IBIMA Publishing
Communications of International Proceedings
https://ibimapublishing.com/p-articles/42NRG/2023/4239623/
Vol. 2023 (13), Article ID 4239623

Valuation of Photovoltaic Projects in The Development Phase Using the Modified Option Method*

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* Presented at the 42nd IBIMA International Conference, 22-23 November 2023, Seville, Spain

Abstract

The motivation for conducting a study on the valuation of projects in the development phase using a modified option method was the need to test the prevailing view in the literature that the cash flows that a project would generate during the operating period are best used as the value of the underlying asset in an option model. The article verifies this view, shows its flaws and proposes an alternative solution of replacing the project's "operating" value with a "development" value.

As a method, a binomial valuation model was used to estimate the value of a compound option.

The article concludes that when valuing a photovoltaic project in the development phase in Poland using the option method, it is advisable to replace the operating value parameter in the valuation model with the price that an investor could obtain by selling the project. As shown, such a modification gives more reliable results, allows to refer to observable market values and facilitates the interpretation of the obtained results by relating them to the actual economic parameters of the project.

The publication aims to improve the method to make it more understandable and widespread as a practical tool for investment planning.

Keywords: photovoltaic projects, projects development, real options

Introduction

This article addresses the application of the option approach to the evaluation of investment projects in the renewable energy market. These issues have been studied in the literature over the past decades. Different types of decision-making flexibility have been the subject of research, with options such as project deferral described by Martín-Barrera et al. (2016), time determination undertaken by Kozlov et al. (2017), Gong and Li (2014) Sisodia, Soares and Ferreira (2016), staging analysed by Gahrooei et al. (2016), expansion explored in the work of Sisodia et al. (2015) or abandonment described by Mancini et al. (2016). The publications analysed projects in areas such as wind energy in the works of Boomsma and Linnerud (2015), Ritzenhofen and Spinler (2016); Onar and Kilavuz (2015), solar energy of Martinez-Cesena and Mutale (2011); Zhang et al. (2016); Zhang et al. (2017), hydropower of Linnerud et al. (2014) or bioenergy (e Oliveira et al. (2014). The authors tested various valuation methods: Iniesta and Barroso (2015) used Monte Carlo simulations, Gong and Li (2014) - trees, Kim et al. (2016) - binomial lattice, Sisodia et al. (2015) - the Black-Scholes model, Gahrooei et al. (2016) - dynamic programming, among others. In the aforementioned works, as well as others devoted to the option approach, its advantages over traditional discounting methods are widely emphasized. These include the ability to capture and quantify the value arising from active management of the development process and the incorporation of risk directly into the model. On the other hand, since option methods were developed for the financial market, their application requires the demonstration of an analogy between the situation of a stock market investor and a project developer. Failure to demonstrate such an analogy undermines the reliability and usefulness of the results obtained. One of the problems of this analogy is the issue of finding and valuing the underlying assets, which in the case of investment projects are not traded on the stock exchange. In the literature, it is assumed that in the valuation model they are replaced by a twin security, that is, an

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Cite this Article as: Tomasz LUKASZEWSKI, Vol. 2023 (13) " Valuation of Photovoltaic Projects in The Development Phase Using the Modified Option Method " Communications of International Proceedings, Vol. 2023 (13), Article ID 4239623, https://doi.org/10.5171/2023.4239623

instrument whose changes in value are perfectly correlated with changes in the value of the project under development as proposed by Copeland and Antikarov (2001). Most often, this role is played by the sum of the net flows that the project would generate if it were operational for example in Santos et al. (2014). The article verifies this approach, shows its flaws and presents an alternative solution, according to which the value of a project would be defined as the price for which a project in the development phase could be sold.

Decision-making model of the PV project development process

The subject of this study is the process of development of photovoltaic (PV) farms in Poland. These are investments in the creation of infrastructure (including panels, inverters, transformers, substations, cabling) intended to produce electricity from the sun and its integration into the national electricity system. From an economic point of view, the life cycle of such investments consists of three consecutive phases: development, construction and operation. The issues addressed in this article concern the development phase of a photovoltaic farm, during which the documentation necessary to begin construction is prepared. The development process includes the following activities: identifying potential land parcels and establishing the project (EP); signing a land lease agreement (LLA) for the parcels; obtaining an environmental decision (ED); obtaining a zoning decision (DC); obtaining grid connection conditions for the grid connection contract (GCC/GCA); and obtaining a construction permit for the farm and transmission line. Aggregating the activities distinguished the successive stages of the photovoltaic farm development process, which are shown in Figure 1 in the form of a decision model.

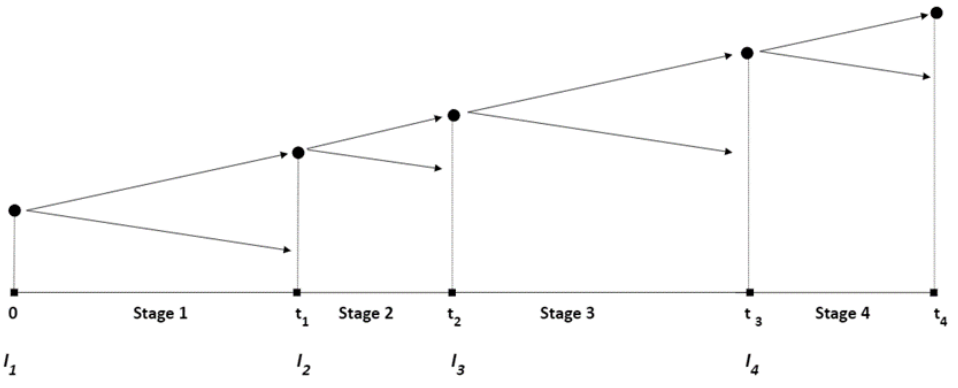


Figure 1: Decision making model of the PV project development process

The entire process consists of obtaining four key decisions issued by administrative or regulatory bodies. The investment activities that make up the process can be grouped into four consecutive stages each of which can be described by economic categories: duration (t_n), investment expenditures (I_n) and the value that the project will obtain after the completion of a given stage (S_n).

Option model of PV project under development

Project efficiency evaluation can be carried out by a developer to choose the best among a number of investment opportunities, to develop or plan the most efficient variant of a project, to control the performance of tasks or to close inefficient projects. The method chosen for project appraisal should enable the specifics of the decision problem to be captured and reflected as accurately as possible and expressed in quantitative terms. The results produced by such a valuation method will be better (more accurate, more complete, more reliable) than if other methods were used as stated by Lukaszewski and Glocko, (2016). With regard to the PV projects considered in this article, the problem can be formulated as follows: How to estimate the profitability of a multi-stage investment, which can be discontinued after each stage, and revenues appear only after the completion of the entire work and depend on both market conditions and the results of the various stages and risks?

Since the implementation of a PV farm is characterized by the phased nature of the development process, the conditionality of undertaking successive stages, the possibility of cancellation during the course of the work, and the irreversibility of the costs incurred, the article proposes to use the Real Options Method to assess its effectiveness and to value the project as a compound call option.

The real options concept involves using models developed for valuing financial instruments on a stock market to assess the profitability of capital investments. This approach implies analogy between the implementation of a phased investment project and the purchase of options on the financial market. Under this approach, an investor starting the first stage of a project obtains an opportunity (acquires an option) to implement subsequent stages and to profit from them, just as an investor buying an option on the financial market obtains an opportunity to profitably buy (or sell) in the future the underlying asset. According to the perspective presented, an option should be treated as the right of an entity developing the project to obtain future cash flows, valid until the investment opportunity expire. An option has value only if two conditions are met simultaneously:

- there is uncertainty about the value of expected cash flows from the project, and
- developer can reduce the uncertainty by taking certain actions. These actions involve taking advantage of potential opportunities or reducing the risks associated with the implementation of the investment, and are referred to in the literature as managerial flexibility.

The real options thus provides a way to conceptualize and quantify the value arising from active management of the investment process. It makes it possible to quantitatively measure flexibility by treating it like an option written on a physical asset and valuing it using methods suitable for financial options. Valuation models have been developed for the financial market and therefore, for methodological correctness, their application to the evaluation of a business venture requires the demonstration of an analogy between the situation of the investor implementing the project and that of the financial option holder. The analogy must relate to two areas: the appropriateness of variables and decision-making mechanisms. In the following, the similarities between the implementation of a photovoltaic project and the purchase of a call option will be analysed. The decision-making model of the photovoltaic project under development is presented in the first part of the article and illustrated in Figure 1. The next part of the paper describes the analogy between the components of the investment and the variables in the option pricing formula and the analogy between the investor's decision-making mechanisms in the capital and financial markets.

The value of a financial option C is the function of five variables: $C=f(S,X,\sigma,t,r_f,)$

- Price of underlying asset (S)
- Strike price (X)
- Price variability of underlying asset (σ)
- Option term (t)
- Risk-free interest rate (r_f)

In the case of financial options, the purchase price (premium) is the amount that the holder pays one time to the issuer. Mathematical models are used to determine its fair value. From that point, the value of the option begins to change continuously, following the movement of the price of the underlying asset. The option's ability to be valued in the financial market makes it an independent asset. In the case of a PV investment, the option price corresponds the project value at the various stages.

The underlying instrument of a financial option can be such assets as stocks, currencies or indexes. By exercising an option, the holder receives the underlying instrument, whose value is determined by supply and demand on the stock market. In PV investment, the underlying asset is the value of the project at the ready-to-build (RTB) stage, i.e. the documentation that allows its owner to build a photovoltaic farm and receive profits from the sale of energy in the future. The above difference between the underlying instruments violates the condition of market completeness, on which the method of valuing financial options is based. The solution to this problem, proposed in the literature, is to make an additional assumption about the existence of the so-called *twin security*. This is an instrument whose changes in value are perfectly correlated with changes in the value of the project. There are several concepts determining how to estimate the value of such a *twin security* instrument. According to the most widely used concept of MAD (Market Asset Disclaimer) by Copeland and Antikarov, its role plays the value of the project's net flows. The authors claim that this is the best estimate of the value the project would have if it were traded on the market (Copeland, Antikarov, 2001). This method of determining this value will be called in paper "operational", while the proposed alternative "developed".

The "operational" approach assumes that the developer, having reached the RTB stage, proceeds to build and then operate the farm. The value of the project is estimated as the sum of revenues from the sale of electricity generated by the farm during the operational period plus any potential revenues from the support system, minus the sum of operating and financing costs incurred during the same period. Forecasting the value of these variables 30 years ahead is difficult to estimate and makes the result subject to considerable uncertainty. Once the cash flows are estimated over the entire operating period, they are discounted to the date (t_4) when the project reaches the RTB stage.

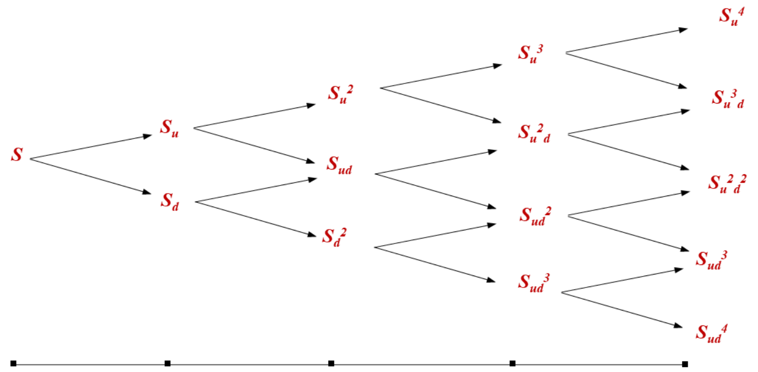
The strike price is the fixed value of the underlying instrument written in the option contract. In a photovoltaic project, this instrument corresponds to the value of capital expenditures incurred at various stages of development ($I_{1,...}$ I_4). Unlike a financial option, whose strike price is known in advance, the development expenditures are not exactly known at the time the work begins, and the payments may be staggered over time, so they must be aggregated and discounted for correct calculations.

The volatility parameter of a financial option represents possible changes of the asset price and is fundamentally responsible for the value of the option. The higher is the uncertainty, the more likely asset price on the exercise date will be significantly different from the strike price. Uncertainty decreases over time, regardless of the actions taken by the investor. In the case of the photovoltaic project volatility refers to the value of the net flows of the project. The volatility parameter therefore describes the uncertainty arising from problems that could potentially occur during development. It will decrease over time as the work progresses as a result of gaining certainty about the values of further parameters affecting the value of the project. Volatility will be described by a discrete process, changes will occur at decision points. It can be caused by one or multiple sources of risk, and it is important to distinguish between project specific risk and systematic risk related to factors affecting all market participants. Specific risk reduces and systematic risk increases the value of an option.

The duration of the financial option is fixed in the contract. In the photovoltaic investment, it corresponds to the duration of the development stages. It represents the date by which the decision to continue or cancel the investment must be made. The risk-free interest rate is the same in both the financial and real option models. It is determined based on the interest rate on risk-free securities, issued for a period corresponding to the duration of the option.

In the PV project under development the following options were identified: the commencement of the first stage of development at (t_0) can be considered the purchase of the *first option* that gives the investor right to continue the project and thus receive benefits in the future. Since there is a compound option, benefits means a project with an environmental decision issued with a value of (S_1) > (S_0). The purchase price of this option is equal to the discounted sum of the expenses of first stage (I_1). At time (t_1), when the first stage is completed and the provisions of the environmental decision are known, the developer decides whether to continue with the second stage or abandon the project. The following analogy emerges here: just as a financial investor would exercise an option only if the price of the underlying instrument is higher than the strike price, the developer will decide to proceed with the second stage only if the present value of the project (S_1) is higher than the expenditures for the second stage (I_2). The developer's decision to proceed with the second stage means starting work on obtaining a Development Conditions Decision (DDC). This is analogous to simultaneously exercising the first and acquiring the *second options* for the cost of (I_2). The second stage ends at (t_2) with obtaining (or not obtaining) a zoning decision (DDC). The continuation or termination of the project depends on the provisions of this document. If the current value of the project (S_2) is higher than the expenses for the third stage (I_3) the developer decides continue, which can be considered as exercising the second option and purchasing the *third option* at a price equal to the (I_3). The third stage of the project is to obtain Grid Connection Conditions (GCC) to integrate a PV farm into the national electricity grid. Depending on the connection conditions obtained by the Operator (or if the Operator refuses to issue them), the developer at (t_3) will decide whether to continue or terminate the project. Apply the same decision-making mechanisms as in previously.

The fourth stage involves obtaining a Building Permit (BP) for the farm. This can be considered the acquisition of the fourth option at (t_3) for the price of (I_4) corresponding to part of the payment due for design work. The result of this stage is a building permit decision. If obtained, the development process ends, the project reaches RTB status and it can be sold or built for the value of S4. If the BP is denied, or if the conditions issued significantly restrict the farm - the developer can decide to terminate the project. The strike price of fifth option (I_4) is the remainder of sum of the designer remuneration to prepare documentation and obtain a final decision on the BP. The option will be exercised at (t_3) if, the expected present project value (S_4) is higher than the developer's remuneration (I_5).
The above model is shown graphically in Figure 2.



Stage	t_0	Stage 1	t_1	Stage 2	t_2	Stage 3	t_3	Stage 4	t_4
Milestone	EP		ED		DDC		GCC		BP
Investement	I_1		I_2		I_3		I_4		I_5
Option decision	Buy first option		Exercise first / Buy second option		Exercise second / Buy third option		Exercise third / Buy forth option		Exercise fifth options

Figure 2 PV project as real option model

Valuation of the PV project under development using binomial model

The valuation of options using the binomial method begins with the determination of the initial value of the underlying asset (S_0). According to the assumptions presented earlier, it is equal to the sum of cash flows of the operational stage of the project (S_4) discounted at the beginning of the project (t_0) at the cost of capital WACC. A tree of possible asset values is then calculated, given that they change in successive stages according to a multiplicative process. For simplicity, it is assumed that the duration of each stage is equal and corresponds to one interval. The increase and decrease factors in subsequent intervals are calculated using the value of the standard deviation of future cash flows (σ). Note that it is necessary to convert the annual volatility to one that corresponds to the length of the adopted interval. Since in the binomial model the volatility is determined by the rates of increase (u) and decrease (d), it is necessary to determine these parameters according to the formulas: $u = e^{\sigma\sqrt{\Delta t}}$ and $d = 1/u.$ Therefore, the project value of (S_0) at the beginning of the period (t_0) may rise to S_u or fall to S_d at the end of the first stage at (t_0), depending on the provisions of the environmental decision. In the same way, the possible values of the project in subsequent periods until the end of the development work are determined, according to the calculations shown in Figure 2.
The next step is to price the options. According to the logic of presented development process, there are four options in the project. The valuation process begins by calculating the value of the last, fourth option, at the exercise date of (t_4). Then, step by step, the value of the option at earlier stages is calculated, until its initial value at date (t_0) is determined. The value of the fourth option at the (t_4) corresponds to the value of the project at the time the development process is completed. If the sum of the expected cash flows of the operating stage (S_4) is greater than the sum of expenditures (I_5), the developer decide to undertake construction phase; otherwise, the project will be canceled. The value of the fourth option (C_4) on the date of exercise is equal to max{(S4 - I4);0}. There are 5 possible variants of the value options can take. For the variant assuming that the value of the project in subsequent periods will only increase, the price of the option will be: $C_{41} = \max\{(S_u^4 - I_4);0\}$

If the value of the project in the first three intervals increases and in the last one decreases, the option will be worth $C_{42} = \max\{(S_u^3{}_d - I_4);0\}$. The value for the other combinations will be determined in the same way. The value of the option each time will be equal to the positive difference between cash flows and investment expenses or zero. The latter case corresponds to the situation in which the investor abandons the construction of the farm. The next step is to value the project at (t_4). The option price is determined as the product of the fourth-period option prices and the corresponding upside and downside probabilities, discounted at the risk-free rate $C_3 = (p \times C_{4u} + q \times C_{4d})/(1 + r_f)$. The probabilities of an increase in (p) and a decrease (q) were determined by the formulas: $p = \frac{e^{\Delta t \times rf} - d}{u-d}$, $q = 1 - p$. Thus, the value of the option is estimated at successive intervals until (C_0) at (t_0).

Unlike a financial option, which is used to value the risk of a change in the price of the underlying asset, in a multi-phase PV project an option can be used to determine the theoretical value of the investment at each stage. It allows to determine the maximum value of expenditures whose incurrence is economically justified at each stage. An example of a decision problem in the considered project, which can be solved using the option: how much is the maximum worth spending on the implementation of the first stage, knowing that the value of the project with the environmental decision issued will be in the range from (S_1) (investment approved in full) to zero (investment rejected due to significant negative environmental impact)? Until the cost of the investment work rises above option value, the project is financially justified. So the option valuation supports the investor during making decisions development process. Its value does not have to be accurate; more than the precision of the valuation, it is about quantifying investment versus the risk.

Modification of option pricing variables for PV projects in Poland

It should be noted that according to the calculations presented above, the value of the project at the RTB stage can take one of 5 variants, 4 of which differ from the previously calculated value for the operational phase (S_4). These variants were determined based on the assumption that the value of the project would increase or decrease from stage to stage, depending on the provisions of the key decisions received. If the development was carried out "optimally" (S_u^4), then the RTB value of the project would be significantly higher than the valuation based on cash flows from the operational phase. This is possible in the case of financing options. However in the case of PV investments, it would mean that the risk factors affecting cash flow in the operating phase would be eliminated or at least significantly reduced through activities carried out during development. In reality, such a situation is unlikely, since different risk factors affect the project at different stages. As a result, the option value derived from the "operational" value of the project is disconnected from the factors that should drive it.

An proposed alternative way to determine the value of a project at the RTB stage is to relate it to the price at which it can be sold. This approach is justified by economic practice in Poland, where exists an informal market in which investors sell and buy projects, making it possible to set a fair price for such a project. The PV projects are mainly carried out by specialized development companies. For the purpose of implementing a PV project, such a company establishes a special purpose vehicle (SPV). Its assets become the documents, permits, contracts and technical designs necessary for the construction and commissioning of the photovoltaic farm, including the building permit. At any time (although usually only after obtaining a BP), the developer can sell the SPV to the end investor, which is usually the power company. This solution is mutually beneficial: specialized developers can focus on carrying out design and preparation work, while operators shed investment risk and save time in exchange for a real low cost of buying the project, not exceeding a few percent of the total investment.

The valuation involves taking the price of a development project at the RTB stage (in EUR/MW) offered in the informal market as the underlying asset of the model's pricing. This value is then discounted to the moment of valuation (t_0). Using the observable values of the minimum, average and maximum price at which a project can be sold at each stage of development, a standard deviation is calculated and then transformed into increase and decrease coefficients. The coefficients describe the possible discrete (i.e., occurring after the final decision or refusal) changes in the value of a project from inception to completion, resulting from subsequent decisions and permits. The subsequent valuation process proceeds as described above. Once a project has received all the necessary decisions to begin construction phase, its price, determined by supply and demand, reaches a value between the maximum and minimum.

Replacing the discounted operating cash flows in the option pricing model with the price the developer would have received by selling the project at the RTB stage provides a number of advantages in valuing such an investment. First, this price is a more realistic representation of the current value of the investment, since it eliminates from the model all risk factors affecting the "operating" value. Moreover, it eliminates the problems of properly discounting the value of a project, which in this approach would take the form of a one-time payment made at the time of the transaction. In addition, due to the quasi-market nature of the valuation, it is possible to differentiate the prices of projects with different stages of development (depending on completeness and quality of decisions and permits obtained, possible defects or legal deficiencies). This in turn makes it possible to determine the value of a project at different stages of the development process and ensures that the volatility parameter used in the model, is based on market fundamentals. Last, but not least, the advantage of using market observable data is that it can be estimated before work begins and adjusted when it changes due to external factors.

Conclusions

In the article, the multi-phase development process of a PV farm was modelled as a compound option and valued using a binomial model. The variables in the model were the relevant components of the project: operating period cash flows were taken as the underlying assets. According to the valuation procedure, the operating value of the DCF project was first estimated and then discounted at the time of valuation. Using the increase and decrease factors, project values were determined for subsequent stages of the development process up to the RTB stage. According to the multiplicative process carried out in this way, the final value of the project can take on any of the 5 calculated alternatives. The value of some of them exceeds the previously estimated baseline value, which means that the value of an RTB project can be much higher than the flows that the project will generate during its operating period. It is difficult to explain such a result and interpret it in a way that makes economic sense. The article therefore proposes replacing the operating value with the price an investor could get by selling the project. The presented inference shows that such a modification gives more reliable results, allows to refer to observable market values, and facilitates the interpretation of the obtained results by relating them to the actual economic parameters of the project. Further work should focus on practical verification of the presented solution.

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