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# A REAL OPTIONS APPROACH TO EVALUATING INVESTMENT IN SOLAR READY BUILDINGS

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**Abstract**
*Sustainable building technologies such as Photovoltaics (PV) have promising features for energy saving and greenhouse gas (GHG) emissions reduction in the building sector. Nevertheless, adopting these technologies generally requires substantial initial investments. Moreover, the market for these technologies is often very vibrant from the technological and economic standpoints. Therefore, investors typically find it more attractive to delay investment on the PV panels. Nevertheless, they can prepare "Solar Ready Buildings" that can easily adopt PV panels later in future at the optimal time; when their prices are lower, energy price are higher, or stricter environmental regulations are in place. The conventional valuation methods such as Net Present Value (NPV) are unable to identify the optimal timing for investing in the PV panels. Hence, in order to avoid over- and under-investment, the decision makers should be equipped with proper financial valuation models that help them identify the optimal investment timing. We apply Real Options Theory from finance/decision science to create an investment valuation framework for finding the optimal time for investing in PV technologies. Our proposed investment analysis model uses experience curve concept to model the changes in price and efficiency of the PV technologies over time. It also has an energy price modeling component that characterizes the uncertainty about future retail price of energy as a stochastic process. Finally, the model incorporates the information concerning specific policy and regulatory instruments that may affect the investment value.*
*Using our mode, investors' financial risk profiles of investment (i.e. Cumulative Distribution Function of the Investment Value) in the "fixed" Solar Building and "flexible" Solar Ready Buildings will be developed. This will determine the Financial Value (if any) of investing in the Solar ready building and identify the optimal time for installing the PV panels.*

**Keywords:** Investment Valuation, Photovoltaics, Real Options

## Introduction

Given the increasing scale of investments in sustainable building technologies such as the Photovoltaic (PV) panels, it is of crucial importance to offer the proper financial decision-making tools to the stakeholders and decision-makers. Without a proper methodology, the risk that funds are misappropriated is imminent, e.g., by choosing wrong technologies or by timing the investment incorrectly.

Proper allocation of resources to sustainable building projects (e.g. installing Solar Panels) requires an assessment of the cost and performance of proposed solutions to establish their profitability. Metrics such as Payback Period (PP), ROI and NPV have been traditionally applied to measure this profitability. Of all these measures, Net Present Value (NPV) is the widely prescribed metric, e.g., in ASTM E917–05 (2010) for conducting life cycle costs and benefits analysis for a building system. Despite the popularity of NPV, this method has serious limitations in financial assessment of an energy retrofit solution.

A NPV analysis approach assumes that all decisions related to an energy investment are made at once and are completely irrevocable. These assumptions are not consistent with real-world decision-making processes for investing in sustainability projects such as installing the PV panels. Many of the PV technologies are still in their early development stages. It is expected that their prices will go down and their efficiencies will improve in future due to the economies of scale and learning by doing effects. Therefore, it seems reasonable that building owners delay investing in these technologies but maintain the capacity to implement them in future when investors become more confident about technical and financial aspects of such investments. Thus, constructing Solar Buildings (with PV panels already installed in the building) may not be an economically attractive solution today. However, it could be a financially-wise choice to prepare Solar Ready Buildings that enable the easy installation of PV panels at the optimal time in the future; when the electricity retail price reaches a new high level or the price and efficiency of PV panels improve significantly. Nevertheless, the NPV method ignores the significant impact of timing on the financial value of investment in the PV technologies. It is inherently unable to address Investment Timing. Hence, if NPV is used, the financial performance of investing in the solar ready buildings is computed erroneously. This, in turn, may lower the overall effectiveness of the sustainable investments.

Any efforts towards advancing the valuation process will improve the quality of investment decision-making in energy interventions and, considering the multibillion dollar nature of the green building industry (McGraw-Hill Construction 2010; SBI Energy 2009), this can lead up to enormous savings through smart investment choices. To avoid under- and over-investment and ensure that scarce financial resources are efficiently allocated an appropriate valuation method is needed (Ellingham and Fawcett 2006). The Real Options Theory from finance/decision science could be utilized to evaluate the investment in the solar ready buildings and price the delayed investments for PV panel installation.

## Real Options Analysis

Generally, the financial assessment of a delayed investment (e.g. installing PV panels in the case of solar ready buildings) is performed under the uncertainty about whether and when the investment should be implemented. Real Options Analysis properly meets this objective. The term “Real Options” refers to the application of financial option pricing techniques such as the Black and Scholes (1973) formula to assessment of non-financial or “Real” investments with strategic management flexibility features like delayed retrofit solutions (see Dixit and Pindyck

(1994) for a detailed overview of real options analysis). This field has gone through a significant transition from a topic of modest academic interest in 1990s to considerable, active academic and industry attention (Borison 2005). However, the applications of real options in building design and engineering have not been numerous. (Greden et al. 2006; Greden and Glicksman 2005; Ashuri 2010; Ashuri et al. 2010). To the best of authors' knowledge, real options analysis has not been applied to evaluate energy investments in buildings including the investments in PV technologies and solar ready buildings. Considering the expected increase in the level of investments in sustainable buildings, creating more appropriate investment valuation models in order to avoid under- and over-investments is crucial and the application of the real options theory from finance/decision science can result in significantly improvements in the investment valuation of energy retrofit solutions.

**Investment Analysis Framework for Solar Ready Buildings**

An Investment Valuation Model based on Real Options Theory is at the core of the framework proposed in this paper. It receives input from external modeling components, which generates the information that proper financial analysis of the investment in solar ready buildings requires. Specifically, the model receives input from an external Building Energy Simulation component, which is used to assess the energy performance of the solar ready building prior and after the installation of the PV panels. Thus, the module determines the potential energy savings resulted from the installation of the PV panels. An important component of our model is Retail Energy Price Modeling module, which shows future projected paths for the energy price. The financial benefit of installing the PV panels will be calculated based on these energy price models. The other component is Experience Curve Modeling, which is used to characterize how price and efficiency of the PV technologies evolve over time. This is critical in finding the optimal investment time for a proposed energy retrofit. The modeling process is described in the following sections

**Building Energy Simulation: Characterize Energy Savings Performance**

The Building Energy Simulation component explicitly addresses the determination of the energy savings performance of PV panels. The analysis first quantifies the performance of the solar ready building prior to the installation of the PV panels considering a variety of factors including the meteorological, urban and micro climate effects, related to the environmental conditions around the building. Next the simulation model quantifies the expected level of energy saving in the building following the installation of the Solar Panel. The detailed discussion about the implementation of Building Performance Simulation is out of the scope of this paper. Our financial analysis only uses the expected energy consumption of the solar ready buildings prior to the installation of the solar panels and after their potential installation as the essential inputs.

**Retail Energy Price Modeling: Create a Stochastic Model for Energy Price**

Retail Energy Price Modeling explicitly addresses uncertainty about energy price as major benefit driver of an energy retrofit investment. Financial benefits of energy savings depend on the price of energy in the utility retail market. Although average energy price rises over time, it is subject to considerable short-term variations (Figure 1). A Binomial Lattice model (See Hull (2008) for detailed descriptions) can be created to characterize the energy price uncertainty. A binomial lattice model is a simple, discrete random walk model, which has been used to describe evolving uncertainty about energy price (Liski and Murto 2010; Ellingham and Fawcett 2006).

The modeling choice of binomial lattice is also consistent with the general body of knowledge in real options (Hull 2008; Luenberger 1998). In economics and finance, binomial lattice is an appropriate model to capture uncertainty about a factor like energy price that grows over time plus random noise (Dixit and Pindyck 1994).

**Binomial Lattice Model**

To define a binomial lattice (Figure 2) for energy price (S), a basic short period with length $\Delta t$ will be considered. Suppose the current energy price is $S_0$. Energy price in the next period is one of only two possible values: $u \times S_0$ or $d \times S_0$ where both u and d are positive rates with $u>1$ and $d<1$. The probabilities of upward and downward movements are p and 1-p, respectively. This variation pattern continues on for subsequent periods until the end of investment time horizon. Binomial lattice parameters can be determined using data on the expected annual growth rate of energy price ($\alpha$) and the annual volatility of energy price ($\sigma$) as explained by Hull formulation (2008). This binomial lattice can be used as a basis to generate future random paths for energy price.

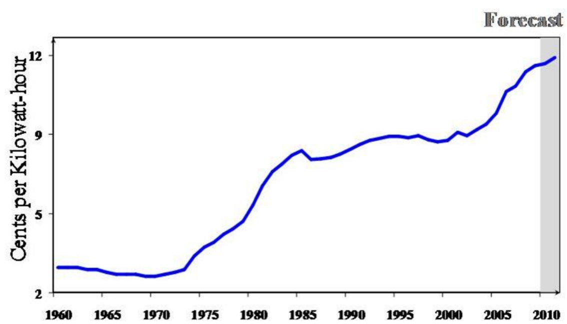


***Figure 1:*** *Annual Average Residential Electricity Price (EIA 2010)*

**Monte Carlo Simulation**

Next, Monte Carlo simulation technique can be applied to generate several random paths for energy price S – from the start to the end of investment time horizon – based on the described binomial lattice. Considering the binomial lattice formulation, energy price in any period of the lattice is a random variable that follows a discrete binomial distribution; this is the basis of applying Monte Carlo simulation technique for generating a large number of random energy price paths along the investment time horizon (Figure 2). Random energy price paths are used to compute respective energy savings series. In addition to benefits, it should be specified how the initial cost of the PV panels changes over time to find when it is optimal to invest in. This is discussed in the following section.

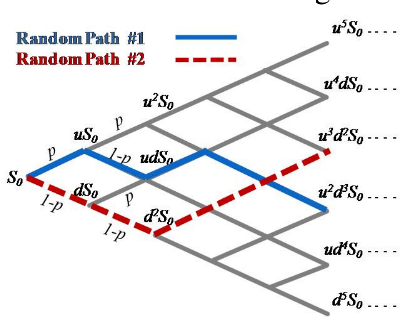


***Figure 2:*** *Random Energy Price Paths along the Binomial Lattice*

**Experience Curve Modeling: Create an Experience (Learning) Curve for the Proposed Emerging Technology**

The concept of Experience Curve describes how the marginal costs decline with cumulative production over time (Hartley et. al 2010; Weiss et al. 2010). Typically, this relationship is characterized empirically by a "Power Law" of the form: $Pt=P_0X^{-\alpha}$ where $P_0$ is the initial price ($ cost of first Megawatt MW of sales), X is the cumulative production in MW up to year t, and $2^{-\alpha}$ is Progress Ratio (PR); for each doubling of the cumulative production (sales) the cost declines to PR% of its previous value. For instance, Figure 3 shows an experience curve created for PV modules. The apparent decline in costs may be due to several reasons, including process innovation, learning-by-doing, economies of scale, R&D expenditures, product innovation/redesign, input price declines, etc. (Hartley et. al 2010; Yu et al. 2010). Experience Curve Modeling characterizes price reduction and efficiency improvement trends of a proposed emerging technology. The parameter α in the experience curve – i.e., $P_t = P_0X^{-\alpha}$ or $\ln(Pt) = \ln(P0) - \alpha\ln(X)$ – is defined using historical data of marginal costs and cumulative productions of the emerging technology. α can be estimated by a standard Ordinary Least Square (OLS) method. Nevertheless, the development of experience curves is not without trouble mainly because the estimation of PR for each technology is subject to great uncertainty (van Sark et al. 2007); it is not easy to forecast whether this PR remains constant or change over time (Yeh et al. 2009). Research has been focused on development of models that incorporate such uncertainties (Yeh et al. 2009; Gritsevskyi and Nakicenovic 2000). The best engineering judgment for the future level of decline in price of a technology can be used in these circumstances to characterize the cost trend of the PV technologies.

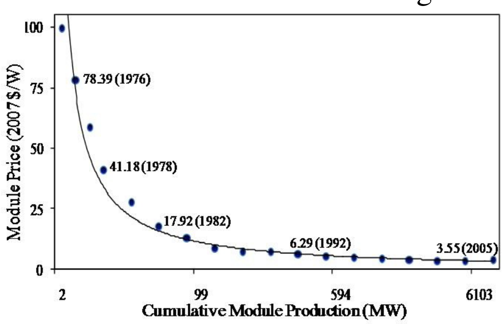


***Figure 3:*** *Experience Curve of PV Modules 1968 to 2006*

**Investment Valuation Modeling based on Real Options Analysis**

With the input from above three steps, Investment Valuation Modeling will determine the optimal time to invest in the installation of the PV panels in a solar ready building. It also establishes the value of embedding flexibility in the building.

A probabilistic NPV analysis can be conducted to describe the financial risk profile of the immediate investment in the PV panels. This is carried out under the assumption that investors adopt the current PV technologies right away at the current price and efficiency rate. Randomly generated energy saving streams are used to characterize investors' NPV distribution (Figure 4). Investors' cost of capital or required rate of return can be used as the discount rate in NPV analysis.

In addition, using the risk-neutral valuation method – developed in mathematical finance for pricing options and derivatives –the correct market-based value of a delayed PV installation in the solar ready house can be determined. In this technique, the probabilities of upward and downward movements in the initial energy price binomial lattice are modified – as described by (Luenberger 1998; Hull 2008) – to conduct option valuation. Risk-neutral binomial lattice can then be used as Decision Tree to determine the optimal investment time. Hence, investors' NPV distribution is calculated considering this optimal PV installation time. The difference between expected investors' value under immediate and delayed investment represents the expected value of optimal delayed investment (Figure 5).

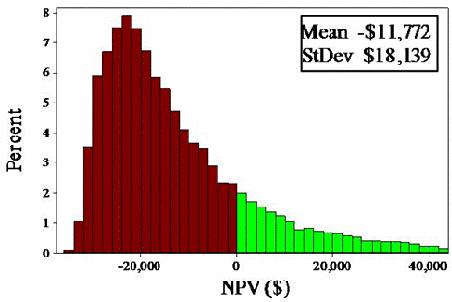


*Figure 4: Investor's NPV Distribution of Immediate PV Installation*

**Impact of the Political and Regulatory Environments**

Political and Regulatory Environments component encompass the impact of energy efficiency policies and incentive programs on investment valuation. Scenario analysis should be applied to specify possible energy targets and their likelihoods. Random upgrade scenarios, e.g., regulatory, political, technical, and/or market environments, in which an energy retrofit solution takes place should also be generated. Each scenario can be investigated with respect to its impact on future level of energy price, as well as its contribution to cost reductions of the proposed energy technology. Through what-if analyses, the impact of the regulatory conditions on the investment timing for an energy retrofit solution can be evaluated.

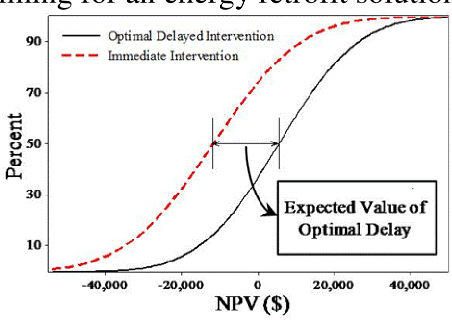


*Figure 5: Investment Value of Optimal Delayed Investment*

**Illustrative Example**

Approximately half of the installation cost of a solar power system on a building is spent on brackets, inventers, structural support (reinforcing the roof, repairing the roof, patching holes, etc.), and reconfiguration of the building electrical system. Rye (2008) summarizes several features, which can be included in the initial design, to proactively build a "Solar Ready Building": (a) Two additional slots on the electrical main panel; (b) A reserve location for an inverter; (c) Two conduits: one from the main panel location to the inverter location and one from the inverter location through the attic and onto the roof where the panels would be installed; (d) Reinforced roof rafter structure to support the weight of solar panels; and (e) Electrical jacks through the roofing material. The total cost of a Solar Ready Building with these additional features is approximately 3-5% higher than of the overall cost of a standard building. However, adding the same features to existing buildings could cost up to $15K in future solar upgrades. Based on the proposed investment analysis framework, the financial performance of the "flexible" Solar-Ready Building was compared with the financial performance of the "fixed" Solar Building. The initial cost of preparing electrical, structural, and roofing systems for PV panels was considered to be $10,000. This is the additional cost of embedding flexible features in a solar-ready building. Also, it was supposed that the purchase price of PV panels with the service life of 40 years is currently $4/W and is anticipated to decrease every year due to experience curve effect (PR=0.46329). It was assumed that the solar panels for this building were will provide 6,300W power. The initial retail price of electricity was also assumed to be $0.1031/kWh; this unit price changes over time with the expected annual growth rate 4% and the volatility of 20%. These values were used to create a binomial lattice to model electricity price variations. Financial benefits of PV panels are in terms of energy savings, which must otherwise be purchased from the utility company. Federal and State tax benefits are $5,000 and the homeowner's discount rate is 7%/year. Under these circumstances, the real options analysis methodology was applied and the financial performance of solar building and solar-ready building under uncertainty about the electricity price were evaluated. It was also determined whether and when it is optimal to convert a solar-ready building to a solar building and how much embedded flexibility in a solar-ready building is worth investing.

Figure 6(a) shows the optimal electricity price, which triggers conversion from a solar-ready building to a solar building; the increasing boundary effect is due to the option expiration in 2030. Below the price threshold, an investor or homeowner should delay the installation of PV panels. When the electricity price rises to a substantially high level, the value of waiting becomes lower than the energy savings benefits of the immediate PV panels installation; therefore, the solar-ready building should be converted into the PV building. Figure 6(b) shows the likelihood profile of the optimal conversion year; this is the probability of the event that the random electricity price path reaches the optimal investment threshold specified in (a) for the first time in the current year. It can be seen that initially waiting is more valuable than immediate exercise; but, as the time passes, the opportunity cost of waiting becomes large enough that triggers investment. Figure 6(c) shows the NPV distribution of a solar-ready building under uncertainty about energy savings. Figure 6(d) shows the NPV Cumulative Distribution Functions (CDFs) of solar and solar-ready buildings. The expected NPV of the solar building is $-11,772 and the chance of investment loss, i.e., Probability (NPV<0), is approximately 75% , which make the solar building an unattractive retrofit solution. Delayed retrofit decision-making can enhance the value of solar upgrade. The two-phase development of the solar-ready building represents the hidden value of flexibility in the solar upgrade. It can be seen that the expected NPV of the solar-ready building is $5,480, which is much larger than the expected NPV of the solar building $-11,772. Therefore, the expected price of flexibility in the solar-ready building is $5,480-($-11,772) =$17,252. Also, due to the two-stage installation of PV systems, the chance of investment loss for the solar-ready building is approximately 35%, which is much lower than 75% for the solar building.

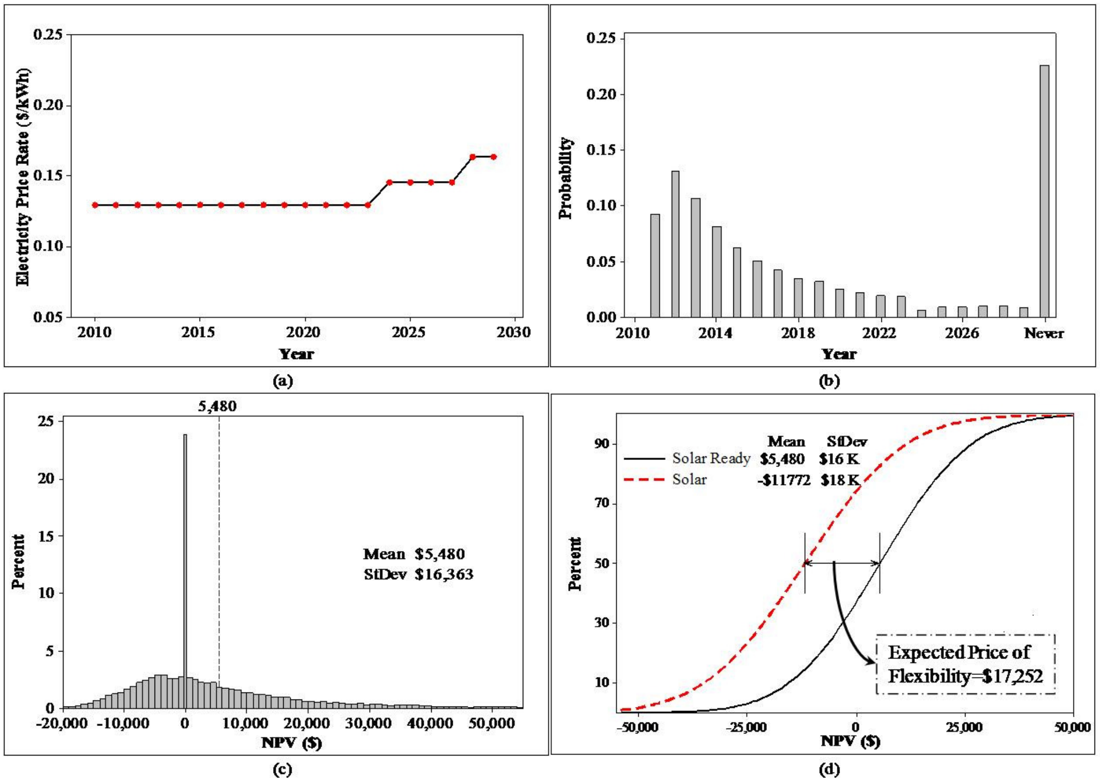


***Figure 6:*** *(a) Optimal Retail Price of Electricity ($/kWh) Triggering the installation of Solar Panels; (b) Installation Likelihood of PV Panels Over the House Service Life; (c) NPV Distribution of Solar Ready Home; (d) NPV Cumulative Distribution Functions (CDFs) of the Solar House and Solar-Ready Building and Price of Flexibility*

## Conclusion

Better investment decision models can facilitate achieving energy savings in the buildings through increasing the efficiency and effectiveness of investments in energy efficiency measures. The proposed investment analysis framework for evaluating investment in solar ready buildings will enlighten investors about the economic inefficiencies that conventional fixed energy investment strategies produce and facilitates the valuation of the flexible solutions that mitigate such inefficiencies. Explicit pricing of flexibility is significant for systematic decision-making beyond the current energy target; embedded options in delayed retrofit solutions reflect on the possibility to meet future stricter targets and prepare for future upgrades.

The proposed investment framework can be used as a decision making instrument, looking at different scenarios in technology and market developments, and deciding between immediate or delayed investment in PV technologies. Thus, it can also become an instrument in the selection of the right government incentives over time. As a corollary, the methodology will be used to single out the type of technologies that are ripe in the expected market of competing sustainable technologies.

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