European competitiveness and growth", European Commission, COM(2013) 25 final, Brussels, On line at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0025:FIN:EN:PDF>
- EC statistical pocketbook (2013), EU transport in figures, ISBN 978-92-79-28860-9, doi:10.2832/19314 On line at: <http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf>,
- EU, (2003), Second ECCP Progress Report, Can we meet our Kyoto targets? European Union, Brussels, On line at: http://ec.europa.eu/clima/policies/eccp/docs/second_eccp_report_en.pdf
- Gelman V., (2014), *Why there is no IGBT traction rectifiers?*, Proc. of Joint Rail Conference, Colorado Springs, CO, United States.
- Jolliet O., Margni M., Charles R., Humbert S., Payet J., Rebitzer G., (2003), IMPACT 2002+: a new life cycle impact assessment methodology, *The International Journal of Life Cycle Assessment*, **8**, 324–330.
- Kang S.S., (2012), *Advanced Cooling for Power Electronics*, Proc. Conference on Integrated Power Electronics Systems, CIPS, Nuremberg, Germany.
- NanoHex, (2013), Final Periodic Management Report, Release 1.0, Deliverable Number: D12.8 and D12.9, Planned: Month 42+60days, Actual Month: 42+60days, Period Covered: 1st Sept 2011 to 28th Feb 2013.
- OECD, (2013), *Ecotoxicology and environmental fate of manufactured nanomaterials: test guidelines*, Expert Meeting of Organisation for Economic Cooperation and Development, Report Series on the Safety of Manufactured Nanomaterials, No 40.

- Pe International, (2014), Harmonization of LCA Methodologies for Metals-A whitepaper providing guidance for conducting LCAs for metals and metal products, Version 1.01 February, On line at: https://c.ymedn.com/sites/www.setac.org/resource/dynamic/forums/20140507_114010_29793.pdf
- Sadiq I.M., Chowdhury B., Chandrasekaran N., Mukherjee, A., (2009), Antimicrobial sensitivity of *Escherichia coli* to alumina nanoparticles *Nanomedicine, Nanotechnology, Biology, and Medicine*, **5**, 282–286.
- SCENIHR, (2007), opinion on the appropriateness of the risk assessment methodology in accordance with the technical guidance documents for new and existing substances for assessing the risks of nanomaterials, Scientific Committee on Emerging and Newly Identified Health Risks, The 17th Plenary on 29 March 2007, On line at: http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_010.pdf
- Uzuka T., Masada E., (2014), High speed rail awaits the next breakthrough of power semiconductors, *Materials Science Forum*, **778-780**, 1071-1076.
- Wang, Y., Jones, S., Dai, A., Liu, G., (2014), Reliability enhancement by integrated liquid cooling in power IGBT modules for hybrid and electric vehicles, *Microelectronics Reliability*, **54**, 1911-1915.
- WSA, (2011), World Steel Association, Life cycle assessment methodology report On line at: <http://www.worldsteel.org/dms/internetDocumentList/bookshop/LCA-Methodology-Report/document/LCA%20Methodology%20Report.pdf>.
- Zhang Y.-H., Wang Y.-F., Wang L.-B., (2013), The water cooling experimental study on train traction converters, *Journal of Engineering Thermophysics*, **34**, 1534-1538.
- Zhu X., Zhu L., Duan Z., Qi R., Li Y., Lang Y., (2008), Comparative toxicity of several metal oxide nanoparticle aqueous suspensions to Zebrafish (*Danio rerio*) early developmental stage, *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering*, **43**, 278-284.



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Handbook, (1951), *Handbook of Chemical Engineer*, vol. II, (in Romanian), Technical Press, Bucharest, Romania.

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Star K., (2008), *Environmental risk assessment generated by natural hazards*, MSc Thesis, Institute of Hazard Research, Town, Country.

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JRC European Commission, (2011), *Supporting Environmentally Sound Decisions for Construction and Demolition (C&D) Waste Management*, A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA), On line at: <http://lct.jrc.ec.europa.eu/pdf-directory/ReqNo-JRC65850-LB-NA-24916-EN-N.pdf>.

EC Directive, (2010), Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (Integrated Pollution Prevention and Control), *Official Journal of the European Union*, **L334**, 17-119.

EC, (2014), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Towards a Circular Economy: A zero waste programme for Europe, European Commission, On line at: <http://ec.europa.eu/environment/circular-economy/>

Law 152 (2006), Legislative Decree No. 152 of the 03 April 2006, Environmental Regulations, *Official Journal*, No. 88 of the 14 April 2006 – Ordinary Supplement No. 96.

GD, (2004), Governmental Decision no. 1076/2004 surnamed SEA Governmental Decision, regarding the procedure for strategic environmental impact assessment for plans or programs, published in Romanian Official Monitor, part I, no. 707 from 5th of August, 2004.

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