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2023

Whitepaper on Risk Management and Mitigation Measures in Solar Power Plants

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Why this White Paper?

The 'National Statement' of India at the 26th Conference of Parties (COP26) presented a five-pronged strategy, *Panchamrit,* to combat climate change, with an emphasis on the accelerated use of renewable energy and the upgrading of Nationally Determined Contributions (NDC) under the Paris Agreement, 2015. The crux of the suggested formula for India's commitment to climate action is a 2070 deadline for transforming into a Net-Zero nation. Here, the key to achieving the ambitious targets laid forth in these action plans is implicitly making the absolute most of Solar Energy, the most abundant of renewables. The greatest proven way to reap the benefits of solar energy is through deploying Utility-scale Solar energy projects, Solar Rooftop, and Distributed Renewable Energy (DRE) systems.

As of the 31st December, 2022, India has installed over 63 GW of solar power capacity (MNRE, 2022). In addition to the current installed capacity, estimates indicate a 50 GW of capacity addition which is in various stages of development. Apart from 100 GW Solar capacity addition by 2022, India also aims to have non-fossil fuel installed capacity of 500 GW in which solar power capacity will have major role to play (Press Information Bureau, 2021).

Accordingly, there has been a promising influx of investment into India's renewable energy sector. In the most recent fiscal year (2021-22), investment in renewable energy in India hit a record $14.5 billion, a rise of 125% from FY 2020-21 and 72% from FY 2019-20, before the global pandemic hit. Since the NSM's launch in 2016, India has garnered a total of approximately $128 Billion through the end of FY 2019 (World Economic Forum, 2022). The flow of capital into the sector is constant and is witnessing a rapid growth. However, achieving the stated goals and realizing Solar's full potential depends on ensuring the projects' financial viability.

As there is always some degree of risk in any endeavor, solar power projects though perceived as Plug & Play solutions are no exception. Sectoral experience suggests that the projects are experiencing severe time and cost over-runs due to a variety of factors that either directly or indirectly impact a project's financial viability. This whitepaper takes this as a cue and stresses on the significant potential risks that Solar projects may face from inception to completion. It also outlines possible mitigation measures to minimize the impact of the identified risks in order to maintain the industry's attractiveness to investors and the sector's profitability.

While this is primarily intended for use by all parties involved in the solar power plant value chain, from conception to operation, it is also intended to aid management at various levels in the decision-making processes of current and future solar companies in the Indian market by prescribing an objective view of a problem and the optimal solution.

Figure 1: Stakeholders involved in solar projects

Methodology

Each stage in the solar project value chain is posed with significant risks that are of different natures and magnitudes. Since assessing potential hazards is the preliminary step in devising a reliable management strategy, it is therefore crucial to identify risks, assess their severity, and plan for their management in order to avoid failures. To preserve the sector's sustainability and continuing the flow of money from domestic and foreign markets, accuracy in the conduct of risk assessment from the stage of project conception to completion is necessary.

Figure 2: Key steps of risk assessment

To achieve this, the ASCI team has adapted a Mixed method research approach that involves the use of both qualitative and quantitative research methodologies. This method of research enabled the team to generate deeper and more reliable research insights of the issue. While qualitative part of research included the conduct of in-depth interviews with a select sample stakeholder (see Figure-1), the quantification of the insights obtained is done through adaption of 'Analytical Hierarchy Process' that prioritizes the risks based on severity and other variables.

The conduct of interviews relied on posing questions within a pre-determined thematic framework which popularly is referred as semi-structured interview methodology. The framework included questions related to all possible categories of risks identified as a part of literature review. All the PESTEL categories along with risks related vendors, time and cost over-runs were a part of framing of questions. Since semi-structured interviews by nature require qualified experts in the field that provide relevant answers, the choice of ASCI team is as such in selecting the sample of stakeholders. A mix of designations ranging from site engineer to Director of different stakeholder organizations have been chosen for interviews.

The risk assessment has been done through a process of risk identification, risk analysis, and risk evaluation (Risk Management Policy, 2018). This method enabled to devise robust risk management measures. The risk mitigation measures are gleaned from the ASCI's inhouse expertise while backed with field level experiences of stakeholders executing and managing solar power projects. A strong literature review on risks encountered by solar power projects provided a base for entire study.

A problem not addressed will turn into a crisis. A crisis not managed well becomes a disaster!

Risk Identification

Risk identification, generally, is the first step in the process of risk management. Risk identification involves in identifying a project's exposure to uncertainties. As a part of risk identification, the following sections deal with elaborating on solar power in India, evolution of solar thought into policy and solar markets in India. A dig into these aspects sets the premise for the sequential steps in the risk assessment process – Risk description and estimation.

Solar Power in India

With over 300 sunny days each year, India has one of the largest solar potentials in the world. The majority of India's landmass receives between 4 and 7 kWh per sq.m energy per day and receives around 5,000 trillion kWh of energy annually (MNRE, 2022). The National Institute of Solar Energy estimates India's solar potential to be around 748 gigawatts. India is one of the few countries next to the US and China that have crossed 50 GW of installed solar power due to its strong governmental focus.

The Indian government has been making consistent efforts and initiatives through a variety of policies, financial mechanisms to ensure the nation meets its solar goals. A deep dive into the evolution of India's stance and efforts on solar energy is believed to provide a holistic perspective.

Development of Indian Solar sector - A policy perspective

The commencement of India's efforts in the field of renewable energy, solar in particular, dates back to the early 1960s (Karan Kapoor, 2014). During India's third five-year plan (1961–1966), recognizing the significance and trend of the globe to study the renewable sector, India targeted it as a technology to adopt. After nearly two decades, in the sixth five-year plan India addressed solar energy and its deployment by seeming Solar energy development with a special relevance for addressing the energy needs of fragmented rural regions and for possible industrial applications. The Department of Non-Conventional Energy Sources (DNES) was established under the Ministry of Energy in 1982 to offer financing for improving research, development, and demonstrations in the field of RE technologies including solar. Through Central Electronics Limited (CEL), the National Solar Photovoltaic Energy Demonstration Program (NASPAD) was implemented with an objective to reduce the cost per Watt peak (Wp) of modules through the development and demonstration of low-cost solar grade silicon material and the improvement of the efficiency of solar cells for energy generation.

Later, in 1987, Indian Renewable Energy Development Agency (IREDA) was established with the purpose of operating a revolving fund for the development, promotion, and commercialization of New and Renewable Energy Sources. In support of its mission, several foreign agencies have provided funds to IREDA. Later, in 1997 in its ninth five-year plan, the GoI encouraged the idea of private sector participation as an effort to mobilize additional funds into the sector. This decision enabled private developers to establish power plants of any size or kind (wind or solar) since it allowed Independent Renewable Power Producers (IRPP) to wheel the (renewable)power through existing transmission lines of the State Electricity Boards (SEBs) on payment of reasonable charges for selling the power to any third party in the country.

Subsequently, a Special Action Plan (SAP) for "Rapid Improvement of Physical Infrastructure" that included solar PV schemes was developed. These projects were pushed in Special Area Development districts (SAD). Subsidies were enabled for the implementation of solar energy programmes. Under this plan the country also made efforts on technological improvements of solar PVs. However, during this period, India also witnessed the issues of viability in commissioning a solar plant (Ex. Solar plant at Mathania, Rajasthan) due to lack of robust technology. Since then, several attempts have been made to enhance technical efficiency, while initiatives encouraging solar energy use have persisted.

Since 2000, the GoI has taken a number of initiatives that either directly or indirectly promoted the use of solar energy in the country. These include the introduction of Electricity Act of 2003, the National Electricity Policy of 2005, the Tariff Policy of 2006, the National Action Plan on Climate Change of 2008. One of the eight objectives of NAPCC 2008, the introduction of the Jawaharlal Nehru National Solar Mission (JNNSM) marked the beginning of a fast expansion of the solar sector in India, both in terms of capacity and technological innovation. Initiatives like Viability Gap Fund (VGF), Domestic Content Requirement (DCR), Common Risk Mitigation Mechanism (CRMM), of Basic Customs Duty (BCD) and the creation of the Approved List of Models and Manufacturers (ALMM) continued the flow with their own mark of influence.

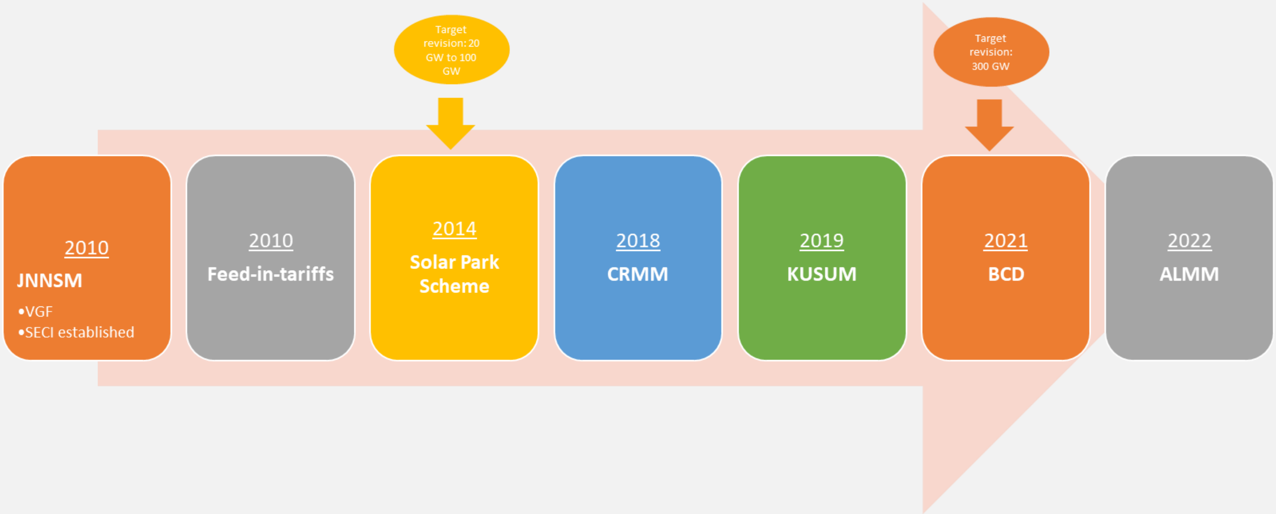

Figure 3: Timeline of GoI reforms, schemes and initiatives

All these reforms in the sector have created the background for the necessary push of solar to make it a mainstream generation source from 2010 till today. From less than 10 MW in 2010, India has added significant photovoltaics capacity over the past decade, achieving over 50 GW by 2022. However, the announcement of '*Panchamrit*', the five nectar elements of India's climate action at the COP26 further emphasizes the ambitious vison that India has to excel in the field of renewables and solar in particular.

This increased responsibility necessitates that the diverse stakeholders of the Indian solar sector execute the process with care by addressing the associated challenges in a timely manner. This will aid in the development of profitable ventures, paving the way for the overall goal to be met.

Accordingly, as previously stated, it is essential to study and analyze the risks in order to devise better solutions.

A peek into Indian solar markets

All solar energy projects follow a common project development pathway from conception to its completion. Each step in this process involves the usage of many resources and tools that facilitate the efficient functioning of the project. The process begins with conceptualization, then proceeds on to site selection, design, financial closure, line construction and project construction, and lastly, handover & takeover before the beginning of operations and maintenance phase. Each stage in the development of a solar power project is depicted in the Figure-4.

Each phase of development involves varied activities and hence calls for a unique set of choices to be made in response to data from market analysis, simulations, and the level of risk appetite for achieving the viability of the project.

Critical information about market and business landscape is necessary to be assessed in terms of microeconomic and macroeconomic indicators like the demand-supply gap, Industry production, government policies, duties & taxes, need for investments, availability of land, energy yield assessment, availability of manpower, Right-of-way (ROW), power evacuation, equipment availability for getting a holistic perspective.

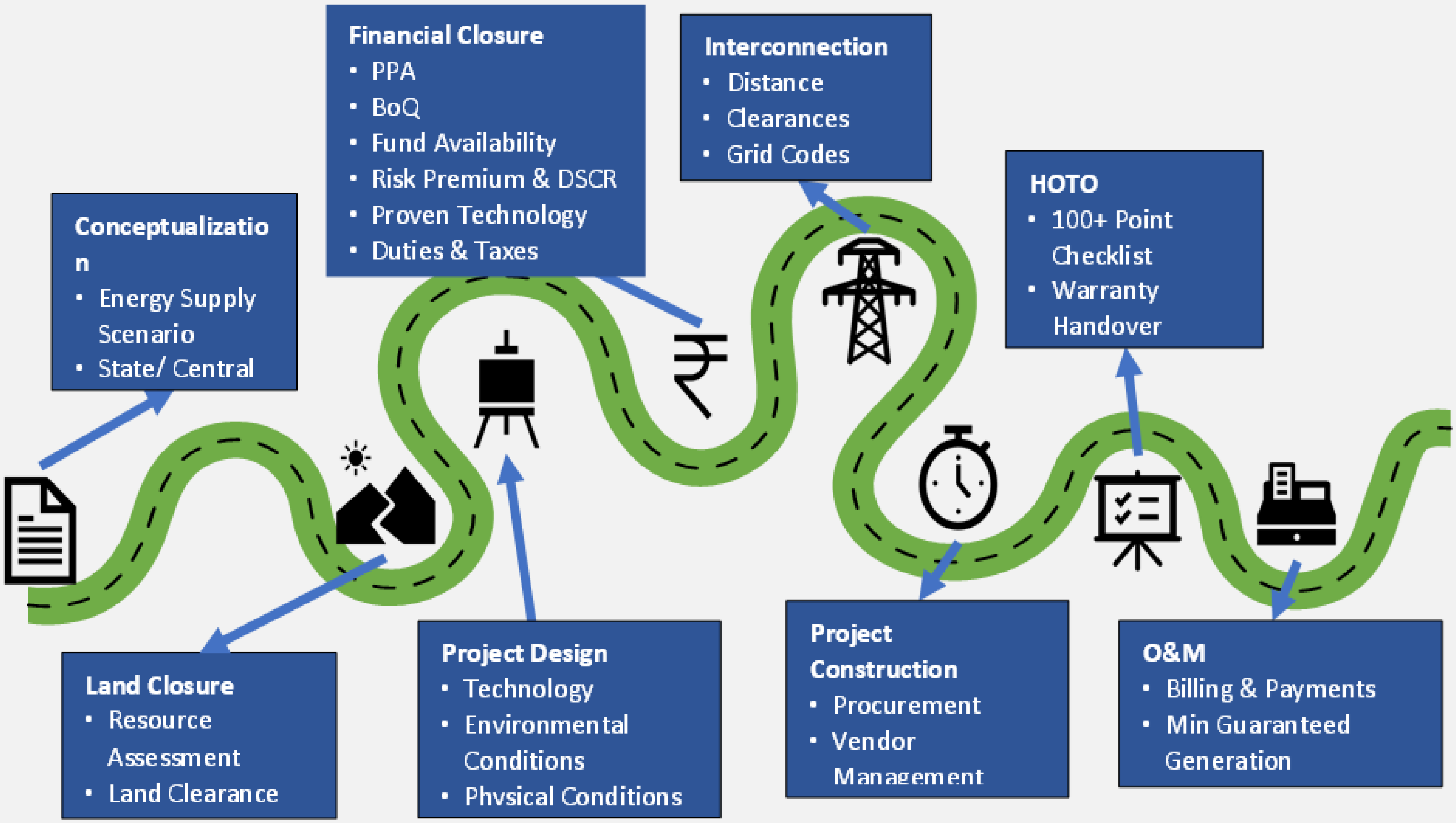

Figure 4: Stages of Solar project development

With a larger impetus from government policies, India exploited a greater solar potential by focusing on facilitating the flow of capital into the sector. As a result, India has attracted massive investments into the sector. In the early days of NSM, solar costs hovered around Rs. 17-18/ kWh. These massive investments in the sector led to develop intense competition resulting in a drastic decline in solar tariffs across the nation to as low as Rs. 1.99/ kWh (pre-BCD regime). The decline in tariffs also caused a sharp decline in return on equity, requiring developers to operate on razor-thin margins. Trends in the industry indicate that the return on equity for Solar projects is in the range of 8 to 10%, and any volatility in equipment prices or delays in the project could result in a further decline in Return on Equity, threatening the project's viability. This decline in tariffs is primarily attributable to favorable governmental impetus, technological advancement, and the achievement of the necessary economies of scale, in addition to the low demand for modules in international markets.

The construction time also plays a key role for solar power plants. It usually varies from 6 months to 18 months. Depending on the DC:AC ratio, the price of a power plant might be anywhere from Rs.3.2 crore to Rs.3.8 crore per megawatt (MW) (JMK Research & Analytics, 2021). On an average, the cost for a standard 250 MW solar power plant ranges from Rs. 800 Crore to Rs. 950 Crore in India.

Table 1: Typical Capital Cost for a Solar Power Plant of 250MW

Particular	Cost (/ MW)	% cost
Land*/ Solar Park	42 Lakhs	11
Inverters	24 - 30 Lakhs	6 - 7
MMS & Civil	67 Lakhs	18
Solar Modules (excl. BCD)	214 - 234 Lakhs	57 - 58
Pre-op, Fin & IDC	14 Lakhs	4
Miscellaneous	10 Lakhs	3
Transmission Line#	4 Lakh	1
Total	**375 - 401 Lakhs**	-

** Land is provided by the Solar Park Developer on Lease rates for the duration of the project for Solar Park based project development*

 # Transmission Line is provided Solar Park Developer in case of Solar Park based Projects. The calculations are made considering 25kms of 220kV transmission Line.

With such a substantial expenditure planned for a single solar project, any fluctuation in the price of equipment, delay in the project, or other financial factor will have a significant impact on the project's viability and investments.

Risk Categorization

The following step sometimes perceived as a part of risk identification is Risk categorization or classifying potential risks into one of several categories. Risk categorization benefits the project in a variety of ways, including supporting in the development of strategies to avoid or minimize impact. Accordingly, the following section recognizes the pressing risks in Indian solar sector.

Pressing risks confronting India's Solar Scenario

Equipment Costs

It is well known that solar modules and inverters form major equipment in the solar energy systems among others and together constitute 64-72% of the total cost of the project. Literature indicates that India has sufficient module production capacity to match current local demand (Though this is contested by IPPs during the discussion. The basic issue with local production is quality and delivery schedules), however this potential is still untapped to its full extent. In case of inverters, India was relying on domestic and international supplies but was primarily depending on Imported modules right from the inception of the National Solar Mission. The price/Wp for Solar Modules has consistently fallen over the years. Average monthly global solar module (crystalline) price fell from $2.649/Wp in 2010 to $0.192/Wp in July of 2020 (JMK Research & Analytics, 2021). This represents an approximate 23% year-on-year fall in module prices in the period. It was an inherent assumption of all stakeholders that this trend will continue. However, in the last 20 months the cost of solar modules increased by 38% from around $0.20/ Wp to $0.28/ Wp disrupting the financials of the new solar projects. The increase in module prices is attributed to supply chain disruptions, augmentation of demand and impact of Basic Customs Duty (BCD) and Approved List of Models and Manufacturers (ALMM).

The causes such as imposition of BCD and ALMM qualify under “Change in Law” and a suitable compensation can be obtained through quasi-judicial process, the other causes of increase in module prices are the business risks which the investor/ developer have to absorb.

It is observed that, parties participating in the public tenders on BOO basis, tend to quote competitively and ultimately tend to compromise on some of the equipment which is perceived as “not-so-important” to overcome the cost increase on major equipment or tend to over-look on the desired specifications, which in-turn leads to performance risk, which is deliberated in the subsequent sections.

Land Acquisition

Land availability has been a persistent problem for solar industry in India despite it being one of the largest nations. However, about land availability and other factors associated with establishing RE projects have further arisen in response to the increase in RE power production capacity goals. Agriculture is the major category of land usage in India, followed by forests and non-agricultural lands. Places further down the list include fallow and barren areas, land used for pasture and grazing, and waste land. Studies have shown that most of the places in India that get sunlight all year are wastelands. The waste land atlas of the country suggests the availability of waste lands is to tune of 5,57,665.51 sq. km. Even if 2% of the same is used for solar power plant development, the space can house up to a 750 GW of solar power plants.

But developers also tend to avoid wastelands. They think that establishing projects in wasteland boosts expenses in part owing to the hostile environment and in part due to the absence of supporting infrastructure like the transmission infrastructure etc. Despite the high transaction costs, developers are compelled to acquire land from smallholders. Nonetheless, this type of acquisition may result in additional issues, frequently in the form of socio - cultural pushback.

As on date with just over 10% of the solar power projects (out of commissioned on ground, there is a huge potential for further addition in terms of land availability. However, land acquisition proves to be a difficult and cumbersome process leading to cost and time over-runs. Since the projects needs a conducive ecosystem in place in terms of infrastructure and logistics, the projects tend to come up as near as possible to human habitats. It leads towards acquisition of land from private owners that attracts issues related to tenancy and transfer of ownership. Such an acquisition, lead to cost and time over-runs which can affect the project viability.

For example, a report claims that the developers of a 15 megawatt (MW) solar power plant in Mikir Bamuni Grant and Lalung village in Assam had to deal with backlash from the villages/farmers when a forceful land acquisition was attempted. In addition to causing a socio-cultural pushback, the land selected also posed environmental threat since the project site was said to be part of an active elephant corridor. (The Anatomy of a Solar Land Grab, 2021).

With the model of Solar Park mode of project development, the issues like Land Acquisition and Evacuation facility are addressed to large extend in addition to addressing issues involved in permits and clearances.

Fly-away sub-contractors
Cash-flow from Lenders
Delay in procurement of Imported Modules
Other Construction Risks

Equipment failure
Lack of skilled labor
Theft and vandalism
Cleaning of modules
Availability of equipment spares (for plants with more than 5 years old)
Deductibles against insurance claim
Accuracy in Scheduling
Other Operational Risks

Figure 5: Other significant risks

Permits and Clearances

In India, Governments at all levels have established well-defined policies to encourage the use of renewable energy sources. While top-level administrators and policymakers have a firm grasp of the big picture, lower-level employees have yet to catch on. This results in the delay in issuing permissions and permits for setting up a project. This is believed to result in significant time overruns threating the project's viability.

In the recent past, for instance, an invitation for the construction of power evacuation bays and transmission lines for 300 MW of solar installations in Maharashtra was issued. The bid received little participation since the bidders found it difficult to coordinate with different government departments like aviation/ environment etc. to obtain clearances. In addition to the challenge of procuring contiguous land, one of India's leading EPC companies identifies permission delays as a major obstacle that adds to the complexity of project implementation. (The Hindu, 2020)

While a lack of awareness is one factor, another is the lack of systems that can operate as a source of information where an investor can monitor status, issue escalations, and other concerns that contributes to time-overruns in obtaining project approvals.

Whilst risks associated with equipment costs, land acquisition, and obtaining approvals are considerable and are directly tied to governmental policies, Figure-4 depicts the non-policy risks that still pose a significant threat to the viability of the project.

Risk Description and Estimation

The next step in the comprehensive risk assessment process is description of risk and the estimation of risk. The method of systematically capturing and documenting the identified risks in a structured template covering a range of information about the risk is referred as risk description. While risk estimation is the process for estimating the cost of likely impact either by quantitative, semi-quantitative or qualitative approach in terms of the probability or occurrence and the possible consequences. A risk assessment matrix has been made use for the record of data and estimation n of impact and occurrence.

Risk Assessment Matrix

The risk assessment matrix was created utilizing data from qualitative research - Focus Group Discussions (FGD) with a representative sample of all parties involved. Furthermore, the matrix was supported by a thorough literature review and ASCI's in-house expertise. Thus, the risks identified as above are further classified into 9 categories as mentioned below.

1. Policy Risks
2. Financing Risks
3. Technical & Performance Risks
4. Weather Risks
5. Vendor Risks
6. Time Over-runs
7. Cost Over-runs
8. Off-take risks

The risks matrix includes information regarding a risk's potential effect, frequency of risk, severity of risk, mitigation/strategy, risk taker, enabler, stage of Action and stage of occurrence. The following chapter elaborates on the aforementioned information attributing to all associated risks within each risk category.

Policy Risks

Policy risks are the risks associated with the unexpected changes to government regulations. These policies may have the effect on changing the investment environment. Traditionally, policy risk has been managed by investors with their own internal resources like creating contingency provisions. In any case, changes in government regulations frequently qualify as a "change in law," which may affect the project's working capital management, cash management, and DSCR until the "Change in law" is adopted and the revenue mechanism against the change in law is put in place for renewed revenue prospects. The matrix below details the policy risks associated with solar projects in India:

Table 2: Policy risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Enabler	Stage of Action	Stage of Occurrence
Levying additional Duties and Taxes	(a) Increase in capital cost of project, leading to issues with cashflow management issues. (b) Delay in Regulatory recognition on "Change in Law" leads to further liquidity issues.	Sometimes	Medium	(a) Absorb (b) Mitigate	(a) Regular Representations to the Government on the market trends on the industry (b) Creating provisions under Contingency	(a) Developer (b) Lender	Union Government State Government	(a) Conceptualization (b) Financial Closure (c) EPC	(a) EPC (b) O&M
Stakeholder (Tax/ customs	(a) Delay in procurement of equipment	Sometimes	Medium	(a) Mitigate	(a) Regular interactions with the	(a) Developer (b) EPC	Union Government	(a) Conceptualization	(a) EPC (b) O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Enabler	Stage of Action	Stage of Occurrence
authorities, Discoms, SNA, Regulators, and CEA) coordination and commitment to Targets	and delivery at Site (b) Delay in recognition of Change in Law (c) Delay in Interconnection				Stakeholders on the policy matters (b) Regular Stakeholder Consultation workshops at State Government levels		State Government		
Ease of Doing Business	(a) Delay in approvals and Clearance (b) Delay in CLU (c) Delay in Project completion and commissioning	Sometimes	Medium	(a) Mitigate	(a) Detailed Due-Diligence before bidding and Signing PPA (b) Regular interaction with the stakeholders (c) Employing local personnel for liaison and seeking approvals from local government	(a) Developers (b) Consultants	State Government	(a) Conceptualization (b) Financial Closure	(a) EPC

All of the aforementioned scenarios have significant implications for ongoing projects with active PPAs and tenders. As a result, the equity fund available to developers would be negatively affected, which has a significant effect on small investors. Large investors, on the other hand, typically manage these risks using income from operational assets. In order to alleviate the cash-flow problems that developers face, the government ought to institute a system that provides for automatic redressal and the adoption of this "change in law." The enabler in these cases is essentially the 'appropriate' Government related to the aspect. However, it is advised that the Developers or Developer's associations do regular interactions with the Government mechanism for representations of impact of the same from time to time on the 'pipeline' projects.

Financing Risks

Financing risks are those associated with financing, such as financial transactions involving debt and equity that are at risk of default. There is apprehension around the possibility of monetary loss and the degree to which that loss might occur. The risks also include the lack of funding for project completion and the lack of liquidity for the successful operation of the project.

Table 3: Financing risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Fluctuation in interest rates	(a) Affects the Viability by increasing hurdle rate (b) Affects DSCR	Sometimes	High	(a) Absorb (b) Mitigate	(a) Assuming Higher inflation while preparing financial model (b) Negotiate for fixed Interest loan	Investor/ Developer	(a) Conceptualization (b) Financial Closure	O&M
Currency Exchange Fluctuations	Hamper the repayment of loans (foreign loans/ bonds)	Always	High	(a) Transfer (b) Mitigate	(a) Fixed rate hedging financial covenant (b) Abiding to PPA	Investor/ Developer	(a) Financial Closure	O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Equity and Leverage	Not sufficient equity, high leverage would worsen the DSCR and make the project not attractive to lenders	Rare	High	(a) Mitigate	(a) Mandate 100% equity spending before the first disbursement of loan	Lender	(a) Financial Closure (b) EPC	EPC
Inflation	Increased O&M costs	Always	High	(a) Absorb	(a) Assuming Higher inflation while preparing financial model (b) Negotiate for fixed Interest loan	(a) Investor/ Developer (b) Lender (c) O&M	(a) Financial Closure	(a) EPC (b) O&M

The risks, omitting 'equity and leverage,' are generally out of the control of any direct or indirect shareholder of the sector and, as such, are categorized as "uncontrollable risks" and are typical business risks that an investor must be prepared for when making assumptions and forecasts. When bidding on projects and determining the tariffs for executing the PPA, investors must be practical and partially conservative in such circumstances. Further, the investors may have inflation-linked tariffs while executing PPAs, which will risk-proof the projects for the investors as well as for the lenders/ financers.

The risk takers, primarily the lenders, will be responsible for ensuring the liquidity of committed equity and mandating the expenditure of equity prior to the first disbursement of the debt amount. Nonetheless, financiers/lenders may choose a set of pre-disbursement criteria containing the aforementioned points as a procedure for loan disbursement in order to mitigate the risks.

Technical & Performance Risks

Technical and performance risks are those related with the performance of equipment relative to the manufacturer's guaranteed technical performance. The risks include low cell efficiency, manufacturing defects, and possibly the fly-away of equipment manufacturers, resulting in the inability to fulfil contractual obligations such as warranty claims and the availability of spares.

Table 4: Technical & Performance Risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Performance of equipment	Reduction in estimated power generation	Sometimes	High	(a) Transfer (b) Mitigate	(a) Selection of best quality Modules, BoP/BoS with standards (b) Manufacturer warranty, Predefined Terms & Conditions[i] (c) Conducting Quality/ Performance investigations of major equipment before delivery (d) Appropriate Sizing (e) Use of Robotics	(a) EPC (b) O&M Vendor	Design	(a) EPC (b) O&M
Availability of spares	Reduction in estimated power generation	Rare	High	(a) Absorb (b) Mitigate	(a) Thorough market research on new technology. (b) Manufacturer	(a) Investor/ Developer	EPC	O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Manageme nt strategy	Risk Management measure	Risk taker	Stage of Actio n	Stage of Occurrenc e
					warranty, Predefined Terms & Conditions	(b) O&M Vendor		
Quality of irradiation data	Variations in power generation	Always	High	(a) Avoid (b) Mitigate	(a) Use of irradiation data from multiple sources	Investor/ Develop er	Desig n	O&M
Energy Yield Simulation	Reduction in Debt Service Coverage Ratio and Returns	Sometimes	High	(a) Avoid (b) Mitigate	(a) Consideration of conservative probability values (P90) & conservative equipment performance parameters (b) Employing a third-party consultant for undertaking Energy Yield Simulation	Investor/ Develop er	Desig n	O&M

The technical and performance risks are completely under control and can be mitigated. While procuring the equipment, the EPC contractor and the developer needs to ensure that the equipment manufacturer manufactures the equipment in an ISO or equivalent certified facilities. In addition, the developer and the EPC contract should employ personnel at manufacturing facility of major equipment like Modules or inverters during the manufacturing process or appoint a third party for the purpose of monitoring and supervising the production process.

Equipment like solar modules may be subjected to tests like (a) Flash Test Report (b) Incoming Raw Material Inspection for Adhesive, Back-sheet, EVA, Frames, Glass, Interconnect, JB, Ribbon, Sealant etc. along with (c) Calibration Certificate for testing equipment in addition to (d) EVA Gel Content Test and (e) Dynamic Load Test / Wet Leakage Test. The developers and EPC contractors may get the above tests done even if the modules are BIS certified for adequate performance of the solar modules. In addition, the balance of system (BoS) equipment like the transformer and cables (AC, DC) may be procured with better technical specifications on ohmic losses and transformation losses and the desired efficiency of the transformer should not be less than 99% at full load at 0.80 Power factor. They may also opt for factory inspection tests like insulation and winding resistance test, ratio, polarity and vector group test, BDV test, Open & Short-Circuit tests, Separate Source Voltage test & Individual Over Voltage test. The developers and EPC contractors may get the above tests done even if the equipment is BIS certified for adequate performance of the solar modules, transformers and other equipment.

It is also observed that the problem of Transformer failures is persistent. Though, the developers do-not want to go on-record, the problem of Transformer failures is persistent and often the developers tend to replace the transformers with a same specification equipment. Few of the developers often go back to the drawing board to understand the reason for frequent failures by adopting root-cause analysis approach by employing load flow studies etc. and in most of the times, the selection of transformer to match the requirement in term of Electrical-Thermal-Mechanical property of the core and winding is often ignored. It is strongly suggested to the developers to opt for best possible transformer suiting the requirement of site conditions and loading prospects. There is also a need for the Government of Technical think tanks to work on standardization of system design with a reliability centric approach. The Government and Private tenders also need to firm-up on the technical performance criteria with heavier dis-incentivization for failure in meeting the performance parameters.

The EPC contractors and the developers may also opt for additional third-party warranty against the equipment to protect against fly-away cases of equipment manufacturers. To protect against potential risks during Energy Yield Assessment and Irradiation data, it is suggested that the developers and EPC contractors use multiple irradiation databases with most conservative numbers on equipment performance with a probability of at-least 90%. Having a third-party report on Energy Yield assessment is a way of covering the risks from a lender’s point of view.

Weather Risks

Weather risks are the risks associated with elements like natural calamities, pollution etc. on the solar power plants. The risks like Sand-storms, soiling loss due to pollutants, Lightning strike, Flood, Cyclones etc. Though the risks are not in control but can be well managed and mitigated by way of addressing the possibilities during the design stage and operations stage. While the risks like lightening, floods etc. are possible throughout the lifecycle of the power plant and the same may become more uncertain owing to climate change, they can be managed by way of incorporating the mitigation mechanisms during the design stage. The occurrence of soiling losses due to pollutants and sand storms needs to be addressed during the O&M stage.

Table 5: Weather risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Sand storm/ Dune movement	Reduction in estimated power generation	Always (in desert region)	High	(a) Mitigate	Ensure Proper cleaning equipment and manpower in place	Developer	(a) Land Acquisition (b) Design (c) O&M	O&M
		Rare (in other regions)	High	(a) Mitigate	Site selection and predictive analysis			
Lightning Strike	Damage of equipment	Rare	High	(a) Avoid (b) Mitigate	(a) Use of adequate (b) Lightening Arrestors	Developer	Design	(a) EPC (b) O&M
Heavy wind conditions	Damage of equipment	Rare	High	(a) Avoid (b) Mitigate	(a) Use of adequate motor strength during piling (b) Use of adequate thickness of Module Mounting Structure and Bolts (c) Having Adequate insurance	EPC	(a) Land acquisition, (b) Design	(a) EPC (b) O&M
Extreme temperatures	Reduction in estimated power generation	Sometimes	Medium	(a) Mitigate	(a) Selection of Equipment with maximum temperature range (b) While preparing the specs the exothermic/ endothermic behavior of	EPC	Design	O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
					aluminum/copper should be considered.			
Flood	Damage of equipment including Cables	Rare	Medium	(a) Avoid (b) Mitigate	(a) Avoiding Low-lying Area (b) Having adequate Drainage system	EPC	(a) Land acquisition (b) Design	(a) EPC (b) O&M
Earthquake	Damage of equipment	Rare (never)	High	(a) Avoid (b) Mitigate	(a) Selection of site in Low Seismic area (b) Performing Geo-technical studies in areas without readily available Seismic data	Developer	Land acquisition, Design	EPC, O&M
Soiling loss	(a) Reduction in estimated power generation (b) Increased O&M costs	Always	Medium	(a) Mitigate	Provision of advanced cleaning equipment	O&M	(a) O&M (b) Design	O&M

Having adequate drainage system, adequate gauging of Module mounting structures & pile strength, placing adequate lightening arrestors, procuring the systems with long range temperatures during the design stage can address the risks. The risks like sand storms and soiling loss due to pollutants can be addressed by way of employing adequate module cleaning systems. Pneumatic module cleaning systems serve better in the desert regions and industrial areas where the possibilities of soiling loss due to pollutants is high.

Vendor Risks

Vendor and supplier risks are among the most typical project risks. According to Porter's five forces, this is one of the key dangers that might affect any project. The dangers can be minimised by increasing the number of available vendors and suppliers. If there are fewer suppliers in an industry, a project will be increasingly dependent on a single supplier, which may result in increased prices and a push for other trade advantages. The solar industry benefits from a plethora of vendors and minimal switching costs, which drives down prices. In the case of India, the developers' reliance on imported solar equipment, particularly solar modules, makes the country's solar ambitions vulnerable to geopolitical issues, leading the government to opt for a "Approved list of module manufacturers" (ALMM). In the initial days of ALMM notification, domestic module prices increased by 3 to 4 cents, which impacted project returns and caused delays in project completion due to demand for the limited supply of modules.

Table 6: Vendor risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Financial strength of manufacturer	(a) Adherence to Delivery Schedules and Quality (b) Settlement against Warranty Claims (c) Loss of payment of Advance	Sometimes	Medium	(a) Transfer (b) Mitigate	(a) Due-Diligence on the Manufacturers and Vendors (b) Having Alternative Arrangements (c) Making payments in the form of LC/ Escrow account	(a) Developer (b) EPC	EPC	(a) EPC (b) O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Market Monopolization	(a) Over-pricing (b) Market Abuse (c) Cartelization	Sometimes	High	(a) Avoid (b) Mitigate	(a) Policy level changes to support and encourage small players in the industry; (b) Ensure perfect competition and diligence against cartelization.	(a) Investor/ Developer (b) EPC	(a) Conceptualization (b) Design (c) EPC	(a) EPC

Developers and EPC contractors must proceed cautiously while selecting vendors and suppliers. A catalogue of vendors and providers for equipment, installation, and civil works is essential. While major developers choose for their own EPCs and have standard operating procedures in place for the empanelment and selection of vendors and suppliers, small developers may hire experienced EPC contractors to avoid the risks. The Government and the Competition Commission may also monitor the markets closely to check and halt any possibility of market cartelization and monopolization.

Cost Over-run Risks

Cost Over-run risks are the risks associated with increase in cost of the equipment and allied services. With increase in competition and falling tariffs, the sensitivity of solar projects' viability to cost have increased manifold. Any slight variation in high-cost equipment can result in reduction in returns and thus affecting the viability of the project. The cost of equipment in solar power projects are highly sensitive to geo-political issues owing to high reliance on import of raw materials even if the solar modules as a finished product is procured domestically. The capital cost increase can also be the resultant of policy decisions of the government. Increase in cost of modules after the notification of ALMM is one such example.

The cost over-runs can also occur at the time of civil works when the EPC contractor finds a localized rock at the time of piling or cable trenching, which increases the cost of civil works and installation works. Such issues may result in utilization of heavy earth moving machines or complete change in AC and DC wiring and sometimes the string arrangements which may result in increase in the requirement of AC and DC cables, which may result in increase in cost of works.

Table 7: Cost Over-run risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
CAPEX	Increase in project cost leading to affect the viability of project	Sometimes	High	(a) Transfer (b) Mitigate	(a) Thorough market research (b) Creatin adequate contingency fund before commencement of construction activities. (c) Additional fund allotment by Lender	(a) Lender (b) EPC	Conceptualization	(a) Financial closure (b) EPC
Fixed expense	Affects the cashflow	Sometimes	High	(a) Avoid (b) Mitigate	(a) Creating adequate contingency fund before commencement of construction activities. (b) Working at better DSCR ratio to absorb the increase in expenses	(a) Lender (b) EPC	(a) Financial closure (b) EPC	O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Variable expenses	Affects the cashflow	Always	High	(a) Transfer (b) Mitigate	(a) Thorough market research; (b) Awareness and Consideration of site realities (c) Employing O&M vendor	(a) Lender (b) EPC	Financial closure	O&M

The cost over-runs issues can be addressed only by way of better bargaining power and creating adequate contingency provisions while preparing the financial model. The risks related to cost over-runs are inevitable. The cost over runs during the equipment procurement can be addressed by way of employing multiple equipment suppliers and order quantity which can assist in advantage by way of gaining bargaining power. The cost over-runs against the civil and Installation works can be minimized by way of better geo-technical studies. The industry standards for geo-technical studies suggest 1 sample for every 1 MW of work. However, better practices by some of the developers suggest the sample count of 1 Nos. for every 2 acres of land.

On the other hand, the increase in operating expenses against Manpower, water etc. can be mitigated by way of employing an O&M contractor on fixed cost basis with a mandatory clause of achieving the desired Plant availability factor along with the clauses on itemized losses.

Time Over-run Risks

Time Over-run risks are the risks associated with the delay in project time-lines from concept to commissioning. The delay in project implementation can start from as initially from acquisition of land, financial closure & failure in compliance to pre-disbursement conditions set-up by the financers/ lenders and can go as the project construction happens like that of delay in delivery of equipment to delay in civil & installation works. The project delay can also happen after the synchronization of the project and before commissioning owing to reasons of failure in meeting desired power input to grid. In addition, based on the availability of man-power and seasonal demand may also result in increase of cost of civil works and installation works As the labour force is frequently comprised of migrant workers who will return home during the sowing and harvesting seasons, there may be a shortage of labour. This may result in cost and time overruns (increased interest during construction).

Table 8: Time Over-run risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Land acquisition	(a) Delay in Pre-construction works (b) Delay in Civil Works (c) Delay in Transmission Line	Always	High	(a) Transfer (b) Absorb (c) Mitigate	(a) Employment of Land Aggregators (b) Signing & Registering of Land Sale Agreement before the pre-construction activities	(a) Developer	(a) Conceptualization (b) Land Acquisition	EPC
Equipment Supply Delays	(a) Increase in Interest during construction (b) Non-compliance of PPA	Sometimes	Medium	(a) Transfer (b) Absorb	(a) Issuing Purchase Orders at the earliest (b) Selection of sound and efficient EPC contractor/ Module Supplier (b) Arrangement for Module Supply from Multiple Sources/ Vendors	(a) Developer (b) EPC	(a) Design (b) EPC	EPC

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
Transportation Delay	(a) Increase in Interest during construction (b) Non-compliance of PPA	Sometimes	medium	(a) Transfer (b) Absorb	(a) Selection of sound and efficient EPC contractor/ Module Supplier (b) Good Understanding on alternative transport routes (c) Tie-up with multiple transportation partners	(a) Developer (b) EPC	EPC	EPC
Completion delay/ non-completion	(a) Increase in Interest during construction (b) Non-compliance of PPA	Rare/ Almost never	High	(a) Transfer (b) Absorb (c) Mitigate	(a) Selection of sound and efficient EPC contractor/ Module Supplier (b) Daily tracking of work (c) Appointing a PMC (d) Having back-stop arrangement	(a) Developer (b) EPC (c) Consultant	EPC	EPC
Fly away Sub-contractors	(a) Increase in Interest during construction (b) Non-	Sometimes	Low	(a) Transfer	(a) Selection of sound and efficient EPC contractor/ Module Supplier (b) Having back-	EPC	EPC	EPC

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
	compliance of PPA				stop arrangement			
Right of Way	Delay in Transmission Line construction	Always	Medium	(a) Transfer (b) Absorb	(a) Pre-marking the route before the acquisition of land (b) Choosing the lines along the road side	(a) Developer (b) EPC	(a) Design (b) EPC	EPC
Evacuation Infrastructure	(a) Delay in Off-take (b) Increase in Cost of project (c) Congestion in further planning & development in the area	Sometimes	Medium	(a) Transfer (b) Absorb	(a) Opting of Solar Parks for setting up Solar Power Plants (b) Diligent Project Management to complete the Transmission Line at-least before 1 months of scheduled synchronization of plant	(a) Developer (b) EPC	(a) Conceptualization (b) Land Acquisition	EPC

The time over-run risks can be mitigated through adoption of measures like micro-Gantt chart for each activity involved. The micro-Gantt chart should even include activities as small as placing a purchase order for appointment of agencies for geo-technical studies to placing an order for purchase of nut & bolts. The purchase orders need to be made well in advance to avoid possible delays in delivery of supply. In addition, it is also advised to have complete details on flow of information and logistics to avoid any issues with respect to excise (now CENVAT) and other clearances (though streamlined). The Gantt charts of subcontractors must also be synchronized with the master Gantt plan to prevent schedule disruptions.

In addition, the elements like the risk of fly-away sub-contractors can mitigated by way of structured payments and to have a pool of sub-contractors with minimum switch time. Also, breaking up the tasks and appointing multiple sub-contractors will also facilitate mitigating the risk. The risks pertaining to availability of manpower can be mitigated by way of employing local manpower for un-skilled and semi-skilled works.

The risks related to land acquisition can only be mitigated by way of acquiring the land along with all the legal processes and the fund transfer, before the commencement of pre-construction works. The risk on Right of Way can be mitigated by Pre-marking the route before the acquisition of land and choosing the transmission line path along the road side. In case of utilization of private land, the Right of way can be attained by way of community engagement & involvement of local government.

Off-Take Risks

Off-take risks are the risks associated with the events resulting in poor enforcement of contracts, which may affect the bankability and viability of the project. The risks are categorized from medium to high and need a conservative and traditional approach in mitigating them. In case of private PPAs, the financial condition of the buyers is very important while signing the PPAs failing which the projects end up being bankrupt. In case of Government The recent events in states like Gujarat, Uttar Pradesh where the states' delaying the signing of PPAs and the events in Andhra Pradesh and Punjab where the states are working towards renegotiation of tariffs, poses serious risks to the developers. The cases where the PPAs are not signed in time will lead to freezing of funds along with the possible increase in price of goods and services in the capex stage, which will eventually result in bankability of the projects. The cases where the tariffs are reneged and renegotiated will result in affecting the viability of the projects.

Such risks are often taken by the developers and investors with an expectation of making higher returns. However, if the risks are not properly calibrated may result in projects flagging bankruptcy.

Table 9: Off-take risk matrix

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
PPA Tenure	(a) Higher Debt repayment pressure (b) Pressure to recover costs within the tenure leading to increase in per unit cost	Sometimes (in Private PPA)	Medium	(a) Absorb (b) Mitigate	Negotiated PPA	(a) Investor (b) Lender	PPA	(a) PPA (b) Financial Closure
Financial strength of purchaser	Effects the cashflow	Sometimes	High	(a) Absorb	Payment Security Mechanism through Revolving LC or Escrow Account	(a) Investor (b) Lender	(a) PPA (b) Financial Closure	O&M
Evacuation of Power	Impacts the Billing and Power flow	Sometimes	High	(a) Absorb (b) Mitigate	Better Due-diligence of Sub-station capacity. Understanding the Harmonics and Voltage fluctuations of the sub-station.	(a) Investor (b) Lender	(a) Design (b) EPC	O&M
Enforcement of contracts	Delay in signing PPAs after issuing LoAs, Cancellation	Sometimes	High	(a) Mitigate	Strong and quick legal support	(a) Investor (b) Lender	O&M	O&M

Risk	Potential Effect	Frequency of risk	Severity of Risk	Risk Management strategy	Risk Management measure	Risk taker	Stage of Action	Stage of Occurrence
	of PPA, non-payment of invoices							

The off-take risks can be mitigated by way of making calculated decisions with respect to financial strength and credit worthiness of the power purchaser. The equity needs to be put in only after executing all the required agreements.

Prioritization of Risks

The risk matrix, developed from the insights of sector players and experts, elaborated the potential risks associated with the stages of solar project along with suitable mitigation measures to adapt in a precise manner. However, the following section presents the results of AHP process utilized to prioritize the risks based on the experienced opinion of a panel consisting of academicians, sector experts and Govt. officials. Since each risk has its role to play in maintaining the project viability, no risk can be ignored or discarded. Hence it is extremely essential to prioritize the risk so that primary emphasis on such risks can be done to prevent it.

The survey was carried out through the conduct of telephonic as well as in person interviews. The risks as mentioned in the above matrix were categorized into 8 different categories namely Technical & performance, Weather risks, Time overruns, Off-taker risks, Cost overruns, Financing risks, Policy risks and Vendor & supplier risks. The survey through AHP model, does the pair wise comparison of each different risk with the rest. AHP uses the rating scale of 1-9 (Saaty, 1980). The table below elaborates the rating scale.

Table 10: AHP Rating Scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, it dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8 can be used to express intermediate values		

On the whole the survey was conducted with an expert panel of 20 members and results are as follows: Among the 8 risks categorized, the panel has prioritized the risk of policy inconsistency to be highest with 22.7% severity, followed by off-taker (17.3%), technical & performance (14.7), financing (11.6%), cost overruns (10.7%) and the rest. A The detailed percentage chart of risk prioritization is presented below.

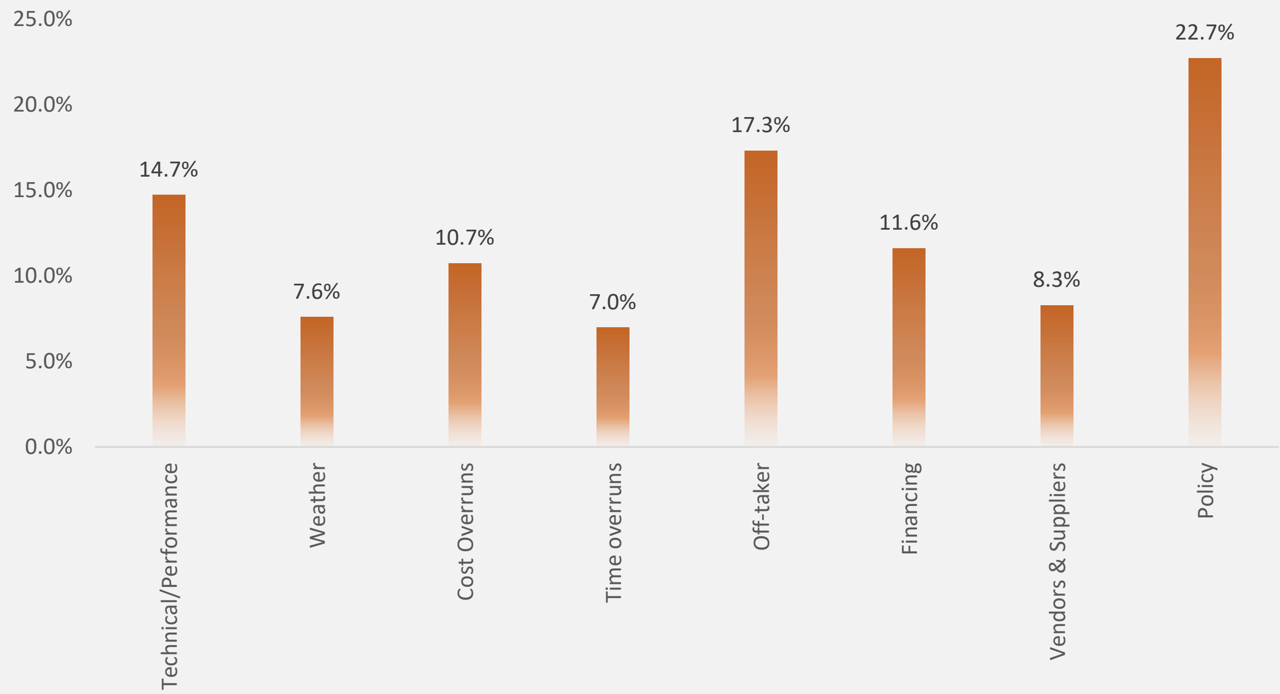

Figure 6: AHP - Risk Priority chart

Observations

The AHP results as shown, revealed that the risks Policy, off taker and technical performance as critical. Since the policy risks and off-taker risks are perceived beyond the scope of solar stakeholders as they are commonly managed by adapting strategy of mitigating through governmental interventions, it is important for the solar players to focus on efficiently managing technical and performance risks to ensure viability. The management strategy of such risks usually involves in transferring the risk to EPC contractors and ultimately to manufacturers in general.

The developers majorly rely on EPC contractors for procurement of equipment & design and hence an EPC contractor must exercise a due diligence in equipment procurement and project design. Apart from the selection of major equipment like Solar PV Modules and Inverters, whose performance parameters are constantly evolving, the other BoP equipment like Transformers and cables also needs to be procured diligently.

The stakeholder discussions too explicitly inferred the same. The procurement of PV modules and Inverters are mostly off-the-shelf based on the cost and delivery schedules (subjected to factory inspection tests before the delivery), the Transformers and Cables need more prudent deliberations particularly on the performance standards & specifications. In selection of such equipment, a developer expects an EPC contractor to ensure on parameters like higher durability, economic viability, higher energy performance that consequently lessen the lifecycle costs. The produce of such equipment requires the EPC/manufacturer to opt for better quality of raw materials including the consciousness of metallurgy of wires.

Accordingly, in particular to transformers, the stakeholders usually are understood to consider the following vital specifications while procurement:

1. Winding conductor should be electrolytic grade copper, free from scales and burrs.
2. Windings shall be subjected to shrinkage treatment
3. Winding assembly should be full vacuum dried and then impregnated immediately in transformer oil.
4. Transformer shall be suitable for operation with the non-sinusoidal current wave shapes and DC components under normal and abnormal conditions of the system without exceeding the temperature.

It is strongly suggested to the developers to opt for best possible transformer suiting the requirement of site conditions and loading prospects in terms of electrical-thermal-mechanical-Chemical property of elements used in transformers, cables etc.

It is understood that if the selection of equipment is based on standard specifications, that are usually outcomes of usage of efficient raw materials & elements, the results are often effective even if EPC contractors and the developers opt for different factory inspection tests. Different factory inspection tests include insulation resistance test, winding resistance test, ration-polarity and vector group test, BDV test, Open-Circuit tests, short-circuit tests, Separate Source Voltage test & Individual Over Voltage test.

Additionally, the procurers may also opt for compliance of European Standards (EN50618) in addition to the prescribed BIS. This standard requires cables to be able to operate at 1,500 V and specify that the DC cables to be low smoke, halogen free and have cross linked insulation & sheath and flexible on the whole. It is implacable from the EN standards that it effectively mandates the use of copper cables that are relatively less prone to failure, no galvanic action, more ductile, high short-circuit withstand capability, less susceptible to metal fatigue and also less expensive in comparison to aluminum that is by virtue a relatively a rigid metal. Indian standards too (IEC 62930) prescribe the parameters of halogen free compound, flame retardant properties of the cable, etc. Thus, as mentioned above, the metallurgy of elements used in manufacturing significantly affect the performance of equipment that in-turn affect the project viability.

On the whole, this whitepaper recognizes selection of better quality and tested equipment manufactured with reliable materials as mentioned above to be key in managing the technical and performance risks the risks which are proven to be managed if an EPCs exercise a level of caution before procurement). Moreover, the cost of BoP excluding the Inverter ranges around 8% of the total project cost. An increase in cost of BoP equipment even by 5% or 10% will result in increase of project cost only by less than 1%. However, equipment with better specifications will certainly be more beneficial in project lifecycle in terms of plant uptime and plant energy generation.

It is also observed that, few of the developers who intend to close the shops by selling the power plants under various transactions under M&As, often make procurement decisions based on capital cost instead of life-cycle cost. This approach in procurement of equipment often results in higher technical & performance risks, which can be mitigated by way of standardization system design with reliability centric life-cycle cost approach.

Conclusion

India is currently placed at a position of becoming a global leader in Solar energy generation by virtue of effective targets, policies, and environment in addition to the favorable irradiation levels. At this stage focusing merely on capacity addition alone may not prove sustainable in long run. Focus should be drawn to energy generation by way of encouraging the produce and use of better equipment. Aiming to serve this and be a go-to resource for stakeholders of the solar sector, this whitepaper deliberated on the risk mitigation measures by considering every last aspect, from materials used in equipment to policy decisions made at the national level.

It is opined that the responsibility also lies with the industry to be diligent in procuring standard equipment even for the Balance of Plant (BoP) to ensure the intended energy generation and thus maintaining project viability. As a final statement, this white paper suggests a few Action points for the Government-Technical think tanks-Developers community to come together to adopt the following:

(a) Standardization of System Design with Reliability Centric Approach especially for Balance of System equipment like Transformers, Inverters, DC & AC cables etc.

(b) Solar power procurement tenders to insist of technical performance of the plants in terms of kWh and heavier disincentivizing/ penalizing for not meeting the performance parameters.

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[i] Specifications considered while procuring AC and DC cables are as below

1. Conductors shall be electrolytic grade high conductivity annealed tinned copper and shall be multi-stranded, smooth, uniform in quality and free from scale and other defects.
2. Electrical (for DC main power cables)
    a. Nominal voltage according to VDE Uo/U 600/1000V AC or DC 900/1500V.
    b. Max. Permissible operating voltage DC 1800V (conductor/conductor, Un-earthed system).
    c. DC test voltage 10000 V/ AC 6500V.
3. Mechanical (for DC main power cables)
    a. Very robust and abrasion-resistant sheath acc. to DIN EN 53516.
    b. Minimum bending radius: 5 x cable diameter.
    c. Safe pulling force -50 N /sq.mm.
4. Chemical (for DC main power cables)
    a. Ozone resistant acc. to EN 50396.
    b. Weather and UV resistant acc. to HD 605/A1.
    c. Halogen-free acc. to EN 50267-2-1, EN 60684-2.
    d. Resistant to acid and bases acc. To EN 60811-2-1.
5. Thermal (for DC main power cables)
    a. The cables shall be designed for a nominal DC voltage of 0.9 / 1.8kV with an operating temperature range of 2°C to 90°C