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Evaluating solar energy profitability: A focus on the role of self-consumption

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ABSTRACT

Renewable energies have a key role in defining an energy policy based on security, independence, and sustainability. The Italian market is characterised by the absence of support mechanisms for photovoltaic sources for electricity and by a high level of maturity in the energy market. Consequently, this paper contributes to, and advances, the debate concerning self-consumption that can support the economic sustainability of photovoltaic facilities. We constructed a database to conduct an analysis. A survey was conducted among 750 companies operating in various stages of the industry supply chain. The survey collected data related to industry turnover, profitability levels, profitability margins of the business areas and employee numbers. The economic feasibility of photovoltaic investment is evaluated for systems of varying sizes (3 kW, 20 kW, 200 kW, 400 kW, and 1 MW) located in two areas of the country to account for different levels of insolation (northern and southern regions). The indicators used are net present value (NPV) and discounted payback time (DPBT). A subsequent sensitivity and scenario analysis is conducted according to the share of self-consumption, investment costs, and financial structure to examine 210 case studies.

1. Introduction

On 22 January 2012, The European Commission issued updates on a strategy to deal with potential damage that may arise from climate change. The update emphasises that it is necessary to reduce emissions by 40% and increase the share of energy by renewable sources to 27% by 2030. The actions are designed to empower consumers and to promote the increase of self-consumption of photovoltaic energy as described in 'Making the internal energy market work', COM(2012) 663 final, and 'Renewable energy: a major player in the European energy market', COM(2012) 271 final.

The generation of electricity, heat, and biofuels from renewable energy sources plays a strategic role in the energy policies of many nations [1–3]. Renewable energy sources are crucial factors in identifying a sustainable energy mix. Therefore, determining how to increase the use of renewables in the energy mix without sacrificing economic sustainability is required [4,5]. Photovoltaic energy is a sustainable choice for the future and continues to attract attention from academics, managers, and policy makers [6].

The Italian market is characterised by the absence of support mechanisms for photovoltaic sources for electricity and by a high level of maturity in the energy market. Consequently, the remuneration of solar energy has been completely detached from self-consumption energy and it could play an increasingly significant role in the harmonisation of the consumption and production of electricity. The changes that have affected the photovoltaic industry require an updated analysis of the economic market opportunities [7–9]. This paper analyses the profitability of investment in the realisation of photovoltaic facilities in Italy with a focus on the role of self-consumption. This paper contributes to, and advances, the debate concerning self-consumption that can support the economic sustainability of photovoltaic facilities.

The paper is organised as follows. Section 2 proposes a literature review and Section 3 presents a sector analysis of global installed capacity and the description of the characteristics of the main contributors (China, Germany, Italy, Japan, the UK, and the US). Section 4 focuses on the Italian market. In the preliminary phase, data are collected through a survey conducted on 750 companies. Section 5 presents a technical/economic model developed and used to evaluate ten case study investments assumed with

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Nomenclature

A_{cell}	area of 1 k Wp cell	$P_{C_{ass}}$	Percentage of C_{ass}
C_{ass}	Total assurance cost	$P_{C_{gse}}$	Percentage of C_{gse}
C_d	total debt cost	P_{C_m}	Percentage of C_m
C_e	total shareholder's equity cost	$P_{C_{Ebit}}$	Percentage of C_{Ebit}
C_{ec}	electrical connection cost	$P_{C_{Ebt}}$	Percentage of C_{Ebt}
C_{inv}	total investment cost	P_f	amount of power from single module
$C_{inv,unit}$	unitary investment cost	p_t^c	electricity purchase price
C_{gse}	administrative cost	p_t^s	electricity sales price
C_{lcs}	loan capital share cost	r_d	interest rate on loan
C_{lis}	loan interest share cost	r_e	opportunity cost
C_m	maintenance cost	SC_{el}	saving energy internal consumption
C_t	discounted cash flow	SP_{el}	sale of energy not for internal consumption
C_{tax}	taxes cost	t	time of cash flow
co_{tax}	council tax	t_f	tax rate
dD_{el}	increase electricity required by users	t_r	mean annual insolation
dE_f	decrease efficiency of system	TaxD	tax deduction
D_t	electricity demand by users	$TaxD_{unit}$	tax deduction unitary
E_t	electricity generated by system	x_t^c	amount of self-consumed electricity
Ebit	earnings before interests and taxes	x_t^p	amount of electricity purchased from the grid
Ebt	earnings before taxes	x_t^s	amount of electricity sold to the grid
I_t	discounted cash inflows	WACC	weighted average cost of capital
inf	rate of inflation	ω_d	debt percentage
inf_{el}	rate of energy inflation	ω_e	equity percentage
k_f	the optimum angle of tilt	$\omega_{self,c}$	percentage of energy self-consumption
N	lifetime of investment	ω_{sold}	percentage of the produced energy sold to the grid
N_{debt}	period of loan	η_{bos}	bos efficiency
N_{TaxD}	period of tax deduction	η_f	number of modules
O_t	discounted cash outflows	η_m	module efficiency

respect to five different installation sizes (3 kW, 20 kW, 200 kW, 400 kW and 1 MW) and two installation locations (northern and southern regions). The results are presented and discussed in Section 6. Additionally, a sensitivity analysis on the critical variables (investment costs, share of self-consumption, financial structure) – Section 7 and a scenario analysis are conducted (Section 8). Section 9 presents concluding remarks.

2. Literature review

The installed photovoltaic (PV) capacity has increased significantly in recent years, and incentive policies have encouraged this turn of events [10]. The feed-in tariff (FiT) is rated the most effective tool to encourage and accelerate the deployment of energy produced from photovoltaic sources [11]. A photovoltaic system is designed to supply energy and to cope with the energy demands of ordinary activities and emergency phases [12]. With such systems, it is possible to improve the environment [13] and to achieve grid parity [14]. This aspect is, however, confined to the residential sector because it is often cheaper to realise a power system without incentives than to buy electricity from the grid. In fact, the price of electricity in residential sector has a greater value than industrial one and so the advantages of self-consumption will be more substantial. The grid parity is expected to become more widespread because of a declining trend in PV investment costs, the constant increase in the price of grid electricity, and the increasing experience of the associated industries.

The impetus behind the photovoltaic solar power sector is the demand for a sustainable energy supply. Several indexes are required to assess the energy, environmental, and economic factors [15]. Moreover, the sizing of a proper energy system for distributed generation [16] requires the programming of facilities that are energetically self-sufficient as well as supported by appropriate storage systems [9]. The changes that have affected the photovoltaic industry (mainly in terms of reductions in production costs, market prices, and photovoltaic systems) require an updated analysis of the economic market opportunities [17] to promote distribution energy models [18]. Additionally, any energy saving technics can represent the core business of the industry [19].

The profitability of investment toward realising photovoltaic facilities in the Italian market is analysed in this paper. Investment activity in this sector is currently characterised by the absence of incentive support systems and a high level of market maturity.

Previous studies have highlighted the high variability of economic results, are in fact many variables that must be contemplated: the annual average insolation, the combination between energy supply and demand, the incentive system, the nominal power and PV modules performances, the income of the investor, the availability of installation surface, the facilities cost and size. Below are some examples:

- if located in Sicily (area heavily insulated) a 20 kW system that benefits from the incentives granted by IV Conto Energia, has a NPV that ranges in 60,000–110,000 € and DPBT 2–6 y: present result is influenced by the method of financing [20];
- residential systems located in Italian territories with medium–high insolation, which benefit from the incentives of IV Conto Energia, have an NPV equal to 2000 €/Wp, while for industrial facilities the NPV is 1100 €/Wp. If incentives are not recognised the economic performance of residential systems decreases on average to 400 €/Wp, while for industrial plants there is a strong likelihood of having a negative NPV [21];
- plants ranging from 3 kW to 6 kW and that receive incentives from IV Conto Energia, have a NPV that range from 3300 to 13,000 € and DPBT equal to 4–19 y. Since the plants are located in all Italian regions, these results are so different for double reasons: annual insolation values, and, the combination of supply of energy and energy output from facilities [9].