**International Journal of Civil Engineering and Technology (IJCIET)**
Volume 10, Issue 02, February 2019, pp. 2301–2307, Article ID: IJCIET_10_02_229
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJCIET&VType=10&IType=2
ISSN Print: 0976-6308 and ISSN Online: 0976-6316



# SUSTAINABILITY OF TECHNOLOGICAL INNOVATION INVESTMENTS: PHOTOVOLTAIC PANELS CASE STUDY

**Giuliana Vinci**
Department of Management - Sapienza University of Rome,
Via del Castro Laurenziano 9, 00161 Roma

**Fabrizio D'Ascenzo**
Department of Management - Sapienza University of Rome,
Via del Castro Laurenziano 9, 00161 Roma

**Andrea Esposito**
Department of Management - Sapienza University of Rome,
Via del Castro Laurenziano 9, 00161 Roma

**Mattia Rapa**
Department of Management - Sapienza University of Rome,
Via del Castro Laurenziano 9, 00161 Roma

**Andrea Rocchi**
Department of Communication and Social Research – Sapienza University of Rome,
Via Salaria 113, 00161 Roma

**Roberto Ruggieri**
Department of Management - Sapienza University of Rome,
Via del Castro Laurenziano 9, 00161 Roma

## ABSTRACT

*Process innovations in recent years are based on renewable sources processes, such as photovoltaic panels. In the case study analysed are shown the benefits obtained from the investments of the central Italy after installing photovoltaic systems. The total expenditure for the electricity purchase is € 52.326, while the total benefit of the investment is € 18.789, equal in percentage to a 53% energy saving over a period of 20 years. The company expeniture in the absence of a photovoltaic system is equal to € 109.03, while in the presence of a plant, considering also all costs incurred for € 93.090, with a percentage of profit on the investment made equal to almost 15% in 20 years.*

**Key words:** Circular Economy, Sustainable Development, Process Innovation, Photovoltaic Panel, Energy Saving.

**Cite this Article:** Giuliana Vinci, Fabrizio D'Ascenzo, Andrea Esposito, Mattia Rapa, Andrea Rocchi, Roberto Ruggieri, Sustainability of Technological Innovation Investments: Photovoltaic Panels Case Study, *International Journal of Civil Engineering and Technology* 10(2), 2019, pp. 2301–2307.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=10&IType=2

# 1. INTRODUCTION

Renewable Energy Sources (RES), such as hydroelectric, biomass, geothermal, wind and photovoltaic, represent a valid alternative to traditional fossil sources both for the advantages in terms of lower environmental impact and for their ability to be renewable and not subject to exhaustion [1, 2]. Among the RES, the use of photovoltaic systems (PS) is becoming more and more interesting, able to transform solar energy into electricity [2,3], even if their contribution to energy production is still limited: in the European Union, according to data from the Statistical Office of the European Union (Eurostat), in 2009 they contribute only about 0.3% to gross domestic consumption of electricity, whereas if we considered all RES, this percentage would increase at around 18% [4].

Recently, albeit with a certain delay compared to other European countries, also in Italy there is a strong growth of PS systems: in the last three years from 7,647 plants corresponding to an installed capacity of 87 MW (December 2007) a total of 128,419 plants with an installed capacity of 2,430 MWh (December 2010). However, their contribution to domestic electricity consumption is still very limited and in line with the European average (around 0.3% in 2009) (Source: Electrical Services Manager).

The application of PS has transversely involved all sectors that use electricity. Among these, the agricultural sector has started to play a significant role, involving a share of 9% of installed capacity on a national basis [5, 6]. In fact, agriculture presents a wide availability of surfaces for the installation of PS panels both in terms of unused land and of houses and rural buildings (with reference to the possibility of installing panels on buildings). This wide potential can be exploited by farms in compliance with the environmental and landscape balances of the territory for the benefit of a new eco-sustainable image of its agricultural activity [7]. Firms can also derive an economic advantage, integrating their income with that deriving from the production of electricity, also benefiting from specific incentives, as we will see in the next paragraph [1,8]. In recent years, in fact, thanks to a new legislative framework that has encouraged PS in general, but especially in the agricultural sector, and thanks also to technological innovation [5], we are faced with a scenario in continuous evolution on which it is useful to deepen the research for the benefit of all the parties interested in the use and diffusion of this clean technology [9, 10]. The purpose of this contribution will therefore be to evaluate the economic advantage to invest in PS in the farms of central Italy, with the aim of highlighting the possible advantages for the agricultural sector.

Italy, after spending several years with policies on the promotion of photovoltaic inefficient, receives a significant impetus with the application of Legislative Decree n. 387 of 29 December 2003 which launches the incentive system called "Conto Energia". The Energy Account consists of a public loan aimed at individuals who start producing electricity through PS. The contribution is paid on the basis of the kWh1 produced and extends for a period of 20 years from the entry into service of the plant. Two different incentive schemes can be distinguished: on-site exchange and transfer to the network. The first consists of the total self-consumption of the energy produced, while the second, the sale to the network, allows the

sale of part or all of the energy produced that is not self-consumed. The incentive rates vary depending on the architectural aspects of the plant and its power [11].

The Energy Account system was then changed over the years, and, to date, we have the third version, introduced by the Ministerial Decree of 6 August 2010: "Discipline of the incentives for the Energy Account 2011 for photovoltaic plants". The Energy Account 2011, although presenting a reduction in incentive tariffs compared to the previous version, remains the most important and advantageous incentive system for investing in PS [11].

It is important to underline that since 2005, following the law of December 23rd 2005 n. 266 (and subsequent amendments of 2006 and 2007), the production of photovoltaic energy is part of the firms activities and can be considered as part of the income with the relative tax advantages [12]. In particular, "the production and sale of photovoltaic energy by entrepreneurs is always productive of income for the part generated by the first 200 kW of photovoltaic power" [11], while that exceeding this threshold, can consider itself productive of income only if it meets the requirements of article 4 in points a), b) and c) of the circular 32 / E of 06/07/2009 of the Revenue Agency. Also, the various Rural Development Plans (RDPs) of the Regions (2007-2013) come into play, in which capital incentives are envisaged in the amount of 20% of the installation cost. According to the Ministerial Decree of 6 August 2010 (Energy Account 2011), the incentives of the 2007-2013 RDP can be combined with those of the Energy Account (in the financial year), as it is based on public incentives assigned by calls published before 25 August 2010 (date of entry into force of the provision). However, their accumulation is only possible for plants that enter service by 31/12/2011 and provided that the percentage of RDP funding does not exceed 20% of the installation cost. In this way, the sustained investment, already incentivized by Conto Energia, becomes even more advantageous.

The national incentive policies for photovoltaics are currently in constant evolution. In particular, with the approval of the legislative decree of March 3, 2011 implementing the Directive 2009/28 / EC, the incentives for PS plants placed on land in agricultural areas will be provided only for plants with power less than 1 MWh and in any case for plants which do not cover more than 10% of the agricultural area in the availability of the proposer. However, these limitations do not apply in the case of agricultural land abandoned for at least 5 years. The same decree specifies that by April 30, 2011 the incentive system will be re-regulated and the new provisions will be applied starting from June 2011.

## 2. METHODS

There are various aspects that can affect the economic performance of a PS [13]. Among these, one of the most important is the average annual solar radiation of the place where the plant is installed: in Southern Italy it is larger, in the North it is less and in the Center it has intermediate values [3]. Other significant variables are the size of the plant and its architectural characteristics (where and how it is installed): these two aspects determine different incentive tariffs for the Energy Account. Furthermore, the unit cost per kW installed is inversely proportional to the installed power [10].

Given these premises, in this contribution we want to represent an ordinary and indicative situation at the national level: for this reason, the assessment will be based on a medium-small facility located in central Italy.

This will examine the economic-financial advantage to invest in a 10 kW system in place exchange system installed on a building of a farm in central Italy. Starting from these characteristics of the plant we evaluate the following four types of investment:

- 10kW PS plant without a loan with the incentive of the Conto Energia 2011 and the RDP (20% of the installation cost);
- 10kW PS plant with mortgage with the incentive of the Conto Energia 2011 and the RDP (20% of the installation cost);
- 10kW PS plant without a loan only with the incentive of the Energy Account 2011;
- 10kW PS plant with loan only with the incentive of the Energy Account 2011.

For the calculation of the economic-financial advantage of the investment, it is based on the following data:

- the total cost for the installation of the PV plant is equal to 46.410 euro3. In the cases in which it is to benefit from the PSR contribution, the initial cost of the investment, decreasing by 20%, goes to € 37,128;
- annual average production per kW of 1,350 kWh for central Italy (3);
- incentive rate of 0.36 euro / kWh, for PV plants that enter service between 1 May and 31 August 2011 (Energy Account 2011);
- to calculate the savings due to the auto electricity consumed, a price of 0.145 euro / kWh will be used (price paid on average by the farms for electricity);
- the annual average increase in the price of electricity is considered to be 3.8%. The figure is based on annual increases in electricity prices provided by the National Institute of Statistics (ISTAT) between 2004 and 2010;
- account is taken of the annual yield drop of photovoltaic panels, which is expected to be 0.6%;
- it is assumed, in the types of investment 2 and 4, to access a mortgage that covers the entire initial cost of the plant. The mortgage will become extinct in 15 years and will have a 5.5% interest rate;
- the annual cost of ordinary and extraordinary maintenance plus management costs is 500 euros.

To assess the economic convenience of investments, cash flows are calculated for the entire duration of the Energy Account incentive, ie twenty years. On the basis of this time frame, the following convenience indicators are calculated: Net cash flow at 20th year, Pay Back Period (PBP) or return on investment, Net Present Value (NPV) and Internal Return Rate (SRI) [14, 15]. The cumulative Net Cash Flow at the 20th year represents the algebraic sum of all revenues and costs between the year 0 and the 20th year [16].

The PBP represents the number of years needed to pay back the initial investment, ie when the annual net cash flows become positive. The lower the number of years and the more convenient the investment [17].

The VAN expresses the difference between all revenues and costs discounted to current events. This indicator if greater than zero tells us that the investment is economically viable. It can also be compared with the NPV of other alternative investments. For the calculation of the NPV, a discount rate of 5% is applied, which may represent the rate that can be deduced from similar investments by duration and risk (eg long-term government bonds) [10,14,18].

SRI is the wise one that represents the profitability of the investment and can be compared to the SRI of other alternative investments. In this study the 5% discount rate will be used as a comparison [14,15].

## 3. RESULTS AND DISCUSSION

The results show a significant economic advantage to invest in PV systems, especially when the incentives of the Energy Account 2011 and of the RDP can be simultaneously granted. This is the case of investment 1 (without loan) where we have a net cash flow at the 20th year of 98.283 euros, a NPV of 46.159 euros, an SRI of 16.8% (higher than the discount rate considered) and a 5.8 year PBP (Table 1 and Figure 1). When, on the other hand, the investment is supported only by the Energy Account 2011 (Table 1 and Figure 2), again in the case in which a mortgage is not accessed (investment 3), the net cash flow in the 20th year decreases by 9%, the NPV of 20%, the SRI of 23% and the PBP increases by 24%.

**Table 1** Convenience indicators for 10 kW PV systems in the field exchange regime calculated over a period of 20 years

| Investment type for 10Kw PV plant | Plant cost (€) | Cumulative net cash flow at the 20th year (€) | NPV at the 20th year (€) | Internal Rate of Return | Payback Period |
|---|---|---|---|---|---|
| without mortgage, energy bill and RDP | 37.128 | 98.283 | 46.159 | 16,8 | 5,8 |
| with mortgage, energy bill and RDP | 37.128 | 79.929 | 44.893 | - | - |
| without a mortgage, only Conto Energia | 46.410 | 89.001 | 36.877 | 12,9 | 7,2 |
| with mortgage, only Conto Energia | 46.410 | 66.052 | 35.293 | - | - |

In the hypothesis in which the investment is financed by a loan (investments 2 and 4), there is a slight decrease in the NPV and a more substantial reduction in the cumulative net cash flow at the 20th year compared to the same investment without a loan. However, access to the mortgage allows you to have positive net cash flows since the early years, as opposed to non-mortgage investments where they are after about six years. Figures 1 and 2 show the cash flows of investments.

In the event that the same investments examined were in the form of transfer to the network, rather than being exchanged on the spot, in proportion to the amount of energy sold to the network, there would be a slight decrease in the economic advantage. This change is due to the price of energy sold which is lower than the energy purchased [10]. If the same assessment was conducted in the absence of the two incentives examined, all the indicators used would indicate a negative expediency to invest [19, 20].

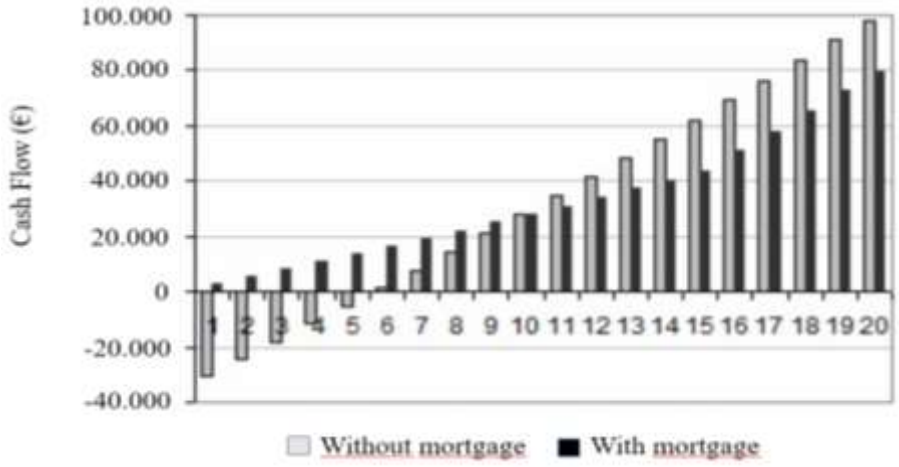


**Figure 1** Cumulative cash flow for 10 kW PV plant in exchange on site with Conto Energia and RDP incentives

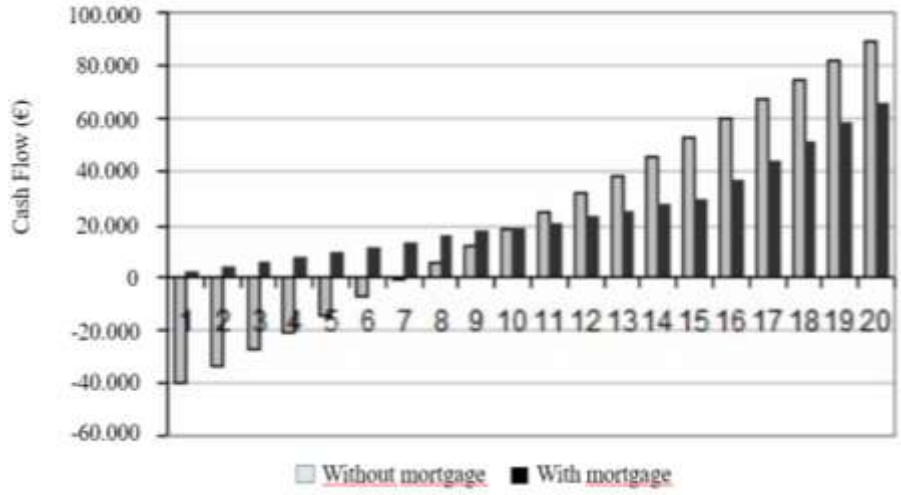


**Figure 2** Cumulated cash flow for a 10 kW PV plant in exchange on site with the sole incentive of the Energy Account

Considering the type of investment 3, without the only Conto Energia loan, the incentive tariff of the Energy Account, below which the NPV becomes negative and therefore there is no more investment, is equal to 0.13 euro / kWh. Therefore, the investment 3 becomes convenient, according to the NPV, only if it can benefit from an incentive rate higher than 0.13 euro / kWh. In the case of the type of investment 4 (with only the Conto Energia loan), the critical level of the incentive tariff rises slightly, going to € 0.14 / kWh.

## 4. CONCLUSIONS

The study conducted highlights a clear economic advantage to invest in PV systems in companies in central Italy. Among the types of investments examined, the most advantageous is the one that benefits jointly from the Conto Energia 2011 and the RDP incentives (VAN at the 20th year of € 46,159). Economic convenience is strictly connected to public incentives, in the absence of which it would be no longer convenient to invest according to all the indicators used in this study. In this regard, when the only public incentive is given by the Energy Account, the incentive tariff below which there is no longer any reason to invest according to the NPV is about 0.14 euro / kWh. This value is indicatively a critical threshold to which reference should be made for the correct promotion of PS systems. On the basis of this information, it is clear that the public decision-maker, through incentive policies at national, regional or local level, has a huge influence on the diffusion of PS systems [21]. The convenience of PV systems should not, however, be read only from an economic-financial point of view, as these systems also represent an opportunity to enhance the eco-sustainability of the company with environmental and social benefits [10].

## REFERENCES

[1] U. Ciorba, F. Pauli, P. Menna, Technical and economical analysis of an induced demand in the photovoltaic sector, Energy Policy, Volume 32, Issue 8, 2004, pp. 949-960.

[2] J. M. Pearce, Photovoltaics - a path to sustainable futures, Futures, Volume 34, Issue 7, 2002, pp. 663-674.

[3] ENEA, L'energia fotovoltaica, Collana "Sviluppo Sostenibile", 2006, Roma, Enea.

[4] M. Peter-Varbanets, C. Zurbrügg , C. Swartz, W. Pronk, Decentralized systems for potable water and the potential of membrane technology. Water Res. 43 (2), 2009, 245–265.

[5] Enerpoint, Enerpoint e Sharp mettono la firma su tre aziende agricole "solari", energia24, anno 2, n.11, 2009, pp. 41.

[6] GSE, Impianti a fonti rinnovabili - Rapporto statistico 2009.

[7] R.M. Bertino, Così il frutteto tecnologico cattura l'energia del sole, Agricoltura, anno 35°, n.6, 2007, pp. 56-58.

[8] D. Coiante, Towards the photovoltaic farm, Photovoltaic Specialists Conference, 1990 - Conference Record of the Twenty First IEEE, Volume 2, 1990, pp 1095-1098.

[9] C. Gardi, Il solare fotovoltaico un'ottima opportunità, Agricoltura, anno 35°, n. 2, 2007, pp.71-71.

[10] C. Daniele, G.V. Lombardi, T. El Asmar, I sistemi fotovoltaici in agricoltura: un'analisi dell'investimento nel centro Italia, Rivista di Economia Agraria, anno LXIII, n.2, 2008, pp. 273-297.

[11] GSE, Il terzo contro energia, Guida alla richiesta degli incentivi per gli impianti fotovoltaici, 2010.

[12] M. Frascarelli, L'azienda agricola, Assago (Milano), 2010, Edizioni Fag.

[13] E. Lorenzo, La energía que producen los sistemas fotovoltaicos conectados a la red: El mito del 1300 y el "cascabel del gato". Era Solar 107, 2002, 22–28 (in Spanish).

[14] M. Merlo, Elementi di economia ed estimo forestale-ambientale, Bologna, 1991, Patron Editore.

[15] V. Gallerani, S. Zanni, D. Viaggi, Manuale di Estimo, Milano, 2009, McGraw-Hill.

[16] M.C. McManus, Environmental consequences of the use of batteries in low carbon systems: the impact of battery production. Appl. Energy 93, 2012, 288–295.

[17] M. Grillenzoni, G. Grittani, Estimo. Teorie, procedure di valutazione e casi applicativi, Bologna, 1994, Calderini.

[18] R. Spinelli, R. Pinelli, C. Nati, N. Magagnotti, Produzione ed uso energetico del legno nell'azienda agricola, Terra e Vita, (supplemento febbraio-marzo), Edagricole Il sole 24 ore, 2006, Bologna.

[19] A. Mastrucci, O. Baume, F. Stazi, U. Leopold, Estimating energy savings for the residential building stock of an entire city: a GIS-based statistical downscaling approach applied to Rotterdam. Energ. Buildings 75, 2014, 358–367.

[20] M. Rapa, G. Vinci, L. Gobbi, Life cycle assessment of photovoltaic implementation: an italian case study. International Journal of Civil Engineering and Technology, 10(01), 2019, 1657–1663.

[21] M.A Massoud, A. Tarhini, J.A. Nasr, Decentralized approaches to wastewater treatment and management: applicability in developing countries. J. Environ. Manag. 90 (1), 2009,652–659.