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LIFE CYCLE ASSESSMENT OF PHOTOVOLTAIC IMPLEMENTATION: AN ITALIAN CASE STUDY

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ABSTRACT

The energy efficiency is the possibility and ability to carry out a production process consume with the involves of less energy and minor environmental impact. Life Cycle Assessment is one of the major tools involved in the economic, social and environmental evaluation. The aim of this work is the LCA application to an Italian company that provides to install a photovoltaic plant for the energy self-maintenance, in order to break down costs and environmental impacts. The photovoltaic business can be an interesting solution especially for companies which consume more energy during the day. In the case study was highlighted that an average of 400.00 €/month was spent, equal to about 900 kWh / month. The company installed a 10 kWp photovoltaic system and with this implementation the energy consumption diminished of 84% and the costs of 57%.

Key words: Energy Efficiency; Photovoltaic; Life Cycle Assessment; Sustainability.

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1. INTRODUCTION

Energy efficiency is the goal of many programs and incentive plans of the last years. The energy efficiency is the possibility and ability to carry out a production process consume with the involves of less energy and minor environmental impact. An efficiency process can be gained through a product innovation that may consist in plants investments for the production of clean energy, such as photovoltaic, wind, biomass power plant. The efficiency can be also achieved through process innovations which allow to have a fast production and a greater energy saving, due to the modifications of some manufacturing processes or interventions on the structure of some used machinery. In this framework some tools are usually involved to evaluate the impact of the product or process innovations [1]. The Life Cycle Assessment is one of the major tools involved in the economic, social and environmental evaluation. It provides useful information to define all the activity possible effects and the direct or indirect environmental consequences. For this reason, LCA is generally used to make strategic decisions or as marketing tool in worldwide companies. The aim of this work is the LCA application to an Italian company that provides to install a photovoltaic plant for the energy self-maintenance, in order to break down costs and environmental impacts.

Starting from 2005, investments in photovoltaics were growing up thanks to incentive programs issued by Government and in compliance with the worldwide objectives of energy efficiency and environmental sustainability set for 2020[2].

Photovoltaics had also become speculation object, due to the possibility to obtain incentives from European or national plan: large projects were presented aimed at installing expanses of photovoltaic panels for the sole purpose of accessing the incentive and, once obtained, left the investment to himself. Nowadays, a domestic use of photovoltaics is gained with many small and medium-sized installations serving homes or businesses, in ordert to exploit mainly or exclusively the savings offered by self-consumption. The photovoltaic can bring, if well exploited, interesting benefits and gains even without any kind of state facilitation or incentive. The photovoltaic business can be an interesting solution especially for companies, which consume more energy during the day, so it is possible to determine at least two orders of reasons that make it convenient: first the company consumes a large part of the day energy produced and, secondly, to optimize the investment does not need special electrical storage devices, managing to consume almost all the energy produced.

In this sense, photovoltaics for companies is appropriate in all cases because it allows the production of part of the electricity requirements internally, necessary above all in the production hours of the plant when the company also carries out its activity [3].

About photovoltaics there are two opportunities that a company can reach to continue making this form of investment convenient, beyond the incentives:

- - it is important that the company's own solar power consumption quotas are sufficiently high: from 70% up on the production of photovoltaic systems, generally over 500 kW of power;
- - it is possible to install a photovoltaic system that is based on efficient user systems.

The real reason to introduce photovoltaics nowadays is the possibility of accumulating energy savings. The decisive push for investment is given precisely by the economic savings on the electricity bill. The real challenge, for a successful investment, consists in the ability to achieve a good economic return plan by calibrating the prices of installations and electricity consumption to be within a short time from the expenses incurred.

In this framework, even in the absence of incentive plans, investment in the photovoltaic resource continues to represent an opportunity for the company to gain, thanks above all to the savings obtained with self-consumption, which offers the highest margins of gains of more than 70%, and opportunities offered by the ESUs, Efficient Utilities, which allow to separate the producer and consumer operating on the same site and benefit from the direct sale between producer and consumer. An Efficient System of Utilities is a system in which production for sale and consumption purposes are located in the same place, where the producer can directly sell the energy produced to the end user without intermediation, without network costs and above all without charges. This system represents those systems that produce energy from renewable sources and make it available to a single user without using an energy distribution network. This system is convenient for both: the producer, who succeeds in obtaining a gain from the energy produced by the plant, selling it at a higher price than that offered by the Electrical Services Manager, and at the same time agrees with the end user, who can buy the energy it needs at a lower price than the one practiced on the market by the reference electric operator [4].

2. LIFE CYCLE ASSESSMENT

In last century, as part of respect for environment in management processes and innovations control began to emerge a method that embraces the entire product life cycle, the so-called "Environmental Life Cycle Thinking [5]. This method involves a “Cradle to Grave” analysis by investigating the environmental impact of raw materials, energy, resource, production, distribution, use, recycling and final disposal [6].

In 1990 the "Life Cycle Assessment" (LCA) concept was finally achieved by the Setac congress (Society of Environmental Toxicology and Chemistry). It was used to define a method that evaluates the interactions of a product or service on the environment, by considering its entire life cycle. Therefore, with this analysis, the process energy consumption its environmental impacts are assessed.

LCA was regulated by the International Standards Organization (ISO) ISO 14040 [7] and ISO 14044 [8] standards of 2006. ISO 14040 reports "Principles and frameworks of reference" and recap how to carry out an LCA evaluation, while ISO 14044 " Requirements and guidelines " guides the operator in the execution of the analysis.

The first standard specifies the LCA processes by considering the environmental impacts of the examined case in relation to human health, ecosystem and resources fields. Its purpose is to realize a framework of the product or service relationships with the environment by considering the positive or negative impacts on it. This led to understand the direct or indirect environmental consequences. Therefore, LCA provides useful information to define all the activity possible effects for this reason can be used to make strategic decisions or as marketing tool [9]. LCA is a great applicability because it allows to make decisions taking account the environmental, economic and social aspects, which are the three main dimensions of sustainable development [10] .

LCA procedure has advantages and disadvantages for companies. There are many reasons that make this procedure complex to be implemented and apparently not convenient, such as the difficulty of primary data collecting and incomplete databases or referring situations. For this problem, numerous public and private research units are active in improving databases that will be useful to overcome this difficulty.

Despite the critical issues highlighted there are many aspects that make LCA a suitable tool. First of all, LCA makes possible to make a complete, synthetic and global process description. This gives a useful perspective on the life cycle of the system under evaluation by identifying the critical points and the positive aspects. In addition, LCA is a valid tool to evaluate the effectiveness of proposed changes and to identify possible improvements in environmental and economic terms. For this reason, it is useful as a decision support tool and to make strategic choices [11].

According to ISO 14040 and ISO 14044, after the definition of the goals and the scopes of each case studied, LCA consist of three stages:

- **Life Cycle Inventory (LCI) Analysis:** the first stage of the LCA, regarding the collection of data and information, analysis and validation of data, by defining and studying the exact amount of input and output derived from the system studied. The results are based on the historical records obtained from the company object of our research study.

- **Life Cycle Impact Assessment (LCIA):** that provides the information to interpret the environmental significance of the comparison. In this phase, the environmental effects are quantified as consequences of physical interaction between the production system studied and the environment. The categories are chosen for the strong relationship between electricity demand and environmental outputs linked to the systems.
- **Life Cycle Costing (LCC):** is a valuation method that determines the overall cost of products and services, considering its entire life cycle (International Standard Organization, 2006). The analysis permits to determine the cost drivers and understand the potential cost savings that can be applied in a system thanks to innovations of materials, processes or products, especially if different alternatives are compared and the cost-effective option can be derived. In the LCC definition methodology, the overall cost is considered with the aim of assisting the decision makers in the choices regarding modification of some variables in the Life Cycle of specific products or services, for determining the most cost-efficiency and competitive solutions for the production process.

3. THE ITALIAN CASE STUDY

3.1. The Company

The activity, was launched in January 2005 and provides for the primary activity of cutting, shaping and finishing of stones, processing of marble, sales of sanitaryware, building materials, ceramics and tiles. The company is situated in the Latina Province of Lazio, a very sunny area, characterized by a mild climate where periods of sunshine prevail compared to rainy ones and where the summer season brings temperatures to 34 - 35 ° C averages. This is an aspect that pushes local entrepreneurs, to believe in the potential offered by renewable energy production and to look at photovoltaic systems as a sure and very sustainable means of investment. The company activity takes place from 7 in the morning to 19 in the evening, so the range of energy consumption involved is mainly that relating to the daytime hours. The company in question can provide high quality materials for quality coatings, focusing on the strength and durability of the materials.

During the first years of activity, the entrepreneur realized that the biggest part of the costs present in his annual budget was represented by the energy consumption. Each month the company uses around 900 kWh, for a total cost of the reference energy equal to almost € 400.

Therefore, the company takes into account the possibility of investing in photovoltaic energy to reduce the costs of energy consumption, thanks above all to the potential offered by the territory in terms of climate and also interested in related environmental impact.

3.2. Photovoltaic Implementation

Following the company inspection, it emerged that the place where the company is located enjoys ideal conditions for the electricity production through photovoltaic modules. The building where the activity takes place is equipped with a 30 ° inclined roof to the south, position that allows the plant to produce efficiently. By evaluating the company energy consumption, it was highlighted that an average of 400.00 €/month was spent, equal to about 900 kWh / month. This analysis revealed an annual requirement of 11500 kWh and an energy consumption equal to approximately 9490 kWh / year in the daytime. This requirement can be absorbed with an investment in a 10 kWp photovoltaic system.

The plant installed is made up of 40 polycrystalline silicon modules, consist of dozens of cells, typically 72, octagonal or square. The cells are formed with multiple silicon crystals, obtained from the waste recycling of electronics industry. They are characterized by intermediate electric yields between those of the monocrystalline modules and in amorphous silicon, consequently for the same installed power the cost of these modules is lower than the monocrystalline ones.

This kind of photovoltaic cells are among the best on the market, in fact they continuously pass the most rigorous test program in the photovoltaic sector and show their quality through the "VDE Quality Tested" certification, issued by the Association of German Engineers. They offer a 12-year product warranty plus a performance warranty for 25 years. Specifically, these installed are the third generation of Q.CELLS modules that is optimized in every aspect, from the best efficiency to greater operational safety and longer life. In this specific type an innovative technology has been introduced that allows an excellent functioning in all seasons, so they are very efficient even in the case of low irradiation and low temperature.

Thanks to the breathable box and the welded cables, the modules are protected against short circuits and loss of power due to summer heat. The weight of the individual modules is only 19 kg and their stability are guaranteed for wind - snow loads up to 5400 Pa. Their design dimension has been reduced, which contributes to reducing logistics costs for transport by up to 31% thanks to the greater capacity of modules to be included in each box. The tolerance (plant capacity to deviate from the nominal power) recognized for these modules is around 3% for the first 10 years and around 8% for the subsequent ones. The technical sheet of the panels informs us that the guaranteed nominal power is 97% in the first year and for the first ten, 92% after 10 years and at least 83% after the twenty-fifth year of life. For this type of modules is then guaranteed a percentage of annual deterioration of 0.6%, as it allows us to see that these are among the most efficient panels on the market, as the average percentage of degradation for normal panels is equal at around 1% per year.

The photovoltaic system has been connected to a three-phase inverter produced by SMA Italia, ideal for roof systems and which meets the needs of almost all photovoltaic systems, being adaptable to different types of voltage. The inverter is a device capable of transforming direct current into alternating current and is used in photovoltaic systems to supply the produced current from the plant directly into the electricity distribution network. The photovoltaic generator supplies direct current, so that the presence of this device, which despite the fluctuations in the voltage coming out of the photovoltaic generator, supplies the enterprises and to make accessible the energy produced for domestic use that requires alternating current. Regarding the problem related to the dismantling and disposal of the panels, these modules were registered by the producer for disposal, to the "PV Cycle" consortium, which is recognized by the GSE as a consortium accredited to the photovoltaic panels recovery and recycling.

3.3. LCI and LCC

The total cost estimated for the installed plant is equal to € 18,000, including 10% VAT, that the company obtains with a loan. The loan has an interest rate equal to 6.15%, to be repaid in 36 months with instalments equal to € 496. The photovoltaic system realization involves a resources outcoming that finds a complete return only after several years. By comparing the systems before and after the photovoltaic implementation was highlighted as the energy costs were € 4,800, before the implementation, and € 2,800 after the implementation. Moreover, the saving in energy consumption is noteworthy. The company usually spent 900 kWh for year that become 150 kWh after the photovoltaic system installation.

By projecting this results in a 25 years periods it is possible to make some considerations, as reported in Table.

The company requires 11,500 kWh / year, which, considering an energy purchase price to the Local Grid Operator equal to 0.26 € / kWh and an annual increase of the same price of

3%, due to the increase of the cost of obtaining fossil fuels in the coming years, leads to estimate a company energy expenditure of € 109,013 in 25 years of business without any plant.

With the photovoltaic system it is estimated that the company succeeds in self-consumption 52% of the energy produced and, the remaining 48% is traded on the spot, then sold to the local energy distributor at a price of 0.08 € / kWh, with an annual increase in the contribution of 1.60%. The plant is deducted from the company according to an amortization rate of 9% per year.

The 25 years – projection can be made based on: savings deriving from the energy produced and self-consumed, revenue deriving from the exchange of energy not consumed and fed into the network and, the variations of energy sales prices, the estimate of the annual level of deterioration of the panels equal to 0.6%. These projections shown that, in 25 years, the total expenditure for the purchase of electricity of the company is equal to € 52.326, for a total savings of € 57.610, equal to 53% energy saving in 25 years.

Table 1 Life Cycle Costing.

Resource	System without photovoltaics	System with photovoltaics
Energy Consumption (from local distributor)	22,500 KWh	3,750 KWh
Energy Costs (including investments)	109,013 €	52,610 €

4. CONCLUSIONS

Life Cycle Assessment is one of the major tools involved in the economic, social and environmental evaluation. It is usually involved to make strategic decisions or as marketing tool in worldwide companies. This work has explored the LCA application to an Italian company that provides to install a photovoltaic plant for the energy self-maintenance, in order to break down costs and environmental impacts. It was highlighted that an average of 400.00 €/month was spent, equal to about 900 kWh / month. The company installed a 10 kWp photovoltaic system and with this implementation the energy consumption diminished of 84% and the costs of 57%.

REFERENCES

[1] Y.-W. Wu, M.-H. Wen, L.-M. Young and I.-T. Hsu, LCA-based economica benefit analysis for builfin integrated photovolatic (BIPV) facades: a case study in taiwan, International Journal of Green Energy15(1), 2018, 8-12.

[2] N. A. Ludin, N. I. Mustafa, M. M. Hanafiah, M. A. Ibrahim, M. A. M. Teridi, S. Sepeai, A. Zaharim and K. Sopian, Prospects of life cycle assessment of renewable energy from solar photovoltaic technologies: A review, Renewable and Sustainable Energy Reviews, 96, 2018, 11-28.

[3] W. M. Soares, D. D. Athayde and E. H.M. Nunes, LCA study of photovoltaic systems based on different technologies, International Journal of Green Energy, 15(10), 2018, 577-583.

[4] G. Constantino, M.Freitas, N. Fidelis and M.G. Pereira, Adoption of Photovoltaic Systems Along a Sure Path: A Life-Cycle Assessment (LCA) Study Applied to the Analysis of GHG Emission Impacts. Energies, 11, 2018, 2806.

[5] J. A. Mathews AND H. Tan, Progress Toward a Circular Economy in China The Drivers (and Inhibitors) of Eco-industrial Initiative, Journal of Industrial Ecology,15, 2011,435–457.

[6] F. Preston. A Global Redesign?: Shaping the Circular Economy (Chatham House The Royal Institute of International Affairs, 2012).

[7] International Organization for Standardization (ISO). (2006). Principles and Framework of Life Cycle Assessment (ISO 14040). Geneva, Switzerland.

[8] International Organization for Standardization (ISO). (2006). Environmental management,Life cycle assessment,Requirements and guidelines. (ISO 14044). Geneva, Switzerland.

[9] J.X. Johnson, C.A. McMillan AND G.A. Keoleian, Evaluation of Life Cycle Assessment Recycling Allocation Methods: The Case Study of Aluminium, Journal of Industrial Ecology Explore,17, 2013, 700-711.

[10] B. Kim, C. Azzaro-Pantel, M. Pietrzak-David and P. Maussion, Life Cycle Assessment for a Solar Energy System Based on Reuse Components for developing countries, Journal of Cleaner Production, 208, 2019, 1459-1468.

[11] E.G. Hertwich, Life Cycle Approaches to Sustainable Consumption: A Critical Review, Environmental Science & Technology,*39* (13), 2005, 4673-4684.