The Future of PV Farms- Evaluation among Methods of Solar Panel Installation

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Abstract

Drastic effects of global warming have been pushing for the utilization of renewable energy sources where solar energy has been established as the source with the highest energy potential. On that premise, innovative techniques on how to utilize this power source are currently being developed but crucial investment decisions, technical constraints and lack of awareness are hampering the adoption. Five different methods of solar panel installation, that includes conventional ground mounted and floating, were evaluated and gauged against quantifiable and non-quantifiable factors towards strategic project assessment. A framework to determine which method of solar panel installation is more appropriate for use was generated and can be utilized in conceptualization as well as the pre-feasibility stages of a solar panel installation project.

Keywords

PV Farms- Evaluation, Solar Panel Installation.

1. Introduction

1.1 Research Question

Innovative techniques on how to make renewable energy sources more sustainable and practical are now being developed but technical constraints, lack of awareness, and critical investment decisions are hindering some companies from adopting technologies such as Floating Photovoltaic Farms. A central issue on how to gauge the efficiency, mobility and practicality between conventional and floating photovoltaic farms will be assessed taking into consideration the benefits and enablers as well as the barriers and limitations of both methods.

1.2 Objectives

To evaluate the difference between floating and conventional ground mounted PV

To assess the advantages and disadvantages of the five basic methods of solar panel installation

To determine the vital factors towards strategic project assessment in Phase 1, Site Identification/ Concept and Phase 2, Pre-feasibility Study as shown in Figure 1-4

To develop a framework for strategic decision making prior the design phase.

2. Literature Review

2.1 Solar Energy

Methods of Photovoltaic Installation

There are five main methods of Solar Photovoltaic Installation as mentioned in Sahu, Yadav and Sudkahar's (2015) review about Floating Photovoltaic Power Plant. It includes ground mounted, roof top, canal top, offshore and floating. These five methods can be categorized into two; conventional installation methods which includes ground mounted, canal top and roof top, and the floating PV Systems which includes offshore and floating PV Systems on reservoirs. PV panels for conventional projects are usually mounted on a rigid and fixed structure, but the concepts which have been proposed for future is using relevant stacked thin PV slides installing on the floating pontoons in marine and lacustrine. In this case, the PV panels could have flexible mobility and even be able to generate electricity in some harsh weather conditions.

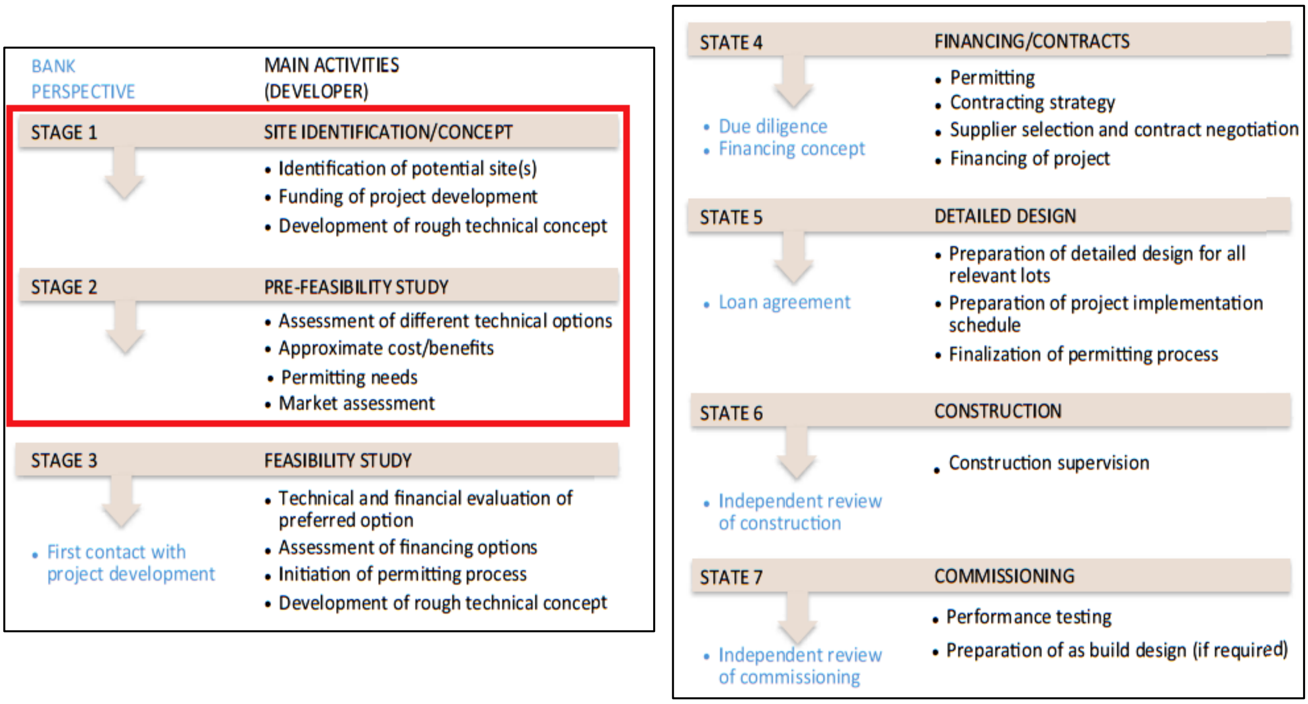

Figure 1-4 | Project Development Stages. Retrieved from Utility-Scale Solar Photovoltaic Power Plants, Copyright 2015 by the International Finance Corporation.

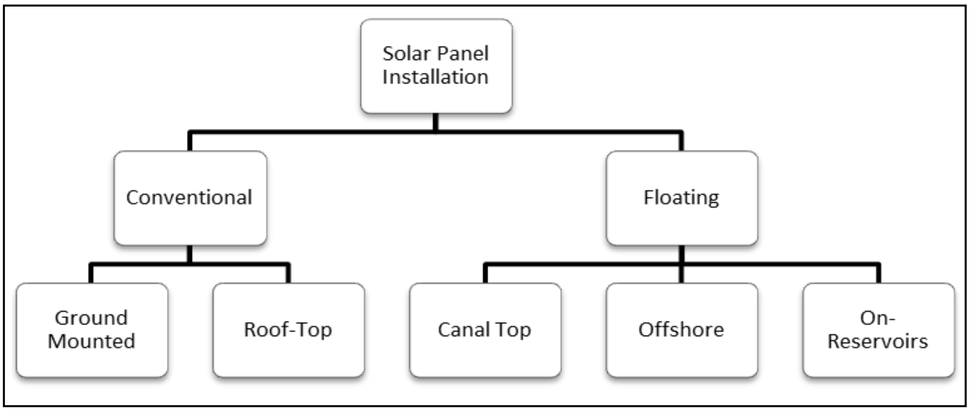

Figure 2-4 | Solar Photovoltaic Installation.

Flexibility and Location

Conventional Ground Mounted PV Systems

Ground-mounted photovoltaic panels usually tend to be large and vastly scattered. This type of panel modules are fixed and stabilized by steel skeletons or frames those ones are attached to mounting bases on the ground, as shown in Figure 2-5. Ground based panels are quite suited for overland sites where it is impossible to dig in, for instance capped landfills. Additionally, it simplifies some relocation and demolishment of solar PV systems.

Figure 2-5 | Conventional Land-Based Solar Panels.

Retrieved from Floating photovoltaic power plant: A review, Copyright 2016 by Elsevier Ltd.

Conventional Roof-top PV Systems

Rooftop photovoltaic systems often have the solar panels mounted above the flat rooftops (Figure 2-6) of some residential or commercial constructions. A rooftop photovoltaic energy station could be either an on-grid or an off-grid one, and it can also be utilized as original power sources for lightening, water heating etc. Rooftop mounted systems are smaller compared to other solar PV systems with generation capacity and size.

Figure 2- 6| Rooftop Solar Project.

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Floating PV Systems on Self-Contained Waters

The Floating PV is a fresh idea for energy collection, only implemented in few countries without any commercial employment. In order to resolve the problems of scarcity of land for PV installations in some countries, such as North Korea, Japan, Singapore, Philippines and some other island nations, a great requirement for Floating PV system is becoming an urgent issue. Floating PV systems can be mounted in enclosed waters like lakes, reservoir, dams, fish farms, ponds and irrigation canals etc. One particular PV module can convert 4.2–18.3% of solar energy to electricity generation, relying on the type of panel cells and weather conditions.

Floating PV Systems – Offshore

Over the past 8 years, all the floating projects belong to enclosed water environments such as ponds, lakes or reservoirs. This implies that if the PV panels need to be made available to be used on seas, some requirements for flexible structure and highly adaptive components are to be developed. Theoretically, the structure should adapt to marine environments, which can endure extra pressure and forces from the waves, strong winds and tides. These concepts for such offshore environments basically have a quiet similar theory in design but different installation from the enclosed-water floating PV panels. The design is mainly crystalline PV panels which are fixed and flexible thin PV slides (Fig. 2-7) can generate electricity. This structure can yield with the wave motion, instead of the tolerance from additional forces, allowing the mooring components have conformance to flows and withstand less loading forces Figure 2-8 summarizes the main methods of PV System installation according to factors such as location, maintenance and the environment. The overall advantages and disadvantages of the different types of PV Installation are further outlined in Figure 2-8 where significant factors in deciding which method of installation is the most suitable are evaluated. These methods as well as the factors mentioned will be the basis of the development of the framework for decision making as well as the analysis of data. Moreover, the variables that will serve as the foundation of the framework will be extracted from the figure along with the information from other literature sources cited in this paper.

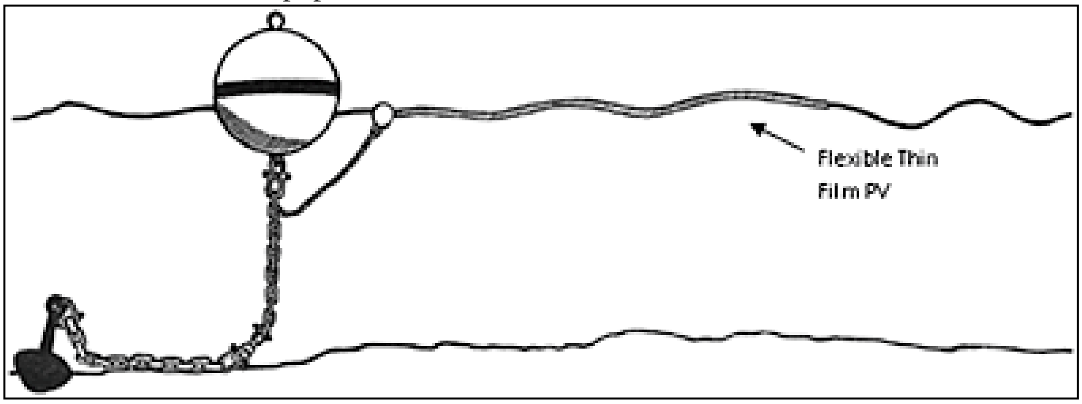

Figure 2-7 | Schematic of Thin-Film Floating PV.
Retrieved from A review of floating photovoltaic installations: 2007–2013,
Copyright 2015 by Progress in Photovoltaics.

Ground mounted	Roof top	Canal Top	Off Shore	Floating solar
Advantages: • More scope and lower cost to install a sun tracking system. • Facility to operate a manual seasonal tilt adjust system. • Larger systems can be installed because additional space on the ground then on the roof in rural settings. • Panels are easier to clean and maintain. • It also facilitates to avoid 'voiding roof warranties' as no connection between the system and the roof is involved.	• Aesthetics: the panels fit impeccably with the pre-existing rooftop for a more efficient appearance. • Space optimization: with rooftop solar, there's no need to clear away extra land. • Fortification: solar panels shield roof and protect from weather and wear-tear. This, in turn, increases the lifetime value of property. • Speed: rooftop solar is usually easier and faster to install than ground-mounted systems.	• Save precious and costly Land. • Save canal water from evaporation. Generate power with higher efficiency compared to land based solar power plants due to cooling effect on solar panels by evaporating canal water. • Extended Service Life and Energy Gain (Reduced Degradation of Semiconductor).	• Due to direct contact of PV panels with water, the negative coefficient efficiency (%/K) of the PV junction can be used to generate a higher electrical acquiesce for the same area occupied onshore; • As the PV panel temperature falls, the efficiency of panel increases. • In hot conditions it solves dual purpose of power generation and prevents water from evaporating from beneath. • Takes full advantage of sun rays during the day.	• **Increased Efficiency:** Reflection of light from the water and the natural evaporative cooling as an outcome of the water body can maintain the PV panel temperatures lower than land based ones and hence boost their efficiency. • **Reduced Evaporation of water:** Floating PV system provides shading to the water surface and reduces evaporation. • **Improved Water Quality:** It can also lead to better water quality due to reduced photosynthesis and algae growth. • **Less dust effect:** Typically areas with high solar energy potential lean to be dusty and arid, so in comparison to their ground mounted counterparts, floating PV systems perform in a low dust environment. • **Land saving:** It saves precious land for agricultural, mining, tourism and other land-incentive activities and turn unexploited and non-revenue generating water surface into commercial solar power plants.
Disadvantage: • Urban settings often do not have enough land space. • Solid foundations and concrete footing will need to be built to provide stable structure protecting from storms and high winds. • Construction time is more because of Civil and engineering work than other system.	• Roofs may have too many obstacles like chimneys, trees, vents, satellite dishes, etc.) Leading to shading losses. • Roof may not properly fit to the required system capacity. • Lack of Southward facing roof which may affect yield • Labour intensive.	• Lack of availability of Canals for such projects. • Socio economic and political issues of using rivers and canals. • Complicated and lengthy structures to accommodate modules. • Maintenance of such systems is an issue due to sub-optimal location. • Local shading by trees surrounding canal which cannot be uprooted for ensuring soil's stability and preventing erosion. • Covering such canals with PV panels essentially destroys the wetlands for birds and greenery areas. • Panels, structure etc. may lead to contamination issues of fresh water. • Better (structural and design strategies is required which will increase the cost. • Power evacuation of small capacity over a long path would be difficult and costly due to increased Cable costs. • System spread over such a large length cannot be protected by boundary walls or fencing, thus security concerns are very major in such cases.	• Since one of the key components in PV panels is cadmium chloride which is expensive and enormously toxic, it affects both the manufacturing process and the price of solar panels. Researchers found that seawater contains magnesium chloride, which could replace cadmium chloride. • The panels are designed to be waterproof. • Panels are to be made lighter so that they can float which require high cost material or otherwise we have to use some structure which makes whole installation costly. Connecting of solar panels and their maintenance in water as well as connecting to the grid could be a major issue for this type of plant.	• The system is prone to more threats like High tides, storms, sea waves, cyclones and tsunami. • Increased corrosion of the metallic structure and components which can reduce the life of the system. • Causes reduction in penetration of the solar lights into the water bodies which may affect the growth of aquatic animals and seaweed etc. • Reduced Humidity and Temperatures on the panel cause negative thermal drift which may decreases the overall efficiency. • Regular Cleaning of clay accumulated on the sides of the river/lake is needed. • Fishing and other transportation activity may be affected depending the selected site.

Figure 2- 8| Advantages and Disadvantages of Five Methods of Solar Panel Installation.
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2.2 Conventional Photovoltaic Farms

General Definition

A conventional photovoltaic farm is a large photovoltaic system that consists of huge amounts of solar cells, in order to produce electricity (Figure 2-9). Photovoltaic is a kind of technology which transforms solar radiation into electric power by using solar cells. When the sun is shining on the semiconductor, part of the light is reflected by the surface and other is absorbed or penetrated through the semiconductor. During this process, photons crash electrons in the semiconductor, and thus produce electricity. According to Haberlin and Eppel (2012), the technology of photovoltaic was developed rapidly during the past decade, and from 1997 to 2012, the sector of countries using photovoltaic around the world increased from 30% to 85%.

For this method of installation, vast land is commonly required to put up the system. Unlike domestic solar panels, photovoltaic farms supply electric energy at the utility level, and can meet the demand of a small city or even industrial utilizations.

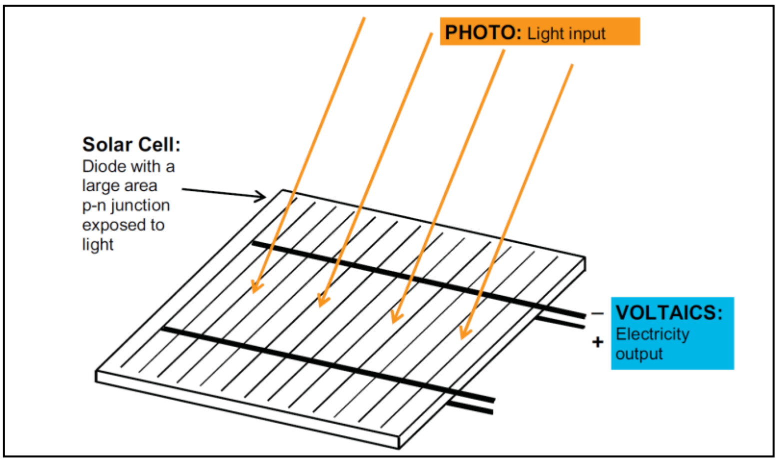

Figure 2-9 | Theory of Solar Panels

Retrieved from Photovoltaics System Design and Practice, Copyright 2012 by Haberlin & Eppel

Location

When choosing the location of conventional photovoltaic farms, two main factors must be taken into consideration: temperature and shade. High temperature may significantly reduce the efficiency of producing power from solar panels. When the semiconductor suffers a high temperature, the conductivity of it will rise. To keep the balance of charges, the strength of the electric field intensity decreases, and restrains the charge separation. Finally, the voltage in cells reduces. The power production will be reduced by 10% to 25% depending on the high temperature of different locations. Shade is another element that inhibits solar efficiency. Solar panels are connected with each other, and the lowest one decides the intensity of current. Therefore, if there is shade on one solar cell, it will have negative effect on the production of the whole system. Before confirming the location of photovoltaic farms, people should do analysis of shade, to ensure that no shadow will cover solar panels during peak hours.

Output and Limitations

During day times, the effectiveness of solar cells decided by the location of the sun, so the maximum output of solar panels is restricted into a limited time, for about two hours per days. In addition, improper temperature and shade can also reduce the efficiency of photovoltaic farms. Compared with traditional fossil fuel plants, the efficiency of photovoltaic farms is much lower, except for peak hours. Although the total energy output of nuclear power or fossil fuel stations exceed photovoltaic farms a lot, photovoltaic farms can still compete with natural gas plants which only runs during day times. A photovoltaic farm can supply 50% of rated power, while natural gas plant can deliver 95% but only for twelve hours (Strang & Nersesian, 2016).

	V	W	X	Y	Z
58	Total Solar Power mW output				34.8
59					
60	Total Solar Energy mWh Output				17.1
61					
62	Fossil Fuel Equivalent (95% for 24 hours)				68.4
63					
64	Relative Effectiveness				25%
65					
66	In competition with fossil fuel daylight hours only				
67					
68	Fossil Fuel Equivalent (95% for 12 hours)				34.2
69					
70	Relative Effectiveness				50%

Figure 2-10 | Solar Power Output Spreadsheet

Retrieved from Quantifying the Uncertainty of Energy Creation from Solar and Wind Farms in Different Locations, Copyright 2016 by Strang & Nersesian

According to the investigation, in 2013, the price for PV systems had significant variations between different areas. In China and Germany, the cost is the lowest, for $1.4 per watt, but in United States, it is more than twice more expensive, for $3.3 per watt. The International Energy Agency (2014) reports that the difference of cost between those countries is due to many other factors, including labour charges, financing costs as well as consumer acquisition.

Country	Cost ($/W)
Australia	2.0
China	1.4
France	2.2
Germany	1.4
Italy	1.5
Japan	2.9
United Kingdom	1.9
United States	3.3

Figure 2-11 | Utility-scale PV system prices of different countries in 2013

Maintenance

Maintenance is an important link during the life cycle of photovoltaic systems. Organizations should follow several steps to guarantee the PV system in a perfect condition. 1. Checking energy production monthly, this could be the reference to test the stability of the system. 2. Ascending personnel should inspection the closing of breakers every weeks, which can protect current relays. 3. Checking and cleaning glass dirt month by month, especially during spring and summer, to increase the efficiency of solar panels. 4. Control the surrounding temperature of cables, because high temperature will shorten their life spans (Spertino & Corona, 2013).

Transmission System

Different from domestic solar panels, photovoltaic farms need to supply energy to the electric system instead of particular consumers, which means while establishing grid codes, some regulations should be followed to content the demand to the electric system. Tobar, Massague, Penalba and Bellmunt (2016) claim that four specific categories should be considered to identify a transmission system, “(a) fault-ride through requirements, (b) voltage and frequency deviation boundaries, (c) active power and frequency control and (d) voltage and reactive power control.

2.3 Floating Photovoltaic Farms

General Definition

Distinct from land-based plants, floating solar power plants are mounted on top of reservoirs which also solve the continuing problems on land scarcity and deforestation. Although the method is rather simple as it only includes solar panels that are fixed on floating podiums which will then be anchored to be able to resist strong winds, there are certain factors that have to be considered unique to conventional methods. These factors include the layout of the reservoir or body of water, the geometry of the floating structure and the orientation of the PV panel. At present, there are only a total 50MW in capacity floating solar power plants worldwide but the number will be doubled by the end of 2017 as per a research analyst Benjamin Attia. (Mearian, 2017). The rising demand for renewable energy resources along with the increasing affordability and accessibility of solar power around the world have pushed for the development of new technologies and methods of installation (Bernard Prouvost, 2016).

Advantages

Benefits that have been driving the adoption of Floating PV Systems are being triggered by the challenge to keep electricity costs down and problems with limited land spaces. Outlined are the major advantages that this method of installation can offer.

Land Availability

One of the main reasons why some countries like Japan and Singapore led the development of this technology is the availability of land. Issues on land acquisition, permitting, leasing, restrictions and improvement are eliminated and available land can be put to other beneficial use such as farming instead. Figure 2-14 shows an example of a floating solar farm in Manchester where the unused space of the reservoir is being utilized. The system highlights the use of these spaces that serve no other purpose and thus can be agreed for very minimal rent.

Figure 2-14 | A Floating Solar Farm in Manchester Reservoir.

Retrieved from Europe's largest floating solar system on Manchester reservoir, Copyright 2015 by United Utilities

Limited Ground Disturbance

While ground Mounted PV Systems need a wide space of land for set-up that would usually include major civil works, use of heavy equipment, terracing and removal of vegetation, floating PV Systems requires very limited ground disturbance during installation and generates a more environmental solution to power shortages. The installation process is fairly easy to execute since the system can be put up together without the need for heavy equipment; thus also reducing installation costs and time due to very few site preparation requirements.

Reduced Water Evaporation

A crucial benefit, especially for countries with dry climate, is that Floating PV Projects reduce water evaporation for a great extent by covering the water surface of reservoirs.

Increased Efficiency

Solar panels are said to drop efficiency as temperature increases, but since the panels will be mounted on water surfaces, the water will absorb the heat collected by the arrays and thus boost productivity due to the natural module cooling that the area can provide. The combination of light reflection from the water and its evaporative cooling help maintain temperatures and gives the system higher peak efficiency.

Panel Maintenance (Less Dust-Effect)

Usual areas where solar energy panels are mounted tend to be arid and dusty therefore in comparison; Floating PV Systems are situated in low-dust environments. Water is also readily available for cleaning the solar panels.

Ecological Effects

There are beneficial effects for ecology as Floating PV Systems avert water from daily temperature oscillations as the sun moves. The synergy between Floating PV Systems and conservation programs is also evident as covering reservoirs provide a solution not just for water evaporation but for algae growth as well wherein which are treated by chemicals. This then will result in improved water quality.

Most PV installations are also developed in areas with sensitive wildlife; this is not typically present on manmade bodies of water. Hence, Floating PV Systems benefits both land and aquatic life and limits eutrophication in the process (Bernard Prouvost, 2016).

Back-up Energy

Some Floating PV Systems, when installed on dams that are used for hydropower, can act as back-up energy source when the water levels are low. (Solar Choice Staff, 2015)

Cost

Floating PV Systems are cost competitive with conventional ground-mounted and roof-mounted solar panels as it utilizes the same panels that are currently commercially available. Most countries that are already using the technology also have incentive programs, federal subsidies and grants to Floating PV Installation Projects.

Key Drivers

Lower investment costs due to eliminated land acquisition and development cost

Higher module efficiency

Grid uniformity

Disadvantages

Although the benefits by Floating PV Installations are apparent, there are a number of disadvantages that has to be taken into consideration as well:

Technical constraints on commissioning and installing of panels

Potential corrosion of panels owing to high moisture content

Steadiness of the panels during severe environmental conditions

Issue on safe transmission and storage of power from the floating panels

Practicability in use of shock-proof equipment

The possibility for the system to encounter rapid water movements from cyclones, heavy winds waves, snow for some areas, floods and varying water levels. The PV Systems have to be designed to withstand such forces of nature.

3. Data Collection and Discussion of Results

3.1 Summary of Variables

Data or factors vital when considering Stage 1 and Stage 2 of the Project Development Stages were obtained from the literature and case studies. These factors were categorized further into quantifiable and non-quantifiable factors wherein quantifiable factors have formulas indicated that can serve as reference for approximate calculations. Non-quantifiable factors, on the other hand, contain subcategories that can be imperative in assessing which method is the most viable among the options of solar panel installation. There are a total of thirteen factors, 6 of which – as shown in Table 4-1, are quantifiable namely capacity factor, efficiency, land rate usage, payback period, rate of installation and cost approximation. Non-quantifiable factors, organized in Table 4-2, are use, location, transmission, permitting, funding, maintenance and locational impact. These aspects that are outlined in the tables below can be the foundation of decision making both in site identification, conceptualization and in the pre-feasibility study.

Quantifiable Factors		
No.	Factor	Formula
1	Capacity Factor [4]	$Capacity\ Factor(\%) = \frac{Generated\ Quantity\ Analysis\ Period\ (kwh)}{Installed\ Capacity\ (kw)\ x\ Analysis\ Period\ (h)}$ x 100
2	Efficiency [7]	$Module\ Efficiency = \frac{Maximum\ Point\ Voltage\ x\ Maximum\ Point\ Current}{Input\ Solar\ Radiation}$
3	Land Rate Usage [19]	$1\ MW\ PV\ Plant\ \frac{4\ Acres\ for\ Crystalline\ Solar\ Panels\ without\ Trackers}{6\ Acres\ for\ Thin-Film\ Solar\ Panels\ without\ Trackers}$
4	Payback Period [20]	$Payback\ Period = \frac{Total\ Cost\ of\ PV\ with\ all\ Auxiliary\ Equipment}{Total\ Annual\ Cost\ Savings\ After\ Installation}$
5	Rate of Installation	$Installation\ Rate = \frac{Number\ of\ Modules\ in\ kw}{Time\ in\ hours}$ (kw/h)
6	Cost Approximation	Conceptualization Cost
		Design and Development Cost
		Manufacturing/Material Cost
		Construction/Installation Cost
		Operating Cost

Table 4-1 – Quantifiable Factors for Options Evaluation

Table 4-2 – Non-Quantifiable Factors for Options Evaluation

Non-Quantifiable Factors	
No.	Factor
1	Use
	Utility Scale
	Commercial Use
	Residential/Domestic Use
2	Location
	Solar Resource
	Land Availability
	Local Climate
	Topography
	Land Development Necessary
	Accessibility/Grid Connection
	Site Security
3	Transmission
	Ease of Transmission
	Tranmission Safety
4	Permitting
	Zoning/Land Use Policies
	Environmental Designations
5	Funding
	Private Fund
	Financial incentives
6	Maintenance
	Water Availability
7	Locational Impact
	Suplementary Significance
	Ecological Impact

Stage 1 of Project Development primarily includes identification of potential sites, funding of project development and development of a rough technical concept. The initial phases of project initiation should be established well because the succeeding phases will be based upon its outcome. The outline of both quantifiable and non-quantifiable factors presents aspects in a manner which is easily understood and grasped and therefore offers support for conceptualization. The next and final stage of project development that will be tackled contains parts for assessment of the technical options, approximation of cost, permitting needs and a market assessment.

3.2 Options Analysis

To provide supplementary support to the analysis of each option, the overall strengths, weaknesses, opportunities and threats was included and evaluated along with the political, economic, social and legal dimensions. The factors contained in each element were grounded on the accumulated information from the literature and case studies. Internal strengths, as shown in Figure 4-1, vital to be considered for each option are higher efficiency, shorter payback period, minimum ground disturbance and significant positive impact based solely on the method of installation eliminating the impacts that solar panels or solar farms can provide in general. The weaknesses include but are not limited to critical investment decisions, technical constraints, difficulties in maintenance and uncertain long-term sustainability. External facets for opportunities, on the other hand, are rapid technological development where innovations can be made cheaper and more available as the advancement progresses and industry competitive advantage. Lastly, the threats are having the option not suitable for usage and shift of focus on other emerging technologies.

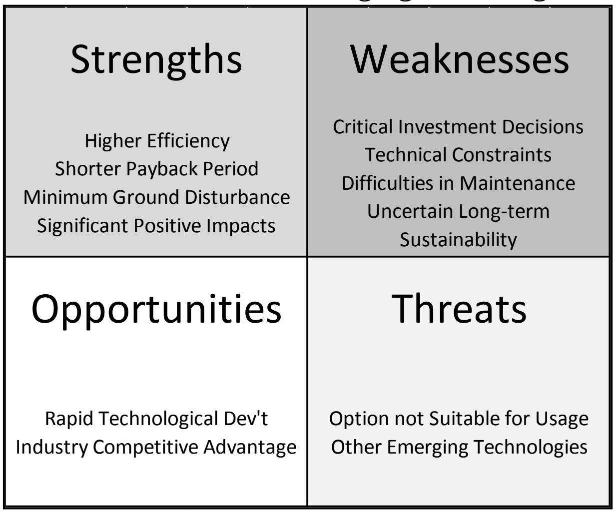

Figure 4-1 – SWOT Analysis

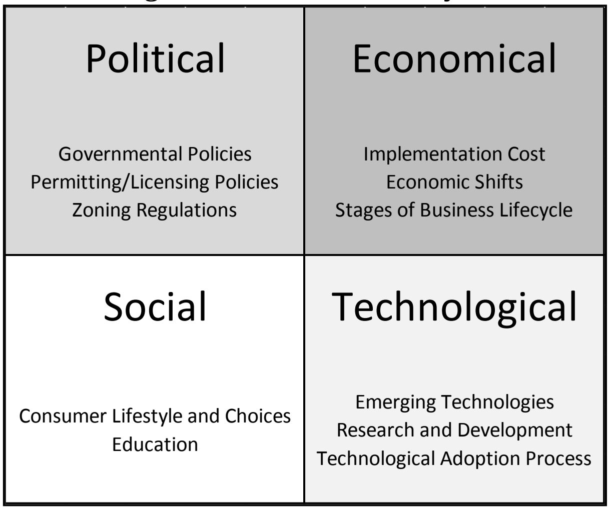

Figure 4-2 – PEST Analysis

Moreover, the PEST Analysis – as shown in Figure 4-2, can give an in-depth evaluation for each option with regards to its political, economic, social and technological aspects. This way, companies can better assess the option for technological adoption externally. Political factors include governmental policies, permitting and licensing policies, and zoning regulations. Economic aspects are implementation cost, economic shifts that can affect the stages of business lifecycle. Consumer lifestyle and choices as well as education are part of the social aspect. Finally, the technological factors are comprised of other emerging technologies, research and development and technological adoption processes.

3.3 Generation of Framework

The framework generated was based on the data and case studies collected throughout the course of the research. It has three major aspects including the strategic decision making flowchart, the representation of five key dimensions for PV Panel installation and lastly, the ranking sheet for the options. The flowchart summarizes the overall concept of the framework specifying the need to undertake an evaluation of technological suitability and alignment of purpose prior to the assessment of the five key dimensions, after being able to select an option appropriate, the implementation of the strategy vital for the next stages of project development will follow.

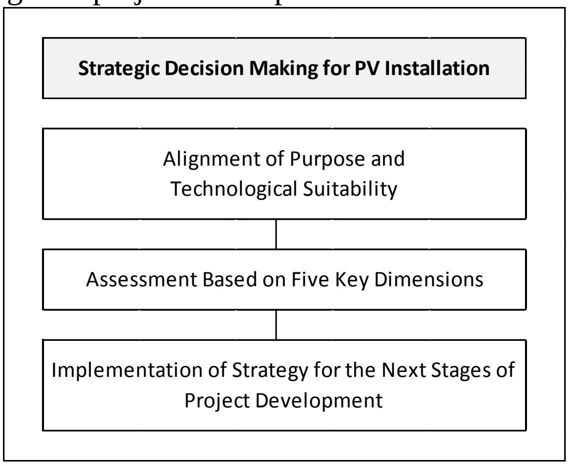

Figure 5-1 – Strategic Decision Making for PV Installation

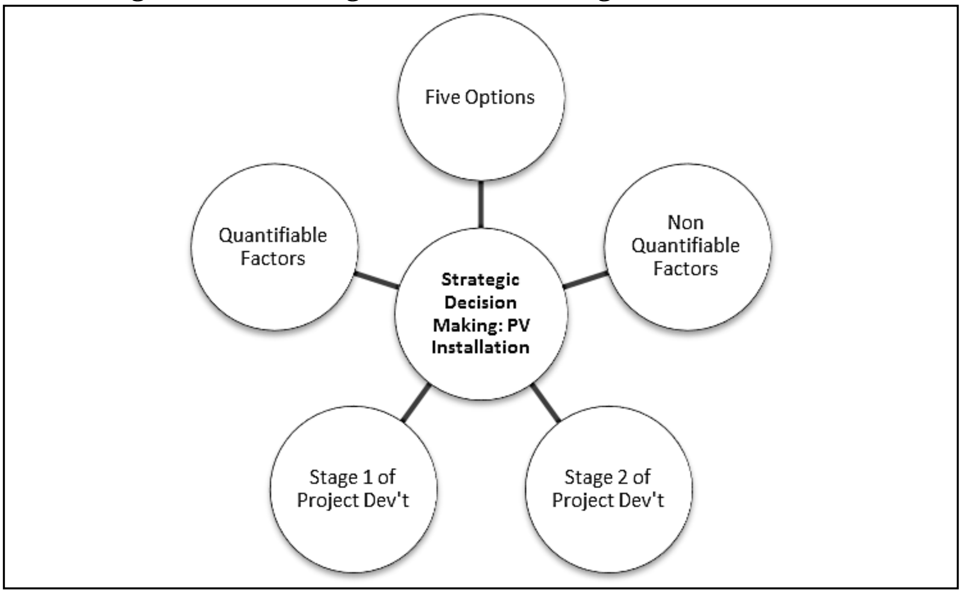

Figure 5-2 – Five Key Dimensions for Strategic Implementation

Five key dimensions crucial for decision making are exemplified in the chart. The representation emphasizes the importance of each dimension namely quantifiable factors, non-quantifiable factors, the five options of installation, and stages 1 and 2 of the project development phase. Stage 1 which is site identification and conceptualization includes identification of the potential sites, funding and a development of the technical concept. Moreover, stage 2 that mainly tackles about the pre-feasibility study contains assessment of different options, approximation of cost, permitting and the market assessment. All of these aspects are geared towards successful decision making, are backed up by literature to exude reliability and was utilized in structuring the ranking sheet.

The ranking sheet towards strategic decision making is incorporated in the framework to assess the options more effectively against both quantifiable and non-quantifiable factors. Bounded by the five key dimensions indicated previously, the factors are based on stage 1 and stage 2 of project development. Options are the methods of solar panel installation grounded on literature that were reviewed; Option 1 – Ground Mounted, Option 2 – Roof Top, Option 3 – Canal Top, Option 4 – Off-Shore, Option 5 – Floating. The process includes giving a score of (1-5), 5 having the highest suitability and 1 for the option that is least suitable. The final score will be tallied and the option that will garner the highest score will be considered the strategic option for implementation.

Areas of Project Feasibility					
Quantifiable Factors					
Factor	Option 1	Option 2	Option 3	Option 4	Option 5
Capacity Factor					
Efficiency					
Land-Rate Usage					
Payback Period					
Rate of Installation					
Cost Approximation					
Non-Quantifiable Factors					
Projected Use					
Location					
Transmission					
Permitting					
Funding					
Maintenance					
Locational Impact					
Score					

Table 5-1 – Ranking Sheet for Strategic Decision Making

Option	Description
1	Ground-Mounted
2	Roof Top
3	Canal Top
4	Off-Shore
5	Floating PV Panels

Score	Description
5	Most Suitable
4	Majorly Suitable
3	Suitable
2	Least Suitable
1	Not Suitable

4. Conclusion

The main objective of the study was fulfilled and the hypothesis was established through generating a framework that can be utilized in decision making for Stage 1 and Stage 2 of the Project Development – which are site identification, conceptualization and pre-feasibility study respectively. The approach was undertaken through emphasizing five different types of solar panel installation, evaluating the difference between conventional and floating solar farms and determining the factors vital towards strategic project assessment. All of which were used to establish the five key dimensions crucial for valuation as well as implementation. Main factors were categorized into non-quantifiable as well as quantifiable factors wherein formulas based from literature were incorporated to allow for a succinct qualitative analysis. SWOT Analysis was also taken into consideration for evaluation each option against its strengths, weaknesses, opportunities and threats for each. PEST Analysis was also included citing a basis for political, economic, social and technological aspects of the adoption. The framework provides a basic structure for ranking methodological suitability of each option for solar panel installation eliminating technological constraints and critical investment decisions through the extensive literature and case studies that were provided.

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