HANDBOOK

Ministry of Industry and Trade
Hợp tác Đức
DEUTSCHE ZUSAMMENARBEIT
EUROPEAN UNION

MANAGING TECHNICAL AND OPERATIONAL RISKS OF GROUND-MOUNTED SOLAR PV PROJECTS IN VIET NAM

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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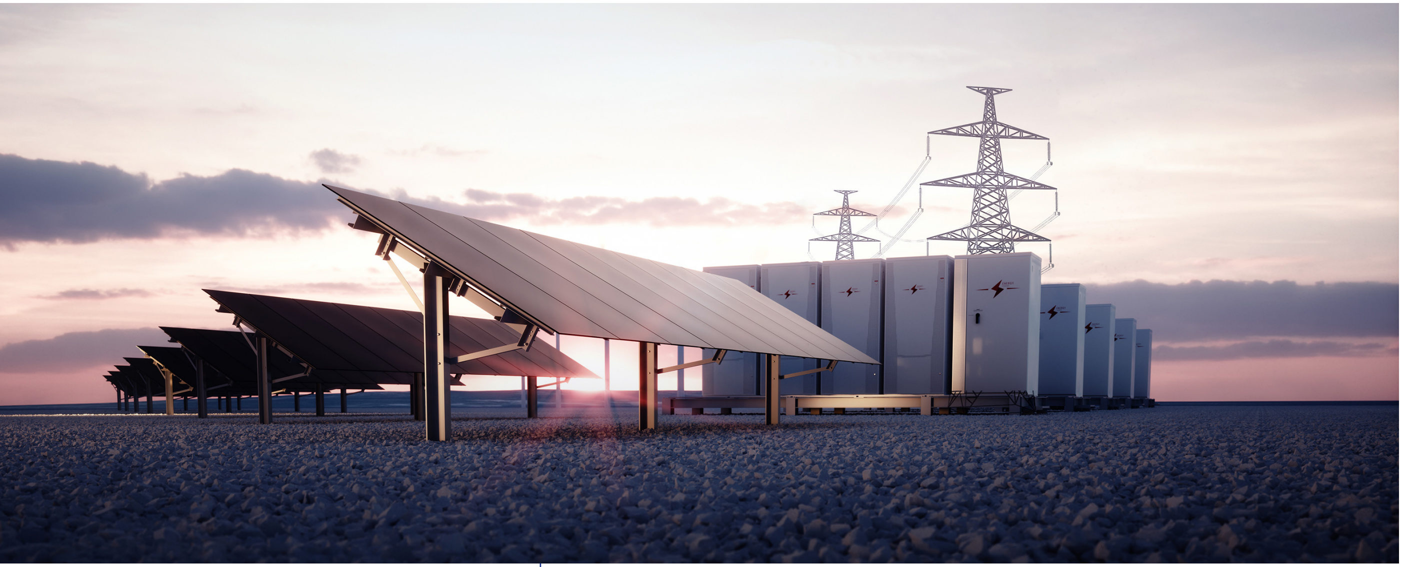

FOREWORD

Over the past few years, the Government of Viet Nam has strived to utilise the big potential of renewable energy (RE) in the country to meet future energy challenges. Numerous important legislation and policies have been introduced, such as RE targets in Resolution 55 on Viet Nam's strategic orientations for energy development to 2030, with the vision to 2045, feed-in-tariffs for wind and solar power, and other non-tariff incentives, such as tax exemptions, etc. This policy framework sets the foundation for increased private participation in the RE sector. Despite the quick and strong development of renewable energy in Vietnam, the technical standards and risk mitigation strategies for the power plants, particularly the grid-connected solar PV projects, are very limited. The project developers or consultants are now making great efforts in understanding and applying both international and national regulations and experiences when available. This leads to different use of standards and procedures in different projects, lack of common references to minimize risks before and during the project operation time.

Since 2008 and on behalf of the German Government, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been providing technical support to the Ministry of Industry and Trade (MOIT) for the development of renewable energy and energy efficiency in Viet Nam, via the Energy Support Programme (ESP). The development of a Handbook for managing technical and operational risks of ground-mounted solar PV projects under the EU-Viet Nam Energy Facility (a project co-financed by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ) and jointly implemented by the MOIT/Electricity and Renewable Energy Authority (EREA) and GIZ, since December 2017) is therefore expected to provide practical references for project owners, developers, financiers and contractors that are currently developing and/or operating ground-mounted solar PV projects in Viet Nam. GIZ believes and hopes that the Handbook will help strengthen the link between advances in knowledge and improved practices for high-stakes decision-making and action by public and private managers/leaders, contribute more efficiently and effectively to the development of the solar energy market, and continuously contribute to the climate resilience of the energy sector in Viet Nam.

Sincerely,

Sven Ernedal,
Project Director
EU - Viet Nam Energy Facility

ACKNOWLEDGEMENTS

This Handbook was developed by GIZ under the EU-Viet Nam Energy Facility, implemented as part of the Renewable Energy and Energy Efficiency (4E Project) – Phase II under the supervision of Mr. Pham Quang Anh, GIZ Project Officer.

Firstly, we thank the main authors of this Handbook, Artelia Viet Nam and Ilka Buss (IB Consulting), as the international consultants, for their engagement to develop a clear set of most common and critical technical risks for solar PV projects, and to investigate the local dimension and importance of these risks, and Power Engineering Consulting Joint Stock Company 3, as the local consultant, for their guidance and support in the field trips to Ninh Thuan and Binh Thuan.

During the development of this Handbook, a number of experts and project developers and investors were consulted and contributed to their knowhow. Furthermore, in October 2021, a consultation workshop and expert review were conducted on an advanced draft of the Handbook by representatives from key stakeholder groups of the Solar PV sector in Viet Nam. The aim of the stakeholder consultation was to validate the usefulness of the Handbook, as well as to collect additional expert contributions to further improve the quality, precision and local added value of the Handbook. We would like to thank the following organisations for their valuable comments and inputs:

- Department of Industry and Trade, Bình Thuận province
- Department of Industry and Trade, Ninh Thuận province
- Power Engineering Consulting Joint Stock Company 3
- Mũi Né Solar Farm
- Hồng Phong 4 Solar Farm
- Phong Phú Solar Farm
- Đa Mi Floating Solar Farm
- Mỹ Sơn-HLV Solar Farm
- Gelex NT Solar Farm.
- Vu Phong Energy Group
- SkyX Solar Joint-stock Company
- Hero Future Energies Company

Finally, we would like to express a special thanks to the New and Renewable Energy Department, Electricity and Renewable Energy Authority (Ministry of Industry and Trade), and colleagues in GIZ who contributed to the development and finalisation of these guidelines with their valuable coordination and support.

DISCLAIMER

The EU - Viet Nam Energy Facility Project (EVEF) is co-financed by the European Union (EU) and the German Federal Ministry for Economic Cooperation and Development (BMZ). This Handbook was produced under EVEF, and its content is the sole responsibility of the consultants and does not in any way reflect the views of the EU and BMZ or the EVEF.

Users of the Handbook should not rely on the content as an alternative to legal, technical, financial, taxation and/or accountancy advice. The authors or publishers will therefore not be held liable regarding any business losses, including without limitation loss of or damage to profits, income, revenue, production, anticipated savings, contracts, commercial opportunities, or goodwill.

Anybody using this Handbook is highly encouraged to provide feedback to GIZ on any legal or regulatory changes they may be aware of, as well as the application and interpretation of them. Feedback on the general usefulness of this Handbook would be much appreciated as well, in order to further improve future versions.

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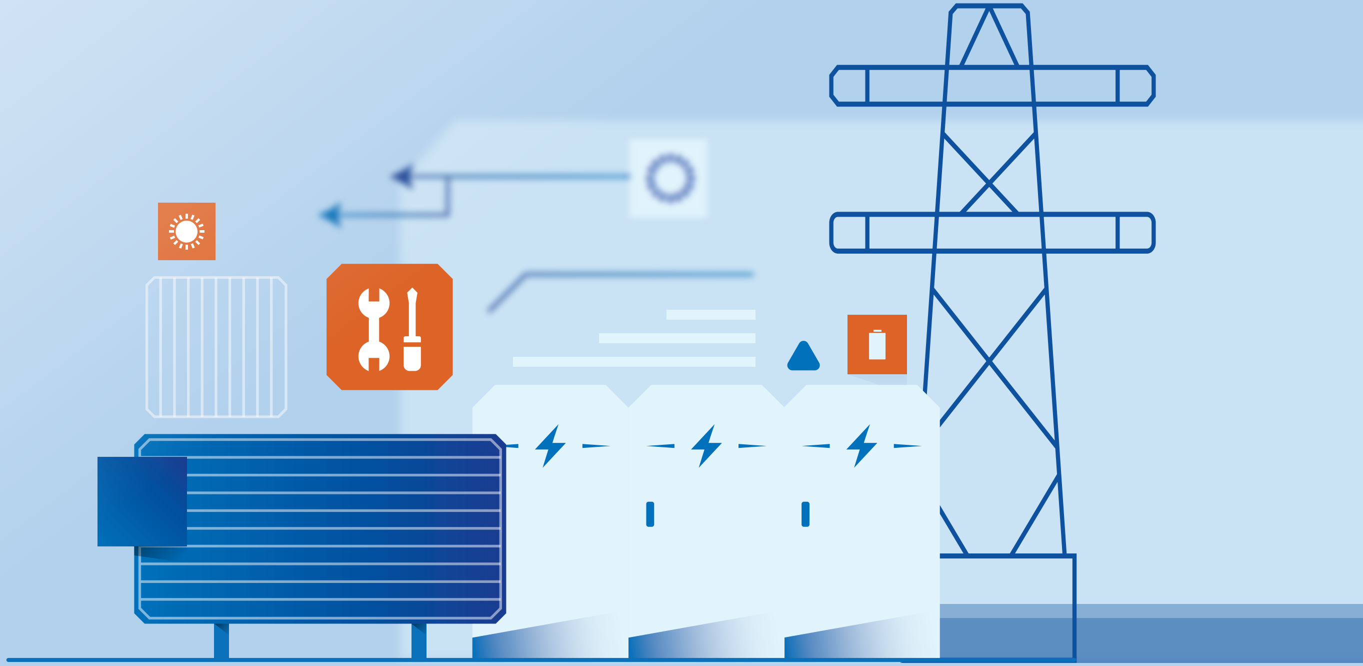

FIGURES

TABLES

ACRONYMS

AC	Alternating Current
BMZ	Bundesministerium für Zusammenarbeit / German Federal Ministry for Economic Cooperation and Development
CAPEX	Capital Expenditures
CCTV	Closed-circuit Television
CMMS	Computarised Maintenance Management System
COD	Commercial Operation Date
DC	Direct Current
E&S	Environmental and Social
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EPC	Engineering, Procurement and Construction
EPP	Environmental Protection Plan
ESP	Energy Support Programme
EU	European Union
EUR	Euro
EVEF	EU-Viet Nam Energy Facility
EVN	Electricity of Viet Nam
FIFO	First-in-first-out
FS	Feasibility Study
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GW	Gigawatt
H&S	Health and Safety
HCMC	Ho Chi Minh City
HSE	Health, Safety and Environment
HV	High Voltage
IAM	Incidence Angle Modifier
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IT	Information Technology
KPI	Key Performance Indicator
KW	Kilowatt
LID	Light Induced Degradation
LOTO	Log-out-tag-out
MOIT	Ministry of Industry and Trade, Viet Nam
MP	Management Plan
MMS	Module Mounting Structure
MW	Megawatt
O&M	Operation and Maintenance
OPEX	Operational Expenditures
PPE	Personal Protective Equipment
PHC	Prestressed High-strength Concrete pipe
PID	Potential Induced Degradation
PM	Prime Minister
PR	Performance Ratio
PV	Photovoltaic
RE	Renewable Energy
SCADA	Supervisory Control and Data Acquisition
UV	Ultraviolet
VND	Vietnamese Dong

01

RATIONALE

Viet Nam is on a steady and strong path of economic growth and has seen an increase in electricity demand of over 10% between 2016-2020. Renewable Energy (RE) and, in particular solar PV, are playing an increasingly important role in meeting current and future demand for electricity as Viet Nam has initiated a transition from an unsustainable and increasingly costly fossil-fuel based energy system, towards a more diverse system that integrates more and more RE into the energy mix.

In early 2019, the Government passed two decisions, which made important revisions to the legal framework for solar projects: 1) Amending and Supplementing PM Decision 11/2017/QD-TTg on the Mechanism for Encouragement of the Development of Solar Power Projects in Viet Nam (PM Decision 02/2019/QĐ-TTg dated 08/01/2019) and 2) Amending and Supplementing Circular 16/2017/TT-BCT guiding Project Development and the Standardized Power Purchase Agreement to be Applied for Solar Power Projects (MOIT Circular 05/2019/TT-BCT dated 11/03/2019). These revisions resulted in a boom of solar projects being commissioned and by 30 June 2019, 4.4 GW of additional solar PV power had been connected to the grid.

In 2020, the GoV passed PM Decision 13/2020/QĐ-TTg on Mechanisms to Promote the Development of Solar Power Projects in Viet Nam (dated 06 April 2020), which mainly focuses on stipulating the FIT for ground mounted (7.09 US cent/kWh (equivalent to 1,644 VND)), floating (7.69 US cent (equivalent to 1,783 VND)) and rooftop solar (8.38 US cent/kWh (equivalent to 1,943 VND)) projects. In addition, MOIT Circular 18/2020/TT-BCT Stipulating Project Development and Standardized Power Purchasing Agreements for Solar Power Projects (Dated on 17 July 2020) not only revises the regulatory framework of PPA for solar power but also has provisions to stimulate investment in grid-connected solar power. This led to a new wave of investments in Solar PV installations, which exceeded all expectations: **by the end of 2020, ground-mounted solar reached a total of nearly 9,000MWp of installed capacity.**

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These developments constitute a great success to RE development in Viet Nam and contribute to the country's transition towards a more sustainable energy system. However, there are also challenges to grid-connected solar PV capacity that need to be curtailed to maintain the confidence in this growing market.

At macro level, the most important risk is related to the limited ability of parts of the existing grid network to absorb large amounts of variable RE. Most of the ground mounted solar and wind energy projects are concentrated in the Central and Southern regions. While this contributes to reducing the energy shortage in the Southern region, especially in HCMC, the operation of the national power grid system is facing new challenges, as the proportion of variable renewable energy increases within the energy mix.

At the project level, the fact that **Viet Nam has moved from having not one single grid-connected project in 2017 to nearly 9 GWp in only 4 years** also has its challenges. For instance, the **lack of experienced workforce** with specialised knowledge in solar PV design, installation, operation and maintenance paired with a **lack of standards and quality control mechanisms,** inevitably **increases the risk of technical mistakes or malfunctions during operations.** This can lead to projects unnecessarily experiencing damages and downtimes, **negatively affecting their return on investment and overall profitability.**

02

OBJECTIVE AND TARGET READERS

The **Objective of this Handbook** is, therefore, to **capture the most common technical and operational risks that Solar PV Projects face in Viet Nam** and around the world, to help project developers and owners to **better plan for these risks** and to define sound risk management measures that **eliminate or mitigate them.**

As a large number of projects are already operational in Viet Nam, the Handbook will also include specific recommendations for project owners on how to address risks if they have not been considered from the project onset or on how to manage the impacts if the risks already materialised.

The **target readers** of the Handbook are, therefore:

- **Project developers and contractors** involved in Solar PV projects in Viet Nam that would like to improve their approach to managing technical and operational risks throughout the project development process.
- **Owners and operators** of solar PV power plants that would like to improve the risk profile of their already existing operations.

03

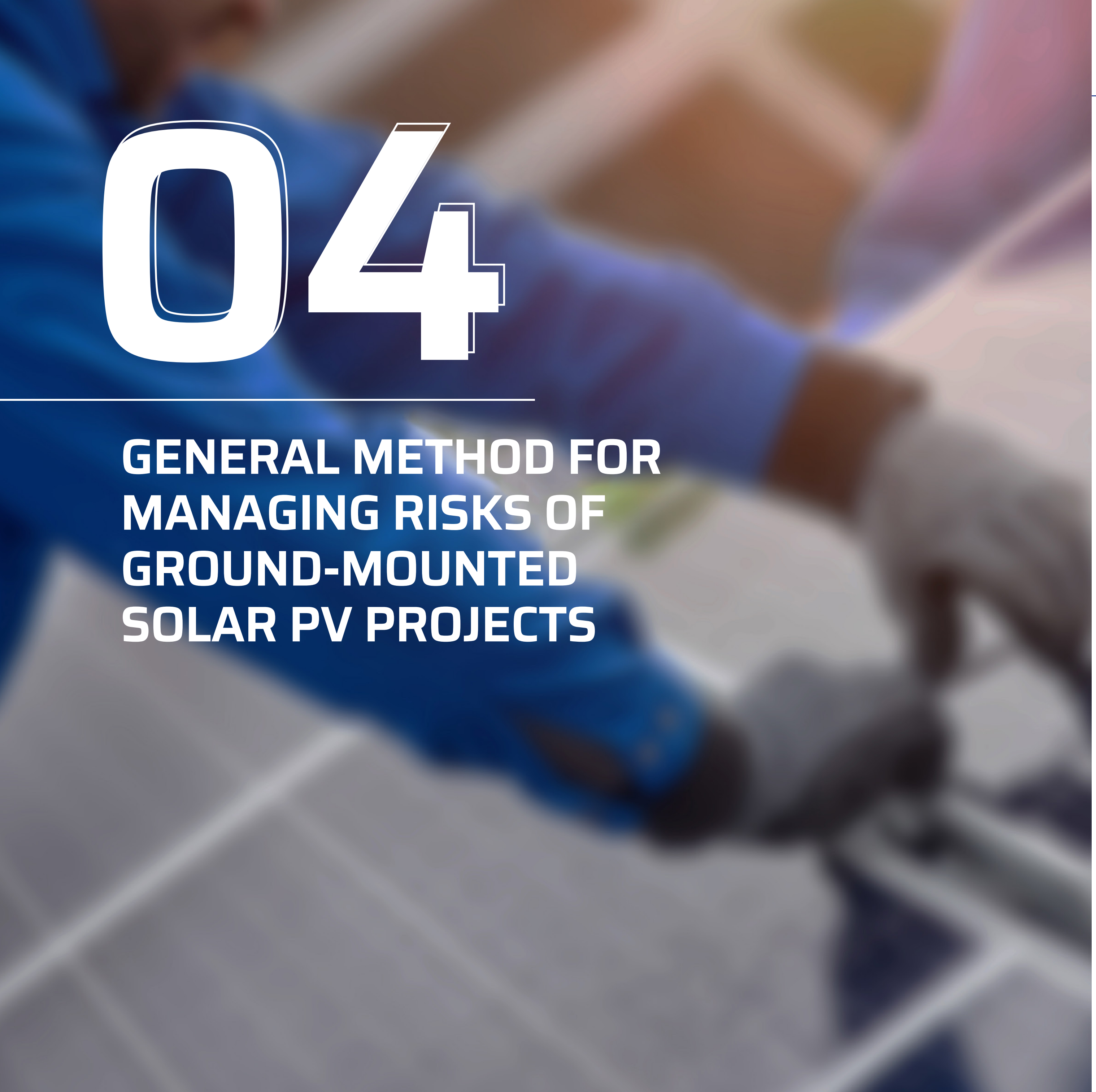
SCOPE AND OUTLINE

The Handbook has a special focus on **technical and operational risks of ground-mounted Solar PV projects.** The Handbook, therefore, does not intend to provide an exhaustive list and classification of all possible solar PV project risks but rather to **highlight critical, technical and operational issues that have repeatedly been observed in projects in Viet Nam and around the world,** to help avoid these - often costly - risks to materialise in future projects and to improve the performance of operating assets.

CHAPTER 4 presents an overview of the risk management process, including a simplified description of the main steps within that process. The aim of this Chapter is to give the readers a basic understanding of the risk dimensions of ground-mounted solar PV, as well as a simple and effective method to risk identification, analysis and management. The Chapter also includes practical examples and tips for conducting risk assessments and setting up a solid risk management system.

CHAPTER 5 focuses on the most observed technical failures in operational ground-mounted solar PV plants in Viet Nam. These have been categorised into 5 main risks categories and corresponding sub-chapters. Each risk category is described in detail, providing a list of possible technical failures, possible sources of risks, as well as impacts. The reader is guided through the risk management method, from the identification of risks, through its analysis and up to identifying appropriate risk management measures. For a deeper dive into the topic, for each category, two technical notes are presented that provide more detailed information of specific and most common technical failures and present case studies to better understand the risk management process. Furthermore, each section also includes resources, such as international and national standards and other relevant literature, relevant in the context of the respective risk.

The Handbook does not advise developers or investors on different technological options. Technologies are the choice of the project developer and investors. To minimise technology-specific risks, technology choices should be based on natural resources, site-specific conditions, on technical and financial considerations and, most importantly, on the compliance of the technology and materials with recognised national and/or international standards.



04

GENERAL METHOD FOR MANAGING RISKS OF GROUND-MOUNTED SOLAR PV PROJECTS

This section provides simplified guidelines on how to develop a risk management system for ground-mounted solar PV projects. Although the Handbook focuses on technical and operational risks, this guidance can also be used to set up a more comprehensive risk management system that also includes other risk categories, relevant to solar PV project development.

Identifying risks and setting up a risk management tool that enables a continuous monitoring and mitigation of risks is a crucial step. Although, ideally, it should be completed at the very early stages of project development, projects that have not done so should still complete this exercise, even if already operational. This allows project developers and managers to proactively foresee potential drawback to project implementation and to react in time to reduce the probability of risks occurring or the degree of their impact if they do occur.

It is important to note, that the different stakeholders participating in a project (e.g., the owner, the EPC contractor, the bank extending a loan, etc.) will develop their own risk management system, as they are affected by different risks, or the same risks may have different impacts for them.

Setting up a well-functioning risk management system requires the following four (04) main steps (Figure 1):

FIGURE 1 — RISK MANAGEMENT CYCLE

- **Risk Identification:**

The aim of this step is to identify and create an overview of the risks that the project is exposed to. Optimally, the risks are categorised (political, technical, environmental, etc.) and captured for each one of the project development phases (point in time when they are relevant and/or more likely).

- **Risk Monitoring:**

Once project development commences, it is important to keep an eye on the identified risks and document critical developments that could increase the chances that a risk occurs. Furthermore, as a project advances, new risks may be identified that should be analysed, evaluated, and added to the risk management tool, with appropriate mitigation actions.

- **Risk Analysis and Evaluation:**

Once the risks are identified, it is important to analyse them (i.e., determine which factors can lead to the risk materialising), as well as evaluating the likelihood that these risks will occur and the degree of impact they would have on the project.

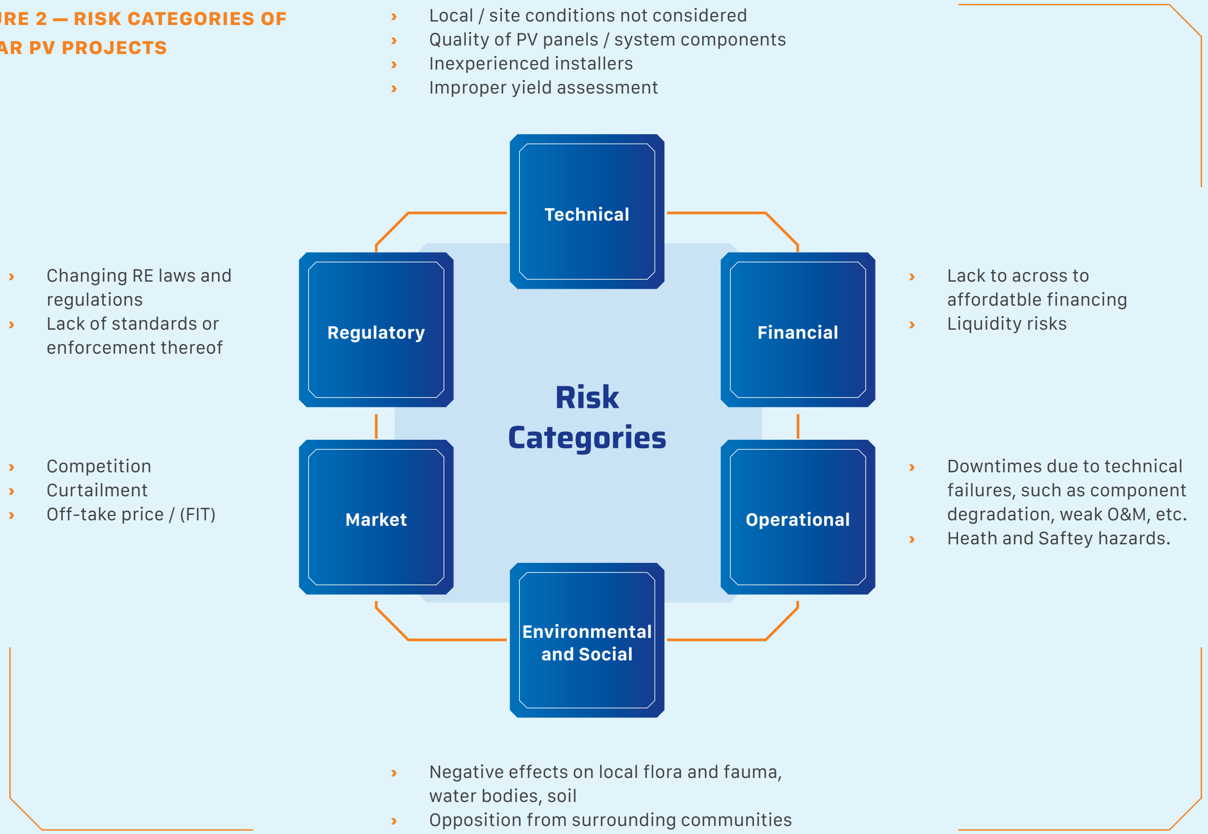
- **Risk Management Measures:**

In this step, actions are defined to avoid or reduce the probability of a risk happening and/or to reduce the impact of this risk on the project as much as possible, should it materialise. It provides project developers with an action plan on how to react if confronted to the risk situation.

4.1. Risk Identification

Solar PV projects are exposed to diverse risks that depend on the context and conditions under which they operate. A number of other risk categories can affect a project's success (see Figure 2). While the Handbook focuses on technical and operational risks, given the growing attention and importance of environmental and social issues, an overview of these issues and risks is also provided in a dedicated sub-chapter (Chapter 5.5).

FIGURE 2 — RISK CATEGORIES OF SOLAR PV PROJECTS



Risk managers and relevant team members can work together – e.g., in a workshop setting - to identify technical (and other) risks, particular to their solar PV project, by creating a systematic overview of the factors that can affect the project, following the above-mentioned risk categories along the different project development phases (Figure 3).

FIGURE 3 — RISK IDENTIFICATION ALONG THE SOLAR PV PROJECT DEVELOPMENT PHASES

In this context, it is important to account for the different steps that need to be taken at each project development phase (e.g., for the licenses and permits phase, establish a list of needed licenses /permits), the processes behind those steps (e.g., for each license/permit have a clear overview of the application process), the stakeholders involved (e.g. for licenses/permits have a clear overview of authorities to be dealt with, contacts, etc.) , including their inputs and outputs (e.g., for licenses/permits have a clear overview of documentation to be submitted and documents that must be received to complete the project file), technologies and/or services required, interdependencies (e.g., in supply) and timelines (e.g., for licenses/permits have an understanding on how long processes take to time them appropriately and avoid delays to the project). , as well as quality and other national standards that need to be ensured throughout the project. Some risks may appear in different phases, while others may be particular to one phase. For instance, when choosing the site for the solar PV plant in the pre-feasibility stage, it is already necessary to bear in mind possible risks that may be linked to the local conditions of that site, in particular. The pre-feasibility studies must, therefore, not only focus on evaluating the solar irradiation but should also look at aspects, such as topography, geology, weather conditions, surrounding flora and fauna and any other locally specific aspect that may influence the speed and cost-effectiveness of the construction phase and/or on how well the plant performs in the operational phase. Existing data should be collected at prefeasibility stage and, if not reliable enough, necessary studies should be planned for in the context of the full feasibility study.

It is therefore recommended to start the risk identification process very early on (prefeasibility phase) to have a clear idea of the main risks the project may be exposed to, especially to ensure that the solar PV plant design is adapted to the specific site conditions and risks (failure to do so could lead to technical failures and more costly risk mitigation and/or replacement/repairs). Establishing a realistic risk profile (see Section 4.2) early on is also important in the context of project financing and also for asset insurance, as both banks and insurance companies will assess the asset's risk profile as part of their due diligence. As the project progresses, the risk identification and analysis should become more detailed and concrete risk management measures should be in place (see Section 4.3), as well as a risk monitoring process and tool (see Section 4.4). However, as mentioned above, projects that did not establish a risk management process early on can and should start this exercise at any given stage to strengthen their risk profile and the project's integrity.

4.2. Risk Analysis and Evaluation

For each identified risk, it is important to define its scope by analysing the sources/factors that could cause it, their likelihood and the consequences/impacts of the risk materialising. In this context it is also important to carefully consider the individual roles but also interdependencies of different stakeholders involved.

The next step consists of evaluating the risk, i.e., analysing the likelihood of the risk occurring, and estimating the degree of the impact the risk will have on the project if it materialises. In ground-mounted solar PV projects, considerations, such as length of downtime for maintenance if a risk materialises or the costs for replacing certain elements of the plant, are important to determine the impact of a risk. The combination of these two evaluation criteria can be used to determine the risk rating and help project developers to rank them and to define and prioritise monitoring and mitigation measures. The risk rating is calculated by multiplying the risk likelihood value with the risk impact value:

Risk Rating = Likelihood x Impact

Figure 4 provides illustrates how to determine the risk rating:

FIGURE 4 — RISK EVALUATION MATRIX

			IMPACT			
			Neglectable (1)	**Low (2)**	**Medium (3)**	**High (4)**
			Little or no effect	Effects are not critical	Effects have a serious impact	Effects are disastrous
LIKEHOOD	**Neglectable (1)**	Risk will probably never occur	🟢 1	🟢 2	🟡 3	🟡 4
	Low (2)	Risk is unlikely to occur	🟢 2	🟡 4	🟠 6	🟠 8
	Medium (3)	Risk is likely to occur	🟡 3	🟠 6	🟠 9	🔴 12
	High (4)	Risk will most probably occur	🟡 4	🟠 8	🔴 12	🔴 16

1-2: Low risk; can be managed by routine check and monitoring procedure.
3-4: Moderate risk; should be considered and managed responsibly.
6-9: High risk; must be managed seriously.
12-16: Critical risk: detailed plan and strict execution required at senior levels.

Naturally, risk analysis and evaluation are specific to each project, as one risk may be significant for one project but less so for another. Hence, it is recommended to perform the risk analysis and evaluation specifically for the project and in consultation with the different teams, based on their experience.

The following example is meant to illustrate a case of risk evaluation: if a project's feasibility study revealed that **the project site is at risk of being flooded at least once per year, based on data from the least 20 years**, it could be said that:

- The **likelihood** of flood risk is **high (4)**
- The **impact** on the PV plant would also be **high (4)** as components would get flooded and likely damaged, requiring repair or even replacement, leading to downtimes, high O&M costs and loss of revenue.
- The overall **risk rating** would thus be: **likelihood (4) x impact (4) = Critical risk (16)**

Once the risk rating for each risk is determined, the next step consists of deciding how to manage the risks.

4.3. Risk Management Measures

Based on the results of the preceding risk evaluation, this step consists of determining the most appropriate measures to minimise the probability of a risk occurring and to minimise the impact if they do occur. Priority should be given to find the best risk management strategies, especially, for those risks that have a high risk rating. In this step, it is also important to carefully weigh the cost of risk management measures against their likelihood and impact. If managing a risk is more costly than remediating the risk when it materialises, then it may be better not to invest in reducing the particular risk. However, if it causes long downtimes, also affecting the technical and economic performance of the plant, the overall cost may be too high to leave the risk unmanaged.

Risk management measures can, thus, have several degrees of ambition, as depicted in Figure 5. In a standard process of defining the right risk management strategy for all risks identified the starting point would be the ambition to eliminate risks as much as possible. Those risks that cannot be fully eliminated would then need to be mitigated. If mitigation strategies are not enough to significantly lower the risk (or if a third party can mitigate or cover the risk at a lower cost), the transferring the risk should considered. Risks that are either very unlikely or have insignificant impact can usually be accepted.

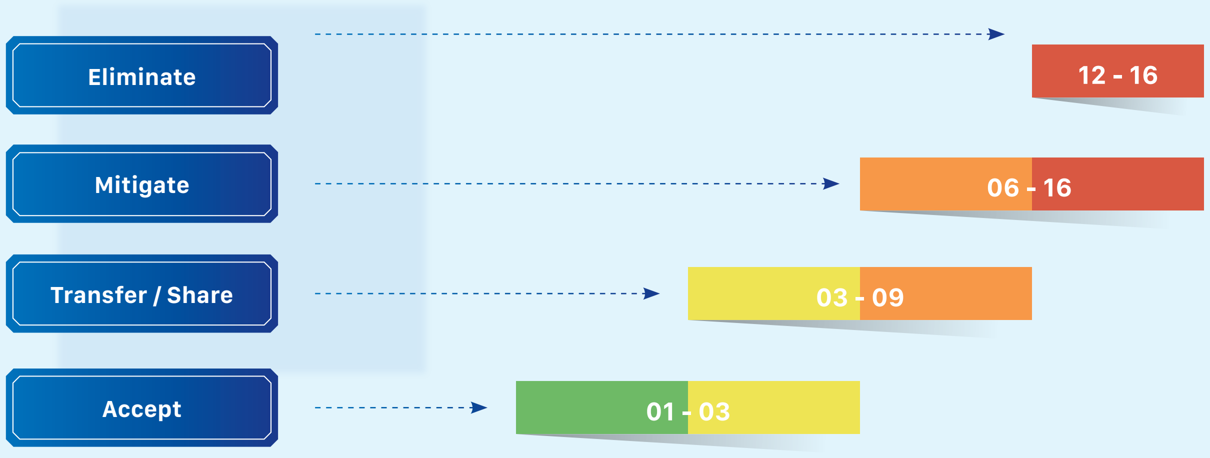


FIGURE 5 — SIMPLIFIED RISK MANAGEMENT STRATEGY BASED ON RISK RATING

Eliminate

ELIMINATE - A risk can be eliminated in different ways, depending on which factors could cause the risk. Most commonly, risks can be accounted for and eliminated by adjusting the scope and/or adding contingency, in terms of time or monetary/human resources to the project. In ground-mounted Solar PV projects, the risk of shading can be eliminated by either placing the panel in areas with no adjacent building or vegetation or by implementing a vegetation management process to regularly trim vegetation that could throw shade on panels. For the example presented in the previous section, where the risk of flooding was found to have the highest rating of 16, possible risk elimination methods could be embankment of the river as per industry practices or making a more detailed assessment of the project site and limit the installations to areas that are not or only slightly flooded, avoiding parts of the site where flooding is worse. In general, a combination of mitigation measures (see below) can also lead to risk elimination.

Mitigate

MITIGATE - Risk mitigation consists of identifying measures that reduce the likelihood of a risk happening or that reduce the magnitude of the impact if the risk materialises to an acceptable degree. In general, it is important to assess the cost of risk mitigation measures against the cost of repairing the risk's impact. Technical failures can be mitigated, for instance, by making sure that system components adhere to nationally or internationally accepted standards and are backed by warrantees. Another example of risk mitigation would be to allocate ample time to, e.g., administrative processes that could take more time than expected, such as grid-connection procedures with EVN. For the example presented in the previous section, where the risk of flooding was found to have the highest rating of 16, there could be several possible risk mitigation methods. One could be to build mounting structure on piles that are reasonably higher than maximum recorded flood level (up to 7 or 8 meters), another to construct a dike all around the solar farm. However, the first option may be more costly, and the second option may not be allowed from an environmental viewpoint (e.g., if certain plant species would need to be removed to build the dikes). This highlights the importance of carefully studying each risk, and their mitigation options, both from a cost-benefit perspective but also from a legal one.

Transfer/Share

TRANSFER/SHARE - Project risks can be transferred to third parties, e.g., when the project developer or owner does not have the capacities in-house to address the risk or when a third party is in the position to address the risk or cover for the negative impact of a risk materialising at a lower cost. Typically, risk transfer is achieved through insurances, performance bonds, guarantees, incentive/disincentive clauses, cost and time contracts, etc. For instance, performance bonds can be used to cover project owners if a contractor (e.g., the O&M contractor) performs poorly, i.e., fails to reach expected performance, resulting in economic losses. For the example presented in the previous section, where the risk of flooding was found to have the highest rating of 16, it would be virtually impossible to insure the asset, as the risk of damage is just too high and no insurance company would agree to cover. However, when risks can be mitigated in such way that the risk rating is reduced (e.g., by mounting the panel on piles), the remaining risk could then be covered through insurance.

Accept

ACCEPT - A project developer or owner may decide to accept a risk either if it is impossible to eliminate the risk or it would be too costly to do so, or if the likelihood/impact of the risk is so low that it will not greatly affect the project. For the example presented in the previous section, where the risk of flooding was found to have the highest rating of 16, it would be very dangerous to accept the risk. However, if a particular project site has only been hit by one storm in a 100-year period, the risk of flooding could be accepted.

4.4. Risk Monitoring

Risks that cannot be eliminated from the project's onset must be monitored throughout the project lifetime. Furthermore, as the project advances and framework conditions change, new risks may arise that were not foreseeable at early stages of the project. This must be continuously captured, analysed and evaluated and appropriate mitigation actions put in place.

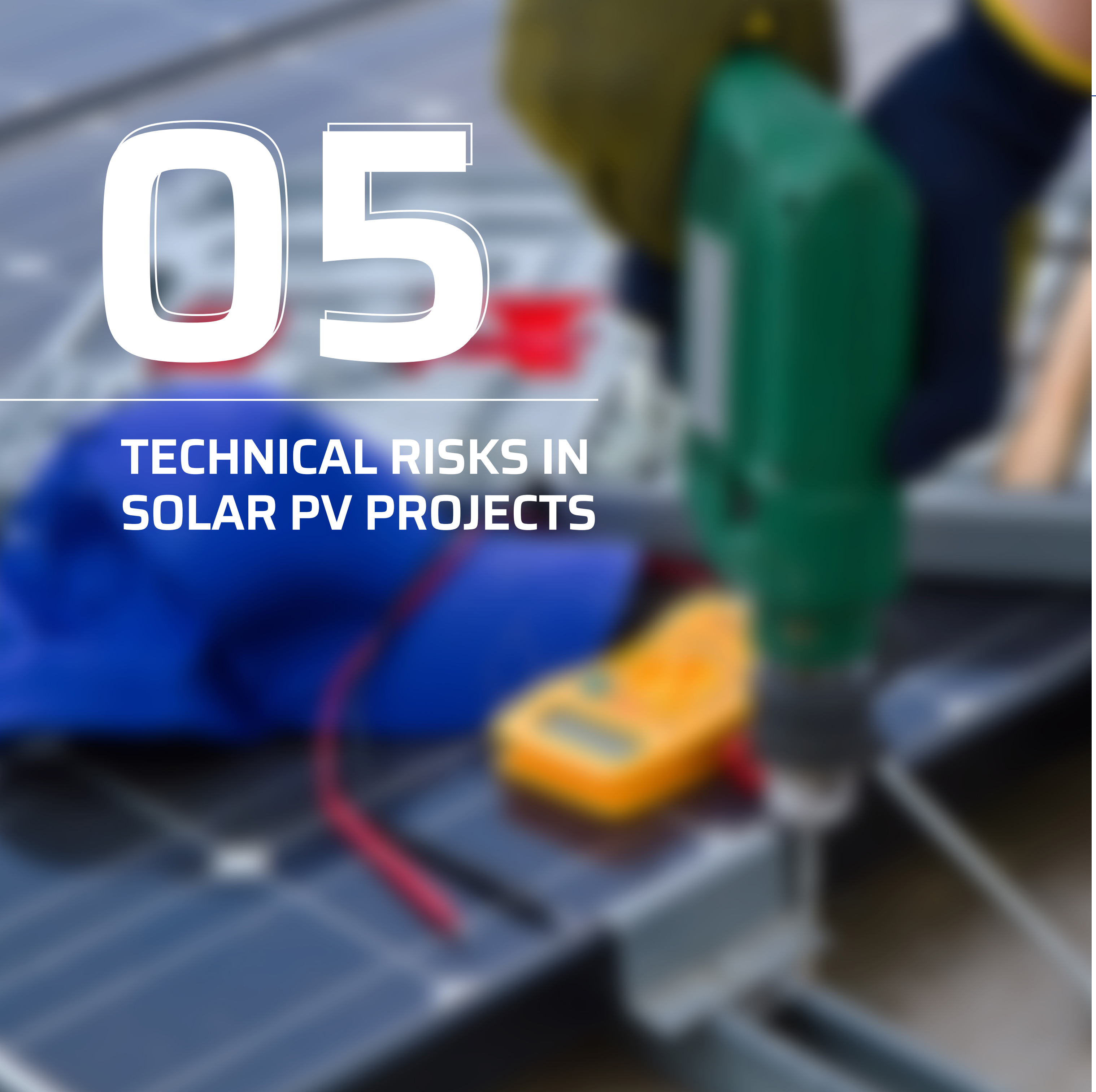
The results of the previous four risk management stages are typically reviewed and monitored through several processes to ensure their continuous implementation:

APPROPRIATE RISK DOCUMENTATION: To allow for a continuous and effective monitoring of risks, the results of the four risk management stages are typically put together in a risk management tool. This allows the team to have a comprehensive overview of the project risks, define clear risk management measures and related plans and schedules, as well as regularly reassessing risks. While many projects choose to develop their own risk matrices, there are also several free or licensed risk management tools available online. As projects, teams and needs differ, this Handbook does not recommend one tool in particular. However, some simplified templates are provided in Section 6.1.

REGULAR RISK MONITORING: As established in the project risk management documentation, regular site visits to verify the state of the plant and of mitigation measures in place need to be conducted by the different team members (internal and/or external) to ensure all is in order and record eventual needs for action. Site visits should be facilitated by verification checklists. These results need to be recorded adequately in a log to ensure monitoring and follow up.

EXTERNAL REVIEW AND QUALITY CHECK: The implementation of each measure will be given to a specific entity (for instance, against flooding, the design team will have the responsibility to adapt the foundations and structures to mitigate this risk). A review by an independent third party (owner's engineer) of the foundations and structure works by the EPC is a way of ensuring that the risk identified, and the associated mitigation measures are properly implemented. This is most critical during the construction stage, to make sure that the construction works match the design based on the risk profile of the project site.

AUDITS: internal and external audits could be organised punctually to review the different risk management measures implemented during operation. Based on the outcomes of the audit, corrective actions would be designed to ensure no risks are left uncontrolled.

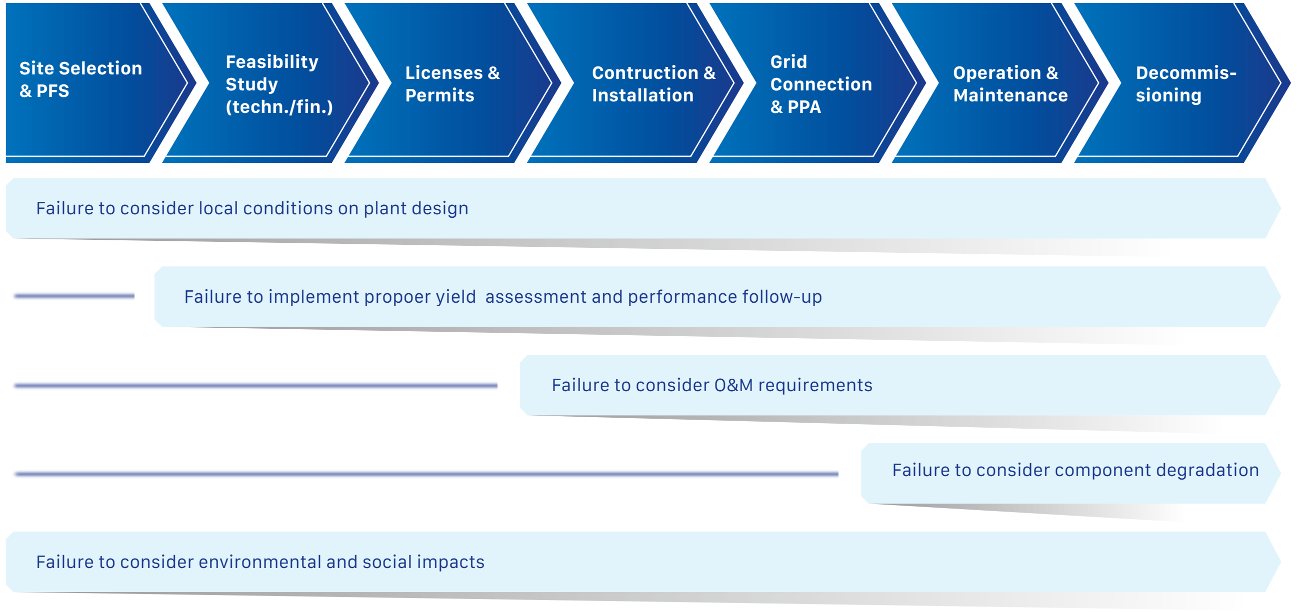


05

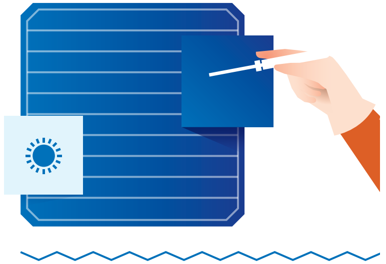
TECHNICAL RISKS IN SOLAR PV PROJECTS

Stakeholder consultations conducted in the framework of this Handbook allowed for the identification of the most commonly observed technical failures in operating Solar PV assets in Viet Nam. These have been assigned into five (5) risk categories as depicted in Figure 6.

FIGURE 6 — MAIN RISK CATEGORIES FOR SOLAR PV ASSETS IN VIET NAM



For each risk category, the following sub-chapters guide the reader through the methodology of how to identify and evaluate the risks and presents various examples of risk management measures. In addition, more detailed **Technical Notes** are presented for the two most technical failures observed in Viet Nam under each risk category, providing more detailed information on how to manage them and including case studies to guide the reader through the risk assessment process and method on illustrative examples.



5.1. Failure to consider local conditions in plant design

Description

A proper consideration of the surroundings and environment of the project site is crucial to reducing the probability of related project risks materializing during the lifetime of the solar farm. Local conditions need to be considered at early stages of the project, as part of the feasibility study, to ensure that related constraints are properly integrated into the solar plant's design and adequately communicated to the EPC.

If this has not been done at early stage, additional studies (structural, geotechnical, hydrological, weather) should be conducted when local conditions become an issue. This would support the definition of appropriate risk management strategies and remove or reduce the risk, as early as possible. For operating assets, low-cost management measures may be limited, as potentially necessary design changes can be costly. A review of existing studies by an independent third party can be conducted to identify risk sources and recommend appropriate measures.

Risk Identification

Table 1 provides an overview of the main risks related to improper consideration of local conditions:

TABLE 1 — LOCAL CONDITIONS: POTENTIAL RISK SOURCES, RELATED RISKS AND IMPACTS

POTENTIAL RISK SOURCES	TECHNICAL RISKS
Weather data, local microclimate and extreme weather events (hurricanes, typhoons, etc.)	› Shift/collapse of the structures, e.g., due to roll-over of tables because of strong winds. › Flooding of installations, e.g., due to unexpected strong rainfalls. › Shift/collapse of the foundation, e.g., due to under sizing.
Soil surveys (mechanical and electrical resistance)	› Unexpected physical damage to components, e.g., collapse of a table causing electrical components to be damaged. › Flooding of installations, e.g., water bodies changing water level. › Loss of plant/equipment warranty, e.g., due to wrong calculation of ground resistance causing defect on equipment. › Shift/collapse of the foundation, e.g., due to backfill of water bodies making soil unstable and causing erosion.
Geological conditions (underground boulders, wandering rocks)	› Unexpected shading, e.g., tables being at different levels due to unexpected obstacles during foundation installation or wrong land levelling. › Shift/collapse of the foundation, e.g., unidentified boulders causing foundation to be forced into the ground and damaged or drainage and erosion issues due to land use change, changes in flow of overflowing water lines.
Natural surroundings (mountains, hills, water bodies, coastal areas)	› Unexpected shading, e.g., mutual shading from one row to the next one, causing hotspots on solar modules. › Corrosion of components, e.g., due to salinity in the air adding constraint on metal parts. › Reduction of performance, e.g., due to increased losses due to shading .
Local tropical climate (humidity, irradiation pattern and UV contents)	› Over-aging of solar components, e.g., UV causing cables protection to disintegrate. › Unexpected shading due to wrong consideration of sun path. › Corrosion of components, e.g., high humidity causing damage to metal parts. › Reduction of performance due to shading.
Surrounding built-up environment (roads and traffic, industry, etc.)	› Important soiling of panels, e.g., due to dust pollution released by surrounding industrial operations. › Theft due to inappropriate securing plant's perimeter in populated areas.
Flora (fast growing vegetation)	› Unexpected shading, e.g., by an omission to estimate surrounding trees' growth. › Unexpected physical damage to components, e.g., due to moss growth on PV panels.
Fauna (birds flight patterns, cattle behaviour)	› Unexpected physical damage to components, e.g., from birds dropping stones on solar panels, intrusion of cattle in the project area, smaller animals nesting in or gnawing electrical equipment. › Soiling, e.g., from birds' excretion on solar panels.

IMPACTS	
› Delays in construction schedule › Underperformance and/or malfunctions of the solar plant › Significant increase of operations costs in the medium and long term	› Low economic performance › Low due-diligence bankability (project transfer) › Loss of equipment warranty or other liability issues.

Risk Evaluation

Based on the outcomes of the identification of risks linked to local weather and other environmental conditions, a risk evaluation needs to be conducted by the project Owner to decide on the best measures to implement. As every project site is different, risk evaluation needs to be conducted on a case-by-case basis by each project, following the method presented in Chapter 4.2. Examples of how to perform a risk evaluation are provided in the case studies developed in the technical notes.

Common Risk Management Measures

For operating plants, where local conditions were either not or inadequately monitored, most common technical failures and particular examples of risk management measures are provided in Table 2 below.

TABLE 2 — LOCAL CONDITIONS: EXAMPLES OF RISK MANAGEMENT MEASURES

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Weather, local micro-climate and extreme weather events (hurricanes, typhoons, etc.)	**Insufficient mechanical resistance of structures**	› Contracting an insurance against damages from extreme weather events (Construction or Property all risks insurance) could be considered after assessing potential risks. However, it will imply that the insurance provider will conduct his own assessment and might increase its cost or might also refuse to cover the asset. › Reinforcing structures could be considered (adding bracing on the metal structure); to be designed based on calculation notes from initial designers (to be collected) and calculations from an independent consultant or contractor (to be hired).
	Inappropriate foundation design	› Based on the magnitude of foundation defects, consider conducting a foundation survey by a third party. Such reviews should take into account design studies and highlight critical failures encountered (for instance visible cracks, misaligned foundations). › Reinforcing foundations can be considered (adding piles or pouring concrete) with a focus on critical foundations first but will require investigation on a case-by-case basis.
Soil conditions (mechanical and electrical resistance)	**Inappropriate ground site preparation and site levelling**	› Conducting a site survey to identify areas with signs of ground collapse or landslide. › In case water bodies (rivers, canals, etc...) are crossing through the project area, which may cause erosion, consider installing embankment. After reinforcing ground based on updated studies, partial ground levelling could be considered duraing the operation phase, in case of significant erosion affecting the foundations (exposed foundations).
	Inappropriate foundation design	› Conducting a site survey to identify critical areas (for instance soil collapse) and for significant damages, strengthening foundations can be considered (by enlarging foundations basis with additional concrete pouring, or adding foundations piles to better distribute the mechanical load). › To consider budget constraints, a progressive strengthening of foundations could be considered (with priority given to critical areas).
	Incorrect estimation of earth (electrical) resistance	› Conducting a new site assessment (with investigation of technical issues on electrical equipment, grounding resistance measurement and review of current earthing & lightning design) to identify adequate risk management measures (for instance, adding earth protection installation, or extending current grounding system).
Geological conditions (underground boulders, wandering rocks)	**Incorrect estimation of ground (mechanical) resistance, inadequate foundation works and unexpected levelling issue**	› Please refer to section on "Inappropriate foundations design mitigation measures" › In addition, in case of critical failure, foundation design adjustment can be considered for critical areas (review as built design and consult initial design consultant to request for review of calculation and possible improvements).

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Natural surroundings (mountains, hills, water bodies, coastal areas)	**Under-evaluation of mutual shading (installation on unlevelled field)**	› Most of the time, this cannot be adjusted during the operation phase, as it would involve heavy CAPEX. This issue needs to be assessed properly right at early design phases. › On case-by-case basis, adjustment of table inclination can be considered.
	Inappropriate component resistance to corrosion	› Increase frequency of preventive & corrective maintenance for potentially affected components (for instance, components more likely to be affected can be busbars, bolts and nuts) to identify corrosion at early development stage and treat it to mitigate the risks of damages over the years. In the case replacement are needed, consider products with certified corrosion and weather resistance, e.g., tested according to IEC 61701 for resistance to salt mist corrosion for plant locations near the coast. › Adapt preventive maintenance content and frequency, based on equipment sensitivity to corrosion.
Local tropical climate (humidity, salinity, irradiation pattern and UV contents)	**Inappropriate component resistance to corrosion**	› Please refer to inappropriate component resistance to corrosion mitigation measures.
Surrounding built-up environment (roads and traffic activities, industrial activities)	**Underestimation of dust level**	› Consider increasing the cleaning frequency (or method / tools) of solar panels, while considering cost benefit analyses. Take into account seasonal changes (e.g., in the dry season more frequent cleaning will be required). › Identifying the source (and schedule pattern) of dirt release ("internal road during dry season during afternoon patrols", for instance) is crucial to designing adequate mitigation measure (watering roads, etc.).
	Inappropriate security system	› Consider additional fencing or gates, security guards, CCTV, alarm system to prevent robberies (to be included in the regular O&M procedures).

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Flora (fast growing vegetation)	**Under-evaluation of shading**	› For greeneries within the project site, adding vegetation management to the O&M team is key to long-term performance of the plant. › For trees planted in neighbouring plots and leading to shading on the solar plant, discussing with surrounding communities could help in finding accepted mitigation solutions (tree topping; compensation), while considering conservation of local biodiversity.
Fauna (birds flight patterns, cattle behaviour)	**No consideration of fauna repelling measures**	› Installing fauna repelling measures can be considered, such as sound systems, bird flight diverters, scarecrows, etc. › Increasing the frequency of solar panel cleaning (or change in cleaning method for proper droppings removal) could also prove to be efficient. › Add pest control as part of O&M scope (paying attention to local protected species) › Installing or reinforcing fences to restrict cattle entering the plant can be considered.

Technical Notes:

Technical notes are provided for the two most commonly observed technical failures in operating Solar PV assets in Viet Nam that have resulted from local environmental conditions, based on the stakeholder consultations conducted for this Handbook, namely:

- Insufficient mechanical resistance of structures
- Inappropriate foundations design

The technical notes provide a risk management process to consider the risk throughout project development and suggest mitigation measures for operating assets.

TABLE 3 — TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES	
Risks	Structures with insufficient mechanical resistance can break more easily when exposed to strong winds, heat, flooding and other weather-related stresses. Module mounting structures (MMS) that have insufficient mechanical resistance may be more prone to displacement or collapsing, and therefore lead to significant damages to solar panels, for instance.
Risk Management Process	1. Identify and collect existing documents related to mechanical resistance of the structures (as built drawings, calculation sheets, method statement, soil survey assessment, geological study, etc.). 2. Conduct a review and gap analysis of existing studies by an external third party for mechanical resistance calculation. Usual studies and data collected for mechanical load are: › Material properties based on related standards (e.g., GB/T700-2006 for Chinese carbon structural steels, ANSI/AISC 360-16 for American National Standard Specification for structural steel buildings) giving ultimate tensile strength, minimum yield strength, material density, Young's Modulus. › For calculation, geometrical properties of material: section area, second moment of area and elastic section modulus. These first data are used for calculation to check for failure of the structure itself. › The design wind load should be calculated using specific standard such as ASCE 7-10. 3. Consider local weather conditions and extreme conditions (wind load as per Viet Nam's provincial data, hurricanes, flooding) in mechanical calculation loads. The project developer should review EPC studies and ensure these above-mentioned parameters are taken into account and are accurate enough. Data should be from a survey/study carried out on the specific site, or from existing plants with similar conditions.
Risk Management Process	4. Take into account the local conditions studies' conclusions in structural assessment and design. Typical failures at feasibility/design stage are due to timeline issues (studies being done simultaneously), insufficient coordination between EPC and designers, inappropriate management (no proper internal review) and short delays. 5. It is highly recommended to hire a proper Construction Supervision team (including Construction Management if no EPC), preferably a third-party Consultant 100% independent from the Owner and EPC, to ensure the overall coordination, quality and timeline. In addition, random control check by the third-party are essential to mitigate the risks of unmanageable quality issues on site (bribery, influence, corruption). 6. After design, ensure that components are matching design requirements. Related to MMS procurement, it is advised to select top-tier suppliers with a proper Quality Management Plan, adequate testing facilities and contract warrantees. 7. Prrefer a well-known EPC contractor with proven track record and ensure that components are properly installed (verification to be conducted by the Construction Supervision team). 8. Ensure that technical transfer of knowledge is included in the EPC Contractand implemented between EPC Contractor and O&M team to reduce dependency on EPC for the operation phase.

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES

Mitigation measures for operating assets

In case structural mechanical structure resistance deficiencies start to appear for an operating asset, following measures can be considered:

- Verify whether the plant is still under the defect liability period of the EPC contract and, if so, re-contact EPC and request repair work.
- Perform a sensitivity analysis on the meteorological parameters and, if necessary, review the design structure to match real local conditions.
- Collect initial MMS calculation and inspection sheets from the Consultant and the EPC / Contractor, ask for expert review to identify structural weaknesses and assess adequacy of the standards applied in the calculations.
- Conduct a site assessment to precisely identify which MMS parts need to be reinforced as a priority.
- Reinforcing structures can often be considered (adding bracing on the metal structure for instance); to be designed by specialists.
- Increase the frequency of preventive actions: site survey and preventive controls (visual observations, torque tightening).

Case study

A solar farm in Ninh Thuan province has been operating for 6 months. Structures started to break apart due to strong winds. First observations on site showed that the base of the structures had weak points that were not able to resist the wind’s force and got twisted as a result.

The first corrective operation carried out by O&M team consisted in securing the surrounding structures of the impacted area (critical zone with strong winds impact) with temporary reinforcement.

Secondly, since the plant was still under the defect liability period of EPC contract, the owner contacted the EPC and requested repair work.

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES

Case study

In the case the accident occurred after the defect liability, that option would have not been available (guarantee not valid anymore). It would have been necessary to identify which step of the plant development and construction was at fault:

Following documents could have been requested for a global review (if necessary, by an independent third party for external and professional advice):

- 1. Design and approval of the structures
- 2. Factory Acceptance Test
- 3. Method statement
- 4. Material inspection sheets at delivery
- 5. Installed structure inspection sheets
- 6. Module Mounting Structure (MMS) warranty

The analysis of these six key documents and milestones would help identify the source of the failure and support to define liability and mitigation measures accordingly.

For instance, if one specific batch is at fault (conception default not identified during material inspection at delivery or factory acceptance test), consider claiming the warranty and replacing damaged structures with a different batch and replacing progressively remaining defective ones in critical areas (regarding strong wind effects) to spread additional OPEX.

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on a case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES

Case study

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Shift/Collapse of the structures	Significant increase of the operation costs over the medium and long term	Likelihood: Low (2) – Shift or collapse of structures were carefully considered at design stage but inappropriate consideration of local conditions could increase this specific risk. Impact: Medium (3) – the shift of the structure would directly impact the power output, which could be worsened with the collapse of the structure and impact significantly the functioning of the solar plant, OPEX and yields/income from electricity sales. **Level of Risk: 6 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis.

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Temporary reinforcement**	Likelihood: Low (2) – temporary reinforcements are only installed on affected structures but do not reduce the risk occurrence for the whole solar plant Impact: Low (2) – temporary reinforcements are short term measures and do not usually fully mitigate the risk in the medium long run **Level of residual Risk after Option 1: 4 (Moderate)**	Acceptable – Given the potential aggravation of the damages, temporary reinforcement is necessary and cannot be avoided.	As soon as possible	Project Owner
Transfer Option 2: **Claim warranty from defect liability period of EPC contract**	Likelihood: Low (2) – remaining unaffected structures can still potentially undergo a shift or collapse Impact: Negligible (1) – replacement of the structure would considerably mitigate the risk **Level of residual Risk after Option 2: 2 (Low)**	Acceptable – Given that the warranty is included in original EPC contract (cost free)	As soon as possible	EPC contractor

In this case, measures were complementary and implemented in parallel by the Project owner. Temporary reinforcements were then replaced during EPC intervention under warranty liability.

TECHNICAL NOTE: INSUFFICIENT MECHANICAL RESISTANCE OF THE STRUCTURES	
Support resources	IEC: 61701:2020, International standards for "Photovoltaic (PV) modules - Salt mist corrosion testing", 2020 IEC, "IEC TS 62738:2018 Ground-mounted photovoltaic power plants- Design guideline and recommendations", 2018 Solar Bankability Consortium, "Technical Bankability Guidelines - Recommendations to Enhance Technical Quality of existing and new PV Investments", 2017 NREL, "Continuing Development in PV Risk Management: Strategies, Solutions, and Implications", 2013 Eurocode 7, Geotechnical design, 1997

TABLE 4 — TECHNICAL NOTE: INAPPROPRIATE FOUNDATION DESIGN

TECHNICAL NOTE: INAPPROPRIATE FOUNDATIONS DESIGN	
Risks	If inadequately taken into account, ground instability can lead to under-estimated or inadequate foundations design. Ground instability (e.g. sub-surface erosion, landslides or similar) are a result of pre-existing soil condition, geological composition, weather conditions or a combination of these factors. In the medium to long term, inadequate foundations can result in their collapse and may damage components that are installed on them. Consequently, it can significantly affect O&M costs and cause technical and economic performance losses.
Risk Management Process	1. Foundation design should take detailed local geological conditions of the site into account. Geological features can greatly vary within the area of the solar plant. Hence, it is necessary to ensure that netting measures and depth are adequate (sufficient measuring points throughout project area). It is recommended to hire a reputed consultant to conduct this study. Below are few technical recommendations: › Depending on the type of foundation, conventional soil investigation and sampling by Standard Penetration Test (SPT, ASTM D-1586) could be carried out (for instance for foundations using long PHC piles). In case of shorter piles, another method such as Kunzelstap Penetration Test (KPT, DIN 4094) can be used (for a depth down to 15m or until refusal). The latter are used to establish the allowable pile capacity. › A campaign of pull-out tests should be carried out to confirm that determined length of piling is suitable, following dedicated standards for compressive, tensile and lateral loads (respectively ASTM D 1143-81, D 3689-90 & D 3966-90). 2. Local weather conditions can greatly affect geological processes. It is therefore important to ensure that design also takes rain forecast, flooding levels, erosion, among others weather related phenomena, into account. It is recommended to also take into account variations to weather data linked to climate change, e.g., by means of sensitivity analyses.

TECHNICAL NOTE: INAPPROPRIATE FOUNDATIONS DESIGN

Risk Management Process

3. Typical failures at feasibility/design stage are usually linked to timeline issues (studies being done simultaneously), insufficient coordination between EPC and designers, inappropriate management (no proper internal review) and short delays.

4. After design, ensure that foundation components and final design are matching design requirements. Prefer a well-known EPC contractor with proven track record and that components are properly installed (verification to be conducted by the Construction Supervision team).

5. During construction phase, hire a proper Construction Supervision team at site (including Construction Management if no EPC), preferably a third-party Consultant, 100% independent from Owner and EPC. Random control check by the third-party are essential to mitigate the risks of unmanageable quality issues on site.

Mitigation measures for operating assets

For operating assets facing foundation issues, several types of failures are possible, and a first step would consist in identifying the origin of the issue. Depending on the origin, the following mitigations measures can be considered:

- Drainage failure is a common cause of foundation issues in Viet Nam. Inadequate or inexistent drainage systems can leave some area of the solar plant exposed to water streams and lead to higher level of erosion, and, hence, to a weakening of foundations. In this case, creating or improving the drainage system could be considered but may prove to be complex and costly, depending on the existing design.
- In case water streams are running through or close to the site area, installing an embankment could prevent flooding and/or landslides. On a case-by-case basis, re-conducting a hydrology study, while taking into account as-built design, can be considered. The updated study would give additional information on the potential drainage upgrade works.
- Reinforcing foundations is also a possible measure, e.g., by adding piles to better distribute the mechanical load, or pouring concrete to strengthen existing foundations, with a focus on critical foundations first.

TECHNICAL NOTE: INAPPROPRIATE FOUNDATIONS DESIGN

Case study

During the design and study phase of a solar plant, geological surveys were conducted hastily due to schedule constraints, therefore only a limited number of core drillings were performed. The design consultant only had limited information regarding project ground composition to conduct the structural design.

In this case, at construction stage, unexpected obstacles, such as rocks and boulders, were found during digging works. Tight lead times to reach COD led the EPC to choose immediate, untested, and unproven solutions (shorten structures length in this case) with the approval and consent of all parties.

No one-fits all mitigation measures exist for unexpected obstacles during construction, which must therefore be dealt on a case-by-case basis. In this situation, thanks to the EPC experience, all difficulties and issues faced during construction were recorded so that sensitive areas could be identified precisely and handled appropriately in a timely manner.

After reaching COD, a review of all technical issues that occurred during construction and led to initial design changes was conducted by the project owner. Based on this assessment, the owner re-assessed these areas and considered reinforcement measures to mitigate risks, such as reinforcing foundations, adding foundations with adequate structure modifications, or increase control frequency of preventive maintenance for sensitive areas.

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL NOTE: INAPPROPRIATE FOUNDATIONS DESIGN

Case study

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Shift/Collapse of the foundation	Significant increase of the operation costs over the medium and long term	Likelihood: Low (2) – Foundation design usually highly reduces the likelihood of shift or collapse. However, inadequate geological surveys or construction works may weaken the initial design's effectiveness. Impact: Medium (3) – the shift of the foundation could cause the structure to bend and eventually lead to its collapse. This would directly impact the power output and impact significantly the functioning of the solar plant and OPEX. **Level of Risk: 6 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: INAPPROPRIATE FOUNDATIONS DESIGN

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Reinforcement based on review of technical issues occurring during construction**	Likelihood: Negligible (1) – additional technical reviews and reinforcement would allow to detect critical areas and reduce the risk occurrence Impact: Negligible (1) – reinforcement would mitigate the risk in the long run **Level of residual Risk after Option 1: 1 (Low)**	Rejected – Even though this option would fully mitigate the risk, additional costs for foundation reinforcement would prove to be too costly	N/A	Project Owner
Transfer Option 2: **Additional targeted preventive maintenance (PM)**	Likelihood: Low (2) – Additional preventive maintenance would not affect the occurrence of the risk Impact: Low (2) – Through additional controls and corrective measures, foundation defects severity would be reduced **Level of residual Risk after Option 1: 4 (Moderate)**	Acceptable – Additional PM activities would provide another layer of security without having significant impact on OPEX	As soon as possible	Project Owner

In order to avoid additional cost after construction, the project owner decided to only adopt additional and targeted preventive maintenance for the area where the obstacles were discovered. O&M team would be responsible of the implementation and follow up.

Support ressources

Eurocode 7, Geotechnical design, 1997

5.2. Failure to implement proper yield assessment and performance follow up

Description

In any solar project, the pre-feasibility assessment stage often involves careful examination of the site conditions to perform a yield assessment, which is predominantly run on dedicated solar design software (PVsyst or Helioscope for instance). Due to lack of prior experience in the solar industry, many contractors and developers often conducted quick and improper yield assessments, thus leading to inaccurate yields and high uncertainty on energy output. Hence, key performance indicators such as predicted yields and Performance Ratios (PR) were not accurately estimated, which had a direct impact on the predicted profitability of the plant. Furthermore, costly technical audits then ex-post remediation would be needed to restore performance metrics to an acceptable level that allows developers to recuperate money on their investment. Poorly performing solar plants upon due diligence would also have a negative impact on the total asset value, causing losses for the investor.

It is crucial that during the assessment stage a clear framework or guideline is provided to properly instruct the EPCs on how to conduct yield assessments. Key areas to consider include solar panel degradation, inverter degradation, irradiance sensors measurement & uncertainties, soiling losses, shading impacts and other types of losses of a typical solar system. A third-party consultant could be hired to independently review the simulation report and assumptions.

For operating assets, poor performance indicators, such as low PRs and low yields, could indicate existing issues and / or unreliable initial assessment. Usually, a technical audit can be performed by the O&M team to identify possible issues (hot spots, panel degradation, cable degradation, inverter issues, and irradiance sensors calibration) and remediation works can follow. If the PR does improve, this is the ideal outcome for the project. However, if no changes are observed post-remediation, an independent consultant with a good track record in the solar industry can conduct another PR test and technical audit (including review of yield simulation) to find the right solutions for the power plant.

Risk Identification

Table 5 provides an overview of the main risks related to improper yield assessment and performance follow up

TABLE 5 — INACCURATE YIELD ASSESSMENT AND PERFORMANCE FOLLOW-UP: POTENTIAL RISK SOURCES, RELATED RISKS AND IMPACTS

POTENTIAL RISK SOURCES	TECHNICAL RISKS
Uncertainties related to irradiance sensors and measurements	› Inaccurate performance assessment during operation, e.g., the sensors are sensitive to factors such as orientation, angles of incidence, temperature; proper and regular calibration is necessary to ensure accuracy of sensors.
Uncertainties associated with irradiation data	› Inaccurate yield assessment, e.g., irradiance data obtained from satellites has limitations and drawbacks, often related to predicting future variability. Effects of global dimming and brightening are often seen across the world and present high variability in the yield analysis.
Inaccurate measurement of actual performance ratios	› Inaccurate or poor measurements of site-specific data (irradiance, temperature, energy), e.g., sensors not properly installed often send erroneous data back, leading to wrong PR calculation.
Shading impacts	› Inaccurate yield assessment, e.g., unexpected mutual shading due to poor land levelling (difference in height between mounting structure) or potential objects are not included in the shading simulation, therefore, leading to a higher yield assessment. › Early degradation of modules that often include hot spots or diode burnout, consequently, leading to an increase of PV panels replacement.

POTENTIAL RISK SOURCES	TECHNICAL RISKS
Grid curtailment	› Inaccurate yield assessment, e.g., grid congestion and curtailment, reduces a plant's availability, hence often reduces the actual yield much more than predicted.
Soiling loss factor	› Inaccurate yield assessment, e.g., soiling loss can vary significantly depending on the project design and its environment (site selection and engineering) and cleaning cycles (O&M). Underestimation of soiling loss will lead to higher yield assessment. › Early degradation of modules due to varying levels of soiling loss across the array.
Module quality loss and Light Induced Degradation (LID)	› Inaccurate yield assessment, e.g., PV module quality can vary significantly from one batch to another. Modules that degrade quickly can affect the energy production in a whole string leading to early defects. This is not often reflected in simulations, leading to overestimations of the yield.
Ohmic wiring loss and AC ohmic loss	› Inaccurate yield assessment, e.g., errors can happen when wrong inputs are entered into the software for cable type, length and characteristics.
Other losses (IAM factor, transformer loss, inverter loss, auxiliaries consump-tion, thermal loss)	› Inaccurate yield assessment, e.g., inputs on different type of losses can often be under or overestimated depending on the context.
Annual variability in model assumptions (P90/P50)	› Long term inaccuracy assumption of yield. If the variability is underestimated, this will affect yield estimates of subsequent years.

IMPACT	
› Lower yields than simulated, which results in loss of income. › Lower performance ratio than simulated. › Decrease of the value of the asset as a result of lower performance.	› Costly technical audits and remediation to bring the performance close to the predicted yields. › Reduced business opportunities and potential partnerships.

Risk Evaluation

Based on the outcomes of the identification of risks related to yield assessment and performance follow-up, a risk evaluation needs to be conducted by the project Owner to decide on the best management measures to implement. As every project site is different, risk evaluation needs to be conducted on a case-by-case basis, following the method presented in Chapter 4.2. Examples of how to perform a risk evaluation are provided in the case studies developed in technical notes.

Common Risk Management Measures

For operating plants where the energy yield was either not or inadequately assessed, most common technical failures and particular examples of mitigation measures are provided below.

TABLE 6 — INACCURATE YIELD ASSESSMENT AND PERFORMANCE FOLLOW-UP: EXAMPLES OF RISK MANAGEMENT MEASURES

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Uncertainties related to irradiance sensors and measurements	**Inappropriate consideration of uncertainties of irradiance sensors in the performance follow up**	› Refer to irradiation sensors manuals for uncertainties due to temperature, calibration, direction. This number is often a single unit, which has been aggregated from the different sources of variability. › Consider purchasing sensor equipment from well-known manufacturers. Compliance with IEC is necessary. › If the current sensors have already been installed, check with the manufacturer for certificates that show the testing process and uncertainties of the instrument. Perform regular calibration according to manufacturer requirements.
Uncertainty associated with irradiation data	**Long-term satellite data often are not reflective of local conditions and can be higher or lower than in reality**	› Choose the most reliable meteorological dataset (most recent 10 years) and adjust satellite data to fit with the local on-site data collected (not only irradiation data but also data on lightning, hailstorms, etc.). At development stage, good practice is to collect at least one year's worth of site measurement data. › Compare against the satellite data to incorporate appropriate adjustments for more accurate long-term data. Overall, if done correctly, the uncertainty of long-term meteorological data could be reduced to less than 2%.

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Inaccurate measurement of actual performance ratios	**Absence of a framework / guideline for best practice of Performance Ratio measurement**	› Define proper guidelines that provides the steps for contractors to perform the measurement, collection, filter and adjustment of the data to follow-up the performance after completion of construction. For instance, irradiance and module temperature sensors must adhere to the guidelines for installation. Data recorded needs to be filtered and adjusted at short intervals to allow for maximum accuracy. When in doubt, refer to the IEC framework for detailed guidelines on PV system performance monitoring. › Hire a third-party specialist to conduct an independent testing and audit to identify any gaps in the current procedure.
Shading impacts	**Shading objects are often not included or not carefully examined in the yield assessment (both near and far shading losses)**	› For near shading profile, consider small and close objects (electric poles, fence, trees, solar array, nearby buildings) to the solar array. This should be either simulated using 3D software for complicated objects, or directly on solar design software near shading simulation for simple objects. › For far shading profile, larger sources of shading (mountains, hills, city skyline) would require specific tools to map out the horizon shading profile, such as the Solmetric SunEye and Solar Pathfinder equipment. Other weather data providers could also provide a solar mapping remotely using their own in-house software and expertise. › Conduct observations throughout the day (both visually or drone footage) for different time periods of the year in order to identify sources of shading on certain areas of the solar array. › Full 3D modelling of the solar farm and its topography can also be considered (rather time consuming), to best address the shading risks.
Curtailment	**Actual grid curtailment and days of unavailability are often not considered carefully in the losses**	› Conduct grid congestion studies prior to the design of the system to evaluate the current grid condition (congestion, future upgrades, potential connection of new power plants nearby, EVN's most recent HV infrastructures changes). › In Viet Nam, many solar plants experienced shutdown due to grid congestion (provincial level) and over supply of renewable energy (national level). This issue is not within the control of the developer, so it is best to anticipate future grid curtailment by collecting updates on the grid situation and, if necessary, reflect potential losses in the yield assessment accordingly. › A potential solution to mitigate grid curtailment is considering energy storage (to be considered on a case-by-case basis).
Soiling loss factor	**Lack of careful consideration of the local conditions, leading to poor design and higher soiling losses than expected**	› Consider revising soiling loss during operation through visual observations. In the Southern areas of Viet Nam, there are distinct dry and wet seasons which leave 6 months of higher soiling losses (dry season from November to April). › Adjust the cleaning schedule & tools based on the season to minimize the soiling loss. › In case of major soiling losses, potentially consider adjustment of the plant design for better control of soiling loss. Some examples include increasing the tilt angles (must be balanced with orientation losses) or raising the elevation of the panels to avoid dirt splashing on top during heavy rain.
Module quality loss and Light Induced degradation (LID)	**Module quality loss and LID input are often too optimistic**	› Before the construction, consider testing of random batches of PV modules in natural lighting conditions to determine the real energy rating (kW). › Current statistical methods to determine the yearly gradual module loss have limitations. Therefore, it is recommended to seek a solar system expert to review this area (LID loss is often assumed to be only around 2%, as a default in solar design software for silicon wafer module type).
Ohmic wiring and AC ohmic loss	**Omission or inaccurate inputs of DC and AC system parameters**	› Refer to independent electrical drop voltage calculations (provided by detailed plant design of EPC) to avoid incorrect inputs for DC and AC parameters. › Revision of the simulation parameters should still be conducted to detect any mistakes or deviations from the "as built" drawings.
Other losses (IAM factor, transformer loss, inverter loss, auxiliaries consumption, thermal loss)	**Omissions or inaccurate inputs of each type of losses**	› Revise all the loss parameters, ideally done by an independent solar expert. Most of these parameters are clearly defined by the manufacturers (like transformer and inverter's loss). › IAM factor usually does not have high level of uncertainty provided the accurate panel type and installation parameters are entered in the system. › Auxiliaries' consumption is also often not large enough to be considered a significant loss. › Verify thermal loss value to ensure appropriate standard value was selected (depending on solar project type).

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Annual variability in model assumptions (P90/P50)	**Lack of careful consideration of annual variability of meteorological data and overall uncertainty of the system**	› For annual variability of meteorological data, revise the time period of the dataset. If possible, consider a dataset that covers the 20 previous years to lower the variability. › Other sources of variability include PV module modelling, inverter efficiency, soiling and mismatch, and degradation estimation; all of which can be consulted with a solar specialist to derive at a reasonable assumption for the total variability of the system. › It is recommended to perform the yield assessment for subsequent years or the average values over the system's lifetime to avoid large discrepancy between predicted and actual yields.

Technical Notes

Technical notes are provided for the two most commonly observed technical failures in operating Solar PV assets in Viet Nam that have resulted from inaccurate yield assessment and performance follow-up, based on the stakeholder consultations conducted for this Handbook, namely:

- Insufficient consideration of all technical aspects for the yield assessment.
- Revenue loss as a result of frequent curtailment by grid operator

The technical notes provide a risk management process to consider the risk throughout project development and suggest mitigation measures for operating assets.

TABLE 7 — TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT	
Risks	When relevant performance parameters of components are not properly and accurately considered and compared to actual site conditions in yield simulations, yield forecasts can significantly differ from actual yield outputs. It is important to note, that initial parameters may change during the course of procurement and construction. When this happens, it is necessary to update yield assessments accordingly. Inaccurate yield estimates would have a significant impact on the whole business model and the bankability of the project.
Risk Management Process	1. Independent third-party consultant can be hired to examine the yield assessment process in the initial design phase. This could help developers avoid the most common pitfalls and allow a more critical review over the simulation conducted by a designer or an EPC. Usually, solar design software provides guidelines online as well as standard values that can be used for reference and comparison with yield assessment conducted. Whenever possible, compare input values with inputs from existing similar system. 2. Below are the main points that need to be considered for yield assessment calculation (for more details please refer to the general note for each section): › Global weather data should be sourced from the best provider (not the default one) to lower the degree of uncertainty. Uncertainty factors regarding the irradiance sensors should also be checked carefully with manufacturer's test reports to properly account for equipment variability. › PV module quality testing should be conducted carefully by arranging factory inspection and flash testing batches of modules before shipping to Viet Nam (as no laboratory is currently conducting such tests in Viet Nam). Dusting measurement tools could also be installed among the array to automatically notify the O&M team about cleaning times. › Shading impacts from objects, array, growing trees, buildings should be forecasted and simulated, in order to be reflected in the assessment.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT

Risk Management Process	› Soiling loss should also be inspected and evaluated carefully based on the current condition of the site and solar panel cleaning strategy & tools (home-made solar panel cleaning systems are seldom cost efficient) › Other losses attributed to modules, inverters, transformers should be carefully checked in the products' datasheets, test reports and quality certificates. › Direction angles (tilt angle and slope) should be considered at early stage in synchronisation with the available area to optimize power output. › Curtailment from local grid congestion and national power dispatch (leasing to plant unavailability) could be somewhat estimated by conducting grid study/analysis. 3. After procurement stage, review PVsyst and crosscheck every single parameter of the initial simulation with actual selected components.
Mitigations measures for operating assets	In case real component performances have not been considered initially, following measures can be considered: › Conduct a third-party technical inspection to identify key issues with the installation and assess real loss values for each above-mentioned item. › In case of shading: shading objects can be removed from the site. If not possible, consider removing string of shaded panels only. However, this option could be costly to the developer and may require a design change. › Conduct regular thermal testing on solar panels to identify any hot spots, cell delamination, etc. Good practice would be to conduct annual testing by drone IR. It is crucial to integrate all panels in the testing to identify defects early and contact the manufacturer accordingly. › Conduct another solar design simulation during the technical audit to reflect real losses parameters. Improper yield assessment is relatively simple to rectify as the simulation can be performed as many times as needed to get to the most accurate result. If the system's performance is much lower compared to the new updated simulation result, the third-party consultant can make recommendations on potential steps to improve the power production. For instance, a quick cost benefit evaluation could be conducted to assess the profitability of changing a piece of equipment or the plant design.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT

Case study	One year after a solar farm reached COD, production data revealed that the output values did not match the expected yield assessment, which was performed during the feasibility stage. The developer conducted a review of yield assessment, and certain losses' parameters were adjusted to match real equipment performances and weather data. Despite the adjustment, output values still did not align with yield assessment simulation. To further investigate this matter, the developer hired a third-party specialist in solar energy to conduct an independent Performance Ratio test (PR test) and a technical audit of the plant. PR testing consists in doing a focused review of equipment performances by measuring irradiation during a defined period with additional accurate sensors (pyranometers, temperature sensors), which would enable to isolate irradiation uncertainties. The test procedures performed by the auditors must strictly adhere to the industry guideline (IEC 61724) with high quality measurement instruments. The result of PR testing would allow assessing the gap between theoretical and measured PR and adjusting the final output expectations and therefore output projections accordingly. Acceptable yearly PR ratio for operating farms would be above 80%, especially for the first years. On the other hand, the technical audit would aim at identifying potential issues (full technical due diligence) and corrective actions to improve performances of the plant.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT

Case study

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to manage the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Inaccurate inputs of losses such as shading and soiling loss and other input data	Lower yields than simulated	Likelihood: High (4) – inaccurate yield assessment occurs frequently in almost all projects. Impact: Low (2) – Output theoretical output production values might not reflect the actual production and hence distort the business model projections **Level of Risk: 8 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis.

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Perform a PR testing**	Likelihood: Low (2) – the source of risk can be mitigated. However, the origin of lower performances will not be identified. Impact: Negligible (1) – Accurate calculation of the PR, will reduce production uncertainties for the developer. **Level of residual Risk after Option 1: 2 (Low)**	Acceptable – External PR testing assignment will allow updating the business model with accurate output and is often required by external investors (part of transaction cost).	When significant gaps are found between yield assessment and actual production values	Project Owner
Mitigate Option 2: **Conduct a technical audit**	Likelihood: Low (2) – the sources of risk can be mitigated, however during the course of operation additional issues can affect the production. Impact: Negligible (1) – Full technical due diligence will allow to have an external review and mitigate most of the inaccuracies **Level of residual Risk after Option 2: 2 (Low)**	Acceptable - External technical audit will allow updating and improving the yield assessment. Technical audit represents significant costs and is recommended for potential sale.	When significant gaps are found between yield assessment and actual production values	Project Owner

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF ALL RELEVANT TECHNICAL ASPECTS FOR THE YIELD ASSESSMENT	
Case study	After designing and selecting the appropriate risk management measures, third party consultant advised project owner to ensure proper follow up activities are implemented. In the case of: › PR testing, it would be necessary to adjust the yield calculation, accordingly, conduct PR calculation on a monthly basis by the O&M contractor and hire independent third party specialist for a yearly audit › The technical audit, corrective action plan and recommendations were provided and should be followed up by the Owner with support from O&M Contractor or and need to be reflected in the updated O&M plan
Support resources	International Electrotechnical Commission (IEC) 61724 -1:2017, "Photovoltaic System Performance Monitoring – Guidelines for Measurement, Data Exchange and Analysis", 2017 IEC 61724, "Photovoltaic System Performance Monitoring", 2017 Solar Bankability Consortium, "Best Practice Guidelines for PV Cost Calculation: Best Practice Checklists", 2017 Report IEA-PVPS T13-12:2018, "Uncertainties in PV System Yield Predictions and Assessments", 2018 Report IEA-PVPS 16-04:2021, "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications", Third Edition 2021

TABLE 8 — TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY	
Risks	One of the most significant risks with solar projects in Viet Nam is linked to grid curtailment. Indeed, the recent boom of the renewable energy market and, more generally, the high increase of electricity demand in the country exerted significant pressure on the grid network. Even though grid refurbishment and upgrade are currently ongoing, grid curtailment remains a significant and major risk for planned and operating projects. This issue can have a significant impact on production values of the plant and affect bankability.
Risk Management Process	1. Prior to project development, a grid development study should be conducted to provide an overview of present and future grid conditions. This service can be provided by third-party consultants. EVN's existing information on the projects that are currently being coordinated within the local provinces should be used. Usually, such information would be available at the local Load Dispatch Center, Transmission and Power companies. Currently planned and operating power plants with their respective capacity should be mapped out for a clear assessment on their impact on the grid. 2. Based on the single line diagram provided for the respective substation, it is recommended to identify the number of plants currently feeding into the substation and remaining available capacity of the substation. 3. The research should then be extended to evaluate the region's current power plants and those that will be constructed within the next five years (thermal, hydro, wind, solar plants). This information should be taken into account to evaluate the risk of future curtailments. 4. Grid quality also must be considered in the studies. This usually includes local regulations and standards for reactive power capability (range suggested by EVN might not be optimal for solar plant equipment), fault ride through (might cause equipment shutdown), frequency response and harmonics distortions (that can damage plant equipment), among other parameters.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

Mitigations measures for operating assets

If a grid development study has not been conducted for operating assets, following mitigations measures can be considered:

- Grid congestion is not an issue that the developer can directly control, since it depends on the future development of the local grid transmission line, which is in the hands of EVN and local planning authorities. It would still be recommended, though, to conduct an up-to-date grid assessment analysis to have a clear understanding of the current state of the grid, whether the substation will be upgraded, and if possible, what timeframe can be expected.
- Constant follow-up with local EVN and national grid load dispatchers is highly recommended to keep being updated with the current grid conditions and future plans for upgrade.
- If possible, consider building relationships between different stakeholders (local government, EVN regulators, solar developers, investors, and contractors, local industries) to create a support network to lobby for grid enhancement or development that would benefit the solar farms' capability to be connected to the grid.
- In the coming years, battery-based storage could be a solution to circumvent grid curtailment. However, financial, economic, technical and legal blockages still prevail, which have prevented such technology from becoming more popular.

Case study

After 15 months of operation, a solar plant has been facing higher curtailment levels than initially evaluated in the yield assessment. Although a grid assessment study was done at the beginning of the studies, it was not updated as the project progressed, and unplanned projects were connected to the grid. Therefore, yield assessment availability parameters did not accurately account for all new projects connected to the grid.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

Case study

In this case, no evident direct measures can be implemented by the developer to solve the curtailment issue. The project owner, with the help of external solar specialist, identified few methods to optimize the solar plant in this context and mitigate the impacts. Among the measures considered were:

- A brief review and update of the grid assessment study in order to have an updated view of current and future potential curtailment levels.
- To adapt heavy maintenance activities schedule to match curtailment period (such as inverters, transformers or ring main unit maintenance).
- To consider battery storage option with cost benefit analysis and potentially mutualise with neighbouring plants to optimize the installation cost.

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Inaccurate inputs of unavailability loss	Lower yield due to unexpected grid curtailment.	Likelihood: Medium (3) – given the current trend of power plant development and grid status, curtailment is bound to occur regularly. Impact: Medium (3) – Frequent grid curtailment can lead to significant losses compared to initial estimation. **Level of Risk: 9 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Conduct further grid studies**	Likelihood: Medium (3) – Additional studies will not provide much additional information to manage the risk of grid curtailment. Impact: Low (2) – The grid study helps the project owner to determine more precisely the curtailment to be faced and perform O&M activities to reduce shutdowns, accordingly. **Residual risk after Option 1: 6 (High)**	Accepted – The cost of the update of the existing study is not significant and would provide insights and support operation decisions.	As soon as important impacts are detected	Project Owner

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

Case study

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 2: **Adjust maintenance activities**	Likelihood: Medium (3) – this measure will not alter the occurrence of curtailment. Impact: Medium (2) – Adjustment of maintenance activities schedule would slightly reduce the losses **Residual risk after Option 1: 6 (High)**	Accepted – There is no cost to this measure as it only requires communication with grid operator and optimisation	As soon as important impacts are detected	Project Owner
Mitigate Option 3: **Consider installing energy storage solution**	Likelihood: Medium (3) – Energy storage solution will not reduce the occurrence of grid curtailment Impact: Negligible (1) – Energy storage could help to face curtailment periods by stocking energy and feed it back into the grid when demand is high. **Residual risk after Option 2: 3 (Moderate)**	Rejected – Due to several reasons (economic, legal and technical) energy storage solutions are not viable measures in Viet Nam.	N/A	Project Owner

TECHNICAL NOTE: INSUFFICIENT CONSIDERATION OF POTENTIAL GRID UNAVAILABILITY

Case study	Based on the current discourse in the solar energy market in Viet Nam, there are currently no clear mitigation measures to tackle grid curtailment issues. Long-term solutions are usually devised and implemented at the national level, coordinated between EVN and local grid operators (grid development investment, batteries facilities, demand response policy, etc.). This highlights the importance of conducting, at preliminary stage, a thorough and complete grid assessment study, based on extensive information regarding current grid use and future development plan. The purpose is to foresee all sources of potential risks that would affect the operation of the power plant.
Support resources	NREL, "Wind and Solar Energy Curtailment: Experience and Practices in United States", 2014 Smart Electric Power Alliance, "Proactive Solutions to Curtailment Risk: Identifying new contract structures for utility-scale renewables", 2016

5.3. Failure to consider operation and maintenance requirements

Description

The swift development of an attractive investment climate for solar PV in Viet Nam has led to an increased amount of new players entering the market, many of which lacking the expertise on both installation and commissioning of facilities, as well as on operation and maintenance best practices.

As common practice in Viet Nam, O&M contract is negotiated at the same time as the EPC (or balance of plant) contract. The same company (but different teams) would be in charge of construction then would commit to O&M for a given period of time, that is usually 2 years, corresponding to the Defect Liability Period of the solar farm. By doing so, tools & equipment needed for O&M can be provisioned from the start (spare parts, O&M toolkit, proper monitoring system, training sessions to O&M team and full O&M manual included in EPC contract).

Many potential technical issues may still occur during this 2-year period as:

- The Owner may not have the proper means and team to follow up the work done by the contractors (and their respective responsibilities).
- The Owners may not always have full clarity about the different roles and responsibilities for O&M, forgetting to plan for certain O&M functions that they would have to perform/provide for or to be able to properly supervise sub-contracted parties.
- Contractors tend to optimise their costs by minimizing effort; maintenance is then only carried out with a short-term vision, e.g., accounting only for the end of the Defect Liability Period of the Contractor or EPC.

As the O&M contract is of much lower financial value compared to the EPC contract, less importance is paid on its terms. For many solar farms in Vietnam, O&M contract are often not signed (apart from HV infrastructures for compliance to grid utility requirements) and the relevant scope of services is not clearly defined or known when implemented internally by the project Owner's team. This leads to several types of potential acute project risks (low plant availability due to component premature failure, low plant performance, higher OPEX than expected, HSE risks on O&M team). Focus should be made on transfer of technology and project data (passwords, datasheets, guidelines, etc.) to ensure O&M team have a complete "toolbox" to operate the plant after termination of EPC contract. Furthermore, sufficient level of liabilities should also be included in EPC/O&M contractor agreements to ensure the enforcement of O&M requirements.

This note focuses on how to cope with this situation and proposes potential risks mitigations solutions by focusing on the key items. O&M (and Asset Management) tasks, teams & tools need to be defined along with proper monitoring systems and set up as early as possible, based on the actual design of the solar plant. Third party specialists could support in conducting an audit of the current O&M procedures and team, in order to help in defining a tailored action plan for your solar farm and come back to tracks.

Risk Identification

Table 9 provides an overview of the main risks related to improper consideration of operation and maintenance requirements:

TABLE 9 — IMPROPER CONSIDERATION OF O&M REQUIREMENTS: POTENTIAL RISK SOURCES, RELATED RISKS AND IMPACTS

POTENTIAL RISK SOURCES	TECHNICAL RISKS
Lack of proper monitoring in the solar farm design (system, software, connectivity)	› Undetected defects, e.g., slight decrease of performance, inverters failures or damaged modules. › Undetected stops of production, e.g., specific string failure or defect cable ramification at inverters entrance. › Overheating of materials, e.g., abnormal increase of inverters or transformers temperature. › Long troubleshooting time, e.g., extensive and random search for origin of issues.
Lack of formalised O&M processes and methodic O&M mechanisms	› Undetected defects, e.g., loose screws or clogged inverter filters, when specific components have not been included in O&M procedure. › Abnormal ageing of equipment, e.g., worn out cables or connectors. › Undetected stops of production, e.g., undetected string or inverter failures. › Overheating of materials e.g., hotspots on PV panels or overheated connection points. › Long troubleshooting times, e.g., undetected technical issues that worsen over time and require extensive repair time. › Theft, usual stolen components are solar panels and mesh fences due to insufficient CCTV monitoring.
Inadequate spare part management (no spare parts stock, supply delays, warranty renewal)	› Long down times, e.g., due to a lack of spare parts in stock paired with supply delays.
Low O&M team capacities and skills	› Undetected defects, e.g., missing slight decreases of performance from string observations or burnt diodes in the PV junction box. › Abnormal ageing of equipment, e.g., undetected corrosion or degradation of inverter connectors. › Undetected stops of production, e.g., undetected string or inverter failures. › Overheating of materials, e.g., aspect changes on busbar or high temperature on transformers. › Long troubleshooting times, e.g., due to inexperienced teams, travel restrictions due to Covid-19 and the need for third-party support.

IMPACT

- Malfunctions of the solar plant
- Increase of plant downtimes and decrease of plant availability
- Significant decrease of performance
- Excessive corrective maintenance costs
- Health, safety and environmental risks
- Underachievement of economic goals

Risk Evaluation

Based on the outcomes of the identification of risks related to O&M, a risk evaluation needs to be conducted by the project to decide on the best O&M management measures to put in place. As every project site is different, risk evaluation needs to be done on a case-by-case basis by each project, following the method presented in Chapter 4.2. Examples of risk evaluation are provided in the case study developed in technical notes.

Common Risk Management Measures

For operating plants where O&M requirements were either not or inadequately implemented, most common technical failures and particular examples of mitigation measures are provided below.

TABLE 10 — IMPROPER CONSIDERATION OF O&M REQUIREMENTS: EXAMPLES OF RISK MANAGEMENT MEASURES

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Lack of proper monitoring in the solar farm design (system, software, connectivity)	Absence of external monitoring system	› Even in post construction phase, the setup of an external monitoring system is highly recommended to ensure appropriate performance monitoring for the coming years. › Conduct a benchmark of available offers on monitoring systems and request a presentation of each platform to the O&M team. › In terms of monitoring features, software usually includes daily production, alarms system, temperature, automatised report, KPI performance and computerised maintenance management system (CMMS), for instance. The selection should be based on these above features and according to tools already available at solar plants, on case-by-case basis. › Other criteria for monitoring system selection would include full installation and configuration at site, "user-friendliness" of the system and language, potential on-site training courses to O&M team and after-sales services in Viet Nam.
	Excessive alarms due to improper setting of equipment	› Review thresholds and criteria of the alarm system per component, based on alarm history and experience. › Identify the indicators that trigger excessive alarms and consider adjusting the thresholds to adequate levels. › Based on undetected issues history, consider setting up additional alarms. › Update the alarm system regularly, while maintaining key alarms on items with the most significant impact on production and farm integrity. › Consider hiring a specialist third party to integrate proper settings into the monitoring system.
	Data communication issues between different components	› Inspect all communication equipment (cables, connection, modem, internet). › Check last preventive maintenance reports to review any past comments and observations that may support troubleshooting. › Verify if all issues identified in the past report have been adequately corrected. › Check that the communication configuration of the system (IT) has not changed since initial setup.
Lack of formalised O&M processes and methodic O&M mechanisms	Absence of overall O&M planning and resources	› Define and implement daily/monthly/annual O&M plans before the start of operation, not only for HV infrastructure but for the full solar farms including all facilities and systems. The project owner should have a plan in advance to manage and allocate appropriate resources for O&M activities, such as allocation of personnel for each shift, routine check plans, etc. › Request the support from a third party to draft an O&M manual based on the plant design (or update and detail the existing one).
	Absence of daily production monitoring (random controls, no recording nor log)	› Implement an internal process for daily production monitoring that includes each plant component (inverter, transformers, high voltage equipment, weather station) and incorporates main values of each component (for instance, active and reactive power, voltage, intensity, temperature, irradiance). › Define a recording process: log of all controls performed with name of controller and date. This could be optimised by implementing a proper CMMS. › If follow-up actions are needed, define a process with clear timelines and responsibilities.
	Incomplete list of values to monitor	› Check monitoring records, in order to identify most recurrent issues and, based on that, determine a list of additional values to be monitored per equipment. › Refer to contractually agreed KPIs and best international practices to identify values that must be monitored (PR, availability, etc.).
	Lack of appropriate maintenance tools	› Review technical sheets of equipment to identify specific maintenance tools needed. › Ensure that each maintenance crew has its own set of tools and, if necessary, complete accordingly while taking into account cost of equipment and frequency of usage. For specific maintenance, punctual subcontracting or equipment renting could be an alternative. › Add this identified set of tools into the O&M Manual as needed.

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Lack of formalised O&M processes and methodic O&M mechanisms	**Lack of CCTV system monitoring**	› Assess the plant's exposure to security issues and identify areas prone to theft or damage by third parties. › Consider installing a CCTV system in identified areas, define an internal process for regular monitoring of cameras (areas, frequency of verification, recording) and define and assign responsibilities among O&M team. › Consider hiring an external third party for surveillance, in particular for solar farms without permanent staff on site.
	Lack of or inadequate preventive maintenance	› Review all equipment manuals to include at least the constructors' preventive maintenance recommendations in the scope of work. › Fine-tune the preventive maintenance framework (frequency and content), based on international best practice guidelines. However, the scope should remain within equipment warranty requirements. Specific conditions of the project site should also be taken into account, such as weather, risk of soiling, etc.
	Lack of log for on-site maintenance activities	› Define recording requirements for all issues, as well as respective corrective maintenance activities (including but not limited to date, plant, equipment, response time, resolution time, impact on production). › Consider CMMS implementation to reduce human error and to achieve time gain (through automatised system).
Inappropriate spare part management (no spare parts stock, supply delays, warranty renewal)	**Lack of spare parts**	› Define an adequate strategy for spare part management: › Create a list of types and volumes of spare parts (potentially) needed for each equipment, based on historical operations (issues occurrence, impact, equipment cost, reliability of equipment, supply delays). › Set-up a process for recording in and out of spare parts, e.g., FIFO (first-in first-out) management and allow for a replenishment of spare parts to avoid future shortages. › Ensure that spare part procurement is properly considered in annual budget allocations (OPEX), including in the contingency budget.

POTENTIAL RISK SOURCE	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Low O&M team capacities and skills	**Inaccurate daily monitoring**	› Set up a robust and detailed internal process for daily monitoring and recording (O&M Manual to be detailed with clear guidelines and if possible, illustrations). › Include specific trainings to the O&M team on monitoring tools in the supplier contract.
	Inaccurate periodic production reports.	› Define a detailed framework for production reports. Usual items to be included are production, irradiance, performance ratios, availability of the plant, major technical issues and detailed daily production per sub-system. › Compare raw production values with electricity sales invoices (from EVN meter) to check reliability & accuracy of recorded data. › Consider a monthly internal review of the production report for consistency check. › Consider hiring a third-party specialist to train the O&M team to ensure adequate data collection and processing for the production report.
	Inaccurate recording of maintenance activities	› Set up proper framework for maintenance reporting, outlining type of maintenance to be performed and processes for completion. › Plan for a second review and quality check on conducted maintenance and the maintenance report, especially at early stages, to ensure consistency and sufficient level of detail, so that different readers can understand and grasp contents at later stage. › Train the O&M team progressively and regularly to increase general knowledge and understanding of recording requirements.

Technical Notes

Technical notes are provided for the two most commonly observed technical failures in operating Solar PV assets in Viet Nam that have resulted from failing to properly consider operation and maintenance requirements, based on the stakeholder consultations conducted for this Handbook, namely:

- Absence of external monitoring system
- Improper maintenance and documentation

The technical notes provide a risk management process to consider the risk throughout project development and suggest mitigation measures for operating assets.

TABLE 11 — TECHNICAL NOTE: ABSENCE OF EXTERNAL MONITORING SYSTEM

TECHNICAL NOTE: ABSENCE OF EXTERNAL MONITORING SYSTEM	
Risks	In Viet Nam, solar farm operators are required by EVN to have a SCADA at substation level. However, a separate SCADA for the solar plant is necessary to perform direct and on-site daily monitoring. When available on site, this SCADA data and interface are usually not particularly user friendly and require in-depth knowledge and experience to adequately interpret and use the information it generates. External monitoring platforms (such as complementary solar PV monitoring software and data acquisition systems) with more user-friendly interfaces could facilitate data management and analysis to most of the O&M team. This could optimise the time spent on data processing and reduce the potential human error. Furthermore, an external monitoring system can provide more detailed and in-depth analyses, e.g., allowing for data comparison between similar sub-systems to detect any inconsistencies. Unfortunately, such systems are not often considered or implemented for cost saving reason. The lack of such a system, however, exposes the plant to an increased risk of experiencing undetected critical defects, which can have a negative impact on the plant's performance.
Risk Management Process	1. When conducting preliminary plant design, make sure to record issues that will be relevant for monitoring, such as areas that will be particularly exposed to potentially negative effects (e.g., soiling, shading, closeness to water bodies etc.) and that would require more careful monitoring 2. At development stage, integrate monitoring requirements in the communication design of the solar farm (format, values to monitor, frequency). If not considered from the design phase, implementation of monitoring systems after construction are likely to be more expensive. 3. During communication system procurement, ensure that monitoring requirements are included in the budget. 4. During construction, ensure conformity with contractual requirements (installation and configuration guide). Ensure coordination between contractors so that configuration between equipment and monitoring components are aligned. A SCADA & monitoring system specialist is advised to be hired within the Owner's (engineer) team. 5. During testing and commissioning phase, verify that all monitoring requirements are met, and that the necessary data is captured, through a dedicated series of tests 6. Hire a third party (e.g., monitoring system supplier) to train the O&M team to adequately use the monitoring system and its functionalities during the first months of operations. A best practices from O&M Contractor is to allocate limited human resources on site and rely on a well-performing remote control system, which leads to a reduction of OPEX. 7. Consider hiring a technical Asset Manager to supervise O&M works and provide an expert and unbiased point of view regarding long term performance objectives and contractor's performance.
Mitigation measures for operating assets	Even if not considered at design stage, an external monitoring system can still be implemented when the plant is under operation. However, this could be more complicated and costly than integrating the system from the design stage. Below are some recommendations for operating assets: › Clearly identify your monitoring needs, list appropriate monitoring solutions for each need and conduct a benchmark on existing external monitoring solutions to identify remaining gaps. Despite high initial cost, the system can be quickly profitable, more user friendly to non-expert staff (and facilitate the work of the Asset Manager, if any). › If an external monitoring platform cannot be considered in the short term, hire a third party to perform a control of plant production, based directly on the SCADA system. However, cumulated costs in the long run will be higher because no proper monitoring tools are implemented, leading to time consuming tasks. › If those solutions are not considered, in-house alternatives are possible: • First level of analysis and monitoring can be performed directly based on SCADA system information. • Request additional training and information on SCADA system from suppliers. • Preliminary analyses could consist in extracting and comparing data of a defective component with similar subsystems of the plant (power generation; active power; reactive power, temperature, voltage intensity) • Implement remote access control of the SCADA system for distant operation. Even though remote access can be unstable, access to distant team/subcontractor is possible if no expertise is available on site.

TECHNICAL NOTE: ABSENCE OF EXTERNAL MONITORING SYSTEM

Case study

After two years of operation, one central inverter of a solar farm burnt. Initial investigation showed that ignition was caused by advanced corrosion of metal plates due to the predominance of heavy rains at the project site. Furthermore, after conducting a review of SCADA data records, a gradual increase of temperature of the inverter was noticed over 6 months, coupled with a progressive decrease in production.

As a common practice in Viet Nam, only a daily control of instantaneous values was being conducted on site for production follow up, while temperatures were not regularly checked. Monthly production reports only displayed main production values without further analysis. The O&M team on site did not have sufficient expertise to fully use the data provided by the SCADA system and to perform long term analyses.

The identification of these issues could have been made easier through an external monitoring platform thanks to:

- User friendly interface
- Easy calibration of analysis period (week, month, year)
- Automation of data processing enabling to gain time on data treatment and perform deeper analysis
- Clear comparison of similar components to detect anomaly (temperature, power output, etc.)

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to implement adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Undetected defects	Overheating of equipment leading to ignition	Likelihood: Medium (3) - even though ignition might not commonly occur, overheating is a recurrent issue in most solar farms Impact: Medium (3) — as illustrated, undetected overheating can easily lead to serious impact on the whole solar plant (e.g., stoppage, decrease production) **Level of Risk: 9 (High)**

Since the evaluation of this risk resulted in a medium level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: ABSENCE OF EXTERNAL MONITORING SYSTEM

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **External monitoring system**	Likelihood: Low (2) — overheating will be detected, and corrective actions can be implemented more often Impact: Negligible (1) — overheating will be detected earlier, hence, will lead to lower impact **Level of residual Risk after Option 1: 2**	Acceptable – External monitoring allows to reduce this specific risk and add several other cost saving tools, sufficiently to compensate initial cost and provide good profitability	Even if the solar plant has been operating for a few years, material and equipment degradation risk are higher at this stage and external monitoring system would be worthy	Project Owner
Mitigate Option 2: **Design alarm system**	Likelihood: Low (2) — alarms will be detected, and corrective actions can be implemented more often Impact: Low (2) — alarms will allow to detect overheating before ignition but will not detect early overheating **Level of residual Risk after Option 2: 4**	Acceptable – cost of alarm system is not significant and only requires the set up	As early as possible	Project Owner

With a long-term view, project owner decided to implement external monitoring system as well as designing a more complete alarm system, to operate more accurately the plant.

TECHNICAL NOTE: ABSENCE OF EXTERNAL MONITORING SYSTEM

Case study

Additional measures could have been implemented to further reduce the risks. As described in the table below:

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Transfer Option 2.1: **Externalize O&M activities**	Likelihood: Negligible (1) – external teams will detect overheating at early stage and reduce frequency Impact: Negligible (1) – external O&M activities would detect the overheating at early stage and reduce significance of impact **Level of residual Risk after Option 2.1: 1**	Rejected – costs of externalising O&M activities are too important whereas risk level has been reduced to acceptability level	If chosen, as early as possible	If chosen, risk would have been transferred to external O&M Contractor

However, the project owner already had in house expertise and kept operations of the plant internally.

Support resources

National Renewable Energy Laboratory (NREL), Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems (3rd Edition), 2018

Solar Power Europe, Operation & Maintenance - Best practice Guidelines / Version 4.0, 2019

TABLE 12 – TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION

TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION	
Risks	As Viet Nam's solar industry is relatively immature, industrials from other sectors are venturing into solar projects without previous experience in the field. Consequently, operation and maintenance specificities are usually not fully understood and/or considered. As a consequence, mainly corrective maintenance is implemented rather than investments in prevention measures and systems that would allow for proper monitoring and forecast maintenance and repair issues. Proper preventive maintenance and recording of errors needs to be an integral part of plant design and its operation to avoid premature aging of operating assets.
Description / Methodology	1. Take into account requirements and needs related to O&M process, such as data storage, in the studies and analyses, so that all documentation and information are accessible during operation. 2. Consider all the needs in terms of tools and human resources for operation and maintenance of the plant at early stage and ensure it is taken into account in the initial budget. 3. Define general framework of reporting and process requirements for maintenance activities before start of operations. Pay particular attention to preventive maintenance contents and frequency, if possible, with the support from manufacturers, to include the minimum maintenance recommendations. 4. During the construction stage of the solar plant, properly record and archive all technical documentation related to the solar plant components, contracts, solar plant studies, as built drawings, and main findings during installation. 5. Define and hire operating teams, as early as possible, to ensure they are adequately trained. It is recommended to have the operating teams (and AM if any) assist the testing and commissioning, as well, for a better understanding of the equipment and ensure smoother transition from construction to operation. 6. Implement proper tools for recording of operations and documentation, such as Computerised Maintenance management system (CMMS) 7. From day 1, ensure that all operation records (data, reports, regulatory controls, etc.) are done properly and stored safely on a dedicated server. 8. Perform regular reviews of processes during operation, depending on historical occurrence of issues and findings, in order to improve solar farm maintenance and ensure its expected profitability and bankability.

TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION

Mitigation measures for operating assets

Even if it has not been considered at early stage, proper maintenance operations and documentation management can be implemented later on and will enhance asset durability, performances and value. Few recommendations are suggested below:

- Update your annual business plan to include expenses related to process implementation, developing teams and purchasing the tools needed for all maintenance activities. Support from external experts could be recommended to support during initial stages.

- Consider hiring an expert third party firm to perform asset management of the plant. Separating O&M from asset management ensures complementary of skills and visions on the facility and operations carried out to keep a high level of control & performances of the solar farm in the long term.

- Refer to equipment manuals and best practice guidelines to define preventive maintenance framework for each equipment including:
  - Controls (visual, mechanic, test)
  - Measures (electrical, mechanic, thermal)
  - Their frequency (monthly, quarterly, bi-annual, annual)
  - Required electrical qualifications of controllers
  - Specific PPE equipment needed

- Implement CMMS to facilitate and improve the reliability of the recording of all operations. Once CMMS installed, consider predictive maintenance to anticipate potential failures and adapt accordingly PM activities.

Case study

After two years of operation, one central inverter of the solar farm burnt. Initial inspection of the material showed that ignition was cause by advanced corrosion of metal plates due to the predominance of heavy rains at the project site. Furthermore, after review of SCADA data records, a gradual increase of temperature was noticed over 6 months, coupled with a progressive decrease in production.

TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION

Case study

The owner did not implement proper preventive maintenance operations and tools from the start, as all equipment was under EPC contract warranty. Only corrective maintenance was performed on defects appearing during daily controls of the production. Hence, the abnormal aging of equipment was not detected at an early stage.

An insurance claim was submitted by the owner, in order to cover the damage (EPC liability period is over, so owner had contracted a separate insurance). To evaluate the case and analyse the origin of the incident, insurance experts required all the following documentation:

- All procurement, construction, operation contracts
- All factory acceptance tests, reception and commissioning minutes
- All values (production, electrical, alarms) recorded in the SCADA system for the specific equipment for the longest available period
- All preventive maintenance records since COD
- All corrective maintenance records on the inverter since COD
- All parts replaced on the inverter since COD
- All discussions with supplier/manufacturer regarding defects that occurred

The project owner only had part of the documentation, which was considered insufficient by the insurance and prevented it from proving manufacturer responsibility. All costs (equipment, losses of production) had to be borne by the owner.

Implementing regular preventive activities from the beginning of operation would have reduced the risk of undetected over-aging. Typically, this specific corrosion failure can be detected through visual observation. However, it is necessary to ensure that regular inspections are conducted by the local team, while following clear guidelines on potential defects that could occur. These inspections should be documented and recorded properly to ensure a good follow-up of equipment state evolution (including precise comments on observations, localization, pictures, and technician)

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION

Case study

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Abnormal ageing of equipment	Overheating of equipment leading to ignition	Likelihood: Medium (3) - even though ignition might not commonly occur, overheating is a recurrent issue in most solar farms Impact: Medium (3) – as illustrated, undetected overheating can easily lead to serious impact on the whole solar plant (e.g. stoppage, decrease production) **Level of Risk: 9 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

Possible measures are presented in the table below with remaining risk management strategy analysis

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Implement preventive maintenance (regular controls and recording)**	Likelihood: Low (2) – overheating will be detected, and corrective actions can be implemented more often Impact: Negligible (1) – overheating will be detected earlier, hence, will lead to lower impact **Level of residual Risk after Option 1: 2**	Acceptable – Preventive maintenance would allow to detect such physical defects at early stage and would not significantly increase operational costs	Preventive maintenance should be implemented as soon as possible	Project Owner and O&M contractor

TECHNICAL NOTE: IMPROPER MAINTENANCE AND DOCUMENTATION

Case study	To decrease probability of further incident related to inverters, the project owner decided to implement preventive maintenance operations with the support of external third party. Hiring an Asset Manager would have ensured a better management of project documentation and follow up, consequently increasing chances of activating the warranty.
Support resources	Solar Power Europe, Operation & Maintenance - Best practice Guidelines / Version 4.0, 2019

5.4. Failure to consider components degradation

Description

Over the course of operation, visual defects and component degradation can be indicators of mismanagement in previous stages. As highlighted in Tables 3 and 7, component degradation is often linked to poor quality or wrong component selection and inappropriate or limited preventive activities. Unfortunately, a common poor practice in Viet Nam is that scope of works related to O&M is usually focused on corrective activities rather than preventive maintenance (PM). Prevention would help in early detection of component degradation and limit its potential impacts.

Maintenance activities should be considered right at commissioning stage by taking into account punch list items. However, preventive maintenance activities can still be deployed at later stages to avoid future problems. The sooner it is implemented, the lower production losses will be. Numerous types of component degradation can be observed on operating solar farm. Even though some are linked to mistakes at design stage, most of them should have been included in preventive maintenance controls. Once again, preventive activities should be defined on a case-by-case basis (from the O&M manual), to be prepared by the EPC and with the support of third parties.

Risk Identification

Table 13 provides an overview of the main risks related to components degradation

TABLE 13 — COMPONENT DEGRADATION: POTENTIAL RISK SOURCES, RELATED RISKS AND IMPACTS

POTENTIAL RISK SOURCE	TECHNICAL RISK
Inadequate electrical equipment design, procurement and installation (equipment features or design)	› Underperformance of equipment, e.g., inverters, power cables excessive heating, transformers overloaded or unbalanced, inadequate MMS frames.. › Overheating, e.g., increased temperature of inverters or transformers. › Stop of production, e.g., insufficient insulation resistance leading to inverter default. › Premature aging, e.g., accelerated wear and tear of cables due to insufficient cable resistance or overload of inverters.
Insufficient prevention and maintenance activity and controls frequency	› Underperformance of equipment, e.g., dusted solar PV panels. › Overheating, e.g., increase of inverters temperature or transformers or electrical connectors. › Stop of production, e.g., cables wear and tear. › Compromised electrical safety, e.g., worn out and bare electrical cables or loose electrical connections. › Fire, e.g., ignition due to electrical imbalance in the modules (overheating of specific diode, for instance). › Important troubleshooting time, e.g., delays to repair power transformer leakage. › Premature aging, e.g., undetected excessive connectors corrosion.

IMPACT	
› Increased spare part consumption, e.g., faster reduction of module spare part stock. › Lower power output than expected.	› Economic losses due to replacement/repair of components and/or lower power outputs. › Safety issues.

Risk Evaluation

Based on the outcomes of the identification of risks related to components degradation, a risk evaluation needs to be conducted by the project Owner to decide on the best measures to put in place. As every project site is different, risk evaluation needs to be done on a case-by-case basis by each project, following the method presented in Chapter 4.2. Examples of how to perform a risk evaluation are provided in the case studies developed in technical notes.

Common Risk Management Measures

For operating plants where components degradation was either not or inadequately monitored, most common technical failures and particular examples of mitigation measures are provided below.

TABLE 14 — COMPONENT DEGRADATION: EXAMPLES OF RISK MANAGEMENT MEASURES

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER…	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Electrical equipment design, procurement and installation (inadequate equipment features or poor design)	**Cable wear and tear**	› Identify batch of cables with accelerated deterioration by scanning through the site. › Implement or increase preventive activities to detect portion of cables that will deteriorate faster (usually cable extremities) and identify cables portion that could be replaced progressively. For underground cables, electrical resistance measurement can be performed in order to detect any potential defect. › Replenish cables spare parts based on preventive activities' observations.
	Power transformer dysfunction	› Review power transformer data from SCADA to detect any past anomalies (e.g., overheating, or higher intensity or tension values at inverters entrance). › Perform oil analysis (for instance, composition change could reflect premature wear of winding) and electrical tests onsite by third parties. › If primary tests are not sufficient or reveal abnormal values, sending transformer to an expert for a complete set of tests can be considered. › Review the adequacy of equipment with regards to electrical calculations, while performing tests (design review to ensure there are no loading imbalances or overloading).
	Inverters tripping due to insulation fault	› Test insulation resistance and adequacy with regards to the inverter resistance range of operation. › Usually, insulation defects from inverters come from the DC circuit; Electrical measurements of the resistance of each string could be performed (with a megohm-meter), in order to identify any drop. After identifying the defect string, check the associated cables and modules. › The possibility of extending the resistance tolerance range of inverters can be assessed (refer to equipment manual or contact suppliers). › This case is further developed in the case study of the second technical note
Inadequate preventive maintenance (PM), in terms of frequency and controls	**Undetected component wear and tear**	› Review PM program: frequency and content can be based on equipment manual instructions or international best practice guidelines. › Site characteristics should be taken into account (e.g., project close to coastal areas, industrial zones or dusty environment) to adapt the frequency of PM activities. › Review the historical occurrence of defects, in order to adjust the PM program and focus on sensitive components. › Assess potential pest presence at site and especially in electrical cabinets areas. Deploy repulsive or control measures accordingly (with the help of a specialist third party if need be) while paying attention to local protected species.
	Insufficient mechanical ventilation of electrical cabinets and inverters due to accumulated dust	› Review component temperature through SCADA, e.g., in case of abnormal elevation, insufficient ventilation could be one origin. › Based on observations during preventive maintenance, if filters appear to contain high levels of dust, consider increasing PM frequency and replacing of filters to ensure sufficient ventilation.
	Undetected electrical arcs	Reduce or eliminate any favourable environment that could lead to electrical arcs by regularly verifying the overall quality of components (damaged cables, inverters, modules), cleaning the inverters to avoid high level of dust around electrical components and ensuring good quality of all connections (for instance, components tightening or MC4 connectors).
	Cable degradation under UV constraint	› Through visual observations, identify cable sections without UV protection (usually, cable junctions or extremities may be under protected). › Perform visual observations throughout the day, as sun path and sun exposure will defer depending on the time. › Add permanent cable protection accordingly and prefer UV resistant protection to avoid frequent replacement.

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER...	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Inadequate preventive maintenance (PM), in terms of frequency and controls	**Untightened connection of components**	› Identify components that require tightening monitoring (frequency and torque), based on equipment manuals and international best practices. › Usual connection verification focuses, for instance, on nuts and bolts of modules structures and all cable terminations within a power circuit. › Define period over which all tightening controls have to be performed for each component, based on equipment manuals, and consider distributing the controls over that period by sampling method.
	Solar panel junction box and diode failure	› Control through the monitoring system (SCADA) the string current to identify any diode failure in the solar panel junction box: a drop of 1/3 of the initial value of the string is usually correlated to a diode failure. › For each string with lower current values, review the corresponding PV modules and, through a thermal testing method, identify any modules with 1/3 of the surface showing higher temperature. Claim the warranty for replacement of defect modules (classic clause) if possible. If not, consider replacing defective diodes only. › An early detection of diode failure would prevent or minimize any domino effects.
	Solar panel delamination and busbar corrosion, glass breakage, cell cracks	› Delamination, corrosion, glass breakage and cell cracks are usually detected through visual observations or IR drone (no typical electrical values are representative of these issues) but cannot be fully prevented. Once detected, consider reinforcing preventive maintenance and observations around affected area (cf. Undetected component wear and tear). › Additional controls can consist in verifying whether defective panels are from the same supply batch and if so, identify location of similar supply batch and define targeted preventive maintenance activities, accordingly.

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER...	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Inadequate preventive maintenance (PM), in terms of frequency and controls	**Potential induced degradation (PID), hotspots**	› PID and hotspots are usually identified through drone thermal control of solar array with the support of a third-party specialized firm. It is recommended to conduct an annual drone thermal control, right after solar panel cleaning. › The service provider should be capable of not only taking pictures, but also of identifying clearly each solar panel to be removed (with economic calculations).
	Circuit breaker dysfunction	› Conduct thermal controls to check for overheating at inlets and outlets of circuit breakers. › Conduct preventive maintenance activities (such as tightening of connection, circuit breaker testing, thermal control); refer to the equipment manual for specificities by types and brands and update progressively the O&M Manual for better knowledge management. › If the issue is recurrent, review adequacy of equipment with regards to electrical calculations (e.g., maximum intensity and voltage range of circuit breaker compared to input from inverters) and consider revamping of equipment, if not compliant.
	Power transformer dysfunction	Refer to above sections on Power transformer dysfunction and additionally, for operation, request electrical grid data to verify if external factors can be the cause (unstable grid network due to surrounding electrical facilities).

Technical Notes

Technical notes are provided for the two most commonly observed technical failures in operating Solar PV assets in Viet Nam that have resulted from components degradation, based on the stakeholder consultations conducted for this Handbook, namely:

- Physical defects of PV panels (hotspot, overheating, glass breakage, cell cracks and micro cracks)
- Inverter dysfunction

The technical notes provide a risk management process to consider the risk throughout project development and suggest mitigation measures for operating assets.

TABLE 15 — TECHNICAL NOTE: PHYSICAL DEFECTS OF PV MODULES

TECHNICAL NOTE: PHYSICAL DEFECTS OF PV MODULES	
Risks	The most usual defects on PV modules are hotspots, overheating of cells, glass breakage and cell cracks. Even though these issues have limited effects on production if taken separately and at limited scale, the cumulative impact and their potentially high recurrence could lead to a significant decrease of production and a rise of maintenance costs. Preventive maintenance activities would not entirely prevent physical defects from occurring but implementing basic and standard PM activities would reduce the impacts (yearly thermal control and regular cleaning). Once defects are detected in certain areas, PM activities should be updated to focus on those zones to anticipate potential future similar damages. This would allow shortening the detection period and therefore, reducing the impact of defects.
Risk Management Process	A general process for physical defect management of solar modules could consist in: 1. Ensuring that all reports related to PV modules, such as thermography, module internal process reports, etc. are available for review and as evidence, if necessary 2. Replacing defective PV modules and contacting suppliers for warranty, if possible. In the case of glass breakage due to external reasons, warranty will usually not apply but for hotspots, overheating of cells and cracks, warranties could be claimed. 3. Based on location of the defects, extending search and visual observations to the surrounding areas to establish a baseline assessment of all damaged panels. 4. Identifying whether there is a potential typical failure linked to a specific defective batch. 5. Based on defect assessment, improving preventive maintenance (PM) activities by adding specific and targeted controls or measures for that area. 6. Following up implementation of PM activities and, if necessary, adjust frequency based on observations. 7. Adjusting spare part stocks according to historical degradation
Mitigation measures for operating assets	For operating assets facing physical defects of PV modules, following measures can be considered: › Perform drone thermal testing regularly to get an updated picture of general state of panels and to be able to replace modules in impacted areas, progressively. › Increase stock of spare modules to avoid shortage (should be 0.2% of total solar modules number). › In case of defective batch of modules, negotiate with supplier to provide spare modules in advance to replace progressively without experiencing production losses. › Perform IV curves testing (control of modules efficiency through measurement of intensity related to voltage evolution compared to initial curves of modules) to assess the performances of strings, to be able to prevent coming defects and to improve plant efficiency. › Consider increasing the cleaning frequency of PV panels to limit potential overheating due to localised shading points. › Damages could also be linked to environmental site conditions (refer to Chapter 5.1).
Case study	After one year of operation, the O&M team of a solar farm noticed a drop in production in a specific area of the plant, by comparing production values of different strings of inverters from the monitoring system. After cleaning solar panels, the team conducted electrical tests on the corresponding strings (intensity and voltage) to try to identify the issue. Following the tests, the O&M team conducted a visual and thermal verification of the impacted area (all modules of defective strings) and detected hotspots on several modules. Hotspots appear when a specific cell of a module overheats, compared to other cells, creating resistance and resulting in a voltage drop. Hotspots can be caused by partial shading, dirt or cell mismatches. In this particular case, cleaning of modules was performed regularly, and no specific shading was found on the modules, which eliminated these two factors as potential causes. Consequently, the O&M team decided to further inspect the modules itself.

TECHNICAL NOTE: PHYSICAL DEFECTS OF PV MODULES

Case study

All the PV panels affected appeared to be from the same batch and the manufacturer agreed to have them replaced under warranty clauses. In order to claim for warranty, the manufacturer requested pictures of both sides of the modules and with a specific focus on the defect and the serial numbers.

Additional preventive maintenance was also implemented by the O&M team to anticipate any future defects and replacement.

Regular thermal testing of the solar plant was added to the preventive maintenance scope of works, to closer monitor remaining panel of the defective batch and to be able to detect any eventual defect as soon as possible.

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and implement adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Undetected defects on solar panels: hotspot	Premature aging leading to underperformance	Likelihood: Medium (3) – Hotspots are recurrent in solar farm, due to insufficient cleaning and undetected shading Impact: Low (2) – As illustrated, undetected hotspots can lead to a decrease of performance throughout the whole plant **Level of Risk: 6 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

TECHNICAL NOTE: PHYSICAL DEFECTS OF PV MODULES

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis.

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Increase frequency of cleaning**	Likelihood: Low (2) – potential shading due to dirt will be removed regularly and reduce the risk of hotspots occurring Impact: Low (2) – the impact of hotspot remains the same **Level of residual Risk after Option 1: 4**	Acceptable – Cleaning will not only enable to reduce the risk of hotspots, but also guarantee a longer lifespan and increase production. In terms of costs, additional cleaning will not have a significant impact compared to the potential gain.	As early as possible	Project Owner
Mitigate Option 2: **Implement regular thermal imaging of the solar plantby drone**	Likelihood: Medium (3) – hotspots will be detected more easily but the measure will not prevent the issue to happen. Impact: Negligible (1) – hotspots will be detected earlier, hence, will lead to lower impact. **Level of residual Risk after Option 2: 3**	Acceptable – Regular thermal drone testing, as part of the annual preventive maintenance, to detect all kinds of defects on solar panels. It is the only complementary measure that provides a global overview of the solar plant.	As early as possible	Project Owner

The owner decided to implement both measures as an increase of the cleaning frequency will contribute to higher power output while thermal drone imaging would detect any early defect and ensure durability of the plant.

TECHNICAL NOTE: PHYSICAL DEFECTS OF PV MODULES	
Support resources	Report IEA-PVPS T13-01:2014, Review of Failures of Photovoltaic Modules, 2014 Solar Power Europe, Operation & Maintenance - Best practice Guidelines / Version 4.0, 2019 Dolara et al., "Snail Trails and Cell Microcrack Impact on PV Module Maximum Power and Energy Production", 2014

TABLE 16 — TECHNICAL NOTE: INVERTER DYSFUNCTION

TECHNICAL NOTE: INVERTER DYSFUNCTION	
Risks	The most significant defects detected on operating assets usually involve communication equipment, circuit breakers and inverters. Inverters are affected by many external factors and being the most technologically advanced equipment of the facility, it is comprised of fragile components, such as the Maximum power point tracker (MPPT) system or the Insulated Gate Bipolar Transistor (IGBT). Dysfunctions on inverters will require technical expertise to be repaired and would significantly affect the production and maintenance costs.
Risk Management Process	A general process for inverter dysfunctions management could consist in: 1. Performing troubleshooting on the inverter, following the warranty terms, with support of the equipment manual and contact manufacturer for advice. 2. Replacing defective inverter or specific parts to limit production losses, as soon as possible. 3. Since monitoring values with high frequency of sampling (voltage, current, frequency, harmonics and temperature) are usually not recorded over a long period of time, it is recommended to save them as early as possible once the defect of the inverter has been detected. They will be needed for a deep analysis to fully understand the incident.

TECHNICAL NOTE: INVERTER DYSFUNCTION	
Risk Management Process	4. Analysing the above-mentioned monitoring values and comparing them with similar systems to identify potential gaps to normal operating values and forecast similar defects on other inverters (predictive maintenance). 5. Based on defects and data analyses, improving preventive maintenance (PM) activities by adding specific and targeted controls or measures (recommendations are usually provided in equipment manual and O&M Manual, if any). 6. Following up implementation of PM activities and, if necessary, adjusting their frequencies based on observation. 7. Adjusting quantities of spare parts according to historical degradation.
Mitigation measures for operating assets	› Ask manufacturer for specific training regarding the equipment in order to reduce troubleshooting times. This training would ideally be performed during testing and commissioning phase, once the O&M team has been selected, and included in the EPC scope of services. Training documents can be added or referred to in the O&M manual. › Increase stock of spare parts or spare inverters to avoid shortage. Even if this equipment is commonly under warranty, investing in additional inverters can be compensated with reduction of losses of production (reduction of troubleshooting and supply times). › In areas prone to extreme weather conditions, adding protection to external elements, even if not required by the manufacturers, can be beneficial if it doesn't affect the inverter warranty terms (for instance, UV and heat protection, air filters, additional forced ventilation)

TECHNICAL NOTE: INVERTER DYSFUNCTION

Case study

After only a few months of operation, several inverters of a solar plant situated in the Central Region of Viet Nam started to have recurrent insulation defaults, strongly affecting the production (due to inverters shutdown), specifically during the most humid periods of the day.

The resistance level at the entry of inverters depends on all the upstream components (solar modules and cables). When facing an insulation issue that caused the inverters to trip, the first step of O&M team was to ask the inverter manufacturer for support, who recommended performing an insulation resistance test of the upstream system to check its consistency with the inverter's operating range (referring to the inverter's manual).

In the case the resistance gap was non-significant, an extension of the resistance tolerance range could have been considered with the approval of manufacturer.

In this particular case, a significant gap was detected, and it was necessary to investigate for any defects in upstream components. Usually, resistance issues are the results of cumulative defects on different components upstream. The methodology was to identify the most important insulation defects through dichotomy process:

- Measure the voltage at each string's extremity to identify and isolate any significant differences and potential defects. In this case, abnormal values appeared, and O&M team disconnected the defective strings from the inverter and re-ran the inverter for testing.
- Further analysis was performed on the defective strings by scanning the associated modules through visual observation and voltage measurement.
- In the case no failure at any specific string has been identified through this method, it would have been possible to consider disconnecting strings one by one and for each configuration re-run the inverter. If one or several strings appear to be faulty, further analyse the DC connection cables and MC4 connectors for any damages.

In this particular case, the results showed that cables were already suffering degradation due to inappropriate protection against UV radiation, and they became porous. The owner had to replace the cables progressively and improve protection on sensitive cable portions, throughout the plant.

TECHNICAL NOTE: INVERTER DYSFUNCTION

Case study

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Premature cables wear and tear	Economic losses linked to replacement and repair of components failures	Likelihood: Medium (3) – Insulation failures are commonly seen on solar farms, due to insufficient protection. Impact: Medium (3) –unprotected cables can lead to important losses of production and increased troubleshooting times. **Level of Risk: 9 (High)**

Since the evaluation of this risk resulted in a high level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

Possible measures are presented in the table below with remaining risk management strategy analysis

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: Improve protection of cables	Likelihood: Negligible (1) improving protections will limit the risks of insulation defects on inverters. Impact: Low (2) – insulation defects will be reduced by protecting cables from UV, even before defects happen. **Level of residual Risk after Option 1: 2**	Acceptable – Protection of cables are not costly and will significantly increase the lifespan of equipment.	As early as possible	Project Owner

TECHNICAL NOTE: INVERTER DYSFUNCTION

Case study

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 2: **Increase frequency and controls of preventive maintenance**	Likelihood: Low (2) – By repairing defective parts quickly after detection, further defects can be avoided. Impact: Negligible (2) – regular controls will enable to detect defects earlier and reduce the inverter stops. **Level of residual Risk after Option 2: 4**	Acceptable – An increase of controls scope and frequency will increase chances of detecting defects sooner on all equipment. Additional preventive maintenance does not have significant impact on OPEX.	As early as possible	O&M contractor or if no third party, directly Project Owner

The measures being complementary, the owner decided to implement both measures progressively. The follow up was conducted through the preventive maintenance activities to ensure no further degradation.

Support resources

National Renewable Energy Laboratory NREL, Field Guide for Testing Existing Photovoltaic Systems for Ground Faults and Installing Equipment to Mitigate Fire Hazards, 2015

SMA Solar Technology AG, Checking the PV System for Ground Faults, online resource

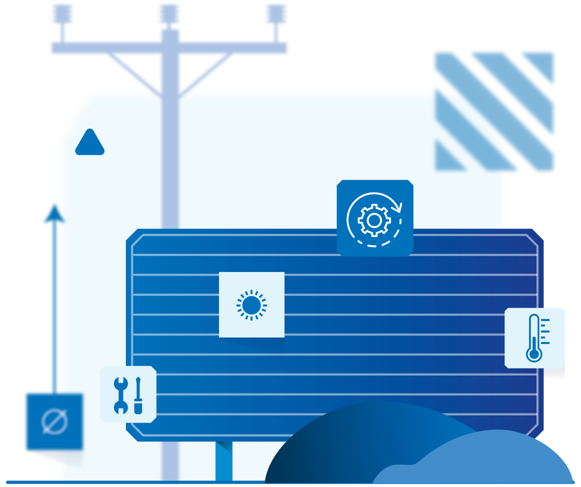
5.5. Failure to consider environmental and social impacts

Description

Due to their "green nature" as renewable energy projects, solar farms are usually considered to be free of negative environmental and social (E&S) effects or at least to be only low- impact. However, solar plants remain large-scale industrial projects with significant engineering works that affect both the environmental and social context of the area. Moreover, solar projects require large areas of land, impacts can be expected not only in terms of land acquisition and change of land use but also, more generally, on the community's livelihood, which will not directly benefit from the project.

Hence, E&S issues should be considered already at the preliminary study phase, in order to ensure a comprehensive assessment of E&S risks and to allow for a design of adequate measures, in conjunction with relevant stakeholders and local authorities.

Furthermore, E&S issues are often not directly visible and evident for operating solar farms, as most significant impacts will occur either during site preparation or construction. Some impacts might also only be detected after a detailed review of the site (for protected species for instance). As funding from international financiers usually requires a thorough investigation of these issues, it is recommended to go beyond national E&S requirements (most of projects would only submit local environmental impact assessment and environmental protection plan) and to conduct an Environmental and Social Impact Assessment (ESIA) based on international standards. Even after commissioning of the plant, corrective measures can still be implemented, which could consist of both mitigation and compensation measures, as it could be too late to prevent the impacts that may has already be materialised. Finally, an appropriate process to safely dispose of damaged PV panels and other solar plant equipment should be in place. If they cannot be recycled locally, they should be returned to manufacturers for appropriate disposal.



Risk Identification

Table 17 provides an overview of the main risks related to improper consideration of environmental and social issues:

TABLE 17 — ENVIRONMENTAL AND SOCIAL ISSUES: POTENTIAL RISK SOURCES, RELATED RISKS AND IMPACTS

POTENTIAL RISK SOURCE	TECHNICAL RISKS
Inappropriate consideration of local environmental conditions	› Environmental pollution during construction, e.g., soiling of nearby water bodies due to unmanaged construction materials and wastes. › Environmental destruction during construction, e.g., destruction of natural habitats or essential ecosystems to certain (endangered) species. › Environmental pollution during operation, e.g., broken solar panels abandoned in uncontrolled landfill or soil and ground contamination due to leakage of hazardous material (oil, chemicals, etc.). › Environmental destruction after decommissioning, e.g., non-rehabilitation of solar plant field after end of project lifetime.
Inadequate health and safety requirements	› Accidents, e.g., during construction phase (worker accident due to inadequate method statement related to foundation works and excavator use). › Accidents during O&M, e.g., electric shocks during maintenance works, fire, explosion. › Environmental accidents: weather (in sunny areas, high temperatures can cause heat shock, dehydration in maintenance workers), animals and plants (such as snakes, mosquitoes, rats)
Inappropriate consideration of local social surroundings	› Grievances during construction, e.g., complaints from the surrounding community related to construction noise, dust emission of transport vehicles or land acquisition process. › Grievances during operation, e.g., from a surrounding village facing water use competition due to solar panel cleaning operations. › Accidents, e.g., increase of traffic both in terms of volume of trucks and speed leading to the site project.

IMPACT

- Impact on local community livelihood.
- Impact on biodiversity and ecosystems.
- Human casualties.
- Unexpected delays.
- Reputational consequences.
- Lower bankability of the project.

Risk Evaluation

Based on the outcomes of the identification of environmental and social impacts risks, a risk evaluation needs to be conducted by the project Owner to decide on the best measures to implement. As every project site is different, risk evaluation needs to be conducted on a case-by-case basis by each project, following the method presented in Chapter 4.2. Examples of how to perform a risk evaluation are provided in the case studies developed in the technical notes.

Common Risk Management Measures

For operating plants, where environmental and social issues were either not or inadequately monitored, most common technical failures and particular examples of risk management measures are provided below.

TABLE 18 — ENVIRONMENTAL AND SOCIAL ISSUES: EXAMPLES OF RISK MANAGEMENT MEASURES

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER...	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Local environmental conditions	**Unregulated deforestation (impact on flora)**	› Review local (or international, if available) environmental impact assessment to identify any deforestation (at solar farm footprint and at access roads and trans-mission lines level). Verify whether adequate authorisations are in place and if processes have been followed and consider contacting local authorities (Department of Agriculture and Rural Development) to enquire about regulation and compliance requirements. › On a case-by-case basis and in accordance with local legislation, it might be required to either relocate destroyed vegetation or provide compensation for damages done.

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER...	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Local environmental conditions	**Inadequate protection of ecosystems**	› Identify, through publicly available information (online maps, national and inter-national references, refer to references in technical notes), any nearby sites of bio-diversity importance (usually a 50km search area is applied, including access roads). › If the project is within range of any area of biodiversity importance, hire a third party to conduct a biodiversity assessment to identify any endangered species or ecosystems of particular interest (IFC Performance Standards 6 is usually used as a reference for biodiversity conservation issues). Re-assess project impacts on biodiversity conservation and, if necessary, identify and implement complementary mitigation and compensation measures.
	Water bodies degradation or filling	› Identify potential pollution sources during the construction phase (usually related to foundations works, backfilling activities, waste and wastewater management) and location of close water bodies in the area. Based on potential impact, include engineering mitigation measures (adequate drainage system) and implement pollution prevention practices based on international standards (refer to references in technical notes). › In case pollution or water bodies filling already occurred, engage with local authorities to agree on mitigation and compensation measures.
	Waste and wastewater management	› Ensure that recommendations related to waste and wastewater management has been implemented. This should usually cover construction and hazardous waste, as well as wastewater issue from cleaning activities and daily operation of the plant. › In particular, specific attention should be given to oil leakage and if any use of chemicals.
Local environmental conditions	**Unplanned decommissioning and recycling**	› Identify, as early as possible, potential recycling options for the solar plant components. Given the growing volume of PV panels in Viet Nam and specific components, ensuring proper disposal of PV panel when available in the coming years.
	Unplanned rehabilitation	› Ensure that adequate budget is allocated, as well as clear rehabilitation plan is established preliminarily, to ensure land can still be used after exploitation period of solar farm
Health and safety requirements	**Lack of Health, Safety (H&S) consideration (among others, personal protective equipment (PPE), training, safety processes and plans, noise, firefighting, electrical risks)**	› If not implemented, a detailed Health, Safety (H&S) management plan (MP) should be established. Based on initial risk assessment, this plan should include a set of measures based on a mitigation strategy (avoid, minimize, offset) for risk management. Usually, H&S MP would include requirements on PPE, trainings related to specific works (electrical works, hot works), noise and traffic management. › Implement a verification log to make sure all requirements and controls mentioned in the H&S MP are implemented timely by the O&M team. › Beyond H&S issues, ensure Contractors' compliance with labour regulations for workers on site by requesting the O&M Contract to establish and update the list of workers with required documents (among others, compliance with requirements on worker insurance, health check, training, contracts with mentions of benefits, working hours and overtime policy). › Even though H&S risks are lower during the operation phase, verify that basic requirements and H&S measures are monitored through logs (firefighting system and control of equipment, electrical risks during maintenance, emergency plans). › Conduct awareness training of E&S issues for operation and maintenance teams.
	Unexpected safety issues	› Include Health and safety scope of services into the O&M Contract with for instance, regular maintenance activities and site inspection to identify potential risk of over-aging of components, which could lead to unexpected safety issues (cable damage, erosion, corrosion of structure). › Verify that O&M contract includes preventive maintenance activities to identify those risks at early stage and implement adequate corrective actions or replacement.

POTENTIAL RISK SOURCE: FAILURE TO CONSIDER...	TECHNICAL FAILURES	POTENTIAL TECHNICAL MEASURES FOR RISK MANAGEMENT (TO BE DEFINED AND REFINED ON A CASE-BY-CASE APPROACH)
Local social surroundings	**Non consideration of surrounding communities (land acquisition, resettlement, livelihood, safety, cultural site, ethnic minorities)**	› Review land acquisition process, decisions and compensation measures to ensure all affected households have been identified and compensated according to the local decisions. › Conduct interviews with community and local authorities to verify if there have been any impacts on households without official land use title (economic resettlement due to non-access to certain land areas). › Assess project risks and impacts on communities' health and safety during construction (usually main impacts are related to speed of vehicles, dust and noise emissions). › Identify presence of ethnic minorities in the project area and any related physical cultural site next to the site and conduct impact assessment of the project on those communities (land acquisition, livelihood, infrastructure, social and cultural, etc.) and organise consultation with affected communities. › Ensure that a grievance mechanism has been established for the surrounding community and that grievances are resolved in a timely manner. › If international standards are required, hire a third party to conduct a full E&S due diligence on and potential gaps between local and international requirements (in addition to local EIA study).
	Non-consideration of surrounding community	› Establish a stakeholder engagement plan to ensure appropriate project information is shared regularly and in a timely manner with surrounding community (for instance, prepare brochures with project progress status, emergency plans, contact point information to be shared with local committee). Install suggestions box at project site and at local committee office to allow stakeholders to raise issues. Ensure these boxes are verified frequently and that all raised issues are addressed.
	Water competition	› During the solar panel cleaning session, if local water resources are used, verify that adequate permitting has been obtained. › Assess water resource availability and potential competition with surrounding households or agricultural/forestry activity. › Implement water efficient methods for solar panel cleaning e.g., semi-automatic tools, such as brush cleaning device, can provide important water consumption gain. Even through efficient manual methods, water use can be reduced. Water volume use can be included in the O&M contract as a performance indicator.

Technical Notes

Technical notes are provided for the two most commonly observed technical failures in operating Solar PV assets in Viet Nam that have resulted from inappropriate consideration of environmental and social issues, based on the stakeholder consultations conducted for this Handbook, namely:

- Lack of HSE consideration during operation phase
- Unmitigated impacts on fauna

The technical notes provide a risk management process to consider the risk throughout project development and suggest mitigation measures for operating assets.

TABLE 19 — TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE	
Risks	Even if most risks related to HSE occur during the construction phase, HSE issues are usually overlooked during operation and inadequately assessed and managed. If no adequate or limited instructions regarding HSE requirements are in place, a variety of related issues can occur, some of them potentially leading to human casualties (for instance non adequate protective equipment, bare part under voltage, no restricted access area) and accelerated deterioration of the site or environmental disturbance (operations affecting nearby species). Overall, beyond grievances and accidents, all these factors will have a reputational impact on project owner in the long term and therefore on the bankability of the project.

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE

Risk Management Process

HSE issues and identification of mitigation measures must be considered already at the early study phase with a proper environmental impact assessment (EIA). Based on results and conclusions of the EIA and good industry practices related to risks at work, an HSE MP should be developed. Main steps for considering those issues are:

1. In the EIA, ensure that all project risks and impacts during the construction and operation phases are identified and assessed adequately. Most common risks and impacts include soil and water pollution due to release of solid, hazardous waste or wastewater; occupational health and safety linked to maintenance activities, site access restriction from non-authorized people, fire safety, equipment and potentially surrounding biodiversity.

2. Verify that the environmental protection plan (EPP), developed during the EIA process, includes measures to mitigate each risk identified. The EPP should be approved by local authorities and detail which entity is responsible for implementing the measures, completion indicators, and monitoring system with frequency of controls. Verify that all measures from the EPP for the operation phase are mentioned in the O&M contract.

3. Owner should ensure that all measures from the EPP are considered and implemented. O&M Contractor should suggest and implement an adequate HSE management plan before operation starts. It is highly recommended to include in the O&M Contract that all workers should go through induction training to ensure contents and measures from the HSE MP are known and assimilated by the team. Regular verification and monitoring process (activities log) should be implemented by the O&M team to report to the owner to ensure all preventive and safety measures are being implemented.

4. Based on site observations and potential new risks, O&M Contractor should review and update the HSE Management plan regularly.

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE

Mitigations measures for operating assets

In case no HSE MP have been implemented for operating assets, initial steps could be conducted as below:

- Review initial EIA and EPP to ensure all mitigation measures from the document are implemented on site. If not, include missing measures into O&M processes.
- Identify any potential gaps based on international standards (refer to references below) and site reviews from external staff or independent third parties (equipment verification, signs of early aging, potential pollution, and interview with surrounding communities).
- Based on recommendations from two above mentioned points, establish a HSE MP dedicated to the solar farm.
- Define a HSE team and organisation with a specific officer responsible for HSE issues on site. The officer should be appropriately trained and have adequate safety certification.
- Implement regular monitoring activities and reporting requirements. Monitoring usually consists in verifying general conditions of the site, pollution sign (remaining of construction on the field, waste from operation), regular equipment verification (PPE, firefighting equipment among others), water consumption, grievances, etc.

Case study

A solar farm has been operating for 2 years with no external O&M Contractor. During inverter maintenance, one worker received an electric shock leading to work disability of several days. Through the incident report, it was highlighted that the worker was not wearing appropriate personal protective equipment (uncertified and worn-out gloves), which led to the incident.

In this situation, to avoid any further incidents, the owner conducted a site assessment with a focus on electrical risks and, more generally, overall safety of the site. Several shortages were detected (no verification of PPE, new workers not adequately trained, lack of documentation on site). In this case, a set of different measures was implemented on site to avoid and mitigate electrical risks:

- Definition of work statement and risk assessment for electrical works: a global document listing all maintenance activities involving electrical risks and providing clear guidelines for performing the work, identifying potential risks and defining adequate safety measures. Usually, a basic process would include verifying that energized parts are deactivated and properly grounded. Before operating on the equipment, a lock-out-tag-out (LOTO) process should be applied
- An electrical protection equipment set (insulated gloves, protective shoes, safety glasses and face shield, insulated uniforms, helmets) should be available for each worker and regularly checked for integrity.
- Training of workers: only trained and certified workers should be allowed to work on electrical equipment. Re-training courses should be followed by workers regularly to ensure current local legislation and good practices are applied.

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE

Case study

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Accident (electric shocks accident during maintenance works on inverters)	Human casualties	Likelihood: Medium (3) – given limited experience locally on solar maintenance activities, accident are more bound to occur. Impact: High (4) – accidents and in particular electric shocks can potentially lead to death **Level of Risk: 12 (Critical)**

Since the evaluation of this risk resulted in a critical level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be implemented.

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE

Case study

Possible measures are presented in the table below with remaining risk management strategy analysis.

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: **Update HSE MP with work statement and risk assessment on electrical works**	Likelihood: Low (2) – adequate safety process would significantly reduce the risk, except for human error. Impact: Low (2) – with clear description guidelines and adequate protective equipment, electrical risks are significantly mitigated. **Level of residual Risk after Option 1: 4**	Acceptable – Adequate HSE MP process on electrical risk would mitigate the risk in the long term and will not imply significant cost	As soon as possible	Project Owner
Mitigate Option 2: **Conduct specific training for O&M teams**	Likelihood: Low (2) – occurrence of electric incident would be reduced with appropriate practices Likelihood: Low (2) – Major safety breach will be avoided with adequate training **Level of residual Risk after Option 2: 4**	Accepted –Training costs are not significant and would reduce probability of fatal and major accidents	As soon as possible	Project Owner

Since both residual risks were still considered as medium and both measures acceptable, the owner decided to implement both onsite to decrease probability of further incidents.

TECHNICAL NOTE: LACK OF HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATION DURING OPERATION PHASE	
Support resources	International Finance Corporation, Performance Standards on Environmental and Social Sustainability, 2012 International Finance Corporation, Environmental, Health, and Safety General Guidelines, 2007 IFC EHS General Guidelines, IFC EHS Guidelines on Electric Power Transmission and Distribution, 2007

TABLE 20 — TECHNICAL NOTE: UNMITIGATED IMPACTS ON FAUNA

TECHNICAL NOTE: UNMITIGATED IMPACTS ON FAUNA	
Risks	If not identified in preliminary stages, impacts on fauna are not usually visible for operating assets. Destruction of ecosystems is mostly apparent when historical data and biodiversity assessments have been conducted. Fatal impacts on fauna are occurring over an extended span of time and specific monitoring activities (such as carcass searching) are necessary to assess the impacts. These risks pose a major reputational risk, especially in Viet Nam given its high biodiversity values, and could be a deal-breaker for international funding if not adequately mitigated.
Risk Management Process	Impacts on fauna are assessed from the preliminary study and generally consists of: 1. Establishing a biodiversity baseline/inventory to identify biodiversity and ecosystems within project area. In particular, the baseline should state whether the project is located within any specific legally protected areas or internationally recognized areas (refer to support resources). Usual verification includes assessing presence of any endangered species in the project area and if the project can be defined as a critical or natural habitat. 2. Impacts should be assessed for all project facilities, not only the solar plant but also associated facilities, such as electrical transmission lines and roads constructed for the project. 3. Based on the environmental assessment, define protection and conservation measures through an adequate mitigation hierarchy (avoid, minimise, restore, offset) to achieve measurable outcomes. It should reasonably be expected to avoid any biodiversity loss. For the baseline assessment and definition of measures, prefer a third-party consultant with experience in international requirements regarding biodiversity conservation.

TECHNICAL NOTE: UNMITIGATED IMPACTS ON FAUNA	
Risk Management Process	4. Good practice prevention and control measures are recommended in any case, especially for transmission lines: avoid critical habitats areas, cover energized parts and hardware, consider installing underground transmission lines for sensitive areas, and install visibility enhancements objects, such as bird flight diverters. 5. If proven necessary by the initial assessment, ensure that adequate management plans (biodiversity action plan) are implemented, and sufficient budget is allocated to cover the entire project lifetime.
Mitigations measures for operating assets	The most common impacts of operating solar farms on fauna consist in birds' collisions or degradation/destruction of habitats. Mitigation measures for solar assets should be defined on a case-by-case basis. Examples of usual mitigation measures are: › Install bird flight diverters: Standards would usually require markers to be as large as possible compared to line thickness, not too far apart, have contrasting colour compared with background and rotating devices. Hire an expert third party for detailed and specific designed solutions. › Consider installing protection devices to prevent birds nesting on solar farm components. › Operational lighting should temporarily be limited and directed away from any natural habitats. › Implement appropriate drainage systems to avoid attracting birds near project vicinity. Avoid creating artificial water bodies, nesting and roosting areas that can attract birds and bats to feed or nest. › Consider investigating on possible birds' food sources and avoid birds to be attracted to these areas. › Adapt maintenance and operation activities to limit impacts on surrounding biodiversity lifecycle (avoid noisy operations during breeding period for instance).
Case study	A ground-mounted solar plant has been operating for a few months and the developer has been considering selling the asset to an international investor. During the course of the E&S due diligence of the plant, it was underlined that the project was located within the breeding ground of several bird species, including some endangered ones. The initial local environmental impact assessment only provided limited information regarding the species impacted with no specific mitigation measures for the construction or operation phases. The sale of the plant to the investor had to be put on hold until a complete biodiversity baseline and environmental impact assessment was conducted. After several weeks of studies, additional mitigation measures were requested to mitigate and compensate past and future environmental impacts on those species, especially regarding power lines impacts (collision). Among usual mitigation measures were the installation of bird flight diverters on power lines, carcass searching monitoring activities, adaptation of schedule for maintenance activities and subsidizing local association for bird protection and support their reproduction.

TECHNICAL NOTE: UNMITIGATED IMPACTS ON FAUNA

Case study

A complete risk assessment and management process at early project stage could have adequately helped to identify this risk and to put in place adequate measures to mitigate the risk. Risk evaluation is highly dependent on each project characteristics and should be performed on case-by-case basis. Evaluation provided below is solely an example.

TECHNICAL RISKS	POTENTIAL IMPACTS	RISK LEVEL BEFORE TREATMENT (EXAMPLE)
Environmental destruction e.g destruction of natural habitat or essential ecosystem to certain species	Lower bankability of the project	Likelihood: Medium (3) – given Viet Nam high biodiversity, likelihood of a project crossing migratory, or trajectory path of birds is common Impact: Medium (3) – as illustrated in the case, the location of the project was within breeding grounds of several bird species with several carcass found close to the project area **Level of Risk: 9 (High)**

Since the evaluation of this risk resulted in a High level of risk, based on the Risk Management Strategy (refer to section 4.3), measures to mitigate the risk should be seriously considered and implemented.

Possible measures are presented in the table below with remaining risk management strategy analysis.

POSSIBLE MEASURES	RISK LEVEL AFTER TREATMENT (EXAMPLE)	COST VS BENEFIT ANALYSIS	TIMELINE	FINAL RISK BEARER
Mitigate Option 1: Installation of bird flight diverters	Likelihood: Low (2) – the occurrence of collision will decrease but will not be fully mitigated. Impact: Medium (3) – installation of bird flight diverters would not change the impact of collision on bird species. **Level of residual Risk after Option 1: 6**	Acceptable – these measures might induce significant cost depending on length but could be a mandatory requirement to international funding.	As soon as possible	Project Owner

TECHNICAL NOTE: UNMITIGATED IMPACTS ON FAUNA

Case study

The project owner did not initially plan to install bird flight diverters, but this mitigation measure, as well as the other above mentioned, was included as condition for final transaction agreement. Furthermore, review of bird mortality through regular carcass searching was also required to monitor the residual impact.

Support resources

International Finance Corporation, Performance Standard 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources, 2012

UN Environment World Conservation Monitoring Centre, Integrated Biodiversity Assessment Tool, online resources (https://www.ibat-alliance.org/): online map tool providing zones and areas of significant importance in terms of biodiversity

International Union for Conservation of Nature and Natural Resources (IUCN), The IUCN Red List of Threatened Species, online resources (https://www.iucnredlist.org/)

Few international references related to biodiversity and cultural heritage:

- IUCN Red List of Threatened Species
- Birdlife International Vietnam
- World Heritage Areas, Protected Areas
- Key Biodiversity Areas
- Important Bird Areas
- Alliance for Zero Extinction sites

Few Viet Nam local references and centers to contact:

- Local Department of Agriculture and Rural Development
- Institute of Ecology and Biological Resources
- Center for Biodiversity Conservation and Endangered Species

06

REFERENCES

6.1. Risk Management Tools and Templates

Template 1: Risk Identification and Assessment

RISK MANAGEMENT PLAN

Provide basic information about the project including: Project Title – The proper name used to identify this project; Project Working Title – The working name or acronym that will be used for the project; Proponent Secretary – The Secretary to whom the proponent agency is assigned or the Secretary that is sponsoring an enterprise project; Proponent Agency – The agency that will be responsible for the management of the project; Prepared by – The person(s) preparing this document; Date/Control Number – The date the plan is finalised and the change or configuration item control number assigned.

Project Title: ____________

Project Working Title: ____________

Proponent Secretary: ____________

Proponent Agency: ____________

Prepared by:

Date / Control Number:

B. RISK MANAGEMENT STRATEGY

1. Risk Identification Process - Describe the process for risk identification.

2. Risk Evaluation and Prioritization - Describe how risks are evaluated and prioritised.

3. Risk Mitigation Options -Describe, in general terms, the risk mitigation options.

4. Risk Plan Maintenance -Describe the methods for maintaining or updating the risk plan.

5. Risk Management Responsibilities -Identify individuals with specified risk management responsibilities.

Individual	Responsibility

Note: More templates at https://www.engineeringmanagement.info/2021/06/risk-management-plan-template-in-excel.html

Template 2: Risk Identification and Assessment

<table>
<tr><td colspan="3">PROJECT NAME</td><td><optional></td><td colspan="8"></td></tr>
<tr><td colspan="3">PROJECT MANAGER NAME:</td><td><required></td><td colspan="8"></td></tr>
<tr><td colspan="3">PROJECT DESCRIPTION:</td><td colspan="9"><required></td></tr>
<tr><td>ID</td><td>Current Status</td><td>Risk Impact</td><td>Probability of Occurrence</td><td>Risk Rating</td><td>Risk Description</td><td>Project Impact</td><td>Risk Area</td><td>Symptoms</td><td>Triggers</td><td>Risk Response Strategy</td><td>Contingency Plan</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

Note: More templates at: https://www.engineeringmanagement.info/2021/03/risk-management-log-template-excel-free.html
https://www.engineeringmanagement.info/2021/01/risk-management-tracker-template-in.html

Template 3: Operational Risk Management Reporting

<table>
<tr><td colspan="3">1. Mission/Task/Process/Operation/Event:</td><td>2. Date</td><td colspan="2"></td><td>3. Date Prepared:</td><td rowspan="2">4. Designator Number</td></tr>
<tr><td colspan="3"></td><td>Begin:</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="3"></td><td>End:</td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>5. Prepared By:</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="4">Name / Duty Position</td><td colspan="3">Signature</td></tr>
<tr><td>6. HAZARD</td><td>7. INITIAL RISK</td><td>8. CONTROLS</td><td>9. RESIDUAL RISK</td><td colspan="2">10. HOW TO IMPLEMENT</td><td>11. HOW TO SUPERVISE</td><td>12. CONTROLS EFFECTIVENESS</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="5">13. OVERALL RISK LEVEL AFTER CONTROLS ARE IMPLEMENTED (circle one)</td><td colspan="3">14. RISK DECISION AUTHORITY:</td></tr>
<tr><td colspan="5"></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">RAC 1 - (CRITICAL) RAC 2 - (HIGH) RAC 3 - (MODERATE) RAC 4 - (LOW)</td><td>RANK OR GRADE/NAME/ DUTY POSITION</td><td colspan="2">SIGNATURE</td></tr>
</table>

Note: More templates at: https://www.engineeringmanagement.info/2021/06/risk-management-plan-template-in-excel.html

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