The land of rising risk?

Due diligence | A significant part of the risk management process associated with large-scale solar PV installations is 'technical due diligence', which seeks to define and minimise all technical risks associated with the project. Fred Martin and Nick Morley of TÜV Rheinland explore due diligence challenges for PV power plants in Japan

Rapidly declining production costs and various government incentives have created an attractive investment environment for large-scale solar PV in several countries, leading to massive increases in PV power plant installations around the world – particularly in Japan. Several gigawatts of utility-scale solar have been installed in Japan in just a few years following the introduction of a feed-in tariff (FiT) in 2012. Capital for these projects is often acquired through project financing, and therefore the participation of financial institutions and investors has been essential to the rapid development of large-scale PV installations in recent years. Given the large sums involved, banks and other investors require assurance that they will see a return on their investments through the long-term cash flow generated by the power plant; in order to do this they will typically contract the services of independent specialists to advise them on project-specific risks.

Risk factors

Risk factors at the project level can be roughly categorised into financial, legal and technical risks, each managed in a different way. The financial structure of the project is designed to ensure sufficient cash flow in order to manage the project's ongoing debt obligations under a variety of scenarios. Legal risks are usually managed with the aid of specialised legal firms who ensure all applicable regulatory requirements have been adhered to. Legal advisors also assist in managing the contractual structure to ensure that the project owners are protected – through an array of warranties, guarantees and insurance – from risks arising from the work of various contracting parties.

Technical risks can be found throughout the legal and financial structures and arise at all stages in the project life cycle: from design and performance modelling, through construction and operation, to decommissioning. The opportunities to control these risks, however, are concentrated in the initial phases of the project development. To that end it is common practice for lenders to contract a technical advisor whose job it is to review all technical aspects of the design, specifications, contracts, commissioning tests, and technical inputs for the financial models, with the aim of detecting, quantifying and mitigating potential risks.

Quality and minimising risk

The 'bathtub curve', which shows the failure rate of components and systems over their lifetimes, is helpful for explaining the effect that quality has on risk (Fig. 1): it includes four lifetime segments in which failures occur. Taking the example of a power plant, early failures, called *primary infant mortalities*, could be caused by component-manufacturing errors or by damage that occurs during installation. *Residual failures* are those that occur indirectly through stress or as a follow-on from infant mortalities; an example is incorrect dimensioning of string inverter ratios or components, which present faulty operation at a later stage.

"To minimise failures and the associated risks to the project, it is essential to achieve high quality with the help of technical due diligence"

During its *service life*, a well-designed power plant will usually operate without major incidents apart from some planned maintenance, such as inverter replacement, which normally occurs after around 10 years. Finally, materials age and fail during the *wear-out period*. In a PV power plant it is essential to either plan ahead for maintenance at or before the wear-out period, or ensure that the component lifetimes are longer than the intended lifetime of the plant.

Quality can be described as the area lying between the two failure rate peaks – an increase in quality translates to a decrease in the failure rate at the beginning of the component lifetime and an increase in the lifetime at the end. In order to minimise failures and the associated risks to the project, it is essential

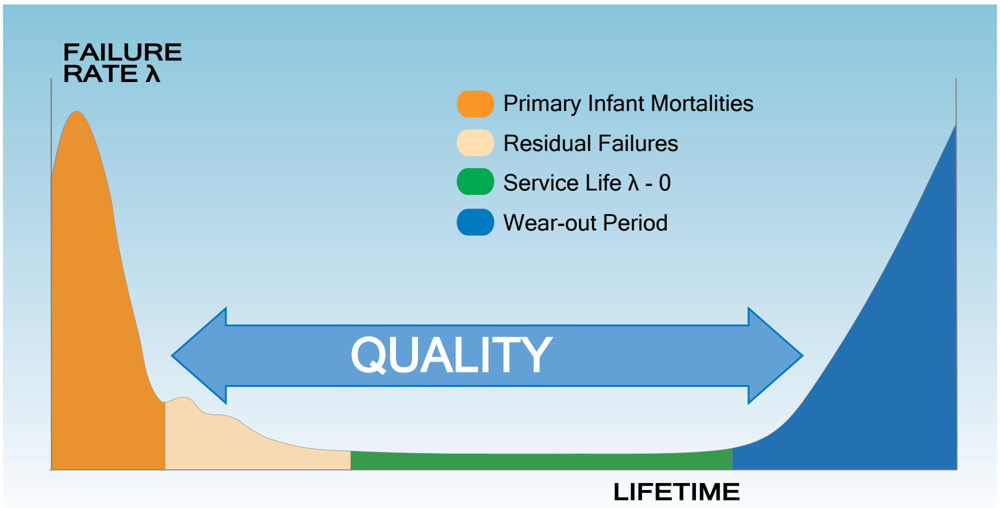


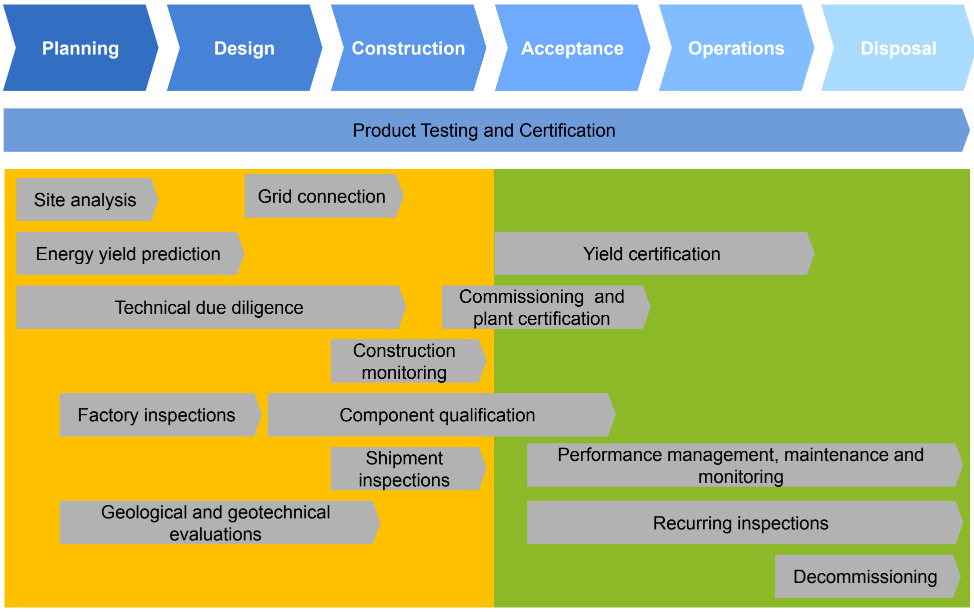
Figure 1. The bathtub curve: quality reduces failures and risks, increasing usable lifetime.

to achieve high quality with the help of technical due diligence.

Project technical due diligence

While some large banks may possess the necessary technical knowledge to perform their own technical analysis in-house, often they do not, and in any case it is necessary for the group of lenders to receive opinions from third parties who do not have a conflicting interest in the project. For large projects it is important that the due diligence providers are not only technically competent, but also established businesses with proven track records that are likely to continue operating in the region throughout the lifetime of the project. This is particularly important if the project is to be sold later on as an investment product, since the technical advisor may need to stand behind their work or provide additional consultations and services to satisfy future investors.

Fig. 2 shows the project phases in the lifetime of a PV power plant, along with the associated services that can accompany each phase. The inspectors perform initial assessments during the site analysis, covering the site topography and other local factors – such as soiling, slope, vegetation, and construction logistics – that may affect the suitability of the site for the PV project. If a site visit is performed, photographs and shading profiles are also taken in order to evaluate the quality of the solar resource at the site. This information can then be used as input data for the energy yield prediction (EYP). The EYP involves gathering a range of technical inputs that also include the PV module performance characteristics and weather data specific to the site, and using them with commercial software to predict the amount of energy that will be generated by the power plant. To complement a more extensive site analysis and EYP, initial technical due diligence also includes a complete review of the engineering, procurement and construction (EPC), and operations and maintenance (O&M) contracts. These contracts cover the electrical design, contractors and suppliers, warranties, guaranties, and acceptance criteria for the completion of the plant.



▲Figure 2. Project phases in the lifetime of a PV power plant value chain, and the associated services.

During the construction and acceptance phases, a due diligence service provider may be utilised to:

- inspect shipments of components, such as the PV modules, to ensure that they are packaged and handled in accordance with the manufacturer's instructions;
- supervise construction and verify project milestones;
- ensure that the commissioning tests are performed in compliance with procedure at provisional and final acceptance, as often defined in the EPC contract (time frames between provisional and final acceptance vary from a few months to three years).

▼Table 1. Important PV areas and their main respective standards. Some of the JIS equivalents may be adopted in the near future.

Area	Japanese Industrial Standard (JIS) and International Electrotechnical Commission (IEC)
Module	IEC 61215:2005, IEC 61730-1,-2:2004, IEC 61646:2008 JIS C 8990:2009, JIS C 8991:2011, JIS C 8992-1:2010, JIS C 8992-2:2010, JIS Q 8901:2012
Inverter	IEC 62109-2:2011, IEC 62116:2014 JEAC 9701:2012 (Japan Electric Association Code) Grid connection guidelines No IEC equivalent certification scheme for commercial inverter available in Japan (>20kw)
Cable (string)	JCS 4517:2013 (Japanese Cable Makers' Association Standard) Halogen-free cable for PV applications
Mounting system	JIS C 8955:2011 for rack design and JIS A 1221:2002 for geotechnical testing
System	IEC 60364-7-712:2002 Requirements for special installation or locations solar PV power supply systems JIS C 0364-7-712:2008 Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems
Testing, commissioning and documentation	IEC 62446 ed1.0:2009 Grid-connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection No equivalent available in Japan – Electric business act (laws) where applicable
Design	IEC 62548:2013 Photovoltaic (PV) arrays – Design requirements No equivalent available in Japan

Further into the project lifetime during the operational phase, technical advisors are occasionally required to verify the power plant performance level through a yield or performance ratio (PR) certification in order to resolve disputes, or to verify to a new investor or buyer that the plant is operating correctly.

Challenges for due diligence in Japan

There are specific challenges related to the Japanese market that are important to consider in terms of the technical due diligence process. The first of these is the issue of standards and experience. Japan has long been one of the largest solar markets in the world; however, before the introduction of the FiT in 2012, this was almost entirely due to residential and small commercial rooftop installations. With several gigawatts of utility-scale PV projects now being added to the grid, this trend has begun to change dramatically. Because of this rapid development, a comprehensive set of local standards does not yet exist for PV power plants, and the use of international equivalents has been sporadic because of language barriers and differences in established practices. The high project returns made possible by the FiT also attracted many new and inexperienced players to the market, further exacerbating the issue of inconsistent design and construction. For example, there have been multiple instances where module-mounting structures were not adequately designed to support heavy, non-uniform snow loads, and as a result of heavy snowfalls in 2014, several systems across Japan suffered severe damage [1].

Additionally, since many projects in Japan are being developed in mountainous areas the subsoil content is often inhomogeneous, and therefore multiple geotechnical tests are usually required to ensure that the ground is suitable for the mounting structure design. Geotechnical investigations performed during the planning stages have occasionally been inadequate, with developers later discovering that the intended structure design could not be driven into the ground because of large basaltic layers and rocks under the surface, leading to late-stage design changes at much higher costs during the construction phase.

Table 1 lists some relevant standards for PV power plant design, testing, commissioning and documentation. These standards not only support developers by increasing efficiency, reducing risks and driving down overall costs of their design processes, but also help banks, investors and relevant stakeholders by allowing them to easily verify whether a project meets a minimum set of technical requirements. Without an agreed standard, the quality, the results of the contract negotiations and the degree of risk in each project become almost entirely subject to the opinions of the technical advisors and the EPC manager and to the experience level of the banks and investors. These factors can be different from project to project, and, unsurprisingly, projects in Japan have been seen to vary widely in quality over the last few years.

With regard to PV modules, IEC 61215, 61646 and 61730 are essential qualification test standards designed to identify infant mortalities and are a basic requirement for modules to be considered for a large-scale project. In the Japanese market, JET PVm module certification and JIS Q8901 quality system audits have also become commonplace. Neither is obligatory; however, they help manufacturers to demonstrate a long-term commitment to their Japanese customers and are well regarded by local investors and developers.

> "Another major challenge for PV power plants in Japan is accurate modelling of the expected yield and performance"

Although various certifications may aid manufacturers to sell their products in a competitive market, from a risk standpoint they are of secondary importance, since none of the current testing programmes can guarantee a module's lifetime and degradation rate. Banks and ratings agencies instead look for a successful track record and real data from previous projects where the modules have been used, in order to judge their reliability. This can be particularly challenging for newer manufacturers whose products may not yet have been deployed for long periods of time. In these circumstances, a technical due diligence advisor will look for extended accelerated stress test programmes that the modules have completed. While these programmes do not guarantee the module lifetime, they nevertheless provide indications of long-term quality and data about the module's behaviour during its service life and wear-out period. One way or another, it is important to establish that the modules are likely to perform well in the field, since the degradation rates assumed in the project financial models are typically less than those guaranteed by the manufacturer. This risk should be managed by verifying the plant's performance at regular intervals, and in some cases by also taking samples from the module shipments and testing them at an accredited laboratory using a calibrated solar simulator.

It is important to keep in mind that while much emphasis is often placed on PV module reliability and 'bankability', from a risk perspective the module is just one part of a much larger project system requiring comprehensive risk management.

Performance prediction models

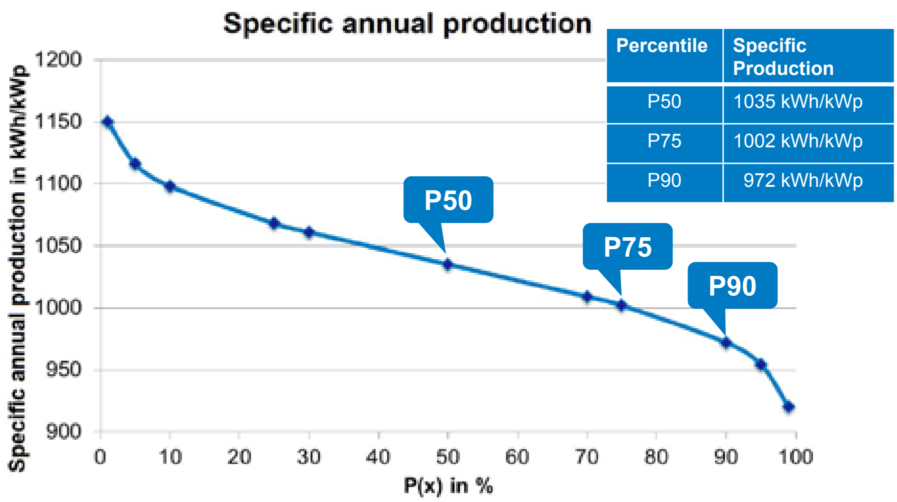
Another major challenge for PV power plants in Japan is accurate modelling of the expected yield and performance (Fig. 3). This is done by selecting an appropriate irradiation database and horizon shading profile, and then combining them with a model of the power plant using commercial software that calculates monthly yields and performance ratios (PRs). The PR is the ratio of the actual output compared with the maximum theoretical output, and is one of the most important values associated with determining the efficiency of a PV power plant [2]. It is essential in the technical due diligence process, since while the EPC manager cannot guarantee the amount of incident sunshine over the year (and, in turn, the plant yield in kWh), they can, and should, guarantee a minimum plant efficiency level based on a realistic performance model, in order to minimise the performance risk borne by the lenders and investors.

The first challenge here has been a reluctance of some EPC providers to guarantee their work through the PR. For a company inexperienced in solar construction, such a guarantee may be viewed as too risky, since they do not have data from similar projects that they can use to confidently guarantee the plant's performance. In addition to this there are also particular challenges in ensuring the accuracy of the energy yield model in Japan, where microclimatic conditions caused by the mountainous island geography increase annual variations in irradiation. Compared with zones that have previously been popular for utility-scale PV power plants, such as Spain and the USA, Japan also has relatively large differences in average annual irradiation over smaller areas, leading to increased uncertainty. This uncertainty carries over into the financial model, as cash flow is directly affected by the amount of available solar irradiation.

Several different irradiation databases map estimates for expected irradiation over both Japan and the world using ground-based measurements, satellite data, or a combination of both. While ground-based measurements are generally considered to be more reliable, the further the site is from the measurement station, the greater the uncertainty will be. When selecting the database for a site, there may be several nearby ground-based stations showing different levels of irradiation, and it is not always clear which one is most appropriate. Significant differences in altitude and topography can also have an effect on reliability because of microclimates, reducing the accuracy of both satellite and ground-based measurements.

A variety of different irradiation databases exist for use in Japan. Japan's New Energy and Industrial Technology Development Organization (NEDO) operates an extensive network of ground-based measurement stations in cooperation with the Japan Meteorological Association (JMA), called MONSOLA. The NASA SSE satellite radiation data is also frequently referred to, and comprises a grid of resolution 1° × 1° (approximately 111km × 111km) built from average irradiation data collected between 1983 and 2005. Meteonorm is a commercial software tool that uses up to six nearby ground-based stations (NEDO stations are used for Japan) and interpolates between them with reference to the coordinates of the installation site.

Several other satellite-based sources exist, including SolarGIS and OREL, which have more recent datasets, often covering a shorter period of time (Fig. 4). These newer datasets generally show higher



▲**Figure 3. Energy yield prediction models are statistically validated and presented in probability values with given uncertainty (50th, 75th and 90th percentiles).**

irradiation values as a result of increasing amounts of solar irradiation experienced in recent years. It is also generally understood that the satellite method tends to overestimate radiant exposure in wet, cloudy conditions, and to underestimate it in dry conditions [3]. It is essential to take these effects into consideration for the humid sub-tropical climate that exists in Kyushu, Shikoku and most of Honshu, and for the humid continental climate in Hokkaido.

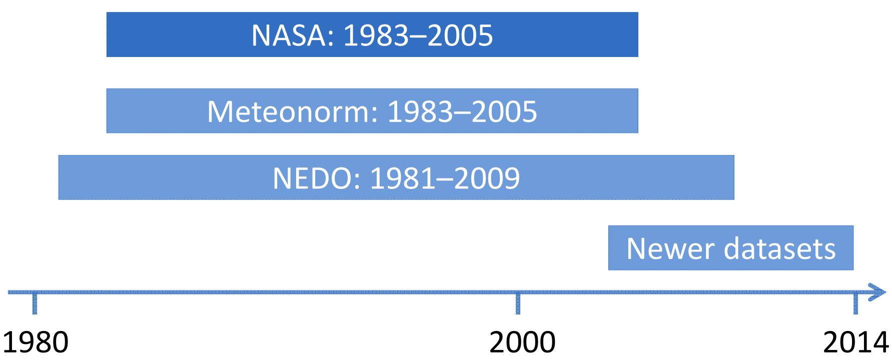
Unlike in the USA and Europe, where PV power plants are usually constructed in desert regions or open fields, because of a lack of available land in Japan, PV power plants are often placed in more mountainous areas, such as old golf courses (Fig. 5) or terraced fields, making the selection of an appropriate irradiation database particularly challenging. In their risk methodology for utility-scale solar PV projects, Standard & Poor's state that "it is important to have conservative resource data, given that we rely on predictions of cash flow in our credit analysis" [4]. But being conservative can be challenging when developers are faced with large differences between reputable sources, as there is significant temptation to adopt the database that delivers the highest results to the financial model.

A brief comparison of a variety of satellite irradiation databases with several nearby NEDO ground-stations that was recently performed for a site north-east of Tokyo showed a maximum difference in expected irradiation of 14.5%. In another analysis, ground-station irradiation measurements from different regions in the last two years were compared with the 20-year average: a maximum increase of 8% was found. Despite a trend of higher values in recent years, it was also observed that several areas received less irradiation. Long-term mean values from a traceable source are therefore more relevant for prediction discussions, since they are less affected by natural yearly fluctuations.

In some cases, due diligence providers will seek to account for these uncertainties by averaging data from multiple sources, asserting that the calculated mean will be a conservative value. However, not all of these sources are independent, since they often use the same meteorological data sources, and the mean can easily be manipulated by selecting which database values are included in the calculation. Both satellite and ground-based measurements have their own advantages, and the database selection in each performance model should rather be based on a thorough investigation of the conditions specific to the site, with the aim always being to deliver a performance model that is realistic.

Despite the challenges of building a consensus around the underlying assumptions for factors affecting the project yield, improvements are gradually being seen over time in average modelled PV power plant efficiencies compared with actual values, which is a promising indication of

▼**Figure 4. Main datasets and their durations. The period and type of data are essential for any statistical validation, and should be taken into account when comparing data values and results.**



Credit: TÜV Rheinland

◄ Figure 5. Aerial perspective showing typical inhomogeneous topography, taken via drone during construction monitoring of a golf course being prepared for a PV power plant. Many PV projects are being developed in Japan at decommissioned golf courses, which were developed during the 1980s but later proved to be unprofitable. They have found a second life through PV plant development.

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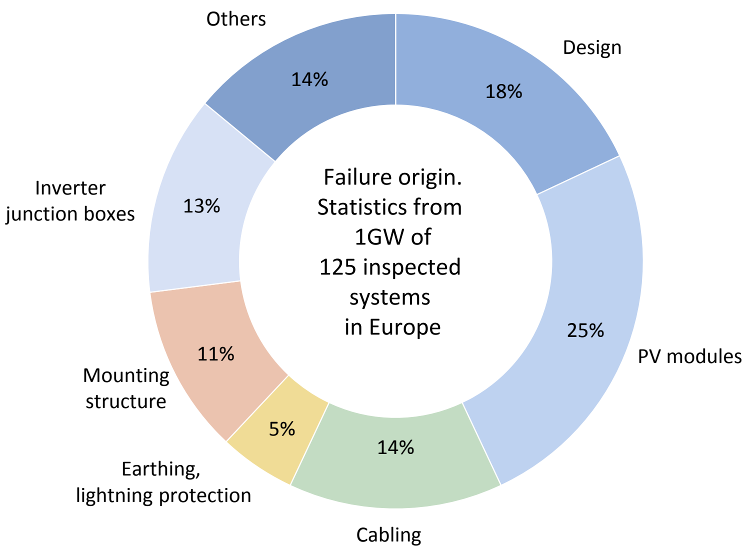
increasing overall quality, in line with other markets worldwide [5].

Japan – land of the rising risk?

Although the Japanese market remains one of the strongest in the world, there are several factors that may hamper growth in the near future and represent long-term risks to project returns. For example, the extremely large number of projects vying for connection to the grid that have materialised as a result of the uncapped FiT has placed stress on the capacity of smaller utilities to absorb further sources; as a result, Kyushu Electric, Hokkaido Electric Power Company (HEPCO) and Tohoku EPCO have all recently taken various measures to suspend new applications [6]. While it is currently unknown if other Japanese electric utilities are considering similar action, it is clear that intense competition for connection approvals in Japan is a rising source of risk. It is also expected that the FiT rates will be revised again around the new Japanese fiscal year in 2015.

Despite the progress made so far, failure to quickly agree on a set of design and documentation standards for the industry will continue to keep costs high in this area and increase the likelihood of errors. As the majority of large-scale projects in Japan are still in their early stages, it can also be expected that infant mortalities, residual failures, and associated performance issues resulting from poor design and inappropriate installation practices will begin to appear in some of the affected projects over the next two to seven years, as witnessed in other markets (refer to Fig. 6). High-quality O&M will be able to manage some, but not all, of these, and the impact on investors will depend on the quality of the industrial contracts that have been put in place to protect them.

Figure 6. Research done by TÜV Rheinland in collaboration with Mannheimer Insurance showed that around 50% of failures are traced back to installation mistakes [7].



Conclusion

The take-away here is that an array of solutions exists for controlling risk factors in PV power plants, and that it is most important – and economical – to address problems at the early stages of development. Careful selection of a professional project due diligence service that is integrated into the project planning at the beginning will help to ensure a smoother design phase, reduce risk and significantly increase the likelihood of healthy project returns. ■

Authors

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