Comprehensive Financial Modeling of Solar PV Systems

Baschieri, Davide and Magni, Carlo Alberto and Marchioni, Andrea

Università degli studi di Modena e Reggio Emilia (UNIMORE) - School of Doctorate E4E (Engineering for Economics-Economics for Engineering)

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Davide Baschieri
"Marco Biagi" Foundation, University of Modena and Reggio Emilia, Italy
and GRAF S.p.A., Italy
email: davide.baschieri@unimore.it

Carlo Alberto Magni
Department of Economics "Marco Biagi" and
School of Doctorate E4E (Engineering for Economics - Economics for Engineering),
University of Modena and Reggio Emilia, Italy, viale Berengario 51, Modena,
email: magni@unimo.it

Andrea Marchioni
"Marco Biagi" Foundation, University of Modena and Reggio Emilia, Italy
email: andrea.marchioni@unimore.it

ABSTRACT. The adoption of a photovoltaic system has positive environmental effects, but the main driver of the choice in the industrial and commercial sector is economic profitability. Switching from acquisition of energy to production of energy is an investment with costs (e.g. leasing annual payment, O&M costs, capital expenditure) and benefits (e.g. savings in the electric bill, sale of the energy exceeding consumptions). In this work, we use an accounting-and-finance model to calculate the Equity Net Present Value in different scenarios and a sensitivity-analysis method (Finite Change Sensitivity Index) to explain the reasons for differences in results. This technique enables identifying the contribution of any input factor in the output value variation. In this way, the investor can draw attention on the most significant critical variables in the initial estimations to ensure success in forecasting.

Keywords: photovoltaic, economic analysis, financial modelling, financing, estimation, decision.

1 AIM AND APPROACH USED

Solar energy undeniably brings about environmental benefits, but the adoption of solar energy by the industrial, commercial, and residential sectors is strongly affected by economic considerations (e.g., Cucchiella et al 2018 [3], Dong et al 2017 [4]). The mapping which links the key performance drivers and the investment's economic profitability entails understanding of the intricate network of relations among technical aspects, accounting magnitudes, forecasting of financial data, and assumptions on financing decisions, which makes the determination of economic profitability particularly complex. It is then important to provide decision-aiding tools capable of measuring the investment return, taking into account uncertainty and providing insights on possible managerial actions that may affect the decision to adopt solar energy.

Building upon Magni and Marchioni (2019) [8], we propose a comprehensive framework for modeling investment decisions in solar photovoltaic (PV) systems, aimed at helping analysts, advisors, firms' managers to assess the economic impact of solar energy, manage uncertainty, distinguish the high-impact drivers from the low-impact drivers, calibrate the structure of the model (increasing the depth of analysis for those drivers which have major effects on the investment financial efficiency), and choose various alternative proposals (e.g., alternative capturing technologies).

Specifically, the proposed model makes use of Magni's (2020) [6] accounting-and-finance system to engineering economic decisions. It accomplishes a detailed analysis of the sources of value creation in both absolute and relative terms, always supplying the net present value (NPV), the rate of return, and the financial efficiency, thereby overcoming the limitations of the internal rate of return (IRR), usually recommended in benefit-cost analysis (Sartori et al 2014 [10], Mangiante et al 2020 [9]), but most likely to be undetermined in this kind of projects.

The model acknowledges the distinction between *estimation variables* and *decision variables* on one hand and between *operating variables* and *financial variables* on the other hand: The estimation variables necessitate some estimation process to be determined (e.g., operating and maintenance costs, disposal costs, interest rate on debt financing) while the decision variables are under the managers' control (e.g., timing and size of distributions to shareholders, recourse to debt borrowing or to cash withdrawals for covering the financial needs). The operating variables express the factors which have a direct impact on the firm's costs and revenues as a result of the adoption of solar energy (e.g., solar panel efficiency, the avoided electric bill, energy price, amount of self-consumption, credit terms for energy sales to the grid). The financial variables regard the factors which affect the mix of financing sources and the amount of incremental liquid assets in the firm's balance sheets (e.g., interest rate on liquid assets, risk-adjusted cost of capital, distribution to equityholders).

We also aim at validating the model by means of sensitivity analysis (SA), which confirms that the presence or absence of relevant drivers may affect the increase in investors' wealth and may affect the decision. In particular, we assess the contribution of financial variables and decision variables to the output variability. With the aid of the recently developed Clean FCSI (Magni et al 2019 [7]), based on Borgonovo's (2010) [2] FCSI, we aim to detect the most critical drivers and understand which driver is more likely to cause a change in the decision. SA will also be of help to analysts for calibrating the model: if the contribution to value of some parameters is small, then there is no need of modeling those inputs in more detail;

in contrast, if some parameters contribute significantly to value creation, then the analyst may consider a further development of the model for gaining deeper insights. Clean FCSI will also be of help to show that interactions among all the variables substantially affect the investment's economic profitability. This testifies to the importance of modeling the project to take account of all relevant value drivers and to make analysts aware of the effect of estimation process on the accept/reject decision.

2 SCIENTIFIC INNOVATION AND RELEVANCE

This work presents a comprehensive approach to financial modeling of investments in solar energy which differentiates itself from the traditional financial modeling derived from finance. The innovation of the approach may be summarized as follows:

1. as opposed to traditional models, the proposed model acknowledges that the investment value (and related decision) depends on both operating variables and financial variables. Also, it depends on decision variables such as the distribution of cash to shareholders and the reinvestment of cash, which may affect the return on solar investment. The proposed model is transparent, for it takes distribution policy in explicit consideration as well as borrowing policy, and appraises the interaction with the operating variables, reflecting their impact on the firm's pro forma financial statements and, hence, on the investment value and return
2. in real life, a substantial amount of solar PV plants is financed by firms with internal funds (i.e., cash withdrawals from bank accounts) and/or by debt, with no recourse to equity issuance. In traditional financial modeling, this form of financing is not taken into explicit account. The proposed model takes account of any mix of financing sources, either internal (cash withdrawals) or external (debt and/or equity)
3. contrary to traditional financial modeling, the proposed model apportions the overall investment value according to the various sources of value, namely, the operating activities, the financial activities (reinvestment of excess cash and cash withdrawals), and the debt borrowing
4. in this kind of investments, it is likely that financial efficiency may not be determined with traditional tools such as the internal rate of return (IRR) (see Magni and Marchioni 2019 [8]). Equipped with Magni's (2010) [5] Average Internal Rate of Return, the proposed model always provides an appropriate measure of financial efficiency, in terms of Return On Investment (entity perspective) or Return On Equity (equity perspective)
5. we validate the model with the aid of SA, which also supplies helpful information to calibrate the model for a more careful treatment of the highest-impact value drivers and confirm the relevance of the interaction effects and the importance of fine-tuning the estimation process.

3 RESULTS

The accounting-and-finance model we propose is able to make a thorough evaluation of the various aspects of the option of switching to solar energy for an agent (e.g., a firm) currently importing energy from electric grid. Switching to a solar PV system entails cost savings equal to the electric bill and incremental costs due to the purchase of the solar PV system. This may be purchased with an upfront payment or, as frequently occurs, with lease contracts (or power purchase agreements); at the end of the contract, the lessee may pay a lump to acquire the plant. The lump sum will be financed either with debt, equity, or internal financing (withdrawal from liquid assets, i.e., cash and cash equivalents). The amount of power which will be produced in excess of self-consumption will be sold to the grid operator, generating cash inflows after some period (depending on the credit terms); in contrast, if energy consumption is smaller than energy production, the firm will buy the residual energy from the grid. For example, consider the case of a ground-mounted solar panel system to be installed in a currently rented land, associated with a lease contract and with no equity financing. We use data for a solar PV plant proposed by GRAF Spa, a solar PV installer company, to an Italian firm located in Northern Italy.

Table I: Equity NPV in two different scenarios

Variables	**Scenario 1**	**Scenario 2**
Operating variables (estimation)		
Nameplate capacity [kWp]	92	92
Unit cost [€/kWp]	1,050	1,050
Useful life of PV plant [years]	22	28
Annual unit prod. (Y 1) [kWh/kWp/y]	1,000	1,130
Solar panel degradation rate [%/y]	1.15%	0.65%
Lease term length [years]	20	20
Lease interest rate [%]	4%	4%
Purchase price of plant (year 20) [€]	25,000	25,000
O&M, insurance, etc. [%]	4.00%	2.75%
Disposal costs [€]	3,000	2,500
Lost rent from land property [€/y]	1,500	1,250
Growth rate for costs [%]	1.50%	0.50%
Annual energy consumption [kWh/y]	62,500	87,500
Tax rate [%]	30%	20%
Energy purchase price [€/kWh]	0.140	0.180
Energy selling price [€/kWh]	0.105	0.155
Growth rate of energy price [%]	0.50%	2.00%
Credit terms for energy purchases [dd]	0	0
Credit terms for energy sales [dd]	365	365
Financial variables (estimation)		
Interest rate on liquid assets [%]	4.00%	-0.50%
Interest rate on debt [%]	6.00%	2.00%
Required return on oper. assets [%]	6.00%	6.00%
Required return on liquid assets [%]	2.00%	2.00%
Required return on debt [%]	3.00%	3.00%
Financial variables (decision)		
Internal financing (cash) [%]	60%	60%
Debt borrowing [%]	40%	40%
Equity financing [%]	0%	0%
First CFE distribution [y]	1	1
Payout ratio [%]	50%	50%
Equity NPV [€]	**−15,494.88**	**84,570.02**

In Table I, column 2 (scenario 1) reports the estimated input data, for a given set of financing and distribution policy. These input data are used for drawing up three pro forma financial statements (balance sheets, income statements, cash flow statements) which are logically interconnected in a non-trivial way, since decisions on financing and cash flow distribution will affect the amount of liquid assets and debt outstanding in the firm. This in turn affects next-period interest on debt and on liquid assets, which in turn affects next-period income and, therefore, the equity. With these data, shareholders' wealth increase, as measured by the shareholder net present value (NPV), is negative and equal to −15,494.88, so the project is not worth undertaking. (It is worth noting that neither the project IRR nor the operating IRR nor the equity IRR exist).[i]

Consider now a different set of estimated parameters, as described in column 3 (scenario 2). Shareholder value created increases by almost 100,000 to 84,570, so making the project highly profitable.

Table II breaks down the equity NPV into operating NPV (i.e., NPV of the operating assets), non-operating NPV (i.e., NPV of the liquid assets), and debt NPV (i.e. NPV of the debtholders).

Table II: Equity NPV

	Scenario 1	Scenario 2
+ Operating NPV	−12,110.92	+108,603.47
+ Non-operating NPV	−3,142.14	−24,264.57
− Debt NPV	−(+241.83)	−(−231.12)
= Equity NPV	**−15,494.88**	**84,570.02**

The FCSI helps explain why this dramatic change occurs, providing the change in NPV due to the change in estimate of the drivers (columns 2 and 3 in table III. See Magni et al 2019 [7] for details on FCSI). It is worth noting that the most important driver of change is a financial driver, the interest rate on liquid assets (rank 1). This means that attention should be drawn on the estimation of such a variable and it is worth modeling such an aspect in greater detail and/or refining the estimation process. Energy prices and O&M (operating drivers) are next in importance (ranks 2, 3, and 4). Somewhat unexpected is the negligible effect of the efficiency loss (rank 12). Disposal costs are also negligible (rank 13). Even the sharp deviation of estimate in the interest rate on debt is irrelevant (rank 14), suggesting that, in this case, the conditions of the loan contract are non-significant.

Once calibrated the model and obtained a reliable set of estimated data, the analyst should fine- tune the borrowing policy and the distribution policy in order to increase the project's value and get the best output for the investors. Preliminary results show that a change in such policies may have a remarkable effect on the output and, in some cases, may even cause a change in the decision to adopt solar energy (and distribution policy may have an even greater effect than borrowing policy).

Table III: Changes in NPV (%) and Rank of input factors

Variable	Change in NPV (%)	Rank
Operating variables (estimation)		
Useful life of PV plant	−6.09%	9
Annual unit prod. (Y 1)	7.27%	8
Solar panel degradation rate	0.70%	12
O&M, insurance, etc.	13.10%	4
Disposal costs	0.16%	13
Lost rent from land property	3.28%	11
Growth rate for costs	5.61%	10
Annual energy consumption	10.17%	5
Tax rate	−9.04%	6
Energy purchase price	19.91%	2
Energy selling price	14.18%	3
Growth rate of energy price	8.79%	7
Financial variables (estimation)		
Interest rate on liquid assets	31.99%	1
Interest rate on debt	−0.03%	14

4 CONCLUSIONS

Since solar energy undeniably contributes to a sustainable economy, the decision of adopting a solar energy system by firms is important to achieve a substantial cumulative effect in the environment. However, firms' decisions are mostly motivated by financial efficiency and shareholder value creation. We present an operational tool increasing analysts' and managers' awareness on the financial impact of solar energy on these economic measures. This model blends accounting and finance and takes account of the subtle network of relations between operating variables and financial variables on one hand, and estimation variables

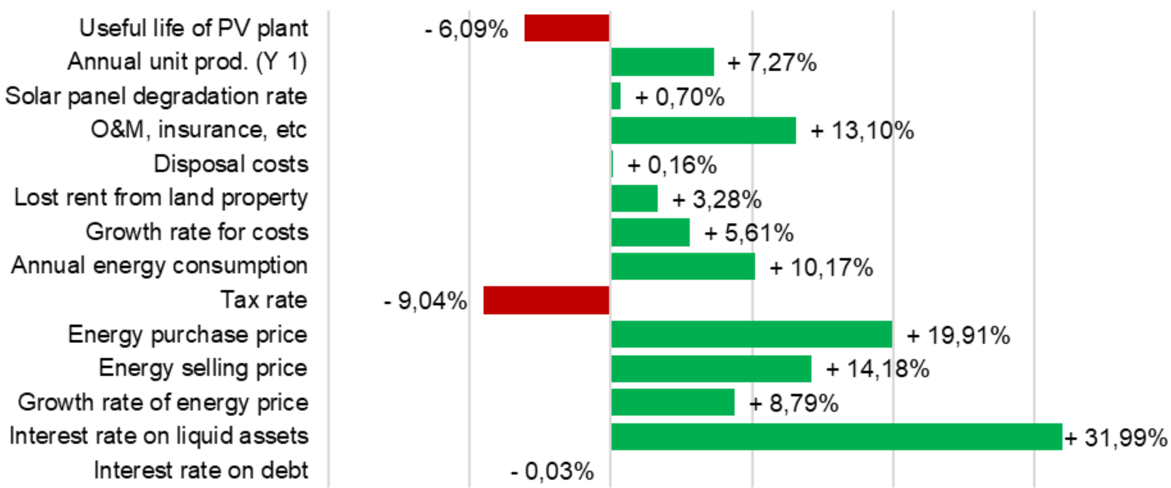

Figure I: Changes in NPV (%)

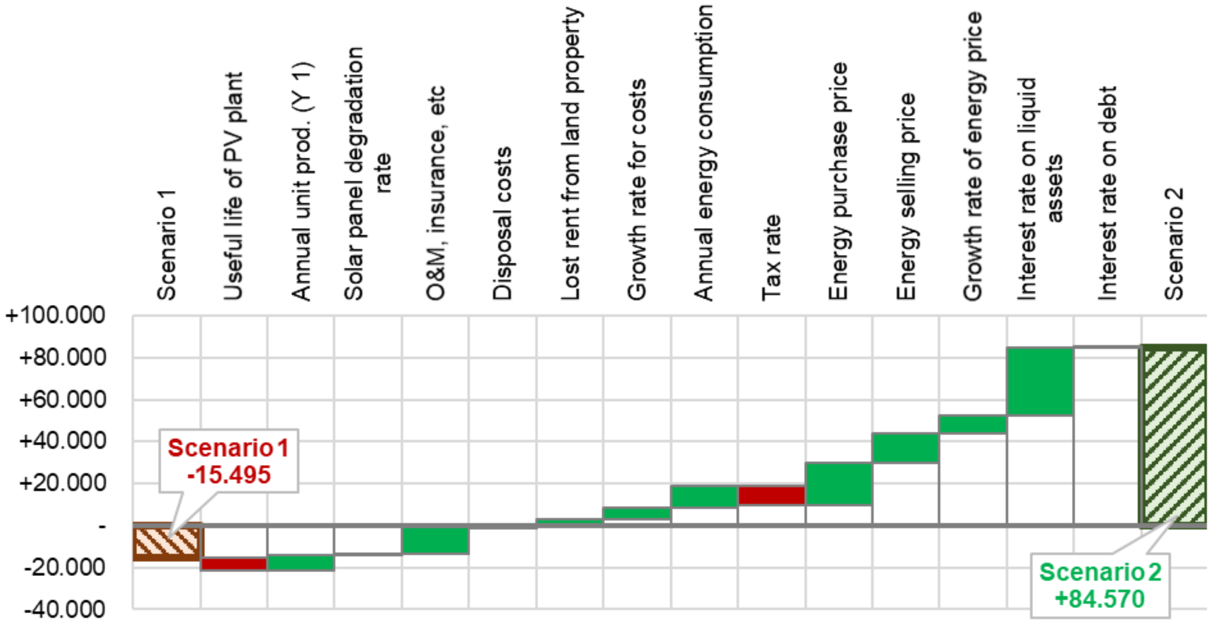

Figure II: Changes in NPV

and decision variables on the other hand. In particular, it explicitly takes account of the impact of internal financing as opposed to equity financing as well as of the reinvestment of retained cash as opposed to a full payout policy. The model is associated with a sensitivity-analysis technique which validates the model and provides managerial insights on the most critical drivers, which helps calibration of the model to the firm's needs. It also helps analysts to fine-tune the firm's borrowing and distribution, for any given set of estimated input data, in order to increase the financial benefits of solar energy.

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[i] It is interesting to note that the initial cash flow to equityholders is equal to 0 (they do not provide any capital injection) while it is positive in the following years. This is the reason why the equity IRR does not exist.