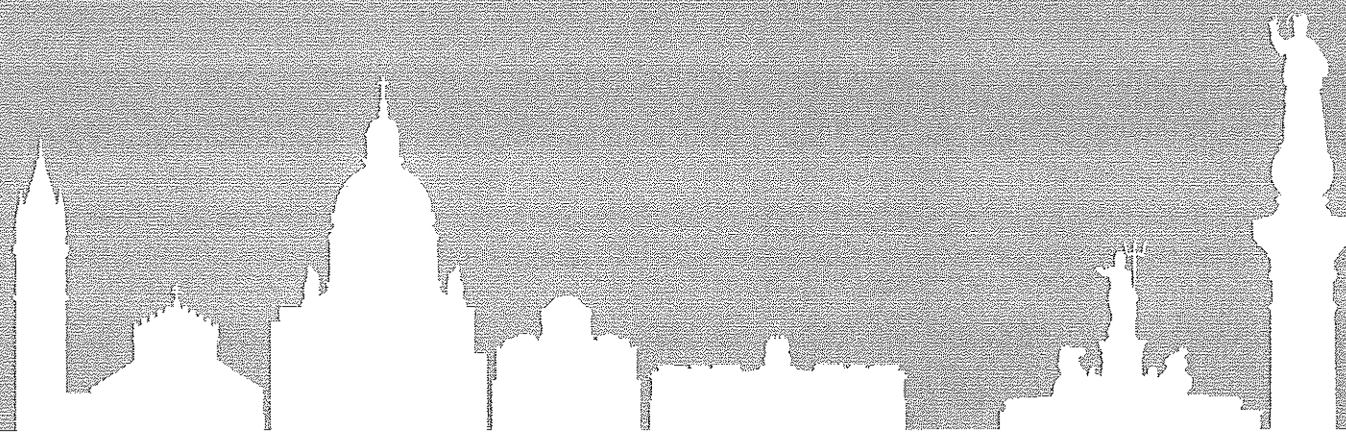
ACTIONS FOR A SUSTAINABLE WORLD

FROM THEORY TO PRACTICE



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Industrial symbiosis to improve zero waste production system: middle Italy wine district case study

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Abstract

This article studies the energetic potential of biogas obtainable from winery waste production through an anaerobic digestion (AD) process, within the territorial context of Emilia Romagna in Italy. The winery district produces about 5.2 million tons of grapes. These wastes are processes by anaerobic digestion in 5 biodigesters, this methodology allows to re- introduce in the production process 800,000 tons of food waste, consisting of: vegetable waste, wood chips and waste from pruning. Reusing production waste generates 12,236 million Nm^3 per year of biogas and 104,283 million kW/h per year of electrical energy. These results show that partnership between companies and the implementation of process innovations, could be reached by food manufacturers which requires a high energy needs and that produce significant amounts of organic waste, reusable by-products as raw material for biogas production.

1. Introduction

From the beginning of the 70s, the relationship and the interconnection between economy, environment and wellbeing has become more preponderant, especially for human activities and their effects on natural environment. The economic worldwide organization and productive system are based on the neoclassical linear approach, in which the intrinsic value of productive capital is dependent only on manufactured capital and does not account the environment safety, enhancing the weak sustainability vision (Pelenc and Ballet, 2015). According to this vision, the production cycle forces the economic chain in the same stages: mining, production, consumption and disposal.

Differently the circular economy approach, proposed as a sustainable alternative to our current linear economic system (Singh and Ordoñez, 2016), is a model in which the production activities are connected and organised to optimise the resources employed in the processes. The added value in this approach is related to the waste: the waste of some economic actors become resources for other stakeholders. This system is more virtuous compared to the linear economy approach, because it is based on the preferable usage of renewable resources and on the importance of sharing information among the different economic agents. Innovation and ecological design of final products are the other two variables that contribute to the enforcement of this system.

The circular economy concept is strictly linked to the industrial symbiosis model: symbiosis is a biological term referring to "a close, sustained coexistence of two species or kinds of organisms" (Encyclopedia Britannica, 1992), and in the 20th century, the symbiosis in natural systems was adopted as an analogy for understanding how industries interact (Lowe and Evans, 1995; Harper and Graedel, 2004; Korhonen, 2004). This model used for the first time by Valdemar Christensen in 1989 to describe the Kalundborg eco-industrial park (Zhaohua

W. et al., 2010), is based on the collaboration between firms in different sectors with the aim of sharing economic and social capital to optimize resources and costs. The benefit of this model is the integration of the three dimensions of sustainable development (environmental, economic and social) for the strategic management of the companies' factors of production.

More generally, a biomass is considered as any organic and decomposable material from vegetable or animal composition following a biological life cycle. The biomass can be used as energetic commodity, by converting the chemical energy present in the substances in heat, electricity or biofuels. Depending on the processing technology and the energy produced, it is possible to distinguish different types of biomass: solid (firewood, pellets, chips, agro-industrial residues and organic fraction of municipal solid waste wood and agricultural crops and residues, animal dung, herbaceous and woody energy crops, municipal organic wastes as well as manure.); liquid (biodiesel produced from oilseeds and exhausted vegetable oils); gaseous (biogas produced from livestock waste, agro-industrial residues and organic fraction of municipal solid waste) (Gracceva e Contaldi, 2004).

The employment and the consumption vary geographically according to the type of process used for the energy production. In the American continent, USA and Brazil are the leaders in the production of biofuels from corn ethanol and sugarcane ethanol respectively, with a total production in 2012 equal to 79 billion litres (WBA (2014) Global Bioenergy Statistics). In Europe (EU), the biomass is employed mainly for energy production, both heat and electricity predominantly produced from forestry products and residues in cogeneration plants (80%). Differently in Asia and Africa fuel, wood and charcoal are the most used resources, by considering that a significant part of the population do not have access to the electricity grid, but biogas and decentralised bioenergy systems are increasing.

Biomass is often defined as low-fuel carbon content or carbon neutral, indicating that burning biomass does not contribute to climate change.

In 2015 the world wine production reached 274.4 million hectoliters, a slight increase on 2014 (+ 1.3%) (Ismea, 2016). The forecast for 2016 is 259.4 million hectoliters, a marked decline compared to the previous year (-5.5%). In 2015, Italy was the first producer with a share of 18.2% of the world total, regaining the record lost in 2014 in favor of France (17.3% of the total). The advances for 2016 would confirm Italy in the position of the world's leading producer with 48.8 million hectoliters compared with 41.9 million in France and 37.8 million in Spain (Ismea, 2016). In the same year, the value of Italian production is estimated at 12.9 billion euro. The ISTAT estimates for 2015 indicate a share of DOC and DOCG wine production equal to 39% of the total, an increase of 15.8% on 2014; to it are added the IGP wines with 31.7%, + 14.7% on 2014 and, on balance, the common wines that count for the remaining 29.3% (Mediobanca, 2017). A significant share of Italian production is exported, with an operating surplus of 760 million euros in 1990 to 5.1 billion euros in 2015 (6.7 times), a year in which volumes decreased by 1.2% and value increased by 5.4%; the average export price therefore rose from 2.49 euros to 2.66 euros per liter (+ 6.7%). Provisional data from Istat for 2016 show an increase in exports of 4.3%

over 2015 (+ 2.9% in quantity); the average export price increased by 1.4% to 2.7 euro per liter. The provisional surplus in December 2016 rose to 5.3 billion (+ 4.9% compared to 2015) (Mediobanca, 2017).

The companies of this study have a location on the Italian territory that leads to a certain concentration in some regions, also called "wine district". With the caveats due to the multi-regional location, sub-aggregates can be processed on which to calculate significant economic-environmental indicators. In some regions, economic performance is relatively more brilliant than the national average.

2. Methods

The article is based on a quantitative analysis of the data obtained from the study of a wine district involved in the process of industrial symbiosis. The role of networking and innovation in the field of industrial simbiosis (IS) is investigated through direct research in the field with the use of specific and reliable sources. With acquired datas it as possible to investigate the whole production process by life cycle assessment (LCA) methodology. Datas were processed with data-based software such as Simapro v. 7. The study applied the systemic approach to sustainability science, which includes a comprehensive analysis for identifying potential areas for theoretical, methodological and practical progress of IS studies.

Italy has an important tradition in terms of local collaborations between companies, institutions and communities, inherited from the district model. For this work has been studied a Emilia Romagna's wine district. Main product of the district is wine, but it also produces by products that can be used and processed by other companies of the district.

The mission of the entire district is zero waste production, to achieve this goal all organic wastes from production are destined to anaerobic digestion. By anaerobic digestion the wine district can produce energy that can be re-used for energy needs of the production process itself.

Figure 1 describes the production process for biogas fermentation using continuous stirred tank reactor (CSTR) of the middle Italy wine district. The fermentation process is a mesophilic type. The fermentation takes place in large tanks of 500 m3 and the fermentation temperature is kept around 35 °C with recycled hot water. About 80 tonnes of waste water passing through the fermentation process and part of the biogas produced by the anaerobic digester is used to power the wine distillation process or for heating the boiler. Most of the waste to be composted are derived from a winery in northern Italy.

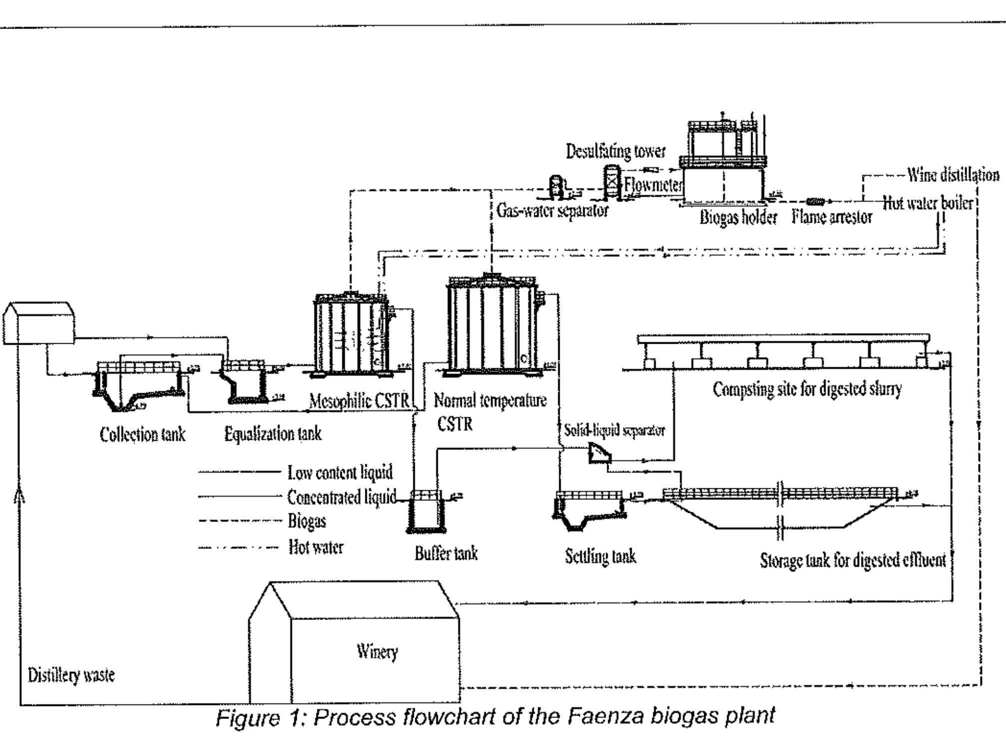

Figure 1: Process flowchart of the Faenza biogas plant

The winery district has embarked on a partnership with an energy company, with which it works in symbiosis. The energy company produces biogas resulting from the waste processing of the wineries. The energy requirements of the winery are totally satisfied by the production of electricity resulting from the biodigester. In Table 1, the energy requirements are listed.

Table 1 – Winery energy requirements per year

Equipment	Electricity Consumption (KWh)
Screw pump for mesophili CSTR	12.946.500
Recycle stirring pump	12.946.500
Hot water recycle pump	3.528.000
Submerged pumps	37.663.500
Overhead stirrer	17.650.500
Submerged mixer for equilization tank	7.056.000
Solid liquid separator	12.946.500
Illumination	262.500

To calculate the energy balance, energy and biogas have been converted into electricity (kWh). The total production of 5,200,000 tons of grapes produces 220,000 tonnes of waste that are destined at the biodigester. Thanks to the anaerobic digestion process the energy company that collaborates with the winery can produce 105,000,000 kWh of biogas and 81 million kWh of electric energy. The use of renewable fuels allows an annual saving of about 35,000 tons of CO2. The total energy produced satisfy the energy needs of the winery that produces food waste.

3. Results and discussion

In this section, we will try to highlight how networking and innovation have progressively become relevant topics in IS studies and how they have been integrated in supporting EU policies and local development models.

The winery district transforms 5,200,000 tons of grapes into wine. Wastes from this transformation process are re-introduced in the production system.

Thought anaerobic digestion wastes are transformed into electric energy and biogas. Environmental and economic impacts from the transformation process has been elaborated by LCA simulation software as Simapro 7.

The following inputs were taken into consideration in the analysis process:

- Total production of grapes;
- Amount of biogas produced by anaerobic digestion;
- Amount of electric energy produced by anaerobic digestion.

The parameters analysed for this case study are listed in table 2.

Table 2 – Environmental and economic parameters from biomass energy production

Parameter	Type	Total	Electricity from biomass	Heat from biomass
Climate change Human Health	DALY	20	6,73	13,60
Ozone depletion	DALY	2	2,08	0,01
Human toxicity	DALY	6	0,48	5,60
Photochemical oxidant formation	DALY	0	0,17	0,00
Particulate matter formation	DALY	9	6,02	2,61
Ionising radiation	DALY	0	-	0,45
Climate change Ecosystems	species.yr	0	0,04	0,08
Terrestrial ecotoxicity	species.yr	2	1,68	0,00
Freshwater ecotoxicity	species.yr	10	9,63	0,00
Marine ecotoxicity	species.yr	8	1,95	6,38
Agricultural land occupation	species.yr	0	-	0,01
Metal depletion	$	3	-	3,16
Fossil depletion	$	5	1,35	4,00

The results from software development show that biomass gas production has a greater environmental and economic impact than biomass electricity production. An economic analysis was conducted for the biogas plant. The biodigestion plant was built in 2009 and has an estimated life span of 20 years. The installation cost was 1,250,000 €. The annual revenue is calculated by adding up the sale of energy produced and the savings resulting from the production of energy from the biodigester. The annual costs include the cost of labor and equipment maintenance fee. The annual income is calculated from the difference between the annual operating costs and revenues. The payback period has been identified by dividing the costs for the installation of the biodigester and annual income (1).

$$Payback\ period = \frac{investment\ cost}{annual\ income} \qquad (1)$$

Il net present value (NPV) It was calculated as shown in equation (2).

$$\mathrm{NPV} = -C0 + \sum_{i=1}^{n} \frac{C1}{(1+r)^i} \qquad (2)$$

- C0: installation cost of biodigester
- C1: annual income
- *r*: rate of interest
- *n*: number of years
- *i*: discount factor at time

Table 3 shows how the payback period and npv returns positive results. Domestic production of electricity and biogas saves in a year: 3.726 € million from electricity costs and 2,195, 545.54 € from gas costs.

Table 3 - Economic analysis of the anaerobic digestion plant

Type	Value
Installation cost	1.250.000,00 €
Annual income	5.921.545,54 €
Equipment maintenance costs	4.830.000,00 €
Payback period (months)	2,56
Net present value	5.529.082,99 €

As a source of renewable energy, biogas and other renewable energy, not only bring environmental benefits but can be economically competitive to attrack new investments.

4. Conclusion

The challenge of our century is to define and apply a new scenario where the production is *re-thought* and *re-launched* for the improvement of environmental and human safety. The territory is the pivotal element that can lead the redefinition of the economic boundaries, by achieving a more efficient process of production based on the revalorisation of waste. The new vision starts from different innovative sectors, from waste to sustainable management and recovery, from agriculture to mobility, to biochemistry, to push the supply of commodities under an innovative low carbon perspective. The process of transition must be taken together with the industrial innovation policy, territorial and environmental, to respond to the dangerous situation of pollution and to create the conditions for new investments in the renewable energy sources, as well as in the optimisation of resources allocation.

Incentives to promote the circular economy approach should be based on two variables, savings on production costs and the acquisition of competitive advantages (a consumer prefers to buy a product from circular rather than linear production process). Prolonging the productive use of materials, the reuse and increasing the efficiency, the competitiveness will be strengthened, the environmental impact and the GHGs emissions will be reduced. The sustainable collaboration will enhance the sharing initiatives between different companies operating in different sectors, with the aim to share initiatives based on common interests, in terms of economic, environmental and social value. Collaborative agreements between companies and industries will optimize the environmental preservation, amplifying the final benefits. Subsequently, collaboration for certain firms has deepened between firms exploiting new opportunities for initiating collaborative practices. Furthermore, the use of biomass in the production process is cost-competitive today, and incentives will lead the generation and the usage of this commodity. Environmental preservation, energy security and socio-economic advantages are associated with sustainable bioenergy, and transitional measure will reduce the cost of the competitiveness in the middle term. Policy frameworks at national and local level should provide the support for the implementation of production waste reuse, by achieving also other important objectives, such as greenhouse-gas reduction, energy security, biodiversity preservation, and socio-economic development.

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