NATIONAL RENEWABLE ENERGY LABORATORY

Continuing Developments in PV Risk Management: Strategies, Solutions, and Implications

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List of Acronyms

ASTM	American Society of Testing Materials
BOS	balance of system
CCIP	contractor controlled insurance program
CGL	commercial general liability
CIC	captive insurance company
CIP	controlled insurance policy
COPE	construction, occupancy, protection, exposure
DOE	U.S. Department of Energy
ECD	Energy Conversion Devices
EERE	Office of Energy Efficiency and Renewable Energy (DOE)
EPC	engineering, procurement, and construction
ESIF	Electrical Systems Integration Facility
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LCOE	levelized cost of energy
M&C	measurements and characterization
NCPV	National Center for Photovoltaics (NREL)
NOTA	Notice of Opportunity for Technical Assistance
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
OCIP	owner controlled insurance program
OEM	original equipment manufacturer
PPA	power purchase agreement
PUC	public utility commission
PV	photovoltaic
RAM	reliability, availability, maintainability
RMS	Risk Management Solutions
RTC	regional test center
SIT	Solar Integrated Technologies
SNL	Sandia National Laboratories
SPV	special purpose vehicle
S&P	Standard and Poor's
WACC	weighted average cost of capital

Executive Summary

Solar photovoltaics (PV), while not new technologies, have only recently begun to penetrate the U.S. energy mix at a substantial rate. The last three years have seen record growth for the PV industry, and, when accounting for the number of projects in the development pipeline, stated investor commitments, the inexpensive supply of panels on the market, and the renewable energy standard requirements of several states, it is likely that deployment will continue through the near-term.

As the PV industry matures, successful risk management practices will become increasingly important to ensure investor confidence, control costs, and facilitate further growth. This study discusses several key aspects of risk management during the commercial- and utility-scale project life cycle, from identification of risks, to the process of mitigating and allocating those risks among project parties, to transferring those risks through insurance. The study also explores novel techniques in PV risk management, options to offload risks onto the capital markets, and innovative insurance policies (namely warranty policies) that address risks unique to the PV sector.

One of the major justifications for robust risk management in the PV industry is the cost-reduction opportunities it affords. PV projects are currently subject to high financing costs, due in part to the market's perception of the risks associated with: (1) investing in an industry that is still perceived to be in a relative stage of infancy; (2) arranging the complex financial structures often necessary to fund projects; and (3) the lingering uncertainty over PV asset performance over time, among other things. If the PV industry can demonstrate the capability to successfully manage its risks, thereby inspiring financier confidence, it may be able to obtain a lower cost of capital in future transactions. A lower cost of capital translates to a lower cost of energy, which will in turn enhance PV's competitiveness at a time when it will have to rely less on subsidies[1] to support its market penetration. Lower financing costs would also contribute to the achievement of the U.S. Department of Energy's SunShot scenario, which envisions an installed system price for utility-scale PV facilities of $1 per watt by 2020 (DOE SunShot 2012a).

[1] Both the 1603 Treasury grant program and the 1705 loan guarantee program expired at the end of 2011, though their effects are still influencing PV market dynamics as of this writing. Bonus depreciation of 50% in the first year of operation expires at the end of 2012 (though the modified accelerated schedule is available across industries indefinitely) and the 30% investment tax credit will revert to 10% at the end of 2016. The combined effect of expiring subsidies and uncertain renewals in 2017 has been a hindrance to long-term investment and corporate strategies for solar stakeholders.

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1 Introduction

In 2010, the National Renewable Energy Laboratory (NREL) published an analysis on the challenges then inherent to insuring photovoltaic (PV) power projects. The analysis, titled *Insuring Photovoltaics: Challenges and Possible Solutions*,[2] found that PV insurance costs may have been inflated largely because of the insurance industry's unfamiliarity with PV technologies and the project development process, as well as the limited availability of historical operating data used to formulate underwriter models (Speer et al. 2010).

It has been over three years since the research for that analysis was conducted, and in that time total grid-connected installed PV capacity in the United States more than quadrupled, topping 5.1 GW in the second quarter of 2012. System prices across market segments have consistently fallen over the same period, with weighted average system costs plummeting over 45% since the beginning of 2010 (IREC 2010; SEIA/GTM 2012).

As downstream investments in PV deployment continue to grow,[3] and as PV comprises a larger portion of the energy mix, it is becoming increasingly important for stakeholders across the industry to understand the particular risks associated with PV and the most effective means of managing them. Anticipation and mitigation of PV risk is not only necessary from the standpoint of reliability and energy security; it could also play a significant role in reducing PV's current high cost of capital.

The risks of lending or investing in a PV project that influence its cost of capital include:

- The PV market is still driven by temporary incentives that have expired or will expire at the end of 2016. This has created uncertainty about the long-term viability of the PV industry, which may limit investments going forward and prevent developers from project planning beyond the near-term.
- Historical performance data for PV systems on which to base risk management strategies and investment decisions are difficult to access by market players, such as investors, insurance underwriters, and power purchasers. According to NREL interviews, reasons for this difficulty include the short time that most PV systems have been operational (almost three-fourths of total PV capacity was installed in the last four years) and a tendency among system operators to guard performance data as proprietary.

This study, produced in collaboration with Sandia National Laboratories (SNL), is an update and expansion of the 2010 NREL study (Speer et al. 2010). Instead of focusing directly on insurance in PV project development as did its forerunner, this study examines the more general field of risk management for commercial- and utility-scale PV.[4] The core of the study begins with an overview of the technical and non-technical risks inherent to the project development cycle

[2] See *Insuring Solar Photovoltaics: Challenges and Possible Solutions*, National Renewable Energy Laboratory report. Available at: http://www.nrel.gov/docs/fy10osti/46932.pdf.
[3] It is likely that this growth will proceed at a somewhat reduced pace as the market effects of the expired 1603 Treasury grant and the 1705 loan guarantee programs wear off (Mendelsohn et al. 2012) and as the expiration of the 30% investment tax credit approaches.
[4] Risk management for the residential sector is quite different from that at the commercial- and utility-scale. System owners in residential PV are usually either homeowners—which can cover their systems under a homeowner's policy—or installation companies (if the system is leased), which often provide their own insurance.

(Section 3). Section 4 surveys several non-insurance risk management strategies common in PV project development, including due diligence practices, contract safeguards, and cross-collateralization. Section 5 examines the current state of insurance in the PV industry and includes discussions on the available coverage types, costs, and market size. Section 6 reviews several innovative solutions for addressing PV's unique risk profile, and Section 7 concludes with recommendations for the role of national laboratories in the PV risk management space.

2 Analysis Objectives and Methodology

2.1 DOE SunShot Initiative and the Interplay with Risk Management

The SunShot Initiative is a program of the U.S. Department of Energy (DOE) and is the locus at the federal level for supporting PV and concentrated solar power technology research, development, and demonstration.

SunShot has identified several objectives for the U.S. solar industry, but its overarching goal is to aggressively drive the cost of solar energy down to a level where it is competitive—without support policies—with conventional forms of generation. To achieve this, the DOE is supporting private companies, academia, and national laboratories—including NREL and SNL—to lower the cost of PV-generated electricity by 75% between 2010 and 2020. SunShot estimates that, with such a steep decline in energy cost, solar power could fill 14% of U.S. electricity demand by 2030 and 27% by 2050 (DOE SunShot 2012a).

Effective risk management practices in the PV project cycle can help to achieve this goal by driving a lower cost of capital and therefore contributing to soft cost reductions. Soft costs, the numerous project expenditures (including financing costs) additional to the module costs, can account for up to 30% of a PV project's total price tag in the United States. Financing (i.e., the cost of capital) to develop a commercial- or utility-scale PV system represents a significant portion of this figure. One forthcoming NREL analysis calculated a weighted average cost of capital (WACC) for a PV project with a typical debt/equity split and yields at current market rates at 9% of total project costs. This analysis assumed a financial structure of 35% debt, 60% tax equity, and 5% sponsor (or developer) equity. The debt interest rate was set at 7.5%, the tax equity yield at 11%, and the return on sponsor equity at 15%. In the analysis results, tax equity accounted for almost 6.6% of the 9% WACC. Debt contributed about 1.8% (Mendelsohn et al. forthcoming).

If developers can successfully demonstrate their abilities to manage the risks inherent to the planning, construction, and operational phases of their projects, PV investment may come to be regarded as less risky than current financing costs would suggest. Moreover, projects with robust risk management practices in place may be able to purchase insurance at lower risk premiums than current market rates. Decreasing both the financing and insurance costs for the PV asset class would put downward pressure on system soft costs, which will in turn drive down the levelized cost of energy (LCOE) of solar energy. A lower (and more competitive) LCOE may drive demand for PV installations in certain markets, thus contributing to the achievement of the SunShot Initiative's deployment goals.

This study attempts to stimulate a dialogue between the PV, insurance, financial, and policymaking communities about the cost-reduction potential of PV risk management by highlighting current best practices and exploring potential solutions.

2.2 Methodology

The data and insights presented in this study were collected from a variety of sources. NREL and SNL have conducted a literature review on the subjects of PV, risk management, and insurance, which was used as a foundation for the analysis. This literature review was substantiated through a series of discussions with industry participants conducted from March until October of 2012.

Interviewees included PV developers, module manufacturers, financiers, and insurance industry professionals (brokers, carriers, reinsurers, underwriters, and consultants) representing some of the major players in their respective industries. Some follow-up correspondences were also conducted, and all participants were given the opportunity to comment on a draft of the report. Because some of the information gathered is viewed as proprietary or sensitive, the identities of the companies and interviewees will not be tied to specific ideas presented in the here.

Additionally, the authors have participated in several conferences related to this topic area, including:

- Renewable Energy Insurance & Risk Management, November 8–9, 2011 Green Power; New York, New York
- Solar PV Asset Class Technical Working Group Q2 Update, June 25, 2012. SolarTech and CalCEF; San Francisco, California
- SunShot Summit, June 13–14, 2012. Department of Energy; Denver, Colorado
- Differentiating Quality PV, March 6, 2012. NREL SNL and Dissigno; San Francisco, California.

3 PV Risk

There are a myriad of risks present in the PV project cycle. Some, such as construction risk, are confined to specific phases of development, while others persist throughout the entire cycle from planning through operation (such as default risk). Most project risks will be allocated to a number of the parties involved in the project's development, and these parties will be responsible for a portion or all of the potential losses arising from these risks. A degree of uncertainty or the total maximum loss for an individual risk will not necessarily disqualify the whole project from acquiring investment as long as the other risks are demonstrated to be under effective management. For example, a project that uses a new technology or is sited in a location without a strong proven resource may be investment grade as long as other aspects of the project's development are perceived as low risk. Tax equity investors may take on high-risk developments if they deem the expected return on capital to compensate for the level of risk. However, these institutions are generally conservative and place greater value on project quality than on higher yields (Mendelsohn et al. 2012a).

A typical risk management strategy during the PV project cycle can be segmented into three steps: (1) *identify* all project risks; (2) *mitigate* the risks and *allocate* them among the relevant project parties (allocation can itself be considered a risk mitigant); and (3) *insure* those risks that cannot be cost-effectively or efficiently absorbed by the project parties (see Figure 1).

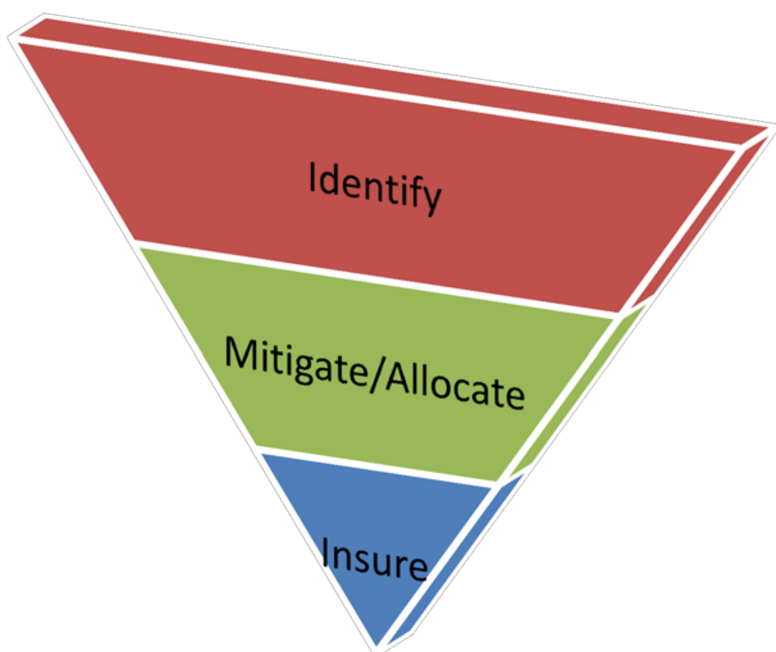

Figure 1. General risk management strategy for the PV project cycle

As shown in Figure 1, insurance is the smallest and bottom-most segment of the inverted triangle. Insurance is a transfer of risk away from the project and onto a carrier's balance sheet[5]

[5] In the case of PV warranty insurance, the carrier will actually underwrite the performance of a module manufacturer. This is a guarantee (much in the way that financial institutions can provide guarantees of payment by underwriting letters of credit, for example) and not a risk transfer.

in exchange for the payment of a premium that represents the probability and size of losses that could arise from that risk. This is an expensive method for managing project risks, and as such, it serves as a "last line of defense" for contingencies that have not been captured through the process of mitigation and allocation. Moreover, insurance coverage is typically available only in one- to two-year increments, after which time policyholders must renew. It is costly for project sponsors to continually renew policies, and they will typically try to minimize these payments by making sure that the policy covers only those risks that could not be absorbed by the project parties. Additionally, the sponsor will try to minimize the effects of future volatility in insurance costs on their project, as the lifetime of a PV system. In other words, the asset life of a PV project could extend 20 or more years, and if a sponsor must renew its policies every one to two years, it could be subject to price hikes that adversely affect project economics.

This section focuses on the first step: identifying the risk. It provides an overview of PV project risks as divided into two categories: technical and non-technical. Both of these categories are further subdivided into development stage risks and operational risks. The following tables are not exhaustive but are instead meant to cover the major considerations. Ultimately, the risk profile for a given project will depend on the location, incentive regime, developer and/or sponsor, and capital structure, among other considerations, so a comprehensive assessment of PV project risks is something of a moving target.

3.1 Technical Risks

Technical risks are those that arise from the module, inverters, and other mechanical and electrical components, as well as system engineering, energy modeling, and installation.

3.1.1 Project Development Risks

The technical risks during the PV project development cycle (planning and construction) include various aspects of system design, resource estimation and validation, siting evaluations, and grid interconnection. Table 1 organizes major development risks by category and lists common techniques for mitigation.

Table 1. Technical Risks During Project Development and Potential Damages or Losses Arising From Those Risks

Risk	Considerations	Potential Damages or Losses
Resource Estimation	What level of confidence should be applied to historical solar data?	Resource-related production shortfalls
		Debt service delinquency or default
Component Specifications	What is the performance history or specification of the selected product?	Manufacturer insolvency
		Serial defects
		Infant mortality
System Design	How well is the system design integrated with the components? Does it ensure reliability, availability, and maintainability (RAM)?	Component failures
		Production shortfalls
		Forced downtime
Performance Estimates and Acceptance/Commissioning Testing	How well validated are the performance estimates? What tests are done to confirm baseline performance?	Production shortfalls relative to estimates—could stress debt service
Site Characterization	What is known and what might not be known about the site? What are the weather, water, geotechnical, and infrastructure conditions?	Environmental constraints/prohibitions
		Infrastructure constraints
		Transmission cost overruns
Transport/Installation Risks	Are components shipped and installed according to best practices?	Equipment damage delays

3.1.2 Operational Project Risks

The principal risk in the operational phase of a project is the uncertainty of energy production. If actual project performance does not meet the budgeted generation estimates, the project will generate less revenue from power sales, and the sponsor may experience difficulty in servicing its debts or earning its investors their returns. Production shortfalls can result from plant operation contingencies, such as component failures (serial and otherwise), latent defects, forced outages, module degradation, and resource variability.

Table 2. Technical Risks During Project Operation and Potential Damages or Losses Arising From Those Risks

Risk	Considerations	Potential Damages or Losses
Operations and Maintenance (O&M) Risks	What are the component failure/reliability risks? Is there adequate availability of spare parts in inventory or rapidly available? What is the strength of the reliability assessment? What is the strength of the system design and production engineering? What is the production availability? Are there equipment warranties? Are the manufacturers still able to service them? How strong is the O&M provider?	Serial failures
		Latent defects
		High rates of degradation
		Module delamination
		Forced outages
		Planned and unplanned maintenance downtime and costs
		Manufacturer insolvency
		Resource inadequacy
Off-Taker Infrastructure Risks	Is the power purchaser adequately equipped to integrate solar power resources?	Curtailment
		Inability of grid operator to handle variability

3.1.3 Non-Technical Development Risks

Two of the largest non-technical risks affecting PV projects are the (1) macroeconomic and (2) policy/regulatory environment that prevails in the market. The former determines capital availability, and the latter determines the facility with which financiers can commit that capital and the certainty that they can earn their returns. Both conditions can significantly influence the volume of development in a given year. Several of our interviewees from the insurance industry indicated that financiers are interested in risk transfer products that would protect against the financial risk of investing in an uncertain policy landscape. One broker said that he had worked with a lender who requested policy coverage for any shortfalls between the expected and the actual 1603 Treasury grant payout (in the end, however, no such policy was written). Our interviewees generally agreed that insurance against policy/regulatory risks is mostly unavailable in the U.S. market, though it is possible to write them on a manuscript basis (i.e., written specifically for the client), usually for a sizable premium.

Almost all of the risks enumerated in both the development and operational tables below (Tables 3 and 4) could affect the financier's commitment to lend or invest and the hurdle rate they would require to do so. Financiers are depending on a project's cash flows, and any risk to a project's functionality or its revenues is relevant to their decision making.[6] Both lenders and tax equity investors are known to be highly risk-averse.

Table 3. Non-Technical Risks During Project Development and Potential Damages or Losses Arising From Those Risks

Risk	Considerations	Potential Damages or Losses
Transmission/Distribution and Interconnection	Are they available? At what cost?	Cost overruns
		Project delays
Developer Risk	Experience with technology, project size, and type? Strength of balance sheet?	Developer insolvency
		Cost overruns
		Project delays
		Project abandonment
Power Purchase Agreement (PPA) and Pricing	Does the project have guaranteed revenues? Do project economics pencil out under-negotiated price?	Underbidding
		Off-taker insolvency
		Project does not secure PPA
Construction Risks	What are the possible losses/damages and their associated costs during the construction phase? What about damage to equipment during transport? Is the engineering, procurement, and construction (EPC) firm experienced and does it have a strong balance sheet? Will the project be completed on time and within budget? Are all the necessary permits in place?	Injuries
		Property/equipment damage
		Fire
		Weather and natural disasters
		Cost overruns
		Project delays
		EPC solvency
Policy/Regulatory Risks	What is the public utility commission (PUC) ruling on the project and its utility contracts? How navigable is the permitting process? What type of government incentives are available and are they stable?	PUC rules against contracts
		Incentives change/expire
		Project delays
		Cost overruns
		Failure to access incentives
		Failure to obtain permits
Insurability	Can the developer access insurance? If so, at what cost?	Failure to obtain insurance
		Insurance too expensive
		Uncovered risks
Site Control	Does the developer own the development location?	Failure to obtain site control and therefore financing, incentives, and other benefits
		Project delays
		Cost overruns

[6] As an exception, construction risks are typically not borne by financiers but by the engineering, procurement, and construction (EPC) contractor, the developer, and the insurer. In the case of a loss from one of these risks, the project is compensated by payouts from the party that had responsibility for the risk. Therefore, the losses from construction risks—if the risks are properly covered or transferred—may not affect debt service or the paying of returns to investors. This would, however, not be the case if construction delays voided the effectiveness of the revenue agreements.

Multi-Contracting Risk	Are risks clearly allocated to the various project parties through contracts?	Uncovered losses Lawsuits
Commodities Risk	Are the commodities necessary for project construction (e.g., steel, silicon) available at sustainable cost and are their supply chains secure?	Price volatility Unavailability of necessary materials

3.1.4 Non-Technical Operational Risks

While the technical operational risks listed above are mostly related to a project's power production, the following non-technical operational risks are associated with a project ability to sell power and maintain its economics throughout its lifetime.

Table 4. Non-Technical Risks During Project Operation Risks and Potential Damages or Losses Arising From Those Risks

Risk	Considerations	Project Losses or Damages
Credit/Default Risk	Do production shortfalls threaten the project's debt service? Is the sponsor's balance sheet strong enough to cover these shortfalls?	Developer/sponsor default Developer/sponsor insolvency
Power Purchase Price Risk	Is PPA price high enough to address project costs? Are regional power prices going up or down, or are they stable? Are PV installed costs trending down?	Price makes completed project uneconomic Market prices for PV systems decline, making project uneconomic in the future Regional power prices decline, making PV project uneconomic
Off-Taker Risk	What is the creditworthiness of the power purchaser? Will they uphold their end of the contract?	Off-taker insolvency Curtailment
Duration of Revenue Support	Debt duration (tenor) no longer than PPA minus 2 years, shorter based on risk perception	Remaining debt without revenues
Insurance	When insurance must be periodically renewed, how do cost uncertainty and future price increases affect project economics? Is the insurance required by the project documents commercially available? Does policyholder fully understand terms of coverage? Can they navigate the claims-making process and will insurance company pay out?	Uninsured losses or damages Unsuccessful claim Changes in policy costs make project uneconomic
Weather and Resource Risk	How does the weather and resource quality affect power generation? Is the project meeting its targets? What is the likelihood of a catastrophe? Is the property insured for capital replacement or business interruption?	Resource-related production losses Sponsor default Catastrophes and force majeure events Unsuccessful claim

4 Mitigation and Allocation

After the various project parties identify the risks of their enterprise, they begin the process of mitigation and allocation (the second step in the inverted triangle). Many solar PV project structures are arranged to divide risks and assign them to the least-cost buyer (i.e., the party that can best address a given risk on behalf of a project). This section surveys some of the methods that project teams employ in mitigating and diversifying risk exposure among parties.

Because there are multiple parties and contracts in the project development process, developers must understand which parties hold what risks and to whom they can place a claim if losses are incurred. If the contracts are not clear and responsibilities remain ambiguous, the developer may not be able to recoup actual losses from other project parties. Moreover, extensive legal battles could ensue that could drain time and capital. Thus, multi-contracting can represent a risk unto itself and should be managed carefully so that all identified risks are assumed by the proper parties.

4.1 Technology and Vendor Selection

PV modules comprise the majority of a project's hardware costs. This, in addition to the fact that the modules are the actual revenue-generating components of a PV system, makes manufacturer and module selection a paramount risk-mitigation strategy.

The progressive contraction of the manufacturing base since 2011 has also prompted financiers and developers to consider the vendor's strength of balance sheet in addition to the quality of product. An industry-wide compression of profit margins and an oversupply of panels (which has seen little relief from the global pace of development) has led to some 24 PV manufacturer insolvencies or bankruptcies in the United States and Europe (at least 4 were U.S. companies) and over 50 in China (Goossens 2012; Wang 2012a). As a result of this shakeout, financiers and developers have fled to quality in the manufacturing base, choosing almost exclusively from a list of what one of our interviewees described as "Tier 1" or "bankable Tier 2" suppliers. These tiers might be further described as:

- **Tier 1:** Large manufacturers with global reputations, several successful utility-scale projects operating within the United States, and strong balance sheets
- **Tier 2:** Smaller manufacturers with global reputations and reasonably strong balance sheets; these projects are getting financed in the United States but most likely via foreign investors and lenders
- **Tier 3:** Manufacturers without strong reputations or balance sheets; these manufacturers may have trouble being financed in the United States.

According to several interviewees, Tier 2 and Tier 3 manufacturers may opt to purchase warranty insurance to improve their perceived ability to be financed. This type of coverage can serve as a stamp of approval from a trusted authority (the insurance carrier) or at least an indication that losses can be recouped in the event that the manufacturer cannot stay solvent long enough to honor its warranties. See Section 5.3 for more on warranty insurance policies.

Module Quality and Bankability

While bankability can have variable definitions in the solar industry depending on the stakeholder (e.g. lender, equity investor, or developer), generally the term is used to describe the extent of project's financial risk (Hampl 2011; ABB 2012). While there are numerous project factors that comprise a bankability assessment, modules are perhaps the most significant material consideration—both because they represent the most expensive capital expenditure and because they are the sole revenue generating assets of the project (Hampl 2011). It naturally follows then, that module quality is of paramount importance to financiers, whose principal interest in the project is to make their return on investment.

According to several PV industry stakeholders, module quality has, however, been slipping recently (Wang 2012b; Williams 2012). As panel-makers compete for orders in a global market of depressed prices and cost-per-watt mandates, some companies have employed lower-cost, lower-quality manufacturing processes and materials in an effort to recapture some of their eroding margins (Wang 2012b). Resulting product defects—pronounced in some brands and present to some degree in many others—have damaged general confidence in module quality across the PV industry. Moreover, this is coming at a time when financiers are becoming increasingly reliant upon module quality to safeguard their investment, as recourse to product warrantees has become uncertain amidst a wave of manufacturer bankruptcies (see Section 5.3) (Williams 2012).

There has been some discussion in the PV industry about implementing quality assurance standards, which could help to reduce incidents of component failure and repair investor confidence. Currently, PV modules are only required to meet a set of standards from the International Electrotechnical Commission (IEC) and the Underwriters Laboratories (UL) before they can be sold, but these standards do not necessarily address the issue of quality (Speer 2011a). For this, additional quality tests are available and may become increasingly necessary for manufacturers looking to sell their products in a highly competitive marketplace that is becoming ever more focused on quality.

4.2 Site Selection

Careful selection of the project site during the development process can serve as a powerful risk mitigant. The quality of the resource, the frequency of catastrophic events (e.g., earthquakes and floods), and access to transmission are major risks that are largely dependent on location. Choosing a site with favorable conditions for project performance is a big step toward making a project financeable and insurable (at least at a reasonable cost).

Table 5 lists the different qualities of a site that developers should review in making their selection, as well as the considerations and risks inherent to those qualities.

Table 5. Site Qualities, Considerations, Risks, and Possible Mitigants

Aspect of Site Selection	Considerations	Associated Risks	Examples of Mitigation Techniques
Solar resource	Global horizontal irradiation, annual and inter-annual variation, impact of shading	Under-performance; over-performance[7]	Performance guarantee, weather derivatives, sophisticated and site-specific resource assessments
Local climate	Flooding, high winds, snow, extreme temperatures	Damage or destruction of plant	Catastrophic insurance, performance guarantee (to protect against degradation)
Available area	Area required for different module technologies, access requirements, pitch angle, minimizing inter-row shading	Difficulty accessing site, lower-than-expected production	Engineering assessment (conducted by EPC)
Land use	Land cost and environmental sensitivities, impact of other land users on the site, decommissioning	Increased construction costs	Legal and environmental assessment, liability insurance
Topography	Flat or slightly south-facing slopes are preferable for projects in the northern hemisphere	System performance, system damage (e.g., are the panels positioned to bear more or less extreme weather or be subject to wind loading)	Engineering assessment
Geotechnical	Including consideration of groundwater, resistivity, load-bearing properties, soil pH levels, seismic risk	Damage or destruction of plant	Engineering assessment, catastrophic insurance (earthquake)
Accessibility	Proximity to existing roads, extent of new roads required	Difficulty or inability to access site	Engineering assessment
Grid connection	Cost, timescales, capacity, proximity, availability	Constrained operation, infrastructure modification, costs	Legal assessment of market rules and constraints, engineering assessment
Module soiling	Including local weather, environmental, human, wildlife factors	Under performance, increased maintenance, potential increased degradation	Site evaluation, module maintenance
Water availability	Availability of reliable supply for module cleaning	System under performs, reduces revenue	Engineering assessment, legal assessment, environmental assessment, O&M contract with original equipment manufacturer (OEM) or third party

Source: Miller et al. 2011

[7] Over-performance is a risk to developers and investors as there is the potential for a less-than-optimal return if actual performance had been better accounted for in, for example, the power purchase agreement. In such cases, revenues are considered as “left on the table” and are not efficiently captured.

4.3 Selection of EPC Firm and Independent Engineer

Solar PV equipment manufacturers do not typically provide construction services; therefore, another party is needed to lead the construction of the plant. Often, the project investors turn to EPCs to provide turnkey services. Careful selection of the EPC can help to convince investors that the project will be completed on time, on budget, and according to all the specifications of the contract (i.e., that faulty materials or workmanship will not hinder the operation of the project). As with vendor selection, developers and investors will judiciously select EPCs, looking for firms with proven track records, strong balance sheets, and experience with the negotiations process. Many of the risks during the construction phase can be mitigated through clauses in the EPC contract that clearly allocate risks. EPCs and developers may also take out builder's risk insurance policies to cover their operations during construction. When explaining their rating criteria for MidAmerican's Topaz solar bond issue in March 2012, Standard & Poor's cited the strength of the EPC contract (more than the credit quality of the contractor, First Solar) as one of the elements that warranted a BBB- rating[8] (Standard & Poor's 2012).

The independent engineer is responsible for assessing the project's various contracts, construction plans, technology, system design, and other aspects of the project. These entities serve to identify risks and assess the quality of the project's construction plan in reports they compile for the financiers.[9] A strong independent engineering team will not only provide valuable insight on a project's risk exposures and the possibilities for mitigation, but can also contribute to the project's financeability by certifying its quality and attracting additional investors. Independent engineers typically do not take on any project risk.

4.4 Surety Bonds

It is a common practice in the construction industry for the EPC firm to obtain a guarantor (known in this arrangement as a "surety") that will back its performance on the project contract. This serves to protect the contract counterparty (known as the obligee—in this case the developer or sponsor) in the case that the EPC firm does not meet its obligations.[10] When this happens, the obligee will receive compensation in the amount of the bond (the penalty) from the surety if the EPC firm (the principal) breaches its contract (see Figure 2). Alternatively, if the EPC fails to deliver on the terms of the contract, the surety may elect to fund another EPC firm if this cost is less than the penalty.

While the principal is the purchaser of the bond, the obligee is the beneficiary. Sometimes the surety (which is typically an insurance carrier) will require the principal to set aside funds or collateral in the amount of the total maximum loss of the bond. In all cases, the surety has the

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[8] This rating is the lowest tier of "investment grade." Receiving a rating of BBB- or above (Moody's Baa3 and above) allows bonds to transact at lower interest rates and also increases its value as a form of capital (which means that banks can use it as higher-tier reserves under their capital requirements).

[9] Independent engineers are hired by banks to help assess a project's financial risks, typically before the banks reach financial close with the developer. When hired before the financial close, the independent engineer is called the "lender's engineer"—it is not until the project begins construction that the "lender's engineer" becomes the "independent engineer." Third-party assessors can also be hired by project sponsors, but in such cases they are referred to as the "owner's engineer" and do not serve the same functions as the independent engineer.

[10] In lieu of a surety bond, project owners can hire a construction risk management firm to implement due diligence, system performance, and funds-control protocols that identify risks and off-load them to the appropriate party (Speer 2010).

right to seek recovery of its funds should it be required to payout to the obligee against the failures of the principal (Vaughan et al. 2003).

One interviewee for this study said that sureties are generally reluctant to support project contracts that extend beyond three years (which can include construction and one to two years of EPC warranty coverage). While there are some five-year bonds in the market, these are almost exclusive to principals with strong financials.

Surety bonds (also called performance bonds) differ from insurance in that they are constituted by a three-party contract (surety, principal, and obligee), whereas insurance contracts are only two-party (insurer and insured). Moreover, the surety generally does not expect losses from their bond and will only issue them to trusted principals with dependable track records (generally, a single bond claim could entirely prevent an EPC firm from obtaining surety bonds in the future). In contrast, when providing insurance to customers, carriers generally expect some degree of loss from their policies (Vaughan et al. 2003).

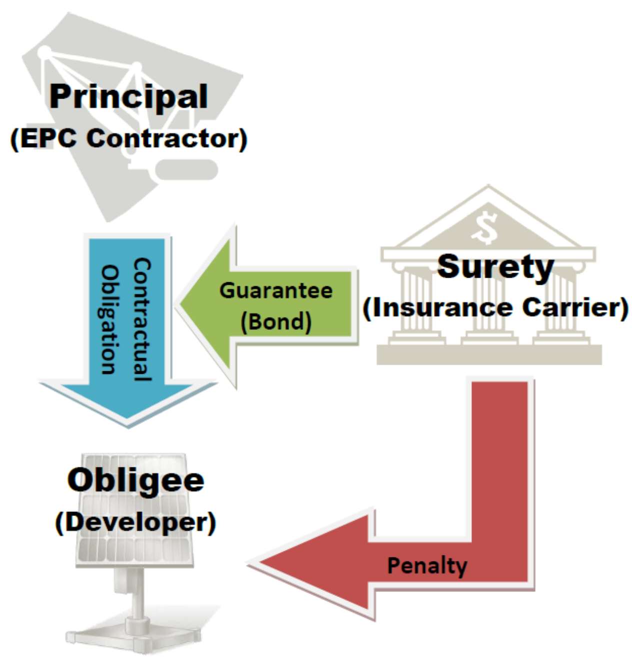

Figure 2. A surety bond arrangement

4.5 Project Financial Structure

In a renewable energy financial structure, the stream of benefits and project risks is allocated to the different owners (equity investors) and lender(s) (if there is debt at the project level), often via a complex and lengthy negotiation process. The total benefits can generally be distinguished as tax benefits and cash benefits, both of which are allocated based on the ability of each investor to utilize them. Solar project finance in the United States is designed to maximize the value of the tax benefits offered by the federal government and relevant state government, if applicable.

This is known as tax equity investment.[11] Financial structures designed to induce tax equity include:

- Partnership flips (either "all equity" or "leveraged" with debt)
- Lease structures (including "inverted" and "sale leaseback") (Mendelsohn et al. 2012b).

In addition to making efficient use of capital and incentives, another key purpose of these financial structures is to distribute project-level uncertainties to the party that is most willing and best suited to take the risk. See Figure 3 for a high-level representation of a project financial structure.

Beyond the direct financing of a project, other risks are allocated among various parties associated with project development, construction, and operation, including the power purchaser, EPC contractor, equipment supplier, facility operator, and insurance carrier(s). These parties are represented by the green blocks in Figure 3, and the contracts executed between them and the project entity (which serve to allocate risk) are represented by the two-way arrows. Table 6 has a more in-depth description of these risk allocations and the mitigation strategies available to each party.

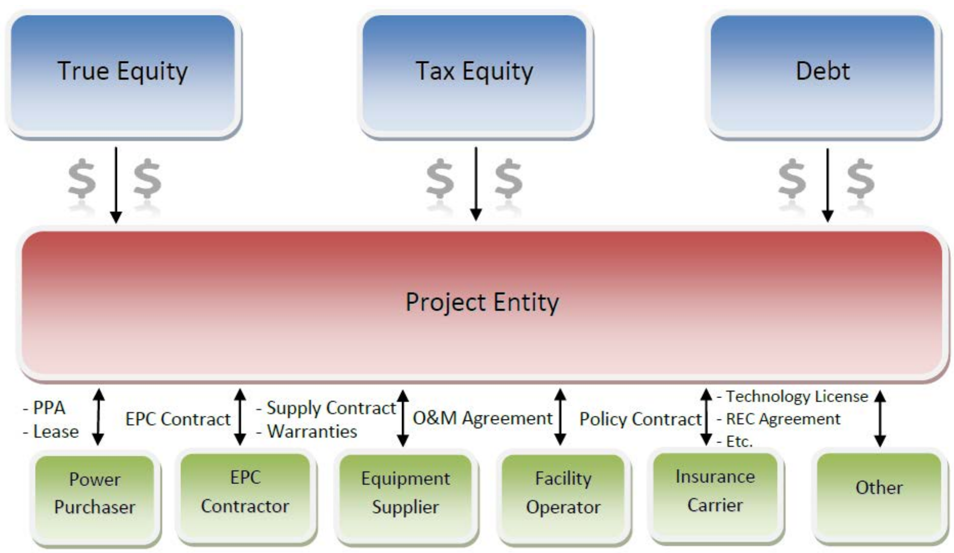

Figure 3. Typical PV project financial structure in the United States
Adapted from Mintz 2012

[11] Tax equity can be more accurately described as a mezzanine product as opposed to actual equity, more senior to a developer's equity investment and thus first in line to receive a return on investment. However, project debt, if applicable, is more senior to the tax equity investment.

Table 6. Distribution of Risk to Project Finance Counterparties

Party	Primary Risk	Risk Mitigation
Utility/ Power Purchaser	Power is not provided, grid reliability	Resource planning, careful contracting with projects
EPC Contractor	Project not built or completion delayed, late project completion	Construction best practices, surety bonds, insurance
Equipment Supplier	Takes risk of equipment failing or not performing to pre-agreed specifications per the warranty agreement	Manufacturing quality assurance standards, product testing, warranty insurance
Facility Operator	Project repairs or replacements	If the module manufacturer is the O&M provider, quality assurance standards in manufacturing process
Lenders and Investors	Project default or developer/sponsor insolvency	Guarantees, contingency budgets, careful developer selection
Developers and Sponsors	Default or insolvency	Secure contracts with counterparties to insulate from risks and potentially terminal losses, reserve accounts to cover production shortfalls, insurance and financial hedges to cover performance

4.6 Cross-Collateralization of a Portfolio of Projects

Cross-collateralization is a technique employed by large lenders to hedge against production shortfalls (and hence debt service defaults) from PV projects in their loan portfolio. This bundling of collateral makes sense for renewable energy projects, which commonly use non-recourse financing structures, which precludes lenders from seeking recourse from other projects owned by the developer. Cross-collateralizations are arranged between lenders and developers and can include both construction debt and term debt within a portfolio of projects (Speer, forthcoming).

Not all project financiers benefit equally from this technique. Most renewable energy projects involve debt and equity. Cross-collateralization primarily benefits the debt provider (i.e., the commercial lender) who will have first recourse in the event one or more projects within a given portfolio go under. Providing collateral across projects may not bring down the cost of financing for the developer's projects, though it can influence a lender's decision to extend debt to that developer. That is, lenders may find additional comfort from increased value of the collateral, thereby lowering the overall risk profile of the loan (Speer, forthcoming).

Equity investors are, however, at additional risk if their project is cross-collateralized, as the failing of one project could hinder their ability to earn the targeted return on an otherwise unrelated investment. Furthermore, if projects within a loan book have linked revenue streams, it may be difficult to securitize the cash flows in the future (see Section 6.4).

Cross-collateralization may be best applied to a portfolio of projects with some variety of technologies and applications to further diversify risk. For example, the portfolio could include both rooftop and ground-mounted projects in diverse locales using various types of modules and other system hardware. One interviewee who works for a lender's engineer said that ideally collateralized portfolios include projects in the 1-MW-or-less size, in a pool of up to 15 to

20 MW. This allows for a larger number of projects within the portfolio (e.g., 15 to 40), thereby reducing the risk of recourse from any one project to the others. Cross-collateralization could be used for either construction or term debt.

There are several parties who must agree to the cross-collateralization, including the investors, off-takers, and perhaps other counter parties (e.g., REC purchasers). One interviewee related how a certain project on which the interviewee served as a lender's engineer had a power purchase agreement (PPA) that required that the project stand alone. Thus, it was contractually ineligible for cross-collateralization with other projects within the developer's portfolio. In cases where projects receive debt from a club of banks (a "club deal"), the difficulties of coordination across lenders could also prove a barrier to cross-collateralization

5 Insurance

Insurance is the last line of defense in the risk management inverted triangle. At this stage, the remaining risks that cannot be efficiently and cost-effectively mitigated and allocated among the project parties are transferred, for a premium, to an insurance carrier. Because transferring risks away from the project is costly, insurance is reserved for only a select few risks.

Generally, PV project developers are required to have their projects insured with property and liability coverage. Property and liability are commoditized lines of insurance and are required of most commercial enterprises, especially ones that involve construction. Additionally, a PV project may be required to purchase specialized policies, such as commercial automobile, workers compensation and employer's liability, crime, pollution liability, marine, and delay in start-up (note: not all of these policies will be required of every project).

A project's insurance requirements (including types of coverage, minimum level of coverage, and minimum rating of insurance carrier) will be specified in the PPA, the interconnection agreement, the lease, and other project contracts. Importantly, project financiers can require a project's developer or sponsor to purchase additional coverage if they do not feel that the project risks have been adequately addressed. However, while they can compel a project to purchase additional coverage, financiers cannot relieve a project of any of its insurance obligations as specified in the project contracts.

The above-named policies are designed to cover the general exposures of many commercial operations, but PV projects have unique risks that these policies may not address. Some industry participants anticipate that as PV risk management matures, and as the insurance industry underwrites more policies for PV customers, more tailored insurance coverage will become available (Economist Intelligence Unit 2011). This has already happened to a certain degree with the advent of warranty insurance coverage (see Section 5.3).

Before proceeding into the following subsections, it is instructive to clarify the following terms, as they are applied in various contexts throughout the remainder of this study:

- **Risk** is a condition in which there is a possibility of an adverse deviation from a desired outcome that is expected or hoped for—in other words, the possibility of loss. Underwriters calculate the probability of a loss occurring for a given risk and price the premium accordingly.
- **Loss** is the unintentional decline in—or disappearance of—value due to the occurrence of a peril.
- **Peril** is the cause of a loss (i.e., the event insured against) (Vaughan et al. 2003).
- **Indemnity** is the restoration paid to a victim of a loss up to the total cost of that loss (IRMIa).
- **Replacement cost**, when referring to the entire project, is the cost to replace all project assets with similar materials (also referred to as the total asset value of the project).

5.1 Property

Property insurance covers direct damage or loss to the property of the named insured by defraying the costs of repair or replacement. It is a "first-party" insurance, which means that it covers only the policyholder and his/her property. Liability insurance is, by contrast, a "third-party" insurance because it covers the wellbeing and property of people unnamed in the policy, provided they incurred damages or losses while working on or with the property of the policyholder (Head 2009).

Typically, a property policy will sit at the project level and only cover losses or damages on the project that it insures. Conversely, liability insurance will usually sit with the parent company (i.e., the developer) as a master policy from which coverage flows out to individual projects under the parent's umbrella.

During the construction phase, project developers/sponsors have the choice to retain their own property insurance policy or to require the EPC to purchase property coverage. In some cases, developers/sponsors may choose to remain insured under their own property policy even if the EPC is required to purchase insurance. One interviewee stated that insurance professionals typically advise project owners to insure their projects' property risks under their own insurance policy. This allows the owner greater control over the policy and claims-making process and can afford better understanding of policy terms.

Property insurance is referred to as "builder's risk" insurance during the construction phase. If the developer/sponsor is the named insured on the project's property policy—and if the insurance company allows them to do so—property policies may be convertible from the construction phase to the operational phase. In the operational phase, the property policy will primarily cover interruptions to business income (these policies are referred to either as business income or business interruption insurance).

Common perils insured against under a property policy include some natural disasters (e.g., hailstorms or lightening strikes), fire, mechanical failure (covered under a sub-policy called equipment breakdown insurance), construction mishaps, and other events that may damage the physical property of the project. Potentially high-loss catastrophes such as earthquakes and floods can be insured under property policies, but this is typically only done with high premiums and a limit that does not cover the full replacement value of the property.

Due diligence in siting a PV project so that it is not built in an area that is historically flood or earthquake prone may save a developer a great deal in insurance costs, which, in some cases, could render a project uneconomic. However, it is sometimes the case that the regions with high catastrophe risk are also the most economic locations to construct commercial- and utility-scale PV projects (for example, California and Florida). One interviewee stressed that in such cases, it is important for the developer to model their catastrophe risk exposure[12] and use the results to negotiate more favorable terms with their insurers and financiers.

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[12] One of the industry standards for catastrophe risk modeling is the Risk Management Solutions (RMS) model, which is currently available in its 11th version.

Property policies can be written on a “named-perils” basis or on an “all-risks” basis. The former covers loss only from a set of perils that are specified in the terms of the policy; the latter will cover losses from all perils except any that are explicitly excluded in the policy documents. While some all-risks policies may come with an extensive list of exclusions, they are generally considered more comprehensive in their coverage and, importantly, they shift the burden of proof onto the insurance company in the case of a contestable loss (Head 2009). According to one interviewee, all-risks policies have become the standard in PV project insurance, as financiers are generally reluctant to accept named-perils structures.

Moreover, property policies can insure against *direct* losses (those incurred from direct and immediate damage to the insured’s property) and *indirect* losses (those resulting from the property damage and not from the perils themselves). Indirect losses are usually characterized by adverse effects to a business’s income stream as a result of:

- Damages to functionality of the asset base
- Extra expenses accrued from continuing to conduct operations at an alternative facility
- Project completion delays on time because of damages incurred during construction.

The three policies that cover these forms of indirect loss are, respectively:

- Business interruption insurance
- Extra expense insurance
- Delay in start-up insurance (also called as delayed completion coverage).

These are known as “time element” insurances because the amount of the loss depends on how much time it takes to repair or replace the property that is damaged.

When purchasing property insurance, developers/sponsors must choose the basis upon which to value the policy. That is, should the policy be priced on—and the limits set by—the replacement cost or the actual cash value of the project? If the developer/sponsor chooses the cash value, depreciation is factored in and deductions can be taken against the policy cost. However, though it may cost more, the replacement cost basis is generally the preferred valuation (Head 2009).

Developers/sponsors may also consider probable maximum loss analyses of their project portfolios in determining what kinds of insurance they require and how they can save on insurance costs. For example, if a developer/sponsor sites two different projects on two different fault lines in two different areas of the United States, they may not need to purchase insurance coverage for both projects (opting instead for a master policy) because the likelihood of two earthquakes happening in these two geographically distinct areas is remote. A probable maximum loss analysis, usually conducted by a third party, determines these sorts of cost saving opportunities, allowing developers/sponsors to minimally but effectively insure their projects.

Several of our interviewees described insurance as cyclical, meaning that when losses are at an industry-wide low and insurance carriers are profitable, the cost of premiums will gradually go down, and vice versa. One interview revealed that the market prices of property policies are trending higher to compensate for an uptick in disasters worldwide (2011 was the most costly year on record in terms of property losses, according to Munich Re[13]) and because investor incomes are down due to the low-interest environment prevailing in the global financial markets.

5.2 Liability[14]

Liability insurance covers bodily injury incurred by persons other than the named insured and damage to property that is not owned by the named insured. These qualities make it a "third-party" insurance. This policy will defray the cost to defend the named insured in any lawsuits, and any costs resulting from judgment or settlement, provided that they are within the limits of the policy and the extent of the coverage (Head 2009).

Developers/sponsors will generally purchase liability coverage at the parent level, and individual projects can be insured under this "master" policy. EPC firms may also purchase their own liability coverage, as there may be difficulties in filing claims under the developer/sponsor's master policy.

The standard form of liability insurance is the commercial general liability (CGL) policy. CGL covers general liability exposures outside of those relating to the business's employees and its automobile fleet. These include premises and operations, products and completed operations, independent contractor liabilities, and any liabilities that have been contractually assumed from third parties (Vaughan et al. 2003).

5.2.1 Umbrella Policies

The CGL is the primary policy, which means that its provisions and terms apply first in the case of a claim. Any costs incurred in excess of the primary limit may be insured by an umbrella policy, which functions as a sort of backstop to excessive damages that surpass policy limits. In some cases, umbrellas may also provide more comprehensive coverage (subject to a deductible) that applies to certain losses unaddressed in the CGL. Most PV projects carry umbrella policies.

5.2.2 Controlled Insurance Programs

An EPC firm will typically price its estimated insurance obligations into its project bids so that they may pass the cost on to the sponsor. If, in reviewing the terms of the EPC's coverage, a developer or sponsor wishes to adjust the policy (e.g., raise/lower the limits or extent of the coverage) or insure risks that are not named in the policy, it may opt for a controlled insurance program (CIP). In this case, it would be an owner-controlled insurance program (OCIP); the EPC may also be responsible for the policy under a contractor-controlled insurance program (CCIP).

Under an OCIP, all parties, including the developer, sponsor (if different from developer), EPC contractor, and all subcontractors, are insured under the builder's risk and CGL policies. While OCIPs may allow a developer/sponsor to dictate the desired level of coverage and therefore the cost of coverage, financiers are generally not favorable to this option, and it is consequently rarely used. One interviewee stated that OCIPs may leave the primary policyholder (i.e., the sponsor) uncovered if significant losses with any of the intermediary insureds hit policy limits

[13] See Munich Re's Topics: Geo 2012 issue at http://www.munichre.com/publications/302-07225_en.pdf.
[14] Liability insurance is sometimes referred to as "casualty" insurance depending on the provider. Casualty can also refer to some types of property damage, though this usage is not generally applied in the insurance industry.

before any claims for sponsor-related losses are made. However, he also said that OCIPs have been more common on utility-scale projects as a way to manage project costs.

5.3 Warranties and Warranty Insurance

Typical PV manufacturer warranties include a 5–10-year workmanship and materials guarantee (which warranties the physical product), and a 25-year performance guarantee (which warranties the energy produced). The performance guarantee usually stipulates that the modules will operate at 90% of their optimal output for the first 10 years and 80% for the remaining 15 years (there are of course variations with different manufacturers) (Warranty Week 2011a).

Almost all major manufacturers offer a long-dated performance guarantee in the warranty, but questions remain about its effectiveness. If the manufacturer goes out of business before the sunset of its warranties, then there is no entity left to backstop customer claims—the policy is essentially rendered null and void (see the text box on the San Diego Unified School District). Moreover, the majority of PV capacity in the United States (approximately 75% as of this writing) is less than five years old, and there is a great degree of uncertainty about how systems will function 10, 20, or 25 years from today. Manufacturers often do commission tests on their panels in addition to the IEC and UL tests to model the degradation, performance, and reliability; however, these tests are as yet unsubstantiated by robust field data (i.e., actual performance). Additionally, continued efficiency improvements, or even technology switching away from crystalline silicon as the primary PV technology at some future time may outdate current PV warranty policies and leave system owners without adequate coverage should they make any claims in the future.

Warranty insurance is a novel, though growing, risk management solution for the shortcomings of PV warranties and can benefit both the upstream and downstream segments of the PV industry. Two market conditions have created emerging demand for these products:

- The manufacturing base is currently shrinking as many panel-makers have not been able to remain solvent in an oversupplied market with compressed profit margins and an investor flight to quality (see Section 4.1).
- Most of the U.S. PV capacity is relatively new, the financial, risk management, and power purchaser communities have voiced concerns about the long-term performance reliability of PV systems.

Manufacturers seeking a competitive edge in a market that is closed to all but the most creditworthy suppliers, and financiers who were looking for guarantees on their PV returns approached the insurance industry to devise products that would cover their risks. In response, underwriters and insurance carriers devised two forms of warranty insurance: **manufacturer coverage** and **system-level performance coverage**.

<u>Case Studies in Solar Warrantees and Warranty Insurance</u>

First Solar

Manufacturers that warranty their products will typically set aside reserve accounts to cover any claims against their products and other related expenses. One way to assess a company's product integrity is to analyze the changes in these warranty funds' accrual rates year-over-year. From December 2010 to December 2011, First Solar's warranty reserves jumped from $28 million to $158 million, an increase of 464%. This was not necessarily from a higher volume of sales, as is the case for some manufacturers whose warranty reserves ramp to such levels—rather it was from a higher volume of claims against their modules (Warranty Week 2012). In 2008–2009, a stated "process control" issue that has since been corrected produced premature power failures in 4%–8% of the modules manufactured in that time period. Customer redemptions involved module removal, testing, replacement, logistical services, and in some cases additional payouts (Trabish 2012a).

These warranty issues have been showing in First Solar's financials since 2010, though a large volume of claims were processed in the fourth quarter of 2011 and have weighed on the firm's 2012 balance sheet (Trabish 2012a). In March of 2012, First Solar's then-interim CEO Mike Ahearn forecasted that the total loss from this process control issue would amount to over $215 million. The company's June 30, 2012, quarterly report states that accrued costs incurred as a result of the excursion and the remedial commitment to First Solar's customers total $112.8 million—that is in excess of the $97.7 million that he firm has listed for its current warranty liabilities (First Solar 2012).

As of this writing, First Solar does not have any warranty insurance coverage or has made no indication of coverage. All payouts related to their warranty issues, including normal warranty expenses and those related to the process control issue have been made by the company. First Solar has, historically, had a sizeable balance sheet, which has allowed it to navigate these recent warranty challenges.

5.3.1 Manufacturer Coverage

Warranty reserve accounts set aside by manufacturers to cover claims against their products may, in some instances, prove insufficient to cover the extent of damages sought by the product customers. In such cases, the manufacturer will either have to allocate more capital to its warranty fund, or—if this is an unfeasible option given balance sheet limitations—seek bankruptcy protection. An insolvent or bankrupt manufacturer is not obligated (and is likely unable) to pay out to warranty claims, leaving its customers without recourse should the products prove defective in the field. If a manufacturer that is undergoing bankruptcy proceedings has customers seeking compensation for valid warranty claims, it can treat these customers as "unsecured creditors" and pay them little or none of the claim. Customers who have not made claims before the company is unwound have no recourse to their warranties should a product malfunction in the future (Warranty Week 2011b).

Manufacturer's warranty insurance can guard against such a situation, providing some comfort for lenders and even some marketability for Tier 2 and Tier 3 manufacturers. This type of insurance policy is also sometimes referred to as a "wrap," because it wraps some of the terms of the module manufacturer's warranty and passes the pooled risk onto the insurance carrier. In other words, the insurer takes on some portion of the manufacturer's responsibilities as stipulated in the terms of the warranty, in exchange for a premium. In essence, the insurance carrier is underwriting the performance of a certain amount (the quantity insured) of a supplier's product. As the named insured, the manufacturer receives almost all of the payout in the event that insured modules perform at levels below the policy trigger. Third-party rights, which allow for the rerouting of payouts to entities other than the manufacturers (e.g., system owners or developers) should the manufacturer declare bankruptcy, are available through at least one policy on the market. There may, however, be legal complications with such redirections, so it is important for policyholders to understand the terms of their coverage.

Warranty insurance for manufacturers can cover any combination of workmanship risks, performance risks, serial defects, and component failures (they are typically written as manuscript policies, which means that they can tailor specifically for the needs of the insured). The length, limits of coverage, deductibles, and cost of the policy are variable, depending on the needs and capabilities of the manufacturer and the carrier. Premiums for this type of policy are usually paid up front in full.

In addition to the practical aspect of warranty coverage, manufacturers may benefit from a boost in market perception that this type of product bestows. A vendor of Tier 2 components, for example, can procure a product-cover policy to ease financiers' reservations regarding long-term performance. Additionally, financiers also have the assurance that the vendor has been certified as insurable by an entity (the insurance carrier) that has conducted its own extensive due diligence process to arrive at that conclusion. Several of our interviewees indicated that even if the jury is still out on the effectiveness of these policies, the boost in bankability that they offer has been tangible.

Despite the enhancement effect that these policies offer, manufacturer's product coverage has been greeted with some ambivalence on the part of the financiers, according to several interviewees. On the one hand, they afford financiers protection on their investment and can ensure project returns; on the other hand, financiers may view them as an admission that a product or system design is expected to fail and that the costs to benefit are unjustifiable. One interviewee for this paper commented that there was no need for warranty insurance if the developer is working with a "perfect product." In other words, manufacturers that can demonstrate effective management of their product performance and solvency risks will have no need for warranty insurance.

That said, our current research has indicated that the demand for these types of policies may be growing as financiers become uncomfortable with long-dated warranties from companies that may not survive the current turmoil in the manufacturing base or may not have adequate reserves to pay off claims. Indeed, some manufacturers have explicitly stated in company documents that there is a considerable degree of uncertainty in estimating the value of their warranty, considering that the cost of future payouts and the frequency of claims for 25 years out require a substantial amount of guesswork. In its 2011 annual report, SunTech, the current market leader in solar manufacturing, stated that "Because our products and workmanship have been in use for only a relatively short period, we cannot assure you that our assumptions regarding the durability and reliability of our products or workmanship are reasonable…Our warranty provisions may be inadequate, and we may have to incur substantial expenses to repair or replace defective products and provide repairs in the future" (Suntech 2011, p. 18).

Case Studies in Solar Warrantees and Warranty Insurance

San Diego Unified School District

Owners of PV systems that have been built and supplied by now-bankrupt companies have little or no recourse to their warranty contracts should they experience defects over time. Bankrupt companies may treat any customers seeking compensation for valid warranty claims as "unsecured creditors" during bankruptcy proceedings. This allows companies to pay a fraction of what they owe as specified in their warranty terms. Additionally, bankrupt companies are relieved of any future obligations to their warranties, leaving these contracts without a backstop for customers that make claims down the road (Warranty Week 2011b).

This is what happened when the San Diego Unified School District sought to remove a number of PV systems on 24 of its buildings because of panel corrosion that posed a fire hazard. The systems were built and installed by Solar Integrated Technologies (SIT) and the panels were manufactured by Uni-Solar, a subsidiary of SIT's parent company Energy Conversion Devices (ECD). GE Financial Services financed and owned the system, and the power was sold (via SIT subsidiary Solar Power & Electric) to San Diego Unified School District under a 20-year third-party lease (Font 2012; Trabish 2012b).

The systems—comprised of Uni-Solar's flexible amorphous silicon panels—were installed in 2005. However, when the district sought to have them removed in 2012, both SIT and ECD (along with all subsidiaries) had already declared bankruptcy and could not honor their warrantee obligations for service, repair, replacement, or removal. GE Financial Services agreed to defray the entire cost of removal, though it bore no contractual responsibilities to do so (Font 2012; Trabish 2012b).

This incident highlights a growing issue in the PV industry, where developers, sponsors, and financiers are becoming increasingly exposed to module and system defects because of a contracting manufacturing base. This has led to an intensive focus on module quality (see text box on page 12) as a revenue guarantee, and it is also the driving force behind the small but growing demand for warranty insurance. In fact, warranty insurance has even become a requirement of some financiers before they commit any capital, though it is likely that such requirements depend on other project specifics (such as credit profile) and are not necessarily hard rules for investors.

Not only may financiers be warming up to manufacturer warranty insurance, but the manufacturers themselves also seem to be taking advantage of the benefits such policies offer. Many have become more open about their purchase of warranty coverage as a signal to the market, whereas less than a year ago only a couple firms publicly disclosed their coverage. According to NREL research and interviews, more than 20 solar manufacturers have insured the warranties on at least some portion of their inventory in the last three years; as many as five of these companies are considered Tier 1 manufacturers.

5.3.2 System-Level Performance Warranty Policies

Warranty policies are also available to insure the entire PV system and its various components—not just the modules. This type of insurance can cover repairs and replacements for modules, racking hardware, inverters, tracking systems, and other BOS equipment. It can also cover workmanship and system design as well. Typically, the EPC will cover any flaws in workmanship and design for up to the first 10 years of operation; a system-level warranty cover would therefore relieve the EPC of some portion of the risk in guaranteeing its work.

The named insured in a system-level policy is typically the system owner, who, in the case of a successful claim, would receive payouts to compensate for revenue lost from equipment failures. The risk management industry's terminology for this kind of policy is "efficacy insurance."

One provider of this type of insurance who was interviewed for this study said that her company regarded the first 8,600 hours of a project's run time (about one year of operation) as critical to establishing whether or not a project will work according to specifications. After this, her company will cover the total system performance for five years. Her company also fields a project analysis team of engineers who perform due diligence to inform the underwriting process and conduct routine equipment monitoring during the policy term. The cost of this team's services is built into the premium. Project lenders and investors may take comfort from such a service as it can improve the detection of O&M risks and provide independent feedback on project performance.

Case Studies in Solar Warrantees and Warranty Insurance

Canadian Solar and SunPower

Canadian Solar and SunPower offer two examples of effective warranty programs devised at a time when warranty management is becoming integral to solar manufacturers' corporate strategies (and financiers' decisions to commit capital).

Canadian Solar, a Tier 1 Chinese manufacturer, offers a warranty that guarantees performance on a linear scale, as opposed to the typical flat 90%–80% protocol of many PV warranties. The warranty stipulates that panels will operate at 97% of optimal output at the end of the first year and will only decline by as much as 0.7% each year thereafter. This means that at year 10, when most manufacturers reduce their products' guaranteed output to 80% of the optimal, Canadian Solar guarantees 90%. Not until the 25th and last year of the warranty will Canadian Solar's guarantee decrease to 80% (Canadian Solar 2011).

The company backs its robust warranty with insurance coverage from the specialty insurer PowerGuard, which underwrites on behalf of several insurance carriers in the Lloyd's market (see footnote 16) (Canadian Solar 2011). Canadian Solar has long been an advocate of quality assurance in PV manufacturing, and aside from being an early adopter of warranty insurance, they are known for their rigorous testing standards and the durability of their modules.

California-based SunPower, which currently supplies one of the PV market's most efficient and expensive modules, also has an industry-leading warranty policy with a 25-year performance *and* workmanship warranty (whereas other companies only provide 5–10 years of workmanship). However, unlike Canadian Solar, SunPower does not backstop this guarantee with insurance.

SunPower also frequently serves as the supplier, developer, EPC, and operator on its projects, which allows it to offer guarantees on their entire systems (Trabish 2012c). Manufacturers that are not vertically integrated cannot back the integrity of the systems in which their panels are installed—such backing usually falls to the EPC. In short, SunPower has effectively created a sort of "one-stop-shop" for warranty claims against its products, and this simplicity of redemption can provide financiers some additional comfort.

SunPower is one of the top 10 selling panel manufacturers because of its strong guarantee and its ability to see projects through from the manufacturing to the operation phase (eliminating the hazards of multi-contracting and complicating the pathways to making a claim). Moreover, having the French oil and gas multinational Total S.A. as a parent company has afforded SunPower access to a balance sheet, credit rating, and cost of capital that gives it a strong competitive edge in the market (Trabish 2012c).

5.4 PV Insurance Costs

PV project insurance costs are largely determined by the specific needs and risks of the project; the type, length, and limits of coverage; and the level of the deductible (higher deductibles can equate to lower insurance costs), as well as other considerations. According to one underwriter, pricing policies is "not an exact science" and can involve the weighing of several "hard" and "soft" factors. Hard factors are a project's tangible qualities, such as:

- The history of the technology and whether it is considered "proven" and bankable (i.e., Tier 1 or high Tier 2)
- The appropriateness of the technology and system design for a given application and site
- Location and soundness of the site (e.g., Is it in a flood zone or near a fault line?)
- Experience of the developer, EPC, OEM (if providing O&M), and third-party O&M provider
- Related contracts and whether clear allocations of risks are made.

Soft factors are less quantifiable, such as:

- The culture of the development team and the confidence they inspire
- The perceived soundness of the development plan and its goals
- The relationship between the development team and the contractors (i.e., have they worked together before and to what success).

Incorporating these considerations into an underwriting model can account for some of the variance in PV projects' insurance costs. Some interviewees said that even the models themselves may be ill-suited to underwrite solar projects. For example, rooftop systems are sometimes assessed using COPE[15] models, which are designed for buildings and do not adequately account for some of PV's unique risks.

Because insurance costs are so variable, it is difficult to provide a general cost assessment. However, several of our interviewees speculated that property and liability costs during the construction phase may currently fall somewhere in the range of $0.09–$0.13 for every $100 of a project's replacement value. On a 10-MW project with a replacement value of $25 million, this would equate to $22,500–$32,500 in property and liability policy insurance in the construction stage or up to a 0.13% of total project costs. Insurance to cover catastrophes such as floods or earthquakes could cost significantly more, perhaps over $3 for every $100 of replacement costs (assuming that the coverage is for only one-half of the insured value of the project).

In the operational phase, the cost of business interruption insurance may be similar to property and liability coverage during the construction phase, or roughly 0.1% of replacement costs (in this case $25,000 annually). These figures are very general estimates; insurance costs, as mentioned, can vary dramatically in the marketplace and will depend on a range of factors not

[15] COPE stands for Construction, Occupancy, Protection, Exposure. These represent main risk characteristics that underwriters review when evaluating property (IRMIb).

considered in this analysis. Deductibles will vary depending on the needs of the insured and can vary these costs even more.

We were unable to collect any cost estimates for either type of warranty insurance, though our interviewees generally agreed that these types of polices can be expensive. Premiums will depend on the amount of inventory covered and perceived risk of the technology (in a manufacturer's policy), the quality of system design and its performance in the first year of operation (in a system-level cover), the level of deductible (in both), and other factors. In some warranty policies, the premium is required to be paid in one lump sum at the time of the policy's activation. One interviewee explained that these policies require upfront payment for two reasons: (1) it is dictated in the terms of the policy, or (2) lenders may try to prevent a project from defaulting on future insurance payments.

5.5 PV Insurance Market

There are generally three parties involved in the process of providing insurance to clients: underwriters, brokers, and carriers. Underwriters assess the probabilities associated with a particular set of risks (usually for areas in which they have expertise) and price policies accordingly; brokers, or retail agents, arrange for the sale of insurance to customers; and carriers accept the underwriting and terms of sale from the previous two, effectively holding the insured risks on their balance sheet in exchange for the payment of a premium or premiums. Additionally, insurance policies may be underwritten by a managing general agent, which is similar to a broker but has the authority to accept policy placements from brokers on behalf of an insurer (Jamison et al. 2011).

Carriers can expand the amount of insurance policies they can offer (i.e., their capacity) by purchasing their own insurance coverage on a portfolio basis. This is known as reinsurance, and the companies that take on this excess risk are reinsurers. Reinsurance is particularly common for catastrophe risks that can and have wiped out the funds of large insurance companies.

In addition to providing coverage to insurance carriers on their liabilities, some reinsurers have also been active in extending coverage options directly to PV projects (through brokerage networks), namely in the form of warranty insurance. Munich Re and Hannover Re are examples of such reinsurers.

Insurers and reinsurers that are currently active in the PV space include, among others, the following firms:

- Ace
- Allianz
- Arch
- Axis
- Chubb

- GCube[16]
- Lexington
- Munich Re
- PowerGuard[17]
- Swiss Re
- Travelers
- Zurich Re.

One insurance industry professional interviewed for this study said that insurance firms will usually specialize in one form of coverage or another depending on their risk appetite and expertise.

Another insurance industry professional said that property and liability coverage lines for PV are not constrained by capacity limitations, as these are "commoditized" lines of commercial insurance and form part of the core business for some of the carriers in this space. Therefore, they will allocate as much capacity as is required to fill the orders in the marketplace (the exception to this would be the smaller, specialty insurers that may not be as well capitalized as the larger players). He did say, however, that warranty insurance capacity currently does have capacity limits in the market and estimated that to be "several hundred million," perhaps half of which comes from Munich Re.

There are many brokerages involved with the PV industry. One interviewee suggested that, when construction slowed down during the financial crisis and as the solar market started to take off, many insurance brokers explored this option as a possible source of revenue. Some brokerages offering PV services in the United States include:

- Aon
- D&M Insurance Solutions.
- Energi
- Lockton Companies
- Marsh
- SolarInsure
- Wells Fargo
- Willis.

[16] GCube insures through Lloyd's of London, an insurance marketplace where independent underwriters will contract with clients (through brokers) to write policies for the client's specific risk exposures (IRMIc). Client risks may be transferred to any number of buyers, creating a kind of stack of risk-holding counterparties, somewhat akin to a capital stack of several different financial entities in a project's financial structure.

[17] PowerGuard is not a true insurance carrier—it functions as more of a brokerage/underwriter/managing general agent, in that it will write the policy but will not carry the risk of indemnifying the policyholder.

6 Innovations and Opportunities in PV Risk Management

In October 2011, the Economist Intelligence Unit, a research and analysis group within the larger Economist media conglomerate, published a report (sponsored by Swiss Re) titled *Managing the Risk in Renewable Energy* (Economist Intelligence Unit 2011). The report was based on a survey of 280 senior executives in the renewable energy industry about the state of affairs and outlook for risk management practices in an ever-growing fleet of renewable projects worldwide.

Of the executives polled, 70% indicated that they were confident in their company's abilities to identify risks, though less (61%) were confident in their company's mitigation capabilities. An even smaller proportion (50%) said that they were successful in transferring risks to third parties. One of the barriers to successful risk management and transfer identified in the report is the currently limited availability of "suitable risk transfer mechanisms." Insurance is currently the most common form of risk transfer used by the renewable energy industry, though as an expensive and limited form of risk transfer, there is interest in the market for products that can cost-effectively cover targeted risks that are difficult to insure (such as resource-related production risk). The survey indicates that industry leaders are anticipating the emergence of these types of solutions (including new types of insurance) (Economist Intelligence Unit 2011).

This section will explore four prospective solutions: weather derivatives, catastrophe (or cat) bonds, captive insurance companies, and securitization. Each addresses a different risk or set of risks, and all but the captive insurance company solution have not yet been used in the PV industry. Their inclusion in this study is to illustrate the maturation of the PV market and its evolving capabilities to exploit sophisticated and targeted risk management tools.

6.1 Weather Derivatives

Weather derivatives are financial instruments designed to hedge against variability in energy generation as a function of the weather (in PV's case, the sunshine). Whereas system-level warranty coverage will cover the technical and mechanical aspects of project performance, weather derivatives could be used to address resource-related performance, thereby covering the spectrum of production risks.[18]

Weather derivatives are essentially bilateral or sometimes multilateral contracts between a risk holder and a risk off-taker (the company structuring the derivative), whereby the off-taker agrees to pay a certain amount in the event that a specified weather event adversely affects business operations. In a derivative contract written for a PV system, the off-taker will cover a portion or all of the revenue shortfall if the quantity of sun—as recorded by a nearby weather measurement device that is mutually agreed upon—dips below the "strike," or the point at which coverage is triggered (Lowder 2012). This level may be indicated in the contract as a "P" value (e.g., P50,

[18] It is unclear what effect, if any, the Dodd-Frank regulations on swap dealing will have on the use of weather derivatives. While weather derivatives qualify for the types of instruments that fall under these regulations, the firms that are targeted may not encompass the kinds of entities that would deal in these types of instruments, particularly renewable energy weather derivatives. One interviewee who issued securities in the weather derivative and catastrophe bond markets suggests that the new regulations seem to be more relevant for traders (market participants that do not generally hold capital to all of their liabilities) and other leveraged buyers/issuers—not necessarily the entities who back their instruments with sufficient capital.

P90, or P99), which denotes a particular system's probability of exceeding a certain level of production (Lowder 2011).

Weather derivatives function like insurance, but they allow projects to offload risk onto the financial markets where it can be efficiently priced. In insurance, the underwriter and/or insurance carrier dictates the pricing of risk based on actuarial modeling.

The first weather derivative contracts were executed in the late 1990s by an independent power producer and a New York City utility. Today, these instruments are still largely used by the energy industry to hedge against weather-related price risks. Use of derivatives in the renewable energy industry is very limited, with most transactions occurring in the wind power sector (Lowder 2012). Products are available in the market for solar power providers, though it remains to be seen whether or not the PV industry will take advantage of these or if it in fact even needs to. More performance data and operational histories could help to determine that need (see Section 7.1).

6.2 Catastrophe Bonds

Catastrophe, or cat, bonds are another type of security designed to offload risk into the financial markets. Insurance companies that cannot or do not want to hold their catastrophe exposure on their books can issue bonds through a sponsor in any amount up to their policy liabilities. To issue a bond, an insurance company or other risk holder contracts a sponsor—typically a reinsurance company, but it can be another type of financial services firm—to create a special purpose vehicle (SPV) that issues the individual cat bond notes to capital markets investors. Cat bonds are typically sold as private placements but can also be tradable on the secondary market. Unlike a corporate bond, the money contributed by investors is held by the SPV in low-risk securities, such as U.S. Treasuries and not on the sponsor's balance sheet. The coupon that is paid to investors is made up of two parts: the return on these low-risk investments and the premiums paid to the SPV by the sponsor (Wiedmeyer 2012).

Cat bonds mature in three to five years (some in one, most are two to three, and the longest ever was 10) and issue quarterly coupons with typical yields ranging from 500–1,500 basis points above benchmark interest rates. They are usually rated from single A to single B by traditional ratings agencies. Because cat bonds derive their value from the frequency of natural phenomena, they are relatively uncorrelated with fluctuations in the traditional bond and equity markets. This, in turn, makes them attractive fixed-income investments for institutional investors looking to diversify their portfolios and insulate themselves from market volatility.

Cat bonds have not yet been issued for any renewable projects, though it may be a consideration for developers of utility-scale projects with more than $100 million in assets that are siting their projects in catastrophe-prone areas and who do not want to pay the high premiums necessary to insure the project. Utilities with high concentrations of assets may also be interested in managing their catastrophe exposure in this way (Wiedmeyer 2012).

6.3 Captive Insurance Companies

A captive insurance company (CIC) is a subsidiary established explicitly as a risk mitigation arm within a larger parent company that wishes to exercise control over the insurance of its own risks. CICs are usually licensed under specialty purpose insurer laws and are not subject to the same regulations as commercial insurers (IRMId). However, like traditional insurance companies, the insured pays a premium in exchange for coverage as outlined in a given policy, and the CIC is managed so that it can absorb the losses of the insured and maintain solvency (Speer 2011b).

CICs can be created to protect against a number of risks but are usually used for low-cost, frequent, and relatively predictable claims such as liability (e.g., worker's compensation) and property (e.g., vehicle coverage). Captives can also be used for other risks, including those that are either expensive (e.g., earthquake coverage or warranties) or not found in the commercial market (Speer 2011b).

CICs could be an attractive alternative to buying commercial lines from a traditional carrier. Some of the potential benefits to a developer or sponsor are as follows:

- Tax advantages, including the possibility of the captive not having to pay income tax and claiming deductions on the reserve funds generated by premiums
- The reserve fund, generated from premiums can be re-invested or loaned back to the parent so long as the captive remains solvent
- A captive, covering some risks with additional coverage sought from the private market, possibly at a lower cost due to the company's existing risk coverage (Speer 2011b).

CICs can be expensive to create, considering the associated transaction costs (e.g., feasibility studies, legal fees, organizational expenses, and actuarial fees). Such costs range from about $50,000 to over $125,000 to establish a CIC, depending on the captive's complexity (Speer 2011b). Developers and sponsors would need to determine their project risk exposures and the potential cost of insuring them in order to justify establishing a CIC. In the end, the captive option may only be available to well-capitalized companies, ones that could not only cover the costs of setting up a CIC but could also fund it with enough capital to withstand a major loss.

It is unclear how many renewable energy companies, if any, have used CICs, as this information is often not made public. In 2010, the insurance broker Beecher Carlson and solar power tower developer BrightSource Energy were considering establishing a captive to cover the developer's Ivanpah project, but in the end BrightSource chose not to proceed with that option (Morris 2010). Because many renewable energy companies may not be large enough to benefit from forming a captive, their use in this sector may be delayed until the industry sees additional growth, mergers, and acquisitions (Speer 2011b).

6.4 Securitization as Risk Mitigation

The U.S. PV industry is subject to a number of financial risks, including a short supply of tax equity capacity in the marketplace, the complexity of executing a financial structure that incorporates tax equity, access to debt, and the limited timelines of federal financial incentives. Solar PV securitization (pooling solar asset-backed cash flows into financial instruments that can be traded in primary and secondary markets; see Figure 6) could help to alleviate some of these pressures and constraints by bringing more capital to the PV market. Securitization could be a tool to manage financial risk.

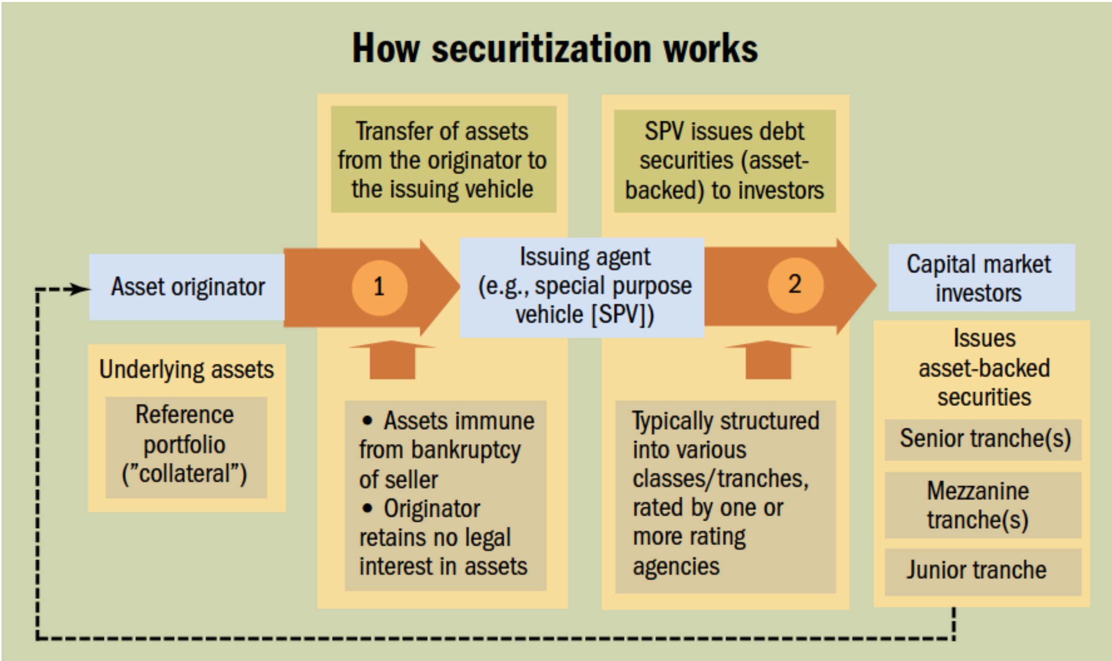

Figure 4. The process of securitization

Source: Jobst 2008

While securitization could be an effective way to manage risk, it may also be aided by effective risk management. The types of investors that are most interested in asset-backed securities include institutional investors, such as pension fund and mutual fund investors. These investors will look for a diversified portfolio of projects with strong cash flows and low risk of off-taker default. Insurance can directly impact the cash flows of a project by enabling the project to maintain a level of electricity production that allows the project to meet any obligations and a targeted level of revenue. For example, if there is damage to a project or a project fails and coverage is provided via a policy, the project owner can file a claim to the insurance carrier. The insurance carrier is likely to either repair the plant, provide cash reimbursement, or both, depending on the coverage purchased. Although insurance does not directly impact the risk of off-taker default, the two are linked by an indirect relationship: If a project were to be underperforming for any reason, including due to an insurable event, the off-taker may default if the project is not meeting performance expectations and there is a better investment opportunity by purchasing electricity elsewhere.

Investors will carefully examine all aspects of the solar PV projects before making a decision to buy. The investors will look at the underlying project finance structures to determine the quality and experience of the counterparties as well as the strength of the contracts: Have all risks been accounted for and are they clearly delineated? Regarding insurance, investors will want to know what the insurance does and does not cover and how they will deal with uncovered risks.

While securitization may be a powerful mechanism for bringing a larger quantity, and potentially lower cost, of capital, it is not likely to be a silver bullet for solar PV project development. It could take several years for solar PV securitization to ramp up, partly due to logistics as well as waiting for the market to mature and weather rapid technology and cost changes. Also, solar PV projects have historically utilized a number of innovative financing models and applications to provide energy to a variety of end-users. These projects may be (and have been) entirely viable without securitization and may not be sufficiently homogenous with other projects to be eligible for securitization.

At least two of the larger ratings agencies have begun looking into the risks of solar PV projects. Fitch issued a paper in 2011 titled *Rating Criteria for Solar Power Projects: Utility-Scale Photovoltaic and Concentrating Solar Power* (Fitch 2011). This study discusses how Fitch would rate solar PV projects and does not look at securitization specifically. However, many of the risks identified in the report may also be applicable to securitized projects. Fitch identified two groups of risks: those relating to financial analysis and those relating to the project.

Financial analysis risks include:

- "Financial strength and experience of sponsors, particularly with newer technologies
- "Reliable and accurate third-party reports on scope and quality of a solar resource and project design
- "Experience and financial strength of construction contractor with similar projects
- "Terms of the construction contracts, and the complexity and time scale of the construction phase
- "Strength of warranties and/or guarantees for project design, parts, and operations.
- "Technology risk associated with the project
- "Strength/weakness of the project cash flow stream" (Fitch 2011, p. 1).

Project risks were cited as:

- "Financial structure including amortizing debt characteristics, covenants, and reserve account mechanisms
- "Financial metrics, flexibility, and sensitivities" (Fitch 2011, p. 2).

In January 2012, Standard and Poor's issued a white paper titled *Will Securitization Help Fuel the U.S. Solar Power Industry?* (S&P 2012b) that concludes that securitization is a viable option for solar developers. However, the report also notes there are several risks associated with solar projects, including "a lack of historical performance data, a limited number of potential servicers, and ongoing downward pressure on solar panel prices" (S&P 2012b, p. 2).

A lack of historical data is both a risk to securitization and a challenge for the insurance industry. NREL is currently reaching out to industry for the purpose of developing a solar PV project database that would be of use both to the insurance and related industries and inform securitization of these projects.

7 The National Laboratories and PV Risk Management

7.1 Data Collection

The 2010 NREL white paper *Insuring Photovoltaics* (Speer et al. 2010) concluded with a section on solutions for, and the role of national laboratories in, improving PV insurance services and costs. The principal recommendation made in that section was for improving the quality and availability of PV performance data. Almost three years since that study was published, this remains a major area through which the PV industry can potentially mitigate risk, reduce soft costs (see Section 2.1), increase investment flows, and expand deployment.

Almost all PV stakeholders stand to benefit from a greater availability of high-quality data:

- Insurance underwriters could calculate loss probabilities with more certainty, which may allow carriers to extend lower cost coverage.
- Lenders could better understand risks, such as O&M costs, degradation rates, and yields over time, and this could help to lower their perception of risk that is reflected in the interest rate.
- Certainty over PV asset cash flows could facilitate the process of securitization and attract investors that are looking for stable, high-yield returns (Mendelsohn et al. forthcoming).
- Demand for solar assets, coupled with lower soft costs, could boost deployment and thus expand the market opportunity for developers.
- Some manufacturers may be able to substantiate their marketing with validated track records, which could win them more orders and establish their brand.

Data is critical to risk assessment and mitigation for both the financing and insuring of renewable energy projects. In recognition of this, NREL, Sandia National Laboratories, and the DOE have launched initiatives to build, analyze, and disseminate datasets for use by various PV stakeholders. NREL's current efforts to collect and organize data include:

- The **International PV Quality Assurance Task Force**, a group of researchers from around the world that pools information about how to test PV modules in order to predict which models will last longest when deployed in various climates and applications. The group aims to influence the development of a single set of standardized tools that will allow PV manufacturers to demonstrate the robustness of their products and PV customers to compare products. Correlating test results with field performance will also inform the insurance underwriting process and could possibly help to lower premiums (http://www.nrel.gov/ce/ipvmqa_forum/).
- Data collection and research within NREL and Sandia National Laboratories to quantify and communicate summaries of PV performance and reliability. Together, the labs have reviewed a collection of over 2,000 reports on degradation rates and reached the following conclusions: Median crystalline silicon degradation rates have remained relatively constant in the last two decades (at around 0.5% annually); the 3% annual degradation rates observed for thin-film modules fielded before 2000 have now dropped to around 1% annually. This research and these findings facilitate statistical predictions in

the absence of product-specific data. An example summary can be downloaded at http://www.nrel.gov/docs/fy12osti/51664.pdf.

- The **Advanced Financing Mechanisms to Achieve SunShot** project, which is designed to enable securitization of solar portfolios in order to access capital more widely and at lower cost. A primary task under this effort is to build datasets relevant to system performance and customer default that can be easily employed by the financial and insurance communities to assess and mitigate risk. This effort will also focus on document standardization as a means to enabling securitization.

The NREL Performance and Reliability Team is also engaged in data collection for the purposes of internal analysis and the publication of technical reports and journal articles. See http://www.nrel.gov/pv/performance_reliability/research_staff.html for a list of publications.

Sandia National Laboratories' current efforts to collect and organize data include:

- Performance modeling. Sandia's PV Modeling and Analysis team develops methods and tools to simulate PV system and component performance while exposed to different weather and environmental conditions. The team also leverages field and laboratory capabilities to characterize performance of modules, inverters, and other BOS components to develop calibrated system models. See http://energy.sandia.gov/?page_id=2493.
- Reliability. Sandia uses field O&M data, degradation studies, failure rates from integrator and utility partners, and detailed statistical analysis to develop systems-level models. These models can be applied by researchers and industry to help determine ways to overcome reliability issues and accelerate high penetration of PV technologies. See http://energy.sandia.gov/?page_id=275.
- Basic and fundamental PV research. See http://energy.sandia.gov/?page_id=272.

These various projects are largely funded by the DOE and DOE's SunShot Initiative.

7.2 Testing

7.2.1 NREL Capabilities

NREL supports performance testing for commercial and developmental PV devices through its Measurements and Characterization (M&C) division and the National Center for Photovoltaics (NCPV). M&C and NCPV provide technical solutions, collaborative research, testing support, and consulting services to private industry to support, among other things, the advancement of reliable and financeable PV products. NREL is one of only two laboratories in the world to hold an International Organization for Standardization (ISO) 17025 accreditation for primary reference cell and secondary module calibration, in addition to accreditation for secondary reference cell calibration under American Society for Testing Materials (ASTM) and IEC standards. It is one of only four laboratories in the world certified in accordance with the IEC standards.

The Device Performance Group within M&C serves as an independent facility for verifying device performance for the entire PV community and helps to reduce large discrepancies between module manufacturers, commercial testing groups, and national laboratories through the following activities:

- Tracing reference cell and module calibration to standard test conditions for commercial test labs, partners, and the U.S. PV community
- Providing independent cell and module efficiency measurements to contextualize industry claims
- Consulting on PV testing procedures and uncertainty analysis
- Supporting U.S. commercial calibration laboratories through primary reference cell calibrations.

These testing activities provide decision makers in the PV and financial communities with the tools to effectively manage technology and performance risks.

Additionally, NREL's newest facility the Energy Systems Integration Facility (ESIF) provides testing as well as advanced modeling and simulation capabilities that can be applied to PV systems and components. ESIF resources will allow researchers and manufacturers to conduct integration tests at full power and at actual load levels in real-time simulations that can mimic location-specific operating and resource conditions. This will allow manufacturers to evaluate, at high granularity, component and system performance before going to the market. ESIF testing and data may help to increase financier confidence in the performance and reliability of PV systems and components, thereby potentially reducing overall investment risk, especially in the case of early adoption.

7.2.2 Regional Test Centers

In March 2012, the DOE SunShot Initiative issued a Notice of Opportunity for Technical Assistance (NOTA) for regional test centers (RTC) to validate and monitor PV modules and systems (DOE SunShot July 2012b). The purpose of this program (for which the next applications were due on December 30, 2012) is to develop PV performance standards and establish a technical basis for bankability that can be applied in financial decision making. Recipients of the award will install their systems at all three of the DOE RTCs and receive independent validation of things, such as:

- System performance
- Consistency of module quality
- Degradation rates
- Reliability.

The RTCs will provide land, grid ties, and the testing/data monitoring components required to support these efforts and focus on using the test data to develop standards that will be useful to the community. Sandia will provide co-leadership through its technology validation efforts along with NREL, which will support the regional testing centers through its activities at the M&C and NCPV divisions.

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