RESIDENTIAL PV SYSTEMS IN THE SOLAR HOME RENEWABLE ENERGY CREDIT (SHREC) PORTFOLIO, TRANCHE 4

Technical Due Diligence Report

Connecticut Green Bank

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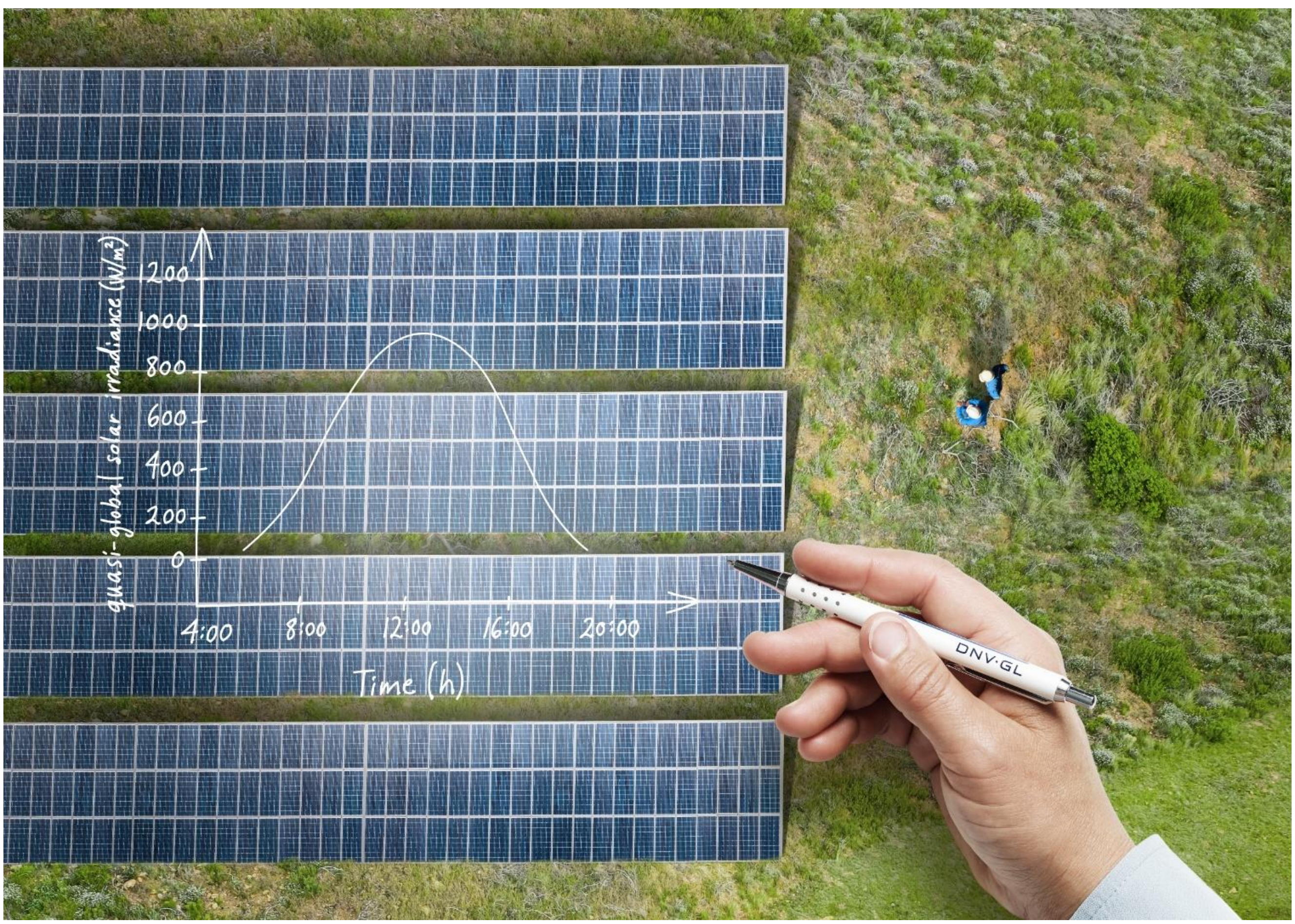

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Issue	Date	Status	Reason for Issue	Prepared by	Verified by	Approved by
A	12 Feb 2021	Draft	First issue	K. Cunningham	B. Dodge	A. Abatzis
B	2 April 2021	Draft	Operating system review, SHREC forecasting procedures	K. Cunningham	B. Dodge	A. Abatzis
C	13 April 2021	Draft	Comments from Issue B	K. Cunningham	B. Dodge	A. Abatzis

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List of abbreviations

The following table lists some of the abbreviations used in this Report.

Abbreviation	Meaning
ac	Alternating current
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BoP, BoS	Balance of plant, Balance of system
CAPEX	Capital expenditure
dc	Direct current
DHI	Diffuse horizontal irradiation
EPC	Engineering, procurement, and construction
GHI	Global horizontal irradiance
IAM	Incidence Angle Modifier
IE	Independent Engineer
IEC	International Electrotechnical Commission
JCO	Job Close-Out
LD	Liquidated damages
LID	Light-induced degradation
LV	Low voltage
MPPT	Maximum power point tracking
MQF	Module quality factor
NOAA	National Oceanic and Atmospheric Administration
NSRDB	National Solar Radiation Database
NTP	Notice to proceed
O&M	Operation and maintenance
OPEX	Operating expense
PID	Potential-induced degradation
PIS	Placed In Service
POA	Plane of Array
POI	Point of interconnection
PV	Photovoltaic
RMA	Return Merchandise Authorization
SCADA	Supervisory control and data acquisition
STC	Standard Test Conditions
TGHIY	Typical Global Horizontal Irradiance Year
UL	Underwriters Laboratories
VA, kVA, MVA	Volt-amp (kilovolt-amp, megavolt-amp) – ac rating of (real and reactive) electrical power
VAR, kVAR, MVAR	Volt-amp reactive (kilovolt-amp reactive, megavolt-amp reactive) – ac rating of reactive electrical power
Wac, kWac, MWac	Watt ac (kilowatt ac, megawatt ac) – ac rating of real electrical power
Wp, kWp, MWp Wdc, kWdc, MWdc	Watt-peak (kilowatt peak, megawatt peak) – equivalent to dc electrical power rating of PV modules

EXECUTIVE SUMMARY

Introduction

At the request of the Connecticut Green Bank (the “Green Bank” or “Sponsor”) DNV Energy USA Inc. (f/k/a DNV GL Energy USA, Inc.; “DNV”) has performed a technical due diligence review of the residential photovoltaic (PV) systems in the Sponsor’s Solar Home Renewable Energy Credit (SHREC) portfolio, Tranche 4 (the “Portfolio”), representing 6,957 residential-scale solar PV systems.

The purpose of this Report is to summarize Portfolio performance, create a production forecast, and perform an equipment review. Specifically, DNV ’s scope of work includes review of the following:

- Engineering process review
- Major equipment review
- SHREC production forecasting procedures
- Production analysis of operational PV systems
- Major agreements
- Operating system review
- Financial model technical input review

Engineering process review

DNV has previously reviewed the Request for Qualifications and Program Guidelines for Eligible Contractors and Third-party PV System Owners to participate in the Residential Solar Investment Program (RSIP) document provided by the Sponsor, dated 1 November 2016. DNV understands the referenced documentation has not been substantively changed since DNV’s previous review, and therefore this review not been updated with the latest Request for Qualifications and Program Guidelines document revised 19 October 2020.

The RSIP document provides the requirements necessary for a PV system to be eligible for CT Green Bank incentives, including requirements for contractors and PV system owners to qualify as approved RSIP-eligible PV system installers.

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary Findings
2.1	**Summary:** The Sponsor has issued a request for qualifications (RFQ), which explains the process and requirements PV system installers must follow to qualify as an eligible Installer and later receive incentives through the RSIP. The program requires that PV system installers pass incentives onto the homeowners as a cost reduction during contracting (i.e. system purchase, lease, or power purchase agreement). The PV system installers do not receive the incentives until they have passed the Sponsor’s completion requirements, which includes review of a self-inspection report following installation and a potential audit of the installed PV system.
2.1.1	**PV system eligibility requirements:** Notably, the RSIP document requires the PV system to be in The United Illuminating Company (UI) or Eversource Energy service territories, to be grid-tied, and PV equipment must be new and listed by the California Energy Commission (CEC).
2.1.2	**Installers eligibility requirements:** Installers must first complete an application process to become eligible to participate in the RSIP. The application process requires the installer to demonstrate experience and licensing/certification, as well as provide subcontractor and homeowner contracts and terms, including a five-year workmanship warranty on all components. The Sponsor will review the installer annually or as-needed to ensure compliance with RSIP standards.
2.1.3	**Installer responsibilities**: Once approved, Installers have responsibilities such as completing accurate pre-construction assessment and calculations, completing RSIP applications, receiving approvals for the PV system from authorities, complying with inspection reports and completion documents, and passing required inspections.

Section	Primary Findings
2.1.3.1	**Installer completion documents:** Upon completing the PV system installation, Installers are required to submit a project completion certificate, utility approval-to-energize documentation, self-inspection report (including all required photos), energy efficiency audit documents, and performance data provider information (e.g. approved revenue-grade meter ID). DNV finds the self-inspection report template is lacking in mounting system structural checks, only including one check to ensure the PV modules are secured to the mounting system.
2.1.4	**Sponsor rights:** Under the RSIP rules, the Sponsor is the owner and receives all renewable energy credits (REC)s. The Sponsor reviews completion documents, specifically the self-inspection report submission and will follow-up with the Installer as needed. The Sponsor has the right to perform an audit of the system to confirm completion documentation submitted is accurate. The Sponsor reserves the right to withhold or adjust incentives based on inspection reports or other information.

Major equipment review

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary Findings
3.2	**PV Modules:** The major module manufacturers in the Portfolio, except for Silfab, are large established manufacturers with some extended-duration test data. Silfab, with 10% of the modules in the Portfolio, is a smaller manufacturer which might be considered to present an atypical reliability risk relative to more established suppliers available in the market. However, accelerated reliability testing results from multiple PVEL Module Reliability Scorecards mitigate this concern and demonstrate that Silfab is capable of consistently designing reliable modules. Therefore, all module manufacturers in the Portfolio are considered to be capable of manufacturing modules without atypical reliability or quality risk as compared to the broader industry. Because of Silfab's small size, production witness oversight when procuring modules is recommended to further reduce potential reliability concerns.
3.3	**PV Inverters**: Over 99% of the Portfolio is represented by SolarEdge, ABB/Power-One, Enphase, SMA, SunPower, and Delta Electronics inverters. Based on past detailed technology reviews of SolarEdge, ABB/Power-One, Enphase, SMA, SunPower, and Delta inverters, DNV considers these manufacturers to be acceptable suppliers of inverters to the Portfolio.
3.4	**Meter:** DNV has not reviewed meters used by individual installers in this Portfolio. DNV considers the technology used in residential meters to provide adequate reliability.
3.5	**Racking:** Though DNV has not reviewed racking used by individual installers in this Portfolio, DNV has reviewed all leading residential racking products in the past. With the adoption of NBC 2018 and ASCE 7-16 building codes and standards, residential racking loads are fully characterized, and the risks of projects being insufficiently designed are low. Therefore, DNV considers residential roof racking to represent low project risk if appropriately designed, installed, and maintained.

SHREC production forecasting procedure review

DNV has reviewed the procedures by which the Sponsor generates energy production forecasts for residential systems with the purpose of evaluating the long-term accuracy of these forecasts and their usefulness for predicting the Portfolio's SHRECs from energy production.

Section	Primary Findings
4.2	**Energy simulation:** Since 2006, PowerClerk has acted as the proposal and system reporting portal for all Sponsor systems, as well as supporting the Sponsor's incentive program. The Sponsor's process requires system information be initially entered in PowerClerk; however, for SHREC forecasting purposes, the Sponsor relies on a parallel calculation in Clean Power Research's (CPR) SolarAnywhere Fleetview.
4.3.1	**Meteorological data:** The Sponsor uses CPR SolarAnywhere data at the site location as the irradiation data input to the energy estimate simulation. The data satellite imagery collected from geosynchronous satellite networks and is applied to 10 x 10 km mesh grids. The data spans 1998 – 2017.
4.3.3	**Loss factors:** The Sponsor applies a 10% loss factor in SolarAnywhere Fleetview to account for all component loss factors except for shading and inverter efficiency. DNV finds the 10% loss factor reasonable for this specific Portfolio of systems based on regional weather.
4.3.5	Validating Sponsor energy estimates: DNV performed validations of the 20 systems reviewed, DNV independently validated 18 of the 20 systems to within ±1%.

Production analysis

DNV has analyzed a production dataset ("Portfolio Data") from the Sponsor's Portfolio of deployed systems to confirm the accuracy of the energy production estimates and to set expectations for future production of these systems.

DNV has also estimated and presented the uncertainty in its production forecast.

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary Findings
0	**Production data set:** The Sponsor supplied DNV with annual production and forecast data for 6,957 systems (the "Production Data Set").
5.3	**Production analysis methodology:** DNV has performed a QA/QC procedure on the monthly data made available by the Sponsor. DNV calculated the extent to which over/under production in a region can be attributed to differences between the irradiance during the operational period relative to the long-term irradiance for that region and applied irradiance adjustment factors. DNV calculated a Performance Index for each system by taking the ratio of the summed irradiance-adjusted annual actuals to the summed annual estimates.
5.4	**Production analysis results:** The Production Sample systems have overperformed their estimates by 2.0% on average. DNV compared the performance of the Production Sample by Installer, PTO date, module manufacturer, and inverter manufacturer.
5.6	**Uncertainty:** DNV has calculated a P50 Portfolio forecast of 97.1% of the Sponsor's first-year energy estimate. DNV has calculated a P99 Portfolio forecast of 90.1% of the Sponsor's first-year energy estimate.

Major agreement review

DNV has previously reviewed the following executed agreements (collectively, "MPAs"), all dated 7 February 2017 with Eversource Energy and UI. SHREC sales to The Connecticut Light and Power Company (dba "Eversource Energy") and UI are provided for using a Master Purchase Agreement (MPA).

The MPAs provide for the Sponsor to sell SHRECs at firm pricing ($50 per MWh for tranche one, $49/MWh for tranche two, $48/MWh for tranche three, and $47/MWh for tranche four) for 15 years. The Buyer, either Eversource Energy or UI, is obligated to purchase those SHRECs in a tranche associated with the energy generated by the projects assuming the pre-requisites have been met and continue to be met through the term. The main difference between the MPAs provided is the Buyer's Percentage Entitlement ("BPE"); Eversource Energy having a BPE of 80% and UI having a BPE of 20%. DNV has not identified other meaningful differences between the individual MPAs.

While the buyer is obligated to purchase all SHRECs from a qualifying tranche, there is not a SHREC guaranty or other performance-based terms that require a minimum amount of electricity be produced from a tranche.

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary Findings

6.1.1	**Parties and contract status:**
	- Buyer of SHRECs:
	  o Eversource Energy (80%)
	  o UI (20%)
	- Contract status: Executed 7 February 2017 (MPA) / 15 July 2020 (Tranche 4 Transaction Confirmation)

6.1.2	**Term:** The tranche delivery term starts on 1 January of a tranche year and continues for 15 years. The Buyer's obligation to purchase tranche SHRECs will end no later than the earlier of when Sponsor achieves deployment of 305.4 MWdc of qualifying residential solar PV installations or 31 December 2022, meaning the final tranche start date would begin 1 January 2022.
6.1.3	**Sale of SHRECs:** The purchase price of each SHREC is $50.00 in the MPAs for Tranche 1, $49/MWh for Tranche 2, $48/MWh for Tranche 3, and $47/MWh for Tranche 4. The Sponsor establishes the price of each tranche in accordance with Connecticut General Statutes. A SHREC is equal to one megawatt hour (MWh) of electricity generated from a qualifying residential solar PV system. The Buyer is obligated to purchase all SHRECs generated by SHREC projects in a tranche. SHRECs are invoiced quarterly.
6.1.4	**Obligations of Sponsor**: The Sponsor is responsible for ensuring energy generation has begun prior to tranche delivery start date, providing the tranche purchase price and project details, ensuring the SHREC projects qualify as residential solar PV system, executing the tranche confirmation (Exhibit B), and completing delivery of SHRECs to Buyer.
6.1.5	**Obligations of Buyer:** The Buyer is responsible for ensuring it has received regulatory and corporate approval and has received tranche detail and executed the confirmation.
6.1.6	**Energy generation and metering:** SHREC projects must be located behind a qualifying utility revenue meter and must have a separate meter dedicated to measurement of SHREC project energy output. The meter shall be installed, operated, maintained, and tested to meet applicable requirements and standards of the utility and electric system operator.

Operating system review

DNV has completed an electrical design audit for a sample of 20 systems within the Sponsor's Portfolio for the purpose of both confirming consistency with the Sponsor's agreed processes and for identifying any specific issues or risks. In addition, 15 sample systems were selected for an on-site inspection.

A summary of the primary findings identified is provided in the following table.

Section	Primary findings
7.2.1	**Electrical audit:** DNV considers the 20 sampled systems to exhibit standard electrical design quality which is consistent with typical practices in the residential market.
7.2.2	**Structural audit:** The Sponsor does not require installers to submit structural design drawings as part of project completion. As such, DNV was not able to inspect a sample of structural designs for the Portfolio.
7.3.6.1	**Electrical inspection findings:** Inspectors from IBTS performed site inspections on behalf of DNV, and DNV reviewed IBTS site inspection reports. Common issues across most sites are inadequate wire management (low criticality in the short-term but high for long-term reliability) and improper labeling. Labeling issues should be corrected whenever service personnel are called to the site for other service needs. A review of NEC required labels during the design stage may help alleviate improper labeling, especially with the use of inverter integrated solar modules.

Section	Primary findings
7.3.6.2	**Structural inspection findings:** Inspectors from IBTS performed site inspections on behalf of DNV, and DNV reviewed IBTS site inspection reports. Among the structural issues noted in the inspection reports, none represent a high criticality. The most prevalent issues noted were improperly fastened module clamps or lag bolts, which represents a low criticality in isolated incidents. Criticality would increase if systemic, as multiple instances represent a medium risk to production and life safety if panels become dislodged during heavy winds or snow. Inspection reports also noted improper conduit flashing, which represent a low criticality based on DNV's assessment of the photos and location. The module damage from an apparent falling object cannot be confirmed to be due to installation.

Financial model technical input review

DNV has not received a project specific financial model for review. A summary of the primary findings and/or risks identified during DNV's review of technical inputs relevant for revenue generation as well as O&M considerations and stress case considerations is provided in the following table.

Section	Primary Findings
8.1	**Revenue:** DNV has calculated a Year 1 portfolio-level P50 correction factor of 108% of the Sponsor's first-year energy estimate. The Portfolio is forecast to degrade at -0.70% per year at a P50 confidence level. When adjusting the correction factor for age and inverter availability, the P50 Year 1 annual forecast, 01 January 2021 to 31 December 2021, is 0.971 and is intended to be applied to the Sponsor's first-year energy estimates for the Portfolio. DNV expects well-designed, properly installed, and well-maintained PV systems to perform in line with expectations for 25–30 years.
8.2	**O&M:** DNV understands that the Sponsor does not have direct responsibility for O&M costs for the Portfolio, as the Sponsor's role is as an asset program administrator. As such, DNV has not reviewed either projected Performance Guarantee payout liabilities or inverter replacement cost projections.
8.3	**Stress cases:** DNV has provided production stress cases as well as consideration for installer bankruptcy / market exit. The Sponsor has contracted with Locus Energy, an AlsoEnergy Company for Portfolio monitoring, and the Sponsor has contracted with SunSystem Technology as a third-party US residential O&M provider. DNV views this as an appropriate risk mitigation step.

1 INTRODUCTION

At the request of Connecticut Green Bank (the "Green Bank" or "Sponsor"), DNV has prepared this technical due diligence report (the "Report") of the residential photovoltaic (PV) systems in the Sponsor's Solar Home Renewable Energy Credit (SHREC) portfolio, Tranche 4 (the "Portfolio"), representing 6,957 residential-scale solar PV systems (the "Portfolio") with a total capacity of 59.37 MWdc.

The purpose of this Report is to: summarize Portfolio performance, create a production forecast, and perform an equipment review.

Issues that would benefit from further clarification or require additional information to resolve are highlighted through the use of ***bold italics***.

1.1 Objective and scope of review

The scope of work for the review was defined pursuant to the Work Order dated 10 December 2020 which was fully executed on 11 December 2020 (the "Agreement"), by and between Connecticut Green Bank and DNV in its capacity as the Independent Engineer. The Report is provided per the terms and conditions of the Agreement, and disclosure of the Report to potential investors and/or lenders is subject to provisions of the referenced terms and conditions and the disclaimer at the front of this Report.

Due to the size of the Portfolio, a technical due diligence review of each PV system would be cost prohibitive. Therefore, the DNV approach has been asked to assess the procedures by which PV systems in the Portfolio have been designed and constructed, and by which the PV systems are operated and maintained.

DNV has reviewed the following items:

- Engineering process review
- Major equipment review
- SHREC production forecasting procedures
- Production analysis of operational PV systems
- Major agreements
- Operating system review
- Financial model technical input review.

Items requiring further clarification or action and identified risks are noted in ***bold italics*** within this Report.

1.2 Method and assumptions

This Report is a technical due diligence review intended for financial institutions, customers, and project developers. DNV is well qualified to conduct this study due to its extensive background and experience in solar independent engineering and technology due diligence work.

This Report summarizes the DNV assessment of the Portfolio and relies on the accuracy of the information provided. DNV believes that the information provided by others is true and correct and reasonable for the purposes of this Report. In preparing this Report and the opinions presented herein, DNV has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. DNV believes that these assumptions are reasonable for purposes of this Report but actual events or conditions may cause results to differ materially from forward-looking statements.

1.3 Connecticut Green Bank overview

Per the Connecticut Green Bank:

> The Connecticut Green Bank (Green Bank) was established by Connecticut's General Assembly on July 1, 2011. The Green Bank's vision is a world empowered by the renewable energy of community. The Green Bank's mission is to confront climate change and provide all of society a healthier and more prosperous future by increasing and accelerating the flow of private capital into markets that energize the green economy.
>
> To achieve its vision and mission, the Green Bank has established the following three goals:
>
> 1. To leverage limited public resources to scale-up and mobilize private capital investment in the green economy of Connecticut.
> 2. To strengthen Connecticut's communities by making the benefits of the green economy inclusive and accessible to all individuals, families, and businesses.
> 3. To pursue investment strategies that advance market transformation in green investing while supporting the organization's pursuit of financial sustainability.
>
> The vision, mission, and goals support the implementation of Connecticut's clean energy policies be they statutorily required (e.g., CGS 16-245ff), planning (e.g., Comprehensive Energy Strategy), or regulatory in nature [1].

1.4 Description of the Portfolio

DNV received a dataset in January 2021 ("Tranche 4 Data") [2], which shows the Portfolio is composed of 6,957 residential PV systems located in Connecticut. The total capacity of the Portfolio is approximately 59.35 MWdc[1]. The top 10 installers by system count represent 90.5% of the installed capacity in the Portfolio as shown in Table 1-1 [2]. The data indicated the Tranche 4 portfolio is 79.8% third-party owned and 20.2% homeowner owned.

The Green Bank manages the residential solar PV state incentive program (the "RSIP"), which enables the generation of SHRECs. SHREC production is directly correlated (on a 1:1 basis) with MWh produced by PV systems in the Portfolio. Further details on the SHREC production process are described in Section 4.

[1] Based upon the Project Size as listed in EDC approval to Energize.

Table 1-1 Portfolio installer distribution

Installer	Total MWdc[2]	Total systems	% MWdc per installer[3]
Trinity Solar	22.7	2,706	38.3%
PosiGen	6.1	890	10.3%
Vivint Solar	6.1	698	10.2%
SunPower Capital	6.0	640	10.2%
SolarCity	3.9	423	6.7%
Sunrun	3.2	391	5.5%
Momentum Solar	2.2	279	3.7%
Ross Solar	1.3	112	2.2%
C-TEC Solar	1.3	107	2.1%
Earthlight Technologies	0.8	84	1.4%
Remaining Installers (37)	*5.6*	*627*	*9.5%*
TOTAL	**59.4**	**6,957**	**100%**

[2] Total may not align to 59.35 MWdc due to rounding
[3] Total may not align to 100% due to rounding

2 ENGINEERING PROCESS REVIEW

DNV previously reviewed the Request for Qualifications and Program Guidelines document for Eligible Contractors and Third-party PV System Owners to participate in the RSIP provided by the Sponsor [3], dated 1 November 2016. DNV understands the above referenced documentation has not changed substantively since DNV 's previous review, and therefore this review of the documentation has not been updated with the latest Request for Qualifications and Program Guidelines document revised 19 October 2020 [4].

The RSIP document provides the requirements necessary for a PV system to be eligible for CT Green Bank incentives, including requirements for contractors and PV system owners to qualify as approved RSIP-eligible PV system installers. While the document provides information on expected performance-based buy-down incentives (EPBB) and performance-based incentives (PBI), DNV review of the RSIP document has focused on PV system installer requirements in ensuring quality PV systems installations.

The RSIP document describes the application and obligations that either contractors or PV system owners, collectively ("Installers"), must meet and maintain to be eligible to receive incentives from the RSIP. The Installers receive EPBB payments upon successful completion of a PV system purchased by the homeowner or become eligible for PBI payments upon successful completion of a PV system with a lease contract or power purchase agreement (PPA).

2.1 Residential Solar Investment Program

2.1.1 PV system eligibility

Below is a list of PV system requirements to receive incentives under the RSIP:

- The PV system must be installed on a one to four family primary residence so long as the homeowner owns the land on which the home is affixed to a foundation (i.e. mobile homes and some manufactured homes are ineligible);
- The home must be in UI or Eversource Energy service territory (not Connecticut Municipal Electrical Energy Cooperative);
- The home must have an energy efficiency audit completed unless the home is new construction or under rehabilitation, has been ENERGY STAR certified since 2005, or the home has a Home Energy Rating of 85 or lower;
- PV equipment must be new and listed by the CEC;
- PV system is grid tied; and
- The equipment and installation must comply with all federal, state, and local laws, codes, and regulations, including Connecticut Building Code and the National Electric Code (NEC).

It should also be noted that for EPBB eligible PV systems, there is a 20 kW_{PTC} limit, limited by homeowner electricity usage, and the system must have a design factor[4] of 75% or greater to receive the full incentive. For PBI and EPBB systems the design factor must be 60% or greater to receive incentives.

[4] Defined as the ratio of the summer output of the proposed system to the summer output of a reference optimal system

2.1.2 Installer eligibility requirements

Approved Installers must be used for all RSIP PV systems. The Sponsor approves each Installer through a request for qualifications (RFQ) process. The Installer submits to the Sponsor an application with supporting documentation, including but not limited to[5]:

- Resumes of key staff;
- Connecticut E-1, PV-1 or Home Improvement Contractor (HIC) licenses;
- North American Board of Certified Energy Practitioners (NABCEP) certification from at least one person;
- Subcontractor agreements;
- Sales contract and terms;
- Bank reference letter;
- General liability insurance;
- PPA contract and terms (if applicable) including details of any performance guarantee; and
- References.

Approved Installers must include a workmanship warranty of 5 years (or more) to cover all components against degradation of more than 10% from the original rated electrical output, and the full costs of labor for repair or replacement of any defective PV system components. The Sponsor will evaluate the application and documentation for completeness and, if deemed to have met requirements, will invite the Installer to attend a one-hour training session with a RSIP representative. Upon completion of the training session, the Installer will be added to the "Eligible Contractor" list with either full status or provisional status depending on experience and number of PV installations or equivalent training. Provisional status will be lifted after enough PV installations have been completed and passing Sponsor required PV system inspections.

The Sponsor will review annually or as needed to ensure continued compliance with the RSIP document standards. An Installer may be placed on probation, suspension, or terminated for program violations such as:

- Poor quality or service or false or inaccurate claims, billing, system capabilities or benefits;
- Failure to ensure all applicable employees and subcontractors are licensed;
- Failure to comply with state and local laws and ordinances;
- Improper incentive activity;
- Consistent inspection failures;
- Failure to respond to requests for information;
- Falsifying documents; and
- Illegal actions.

2.1.3 Installer responsibilities

To maintain their approval, Installers have primary responsibilities that must be met. Key responsibilities are summarized below:

- Conduct accurate site evaluations, including shading assessments;
- Follow RSIP rules to determine eligibility, size, cost and estimated incentive;
- Complete accurate RSIP applications on behalf of the homeowner;

[5] Third Party System Owner requirements were:
- Resumes of key staff
- Bank reference letter
- Agreements with installers
- Lease or PPA contract and terms

- Comply with requirements for inspection reports and completion documents;
- Obtain appropriate permits and approvals;
- Maintain all required insurance, licenses, and certifications;
- Comply with all national, state, and local codes and standards, rules, and regulations;
- Coordinate installation of the PV system through direct employees or subcontractors – note Installers are held directly accountable for work performed by all their staff as well as subcontractors;
- Complete interconnection process and receive approval to energize;
- Collaborate with the Sponsor's third-party inspectors;
- Pass required inspections; and
- Honor five-year workmanship warranty.

RSIP applications are not approved until all required documents have been submitted to the Sponsor's satisfaction. In the event of project cancellation, or if cost, component, or system design specifications have changed from the original approved application, a change order or cancellation request shall be sent to the Sponsor within five business days.

2.1.3.1 Installer completion documents

To receive the Expected Performance Based buy-down incentives (EPBB) or Performance Based Incentive (PBI), the Installer must pass inspections and completion documentation must be submitted:

- Project completion certificate;
- Utility approval-to-energize documentation;
- Self-inspection report (including all required photos);
- Documentation of energy efficiency audit, if not already provided;
- Performance data provider information (e.g., approved revenue-grade meter ID).

Representative self-inspection reports have been shared and DNV 's review is part of Section 7 Operating System Review. The self-inspection reports include pass/fail criteria for the installed system covering:

- Verifying system orientation (tilt and azimuth) and shading;
- Verify module and inverter model installed;
- Verify system capacity;
- PV array, conduits, and cables secured with no visible damage;
- Fuses and circuit breakers (dc and ac);
- Disconnects (dc and ac);
- Inverter and interconnection;
- Installation consistent with manufacturer specifications;
- As-built diagrams and owner's manuals have been supplied;
- Monitoring and metering equipment installed correctly; and
- Methodology for calculating values for labels.

DNV recommends including more detail regarding inspection of the mounting structure in the self-inspection template. For example, inspection of the existing roof framing, verification of positive attachment of lag screws to rafters and inspection of flashing, and verification that the racking, standoffs and module clips are installed according to the plans and manufacturer's requirements. DNV finds the self-inspection report template is lacking in mounting system structural checks, only including one check to ensure the PV modules are secured to the mounting system.

2.1.4 Sponsor rights

RSIP customers and third-party owners (under leases and PPAs) forfeit any ownership of renewable energy credits (RECs) generated by their solar PV systems to the Sponsor. The Sponsor reviews completion documents, specifically the self-inspection report submission, and will follow-up with the Installer as needed. The Sponsor may audit the system to confirm documentation. Upon the second instance of a re-inspection at one or more sites, the Installer will be required to pay the cost of the follow-up inspection.

The Sponsor reserves the right to adjust incentive calculations based on inspection reports or other submitted documentation. If the PV system is not installed properly or in accordance with the proposed system specifications, the Sponsor may withhold or recalculate incentives based on actual installed equipment and actual site conditions.

2.2 Monitoring and maintenance activities

In Q2, 2020 [5] the Sponsor informed DNV that it continues to utilize the production monitoring platform and services of Locus Energy, an AlsoEnergy Company, to monitor Portfolio performance.

As indicated by the Sponsor, the Sponsor utilizes SunSystem Technology (SST) to provide O&M services for systems owned by the Sponsor and is planning to use SST to provide O&M services for other projects where needed. The remaining systems rely on the installer partner and/or third party owners to provide O&M services resulting from warranty claims or other needed system fixes.

2.3 Portfolio installers

Under the RSIP, installation contractors both originate and install systems. Table 2-1 summarizes the installation contractors engaged on system origination within the Portfolio and their respective contribution on a capacity basis. Overall, 47 installation contractors are represented in the Portfolio. The Tranche 4 portfolio is 81.7% third-party owned and 18.3% homeowner owned by system count, and 79.8% third-party owned and 20.2% homeowner owned by system size.

Table 2-1 Portfolio composition by installation contractor

Install Partner	System Count	% of Total System Count
Trinity Solar	2,706	38.9%
PosiGen	890	12.8%
Vivint Solar	698	10.0%
SunPower Capital	640	9.2%
SolarCity	423	6.1%
Sunrun	391	5.6%
Momentum Solar	279	4.0%
Ross Solar	112	1.6%
C-TEC Solar	107	1.5%
Sunlight Solar Energy	86	1.2%
Others (37)	625	9.1%
Total	**6,957**	**100.0%**

Trinity Solar has originated 38.9% of the Portfolio on a system basis. PosiGen, Vivint Solar, SunPower Capital, SolarCity and Sunrun have contributed 12.8%, 10.0%, 9.2%, 6.1%, and 5.6% respectively. Another 41 contractors have also contributed to the Portfolio.

Brief reviews of Trinity Solar, PosiGen, Vivint Solar, SunPower Capital, SolarCity and Sunrun are included here.

2.3.1 Trinity Solar

Trinity Solar, based in New Jersey, began installing solar systems in 2004.The organization now employs over 1,800 personnel serving over 50,000 systems and has installed over 393 MW of solar, primarily on the East Coast [6]. Trinity Solar's service areas include New Jersey, New York, Connecticut, Massachusetts, Maryland, Pennsylvania, Rhode Island, and Delaware.

Though DNV 's direct experience with Trinity Solar is limited, DNV acknowledges the company's strong standing as a national installer and considers them a suitable provider to the Portfolio.

2.3.2 PosiGen

Headquartered in New Orleans, LA, PosiGen was founded in 2011. Now they have offices in New Orleans, Connecticut, and New Jersey [7]. To date, the company has over 14,000 customers in Louisiana, Connecticut, New York, New Jersey and Florida. PosiGen is a residential solar, energy efficiency and energy education provider for low-to-moderate income families. The Sponsor has disclosed to DNV that, pursuant to a request for proposal and subsequent strategic partnership agreements dating to 2015, the Green Bank, as of May 2020, has extended credit facilities to PosiGen totaling $19 million [8].

PosiGen has over 220 direct employees and supports more than 120 employees through its contractors in Louisiana, Connecticut, New Jersey, New York, and Florida [9].

DNV views PosiGen as a suitable provider to the Portfolio.

2.3.3 Vivint Solar

Sunrun completed its acquisition of Vivint solar 8 October 2020.

Vivint Solar, based in Lehi, UT, began installing solar systems in 2011 and employed about 4,000 people at the time of its acquisition by Sunrun, operating in 22 states, primarily in the northeastern and southwestern U.S. [10]. As of 6 July 2020, Vivint Solar had installed 1,350MW of solar PV systems for with 197,000 cumulative installations [11].

Though DNV 's direct experience with Vivint Solar is limited, DNV acknowledges the company's strong standing as a national installer and considers them a suitable provider to the Portfolio.

2.3.4 SunPower Capital

SunPower Capital's global headquarters has been based in San Jose, CA since 1985. SunPower has a global portfolio in residential, commercial, and utility solar energy markets. In 2020, SunPower split into two independent publicly traded companies, Maxeon Solar Technologies and SunPower. Maxeon Solar Technologies will focus on manufacturing the premium Maxeon (IBC-cell) solar panels as well as the Performance Series (shingled-cell) solar panels. SunPower will become a pureplay company focused on distributed energy services including product innovation, downstream high-efficiency solar systems plus high-growth storage and energy services. SunPower is a leading North American residential solar panel supplier, with a total residential customer base of over 338,000 and 2,948MW installed [12].

DNV views SunPower Capital favorably and as a suitable provider to the Portfolio.

2.3.5 SolarCity

SolarCity was listed on the NASDAQ exchange from 13 December 2012 until its acquisition by Tesla, Inc., in November 2016 [13]. Tesla Energy, f/k/a SolarCity, is an energy services provider for homeowners and businesses. Founded in 2006 by brothers Lyndon and Peter Rive, SolarCity's primary business involved the designing, sales, engineering, installation, monitoring, maintenance, and financing of PV systems. The electric output of the PV systems is sold via contract to residential and commercial customers.

In 2016 prior to the Tesla acquisition, SolarCity had approximately 12,000 employees [14]. Since 2006 SolarCity has installed solar energy systems for hundreds of thousands of customers [15]. In 2020, Tesla Energy deployed 205 MW of solar - an 18% increase over 2019 [16].

DNV views SolarCity as a top solar installer indicating good quality and strong installation practice. In light of these considerations, DNV views Tesla Energy, f/k/a SolarCity favorably and as a suitable provider to the Portfolio.

2.3.6 Sunrun Inc.

Sunrun Inc., based in San Francisco, CA, began installing solar systems in 2007. As of 31 December 2020, with the completion of its acquisition of Vivint Solar on 8 October 2020, Sunrun operates the largest fleet of residential solar energy systems, with approximately 3,885MW and 550,000 customers in 22 states, DC and Puerto Rico [17]. In February 2014, Sunrun acquired the residential division of REC Solar, including AEE Solar and mounting company SnapNrack. In 2020, Sunrun had total deployments of 456.6 MW [18].

DNV views Sunrun as a top solar installer indicating good quality and strong installation practice. In light of these considerations, DNV views Sunrun, Inc. favorably and as a suitable provider to the Portfolio.

2.3.7 Installation performance

2.3.7.1 Inspection scoring

The Sponsor does not maintain a database of pass/fail inspection results with inspection criteria fields for all RSIP projects but does retain all inspection reports in the PowerClerk system. The program's self-inspection process, required for all systems, is to provide a completed checklist and a list of required photographs of the system and key components to ensure installation quality and safety. The purpose of the checklist is to provide contractors with quality control guidance and documentation to the Green Bank that systems meet program criteria. The Sponsor notes that it has yet to have an installer fail a "self-inspection" report [8].

Similarly, the Sponsor provided some anecdotal details of installer performance and disciplinary actions:

- If installer fails more than twice on same project (i.e., two times out for inspector to same site), then installer would need to pay equivalent for 3rd inspection.
- The Sponsor can only recall this happening once with installer, Today Electronics, which only installed one project, and is no longer an eligible contractor. The Sponsor took the cost of inspection from final rebate payment.
- Installers that have been removed from the program, all related to contracting issues: BeFree, Catchin Rays, and Sunergy. Additionally, 1st Light Energy was suspended from the program due to alleged violations related to improper incentive activity. [19].

- The installer Skyline was previously suspended from the program but this suspension has been lifted at the recommendation of the Connecticut Department of Consumer Protection, having reached a settlement on customer issues. [19].
- Installers with no prior experience installing PV systems will become eligible contractors once three PV installations pass Sponsor inspections. There have been several installers with ongoing QA/QC concerns that needed to be inspected well beyond the requisite three inspections.
- Inspectors: The Sponsor has always and continues to encourage inspectors to work with installers on issue(s) found in the field; the goal is for the homeowner to ultimately be satisfied. The Sponsor has worked with installers to adjust practices and help them better understand electrical aspects to ensure system longevity.

3 MAJOR EQUIPMENT REVIEW

3.1 Summary

This section includes a review of the major equipment manufacturers used in the Tranche 4 Portfolio.

3.2 Modules

Based upon review of the Tranche 4 Composition [2] data provided by CT Green Bank, the following manufacturers represent over 95% of the PV modules deployed in the Portfolio: Hanwha Q-cells, SunPower, LG Electronics Solar Cell division, Silfab, Trina Solar, Jinko Solar, Canadian Solar, REC Solar, Solaria, SolarCity/Panasonic, and SolarWorld. As noted in Section 1.4, the dataset consists of 6,957 systems with Approval to Energize dates between 13 February 2015 and 22 December 2019. As such DNV 's has focused the manufacturer level review on 2015 – 2019 manufacturer capabilities and quality.

Table 3-1 Portfolio composition by module manufacturer

Module manufacturer	System count	% of total
Hanwha Q-Cells	2,896	41%
SunPower	821	14%
LG Electronics Solar Cell Division	778	12%
Silfab	859	10%
Trina Solar	430	7%
Jinko Solar	272	4%
Canadian Solar	231	4%
REC Solar	237	3%
Solaria	52	1%
SolarCity	66	1%
SolarWorld	88	1%
Remaining (17)	227	3%
Total	**6,957**	**100%**

DNV 's review was conducted primarily at the manufacturer level, rather than the product level. These manufacturer-level reviews are based on publicly available documents to assess the capability of the manufacturer to supply modules that do not pose atypical risks. DNV notes that these reviews do not include an evaluation of the performance or reliability of any specific products or technologies.

Product level reviews were not performed within this scope due to lack of available data for the Portfolio. Specifically, warranties and extended reliability test data were not reviewed for systems in the Portfolio. Manufacturer-level results from the DNV PV Module Reliability Scorecard [20] are referenced, where pertinent.

3.2.1 Hanwha Q-Cells

Hanwha Q CELLS is a global PV manufacturer and part of the South Korean Hanwha Group. Hanwha Group is a diversified company headquartered in Seoul, Korea, with several major divisions: Aerospace & Mechatronics, Chemicals & Materials, Construction, Financial Services, Leisure & Lifestyle, and Solar Energy (which is Hanwha Q CELLS). Overall, the Hanwha Group is vertically integrated along the entire PV supply chain, with capabilities for silicon feedstock, ingots, wafers, cells, modules, turnkey PV plants, O&M services, and financing.

Hanwha Q CELLS is the result of first the acquisition of Q CELLS in 2012, and then the merger of Hanwha Q CELLS and Hanwha SolarOne (formerly Solarfun) in 2015. The combined company is listed on NASDAQ under the trading symbol of HQCL. It is headquartered in Seoul, South Korea, (Global Executive Headquarters) and Thalheim, Germany (Technology & Innovation Headquarters). The company is one of the world's leading PV cell producers and was the 6th largest module supplier in 2019.

Hanwha SolarOne, formerly known as Solarfun Power Holdings, was founded in 2004 and commenced production in 2005. Solarfun joined the Hanwha group in 2010. Q CELLS was founded in Berlin, Germany in 1999 and entered the PV market in 2000 as a supplier of crystalline silicon PV cells. Module production began in 2010. Hanwha acquired Q CELLS in 2012, rebranding the company Hanwha Q CELLS. Q CELLS research and development as well as quality management are operated out of the Thalheim facility which has a pilot line for cells, a module prototyping facility and a large test laboratory for material qualification and testing of finished goods from the global manufacturing sites utilizing the Hanwha Q CELLS technology. In early 2019, Hanwha began module production at a newly constructed 1.7 GW module manufacturing facility in Dalton, Georgia. The company currently has manufacturing sites in Korea, China, Malaysia, and the United States. Hanwha Q CELLS is pursuing patent infringement case against LONGi Solar, JinkoSolar and REC for PERC technology.

Hanwha Q CELLS pioneered one of the earliest full-traceability programs including cell laser coding and tracking as well as a cell level hot-spot screening. Additionally, Hanwha Q CELLS has been on the forefront of a number of technology issues including PID, LID, and LeTID.

The table below summarizes DNV 's high-level review of Hanwha Q CELLS.

Table 3-2 Summary of DNV 's high-level review of Hanwha Q CELLS

Item	Detail (source)	DNV View
PV production (years)	20 years' experience (Hanwha Q CELLS)	Ranks as a highly experienced manufacturer
Size (GW/year)	11.3 GW/year (Hanwha Q CELLS)	Correlated with a more mature quality control system
Total deployed (GW)	23.0 GW deployed (Hanwha Q CELLS)	Larger volume deployed indicates above average manufacturing experience
Manufacturing locations	Korea, Malaysia, China, United States (Hanwha Q CELLS)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Feedstock, ingots, wafers, cells, modules (Hanwha Q CELLS)	High vertical integration offers the opportunity for better quality control
Market standing	Among the top 10 largest manufacturers (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono, multi, black module, PERC, half-cell (Hanwha Q CELLS)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Hanwha Q CELLS)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Hanwha Q CELLS)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Hanwha Q CELLS)	Meets expectations
Extended-duration tests	Top performer in all DNV /PVEL Module Reliability Scorecards, in-house testing >2x IEC. (PVEL/DNV)	Evidence of consistently reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as A (PV-Tech Research)	The rating indicates that Hanwha Q CELLS is among the financially and operationally stronger manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views Hanwha Q CELLS to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.2 Maxeon/SunPower

In 2020, SunPower split into two independent publicly traded companies, SunPower and Maxeon Solar Technologies. SunPower will become a pureplay company focused on distributed energy services including product innovation, downstream high-efficiency solar systems plus high-growth storage and energy services. Initially, SunPower had retained the Hillsboro, Oregon factory which it purchased in 2019 in order to manufacturing the Performance Series module. However, in early 2021, Sunpower closed the factory, thereby completely exiting the module manufacturing business. Maxeon Solar Technologies will focus on manufacturing the premium Maxeon (IBC-cell) solar panels as well as the Performance Series (shingled-cell) solar panels. Maxeon will operate the SunPower brand in all global markets except the United States and Canada.

SunPower was founded in 1985 and is regarded in the industry as a leader in manufacturing high efficiency solar photovoltaic cells. In the early 1990s, SunPower commercialized the Interdigitated Back-Contact (IBC) cell design which had been used to construct the industry’s most efficient silicon-based cells which were originally developed for concentrator and specialty applications, such as solar vehicles and aerospace applications. SunPower (now Maxeon) denotes their various generation of IBC cells as Maxeon cells and achieves average production cell efficiencies exceeding 25%. In 2011, France-based Total S.A. purchased a controlling interest in SunPower and remains a majority shareholder in Maxeon Solar Technologies. As of 2019, SunPower's annual production capacity was approximately 2.2 GW.

SunPower has made several strategic acquisitions or established joint ventures in order to maintain an industry leading position. In 2015 SunPower acquired Cogenra Solar, Inc. for their innovative cell shingling technology used in SunPower's Performance Series modules.

In 2017, SunPower formed DZS, a joint venture with Dongfang Electric Company (DEC) and Tianjin Zhonghuan Semiconductor (TZS), to manufacture their Performance Series shingled modules.
DNV notes that SunPower has described the results of extended-duration tests of its Maxeon modules in publicly available white papers. These results demonstrate the very high durability of the Maxeon cell (IBC) based module.

The table below summarizes DNV 's high-level review of Maxeon Solar Technologies.

Table 3-3 Summary of DNV 's high-level review of Maxeon Solar Technologies

Item	Detail (source)	DNV View
PV production (years)	21 years' experience (Maxeon Solar Technologies)	Ranks as a highly experienced manufacturer
Size (GW/year)	2.0 GW/year (Maxeon Solar Technologies)	Correlated with an improving quality control system
Total deployed (GW)	14.0 GW deployed (Maxeon Solar Technologies)	Medium volume deployed indicates average manufacturing experience.
Manufacturing locations	China, Malaysia, Philippines, Mexico (Maxeon Solar Technologies)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Cells, modules, and systems (Maxeon Solar Technologies)	High vertical integration offers the opportunity for better quality control
Market standing	Not in the top 10 (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	IBC, shingled PERC, AC modules (Maxeon Solar Technologies)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Maxeon Solar Technologies)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Maxeon Solar Technologies)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Maxeon Solar Technologies)	Meets expectations
Extended-duration tests	Top Performer in multiple PVEL/DNV Module Reliability Scorecards, independent extended-duration testing results published in whitepapers. (PVEL/DNV)	Evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as CCC (PV-Tech Research)	The rating indicates that Maxeon Solar Technologies is among the financially and/or operationally weaker manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
DNV Summary		DNV views Maxeon Solar Technologies to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market. DNV notes that the Maxeon (IBC-cell) modules have demonstrated durability leading that of the industry.

3.2.3 LG Electronics

Founded in 1958, LG Electronics Inc. of South Korea, is part of the LG Group and is a large multinational producer of consumer electronics, mobile communications devices and home appliances. While being involved with photovoltaics as far back as 1985, the company entered the PV module industry in earnest in 2009. In that year, LG Electronics constructed PV cell and module factories in Gumi, Korea, as well as a Solar Test Lab which is certified by TÜV and UL. LG began initial mass production of solar panels in 2010.

LG is a vertically-integrated manufacturer producing their own solar cells and assembling their own modules. LG offers advanced monocrystalline modules using innovative PV technologies such as n-type cells PERT and n-type interdigitated back-contact cells.

The firm states that it performs electroluminescence (EL) tests on 100% of modules coming off their manufacturing line, which DNV considers to represent industry best practice. LG maintains their own PV module test laboratory certified by Underwriters Laboratories (U.S.) and TÜV Rhineland (Germany) to carry out a suite of customary UL and IEC tests applied to solar modules. Presently, the firm produces PV modules with module efficiencies exceeding 21%, which is above industry averages for crystalline silicon (except Sunpower and Panasonic). Additionally, LG offers 25-year product warranties on its NeON series of modules compared with the typical 10 or 12-year product warranties in the market.

The table below summarizes DNV 's high-level review of LG Solar.

Table 3-4 Summary of DNV 's high-level review of LG Solar

Item	Detail (source)	DNV View
PV production (years)	10 years' experience (LG Solar)	Ranks as an experienced manufacturer
Size (GW/year)	3.0 GW/year (DNV estimate)	Correlated with an improving quality control system
Total deployed (GW)	No information	DNV notes that total cumulative modules deployed helps gauge manufacturer's reliability.
Manufacturing locations	South Korea (LG Solar)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Cells, modules (LG Solar)	Typical vertical integration with typical quality control challenges
Market standing	Not ranked (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	mono, n-type, PERT, IBC (LG Solar)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (LG Solar)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (LG Solar)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (LG Solar)	Meets expectations
Extended-duration tests	Top Performer in 2018 DNV /PVEL PV Module Reliability Scorecard (PVEL/DNV)	Some evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as CCC (PV-Tech Research)	The rating indicates that LG Solar is among the smaller and/or operationally weaker manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views LG Solar to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.4 Silfab

Silfab Solar was founded in 2011 in Mississauga, Canada, and manufactures monocrystalline modules. Silfab Solar also serves as a contract manufacturer and assembler to companies looking to have operations in Ontario, in order to comply with the Ontario Power Authority's FIT domestic content requirements. Silfab Ontario has a 110,000-square foot, ISO 9001-2008 quality certified, production facility. In Toronto, Silfab says it has a manufacturing capacity of 700 MW/year. SilFab additionally has a 150MW/year manufacturing site in Bellingham, Washington, after its recent investment in ITEK Solar.

Silfab claims its module manufacturing line is among the most automated in the world. DNV notes that automation generally improves repeatability of the module build.

Silfab offers modules with monocrystalline cells and has recently begun offering modules with n-type cells as well as bifacial modules. Additionally, Silfab has partnered with DSM to develop high efficiency modules based on back contact cells and has developed supply agreements with multiple companies for residential systems including roofing companies GAF and PetersonDean, and Titan Solar Power.

While Silfab is not a large manufacturer, Silfab has been making modules for more than 10 years and claims to have a fully automated production line.

The table below summarizes DNV 's high-level review of Silfab.

Table 3-5 Summary of DNV 's high-level review of Silfab

Item	Detail (source)	DNV View
PV production (years)	10 years' experience (Silfab)	Ranks as an experienced manufacturer
Size (GW/year)	0.9 GW/year (Silfab)	Correlated with a less mature quality control system
Total deployed (GW)	No information	DNV notes that total cumulative modules deployed helps to gauge manufacturer's reliability.
Manufacturing locations	Canada, USA (Silfab)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	module (Silfab)	Less vertical integration poses more difficulty with quality control
Market standing	Not in the top ten (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono, PERC, back-contact, reflective film (Silfab)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Silfab)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Silfab)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	No (Silfab)	No information provided
Extended-duration tests	Top Performer in 2017, 2019, and 2020 PVEL/DNV Module Reliability Scorecard (PVEL/DNV)	Some evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as CC (PV-Tech Research)	The rating indicates that Silfab is among the financially and/or operationally weaker manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
DNV Summary		Primarily because of positive extended-duration test results, DNV views Silfab to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market. Because of Silfab's small size, production witness oversight when procuring modules is recommended to further reduce potential reliability concerns.

3.2.5 Trina Solar

Trina Solar, founded in 1997, produces silicon ingots, wafers, cells, and modules and includes a system integration group. The company's corporate headquarters and main factory are located in Changzhou, China. The factory locations are in China, Vietnam, and Thailand. They have over 15,000 employees in 20 offices worldwide. Trina's production capacity is at 11 GW/year in 2019 and estimated at 19 GW in 2020. Trina has produced a cumulative 40 GW of PV modules. Trina Solar offers modules with mono and multicrystalline cells, PERC cells, and half-cut cells, as well as dual-glass modules. In addition, Trina's downstream businesses includes solar PV project development, financing, design, construction, and operations & management.

According to the company's website, Trina's State Key Laboratory of PV Science and Technology has broken 18 world records on solar cell efficiency and module power. In March 2020, Trina announced 23.4% PERC cell using standard production equipment. Trina's average p-type mono-PERC cell efficiency is 22.6%. In June 2020, Trina has announced mass-production of the n-type i-TOPCon double-glass bifacial modules, leading the industry in advanced cell design. Trina claims to use 36 in-house quality tests to ensure product reliability throughout the manufacturing chain from incoming silicon and wafer quality, through cell and module assembly.

The table below summarizes DNV 's high-level review of Trina Solar.

Table 3-6 Summary of DNV 's high-level review of Trina Solar

Item	Detail (source)	DNV View
PV production (years)	20 years' experience (Trina Solar)	Ranks as a highly experienced manufacturer
Size (GW/year)	11.0 GW/year (Trina Solar)	Correlated with a more mature quality control system
Total deployed (GW)	40.0 GW deployed (Trina Solar)	Larger volume deployed indicates above average manufacturing experience
Manufacturing locations	China, Vietnam, Thailand, (Trina Solar)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Ingot, wafer, cells, and modules (Trina Solar)	High vertical integration offers the opportunity for better quality control
Market standing	Among the 5 largest manufacturers (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono & multicrystalline, dual glass, half-cell, PERC, bifacial, TOPcon (Trina Solar)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Trina Solar)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Trina Solar)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Trina Solar)	Meets expectations
Extended-duration tests	Top Performer in multiple PVEL/DNV Module Reliability Scorecards (PVEL/DNV)	Evidence of consistently reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as A (PV-Tech Research)	The rating indicates that Trina Solar is among the financially and operationally stronger manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views Trina Solar to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.6 Jinko Solar

Jinko Solar started operations in 2006 with first modules sold in 2009. It is a vertically integrated manufacturer producing silicon ingots, wafers, PV cells, modules and mounting systems. Jinko states it has a global customer base for its utility, commercial, and residential solutions and services spanning China, the United States, Japan, Germany, the United Kingdom, Chile, South Africa, India, Mexico, Brazil, the United Arab Emirates, Italy, Spain, France, Belgium, and other countries.

Jinko Solar has five manufacturing facilities in Jiangxi and Zhejiang Provinces in China where the majority of the production capacity is concentrated and other minor production lines in Malaysia (for US market), Portugal, and South Africa. In

February 2019, Jinko officially opened its new state-of-the-art 400MW/year solar panel manufacturing facility in Jacksonville, FL, USA.

The manufacturer reported an integrated annual capacity of 19 GW for silicon ingots and wafers, 11 GW for solar cells, and 25 GW for solar modules (2020). Jinko Solar is ranked 1st according to shipments in a worldwide list of module suppliers in 2019. Jinko also states that all modules use backsheets with DuPont Tedlar PVF which is the only material to have a proven field performance of over 25 years. Jinko is also adopting gallium-doped silicon in its PERC cells to mitigate LID and LeTID, as well as developing n-type cell technology, TOPCon.

The table below summarizes DNV 's high-level review of Jinko Solar.

Table 3-7 Summary of DNV 's high-level review of Jinko Solar

Item	Detail (source)	DNV View
PV production (years)	11 years' experience (Jinko Solar)	Ranks as an experienced manufacturer
Size (GW/year)	25.0 GW/year (Jinko Solar)	Correlated with a more mature quality control system
Total deployed (GW)	55.0 GW deployed (DNV estimate)	Larger volume deployed indicates above average manufacturing experience
Manufacturing locations	China, Malaysia, US (Jinko Solar)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Ingot, wafers, cells, and modules (Jinko Solar)	High vertical integration offers the opportunity for better quality control
Market standing	Among the 5 largest manufacturers (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono, multi, black module, PERC, half-cell, bifacial, n-type, TOPCon (Jinko Solar)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Jinko Solar)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Jinko Solar)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Jinko Solar)	Meets expectations
Extended-duration tests	Top Performer in all DNV Module Reliability Scorecards (PVEL/DNV)	Evidence of consistently reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as AA (PV-Tech Research)	The rating indicates that Jinko Solar is among the financially and operationally stronger manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views Jinko Solar to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.7 Canadian Solar

Canadian Solar was founded in Ontario in 2001, and the company went public in 2006 and is listed on the NASDAQ stock exchange. Canadian Solar is a vertically integrated manufacturer producing silicon wafers, photovoltaic cells, and solar modules, as well as providing EPC services for construction of utility scale solar plants. In February 2015, Canadian Solar acquired Recurrent Energy, and is currently one of the world's largest utility scale solar developers and EPC providers with operations in 6 continents. Canadian Solar's energy business develops and constructs utility-scale solar plants primarily in North America, Asia Pacific, Latin America, Europe, Middle East, and Africa. In February 2015, Canadian Solar announced the acquisition of Recurrent Energy, which at the time expanded the company's project pipeline to over 11 GWp. Today, Canadian Solar's EPC division asserts one of the world's largest solar project development pipelines of over 13.0 GWp. The company is headquartered in Ontario, Canada, and conducts its manufacturing operations primarily in China.

According to Canadian Solar's website, Canadian Solar employs over 14,000 workers worldwide and has shipped a cumulative 46 GW over 19 years. Canadian Solar offers a variety of module technologies including modules with mono and multicrystalline PERC cells. Canadian Solar has pioneered the cast-monocrystalline wafer technology in their P5 cell on which they achieved a world record 22.81% efficiency. Canadian Solar also set a world record of 23.8% using an n-type PASCon technology with the cast-monocrystalline wafer.

The table below summarizes DNV 's high-level review of Canadian Solar.

Table 3-8 Summary of DNV 's high-level review of Canadian Solar

Item	Detail (source)	DNV View
PV production (years)	19 years' experience (Canadian Solar)	Ranks as a highly experienced manufacturer
Size (GW/year)	15.0 GW/year (Canadian Solar)	Correlated with a more mature quality control system
Total deployed (GW)	46.0 GW deployed (Canadian Solar)	Larger volume deployed indicates above average manufacturing experience
Manufacturing locations	China, Canada, Taiwan, Vietnam, Thailand, and Brazil (Canadian Solar)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Ingots, wafers, cells, modules (Canadian Solar)	High vertical integration offers the opportunity for better quality control
Market standing	Among the 5 largest manufacturers (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono & multicrystalline, dual glass, half-cell, PERC, black modules, frameless, shingled (Canadian Solar)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Canadian Solar)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Canadian Solar)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Canadian Solar)	Meets expectations
Extended-duration tests	In independent tests, modules performed similarly to 'Top Performers' in the PVEL/DNV Module Reliability Scorecard. (DNV 's Canadian Solar Technology Review)	Evidence of consistently reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as AA (PV-Tech Research)	The rating indicates that Canadian Solar is among the financially and operationally stronger manufacturers. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views Canadian Solar to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.8 REC Solar

REC (Renewable Energy Corporation) was originally founded in 1996 in Norway as a silicon wafer manufacturer, ScanWafer. The company changed its name to REC in 2000 and began cell and module manufacturing in 2003. The former Renewable Energy Corporation ASA had two divisions: REC Silicon and REC Solar. In October 2013, these were split into two entirely separate entities, each focusing on its own core business. For REC Silicon, this was polysilicon and silane gas for the solar and electronics industries with manufacturing facilities in Moses Lake, Washington and Butte, Montana, USA. REC Solar has been sold to Elkem, a large Norwegian conglomerate and continues as "REC" to manufacture wafers, solar cells, and solar panels at its fully automated integrated manufacturing facility in Singapore.

REC employs more than 2,000 people worldwide, producing 1.5 GW/year of solar panels with an estimated cumulative production of 8.7 GW. REC offers a variety of module technologies including modules with mono and multicrystalline standard and PERC cells. REC is now also offering modules with n-type cells for higher efficiencies.

The table below summarizes DNV ’s high-level review of REC Solar.

Table 3-9 Summary of DNV 's high-level review of REC Solar

Item	Detail (source)	DNV View
PV production (years)	17 years' experience (REC Solar)	Ranks as a highly experienced manufacturer
Size (GW/year)	1.5 GW/year (REC Solar)	Correlated with an improving quality control system
Total deployed (GW)	8.0 GW deployed (REC Solar)	Medium volume deployed indicates average manufacturing experience
Manufacturing locations	Singapore (REC Solar)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	Wafers, cells, and modules (REC Solar)	High vertical integration offers the opportunity for better quality control
Market standing	While over 1 GW of production, REC is not in top 10 (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Mono & multicrystalline, half-cell, PERC, black modules, n-type cells (REC Solar)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (REC Solar)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (REC Solar)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (REC Solar)	Meets expectations
Extended-duration tests	Top Performer in all PVEL/DNV Module Reliability Scorecards (PVEL/DNV)	Evidence of consistently reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as B (PV-Tech Research)	The rating indicates that REC Solar, is in the second tier with regards to financial and manufacturing health. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views REC Solar to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.9 Solaria

U.S.-based Solaria was founded in 2000 and is a privately held company. Solaria’s first series of products were low-concentration-photovoltaics (LCPV) with a cumulative installation of over 30 megawatts (MW). Solaria combined LCPV with innovative solar tracking arrays and created NEXTracker. NEXTracker was spun-off as a separate company and was acquired by FLEX in 2015 for $335M. In collaboration with strategic partners, Solaria launched the PowerXT™ series of high-efficiency modules in 2016. By 2018, Solaria had delivered 400MW of PV in the US.

Solaria does not have manufacturing facilities of its own but relies on a manufacturing partnership with the South Korean companies, SolarPark and Shinsung. SolarPark was founded in 2007 with its owners bringing automation experience and looking to expand their business to high potential solar market in Korea. In 2008, SolarWorld Korea was established as a 50/50 joint venture with SolarPark and SolarWorld. Later, in 2011, SolarPark bought out the remaining shareholders from SolarWorld AG. SolarPark has a 650MW/year capacity (as of 2018).

Solaria has been named as a ‘Top Performer’ over 2017 and 2018 running in the DNV PV Module Reliability Scorecard testifying to our industry leading quality. In 2019, the Solaria PowerXT module received the RETC PV Module Index Initiative High Achiever Award. In 2020, Solaria has files patent infringement lawsuits against Canadian Solar on its 'shingled' cell modules. Also in 2020, Solaria modules were chosen by GAF for its roof-integrated system.

The table below summarizes DNV ’s high-level review of Solaria.

Table 3-10 Summary of DNV 's high-level review of Solaria

Item	Detail (source)	DNV View
PV production (years)	21 years' experience (Solaria)	Ranks as a highly experienced manufacturer
Size (GW/year)	No information GW/year	Correlated with a more mature quality control system
Total deployed (GW)	No information	DNV notes that total cumulative modules deployed helps to gauge manufacturer's reliability.
Manufacturing locations	South Korea (Solaria)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	modules (Solaria)	Less vertical integration poses more difficulty with quality control
Market standing	Not among the top 10 (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	mono, shingled cell, PERC (Solaria)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	No	No information provided
ISO 14001 Environmental Management Systems	No	No information provided
OHSAS 18001 Occupational Health and Safety Management	No	No information provided
Extended-duration tests	Top Performer DNV Module Reliability Scorecard 2017 and 2018 RETC PV Module Index Initiative High Achiever Award 2019 (PVEL/DNV , RETC)	Some evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Not rated (PV-Tech Research)	Solaria has not been rated by PV-Tech. DNV recommends a review of the financial strength of the company. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
DNV Summary		Primarily because of the extended-duration test results, DNV views Solaria as being capable of

Item	Detail (source)	DNV View
		supplying modules of similar quality and reliability as modules from established manufacturers in the market. However, because of Solaria's reliance on other manufacturers for its modules DNV recommends on-going diligence and 3rd party production witness oversight when procuring modules.

3.2.10 SolarCity/Panasonic

The modules branded as SolarCity SC315B2, SC320, SC320B1, SC325 and SC330 are manufactured by Panasonic to SolarCity's specifications. Thus, Panasonic is reviewed.

SANYO started the development of the Heterojunction with Intrinsic Thin-layer (HIT) silicon solar cells in 1990. SANYO became a full subsidiary of the Panasonic Group in 2011 and adopted the Panasonic brand name in 2012. The change applied to the brand name only, the modules continued to be manufactured at the same production facilities. At that time, Panasonic produced solar cells at two plants and had three module assembly bases—two in Japan and one in Hungary—with an annual production capacity of 600 MW. In 2012, Panasonic also built a new plant in Kedah, Malaysia to serve as the new solar manufacturing base for Asia, adding 300 MW of production capacity, and increasing Panasonic's overall module production capacity to 900 MW. In June 2015, in view of the rapidly developing solar power market in Japan, Panasonic announced plans to add an additional 150 MW to its solar photovoltaic modules production capacity. Panasonic began expanding manufacturing to Tesla's Gigafactory in Buffalo NY, but in 2020 exited the Gigafactory. Panasonic modules feature module efficiencies over 20%, and low temperature coefficients below -0.26%/°C.

The table below summarizes DNV 's high-level review of Panasonic.

Table 3-11 Summary of DNV 's high-level review of Panasonic

Item	Detail (source)	DNV View
PV production (years)	21 years' experience (Panasonic)	Ranks as a highly experienced manufacturer
Size (GW/year)	1.0 GW/year (Panasonic)	Correlated with a less mature quality control system
Total deployed (GW)	No information	DNV notes that total cumulative modules deployed helps to gauge manufacturer's reliability.
Manufacturing locations	Japan, Hungary, Malaysia (Panasonic)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	cells, modules (Panasonic)	Typical vertical integration with typical quality control challenges
Market standing	Not among the top 10 (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	mono, heterojunction, black (Panasonic)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (Panasonic)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (Panasonic)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (Panasonic)	Meets expectations
Extended-duration tests	Top Performer DNV Module Reliability Scorecard 2018 (PVEL/DNV)	Some evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Not rated	Panasonic has not been rated by PV-Tech. DNV recommends a review of the financial strength of the company. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
DNV Summary		DNV views Panasonic to be capable of supplying PV modules of similar quality and reliability as modules from established manufacturers in the market.

3.2.11 SolarWorld

SolarWorld AG entered the PV industry in Germany in 1998 and became listed on the stock exchange in 1999. In 2006, SolarWorld AG purchased a facility in Camarillo CA that had a substantial PV development history in the U.S. The Camarillo plant was originally founded in 1975 as Solar Technology International. In 1979, Atlantic Richfield Co. (Arco Solar) purchased the Camarillo plant and ramped up the manufacture of making silicon ingots, wafers, cells and modules. It was subsequently purchased by Siemens, then Royal Dutch Shell (Shell Solar), and was finally acquired by SolarWorld in 2006. This became the US entity of SolarWorld named SolarWorld Americas. The significantly larger Hillsboro, Oregon plant was opened in 2008 and housed the SolarWorld Americas headquarters. Eventually the Camarillo plant was closed and operations were moved to Hillsboro. The Hillsboro facility, which shipped product to the U.S., Canada and Latin America, had a maximum production capacity of approximately 500MW/year of modules.

At its peak, the companies SolarWorld AG and SolarWorld Americas employed approximately 3,400 people worldwide and has manufacturing locations in Arnstadt and Freiburg, Germany, and Hillsboro, Oregon. The global manufacturing capacity for EOY 2015 was approximately 1.5 GW with Hillsboro operating at 550MW/year, Freiburg operating at 650 MW, and Arnstadt operating at 300MW/year. SolarWorld also had offered EPC services for utility scale projects as well as system components such as their Suntrac® single-axis tracker and Sunfix ground mount system.

SolarWorld Germany filed for insolvency in May 2017. SolarWorld Americas, while not itself insolvent, was put up for sale. SolarWorld Germany was acquired and renamed SolarWorld Industries in August 2017. However, the newly formed SolarWorld Industries filed for insolvency again in March 2018 and ended production in September. In the meantime, SolarWorld Americas (USA) has become a part of SunPower as of April 2018. SunPower did not assume the liability of the SolarWorld warranties. SolarWorld Americas maintains technical support and warranty for SolarWorld modules. DNV recommends that the Sponsor confirm warranty coverage through contacting SunPower.

The table below summarizes DNV 's high-level review of SolarWorld.

Table 3-12 Summary of DNV 's high-level review of SolarWorld

Item	Detail (source)	DNV View
PV production (years)	18 years' experience (SolarWorld)	Ranks as an inexperienced manufacturer
Size (GW/year)	1.5 GW/year (SolarWorld)	Correlated with an improving quality control system
Total deployed (GW)	No information ( )	DNV notes that total cumulative modules deployed helps gauge manufacturer's reliability.
Manufacturing locations	Germany, USA (SolarWorld)	Section 301 tariffs impact modules produced in China.
Manufacturing chain	cell, module (SolarWorld)	Typical vertical integration with typical quality control challenges
Market standing	Not in the top ten (PV-Tech Research)	The ten largest manufacturers will supply an estimated 75% of all modules to the global market in 2020, thereby setting performance and reliability expectations.
Technologies offered	Multi, mono, PERC (SolarWorld)	More markets can be accessed with wide range of offerings.
ISO 9001 Quality Management Systems	Yes (SolarWorld)	Meets expectations
ISO 14001 Environmental Management Systems	Yes (SolarWorld)	Meets expectations
OHSAS 18001 Occupational Health and Safety Management	Yes (SolarWorld)	Meets expectations
Extended-duration tests	Top Performer in 2017 PVEL/DNV Module Reliability Scorecard (PVEL/DNV)	Some evidence of reliable module designs
PV-Tech rating (AAA, AA, A, BBB,… C)	Rated as Not rated (PV-Tech Research)	SolarWorld has not been rated by PV-Tech. DNV recommends a review of the financial strength of the company. Financial and manufacturing health has implications for manufacturing quality control, module reliability, and warranty coverage.
Summary		DNV views SolarWorld as having supplied PV modules of similar quality and reliability as modules from established manufacturers in the market from 2008 to 2018. DNV notes that the warranty coverage is unclear.

3.3 Inverters

Based upon review of the Tranche 4 Composition data [2] provided by CT Green Bank, the following manufacturers represent over 99.8% of the inverters deployed in the Portfolio. Manufacturers included in the review include SolarEdge, Enphase, SunPower, SMA, Delta Electronics, and ABB/Power-One.

Table 3-13 Portfolio composition by inverter manufacturer

Inverter manufacturer	System count	% of total
SolarEdge Technologies	4,995	71.8%
Enphase Energy	990	14.2%
SunPower	714	10.3%
SMA America	115	1.7%
Delta Electronics	67	1.0%
ABB	59	0.8%
Remaining (3)	17	0.2%
Total	**6,957**	**100.0%**

DNV has utilized its experience in the inverter industry, including that related to performing detailed technology reviews of SolarEdge, ABB, Enphase, SMA, and SunPower inverters, to inform the manufacturer level summaries provided herein. Where available, DNV relied on additional manufacturer-provided reliability data.

3.3.1 SolarEdge

SolarEdge (NASDAQ: SEDG, with a March 2015 initial public offering) is a solar electronics manufacturer which was founded in 2006 and began mass production of module-level power optimizers and inverters in 2009. As of January 2021, SolarEdge has shipped over 21 GW of systems worldwide, with a presence in over 133 countries. In 2020, SolarEdge was ranked 7th in global PV inverter market share by MW shipments, per Wood Mackenzie Power & Renewables. [21]

SolarEdge provides both module level electronics (optimizers) and inverters. SolarEdge is best known for its power optimizers, which are small electronic devices attached to each PV module which operate under the principal of implementing Maximum Power Point Tracking (MPPT) at the individual module level. An additional benefit of this setup is real-time performance monitoring of each PV module. These devices are commonly deployed in situations where a PV array may consist of two or more azimuths and/or complex shading conditions where part of the module or array may be wholly or partially shaded while another part has a clear view of the sun. SolarEdge was one of the first market entrants for this type of component. The systems with SolarEdge optimizers almost always employ SolarEdge inverters as the inverters are designed to work as a system with optimal performance and cost.

DNV is very familiar with SolarEdge's residential product lines, and has reviewed the design for reliability, highly accelerated life testing (HALT), and field track record since the optimizer's introduction. In 2016, SolarEdge also provided DNV up-to-date track record summaries for inverters and power optimizers.

SolarEdge has seen a decline in failure rates for its installed bases of both inverters and power optimizers over time as product improvements have been implemented.

Table 3-14 SolarEdge inverter manufacturing summary

Manufacturing experience	11 years
Size and diversification of parent company	Non-diversified: Pure Play PV electronics manufacturer
Country of origin: **Manufacturing facilities:**	Israel Contract manufacturers in China and Hungary

Power Optimizers

The documentation provided to DNV indicates that the field reliability of the power optimizers is high. Each power optimizer device contains a relatively low discrete component count (compared to solar inverters), utilizes existing mature electronic technologies and fabrication methods, and is subject to rigorous product testing. Short of longer duration field reliability data, SolarEdge has applied established QA/QC and production methods which in their view allow them to warrant the devices for 25 years of operation, based upon a daily duty cycle of 12 hours on, 12 hours off.

Inverters

The single-phase and three-phase inverter data supplied by SolarEdge as part of multiple reviews by DNV (as well as single-phase inverter data from other fleets DNV has reviewed) all indicate that SolarEdge inverters have a good track record and are on par with other leading inverter suppliers in terms of performance and failure rates.

DNV considers SolarEdge to be an acceptable supplier of solar inverter systems with power optimizers. SolarEdge is the leader in module level optimizer technology.

3.3.2 ABB/Power-One

In 2019, the ABB solar business, including the Power-One inverters, was acquired by FIMER, an Italian company. The inverter product support and warranty obligations for ABB solar inverters were also assumed by FIMER. It is our understanding that FIMER is staffed with former ABB employees. The information provided below is historical information about the Power-One and ABB organizations and product, however, DNV has very little experience with the FIMER organization. ABB or Power-One inverter owners should be proactive in establishing a relationship with FIMER so that the level of available support can be understood.

Founded in 1973, Power-One was originally a United States-based manufacturer of alternating current/direct current (AC/DC) and direct current/direct current (DC/DC) power conversion and management equipment. The company was arranged into separate divisions for power solutions and renewable energy solutions. Power-One’s power solutions products are used in computer servers, data centers, network power systems and industrial markets. The renewable energy solutions business produced power conversion equipment for the solar and wind energy markets, including both residential scale and utility scale solar inverters.

Power-One was acquired by the Swiss engineering and manufacturing conglomerate ASEA Brown Boveri (ABB) in July 2013. Their inverter products have adopted the ABB brand as of May 2014. The company was listed as the 4th largest global PV inverter supplier by shipments for 2017 by GTM Research.

ABB has provided a variety of additional documentation regarding company background and testing of their inverters to DNV in Q2 2013, including sales and product failure rate data. These documents provide a synopsis of ABB production to date of various inverter model families. Generic inverter failure modes are presented via Pareto charts. These rates have been reduced since 2009 across greatly expanded production and present a positive picture of Power-One’s efforts to track and measure inverter failures and to implement various corrective actions so as to reduce product returns and/or service calls.

DNV views historical ABB/Power-One inverters as acceptable suppliers of inverters to the portfolio; however, given DNV's limited experience with the FIMER organization which acquired ABB/Power-One, DNV recommends a proactive relationship by the asset owners to understand the level of ongoing warranty support that will be available.

Table 3-15 ABB (Power-One) string inverter manufacturing summary

Manufacturing experience	10 years[1]
Size and diversification of parent company	Parent company is a diversified engineering and manufacturing conglomerate
County of origin	Italy [2]

1. DNV was not able to determine when the first string inverter was manufactured; however, the renewable energy products division was initiated in 2006. Power-One's broader manufacturing experience dates back over 40 years.
2. Power-One also has manufacturing facilities in the U.S. It has advised DNV in December 2013 that Italy is the relevant country of origin for its string inverters.

3.3.3 Enphase

Enphase Energy (NASDAQ: ENPH) is a publicly-held company based in Petaluma, California, and is the world's leading microinverter manufacturer.

Table 3-16 Enphase inverter manufacturing summary

Manufacturing experience	12 years
Size and diversification of parent company	Pure-play microinverter manufacturer + related monitoring services
County of origin	Germany (Phoenix Contact), China (Flextronics), and Canada (Flextronics)

As of Q1 2021, Enphase reported that it has sold approximately 30 million of its microinverters since their introduction in 2008 and is currently on its seventh-generation design. The devices have thus far been well-received by the solar industry and no substantial failures (e.g., serial defects) have been reported in industry press. The use of module-level electronics like Enphase can be particularly beneficial for systems with partial shading or complex roof designs, as the microinverters help reduce mismatch losses (as are incurred with string inverters). Enphase's microinverters are also favored by certain installers due to the simplicity (relative to a string inverter) of installing them and module level performance monitoring, among other reasons.

DNV has reviewed reliability information for Enphase M215 integrated ground (IG) and M250 microinverters which support a 25-year design lifetime, although some proportion will likely fail over this period. DNV has also completed updated Technology Reviews of Enphase's product lines (2015, 2017,and 2020), and such reports may be available via Enphase. The reports include a significant reliability discussion including failure rate projections. DNV views the overall Enphase activities to ensure product reliability very positively. These include:

- Design for Reliability
- Reliability testing (HALT)
- Actual field performance monitoring with low field failure rates.

The approaches used by Enphase are state-of-the-art in these areas.

DNV views Enphase to be the leading microinverter supplier and an acceptable supplier based on our thorough Technology Review.

3.3.4 SMA

Once the largest PV inverter manufacturer in the world, SMA was ranked 3rd in the US residential PV inverter market share for 2019. [21] SMA was founded in 1981,and is based in Germany. SMA was listed on the Frankfurt Stock Exchange (S92) in 2008. The SMA Americas division is based in Rocklin, California. SMA Solar Technology AG is the global leader in the development, production, and sales of PV inverters. SMA is represented in all important PV markets, including 21 countries on four continents. Note that SMA has downsized in the more competitive recent market. SMA produces a wide range of inverters from the smaller string inverters to the larger commercial and utility scale products. While their market share has eroded as other top tier manufacturers have consolidated and entered the North American markets, SMA remains a leading PV inverter manufacturer.

DNV considers SMA to be a top-tier supplier of inverters due to its significant manufacturing history and reliability track record. DNV has performed a detailed technology review of SMA's string inverter products.

Table 3-17 SMA inverter manufacturing summary

Manufacturing experience	30+ years
Size and diversification of parent company	Pure-play solar inverter supplier
Country of origin	Germany

3.3.5 SunPower

The SunPower inverters used in this portfolio are a mixture of string inverters and microinverters. The 5kW and 6 kW string inverters are rebranded SMA inverters. The microinverters used in the AC modules are all the 3rd generation SunPower MI-C-320 microinverters and are the product results of SunPower acquiring SolarBridge in 2014. DNV has performed a detailed technology review of SunPower's microinverters including the MI-C-320 in 2017 and such report may be available via SunPower.

U.S. based SunPower (NASDAQ: SPWR) was founded in 1985. Since their first introduction in 1993, SunPower' s back contact solar cells have been used to construct the industry's most efficient solar systems based on silicon. In 2011, the French oil giant Total purchased a controlling interest in SunPower. SunPower's annual production capacity exceeds 1 GW.

To expand their business and maintain their competitive position, SunPower acquired a number of other companies and entered into several joint ventures over the past several years. For example, in July 2010, SunPower formed AUOSP as a joint venture with AUO. In January 2012, SunPower acquired Tenesol, and in November 2013, acquired Greenbotics, Inc. In November 2014, SunPower acquired SolarBridge Technologies, a developer of integrated microinverter technologies for the solar industry.

SunPower employs a contract manufacturer, Celestica Technology Limited, located in Dongguan, China for their microinverter products. The company operates approximately 20 manufacturing and design centers worldwide. With over 25,000 employees, Celestica's reported 2014 revenues of US $5.6 billion. The Song Shun Lake facility in Dongguan provides printed circuit assemblies and a variety of services in system final fabrication and test.

Table 3-18 SunPower inverter manufacturing summary

Manufacturing Experience	20 years (7 years for solar microinverters)
Size and diversification of parent company	None: pure-play PV manufacturer
County of origin	United States Dongguan, China (ISO 9001), Mexico (Assembly)

SunPower worked with SolarBridge Technologies to develop AC Modules starting in 2010 and sold AC Modules incorporating SolarBridge microinverters starting in 2011. SunPower's acquisition of SolarBridge Technologies in 2014 gave SunPower the capability to deliver ac panels with factory-integrated microinverters, all manufactured under SunPower's control. Through 2016, SunPower has deployed over 235,000 gen 3 ac modules and has a reported annual failure rate of less than 0.2%.

More recently, SunPower has stopped using the SolarBridge microinverters, and now incorporates Enphase inverters to create their ac modules.

DNV considers SunPower to be an acceptable supplier of microinverters although the deployment history is limited on the presently produced products. For the ac modules based on SolarBridge inverters, DNV anticipates warranty and service obligations provided by SunPower to be unaffected.

3.3.6 Delta

Delta Energy Systems ("Delta") develops, manufactures, and markets worldwide, innovative customized and standard power supplies for a variety of different industries, including renewable energies. Delta provides solar inverters and monitoring for residential, commercial, and utility installations.

Delta Electronics Group (founded 1971) is the world's largest provider of switching power supplies and DC brushless fans, as well as a major source for power management solutions, components, visual displays, industrial automation, networking products, and renewable energy solutions. Delta Group has sales offices worldwide and manufacturing plants in Taiwan, China, Thailand, Mexico, India and Europe. The Delta Group is a large company with substantial resources and 80,000 employees in 40 countries. Delta was not ranked among the top 16 PV inverter manufacturers for global shipments in 2019 per Wood Mackenzie Power Renewables. [21]

Table 3-19 Delta inverter manufacturing summary

Manufacturing Experience	40 years
Size and diversification of parent company	Parent company is a global provider of power and thermal management solutions
County of origin	Worldwide manufacturing, R&D Labs, and sales offices

The inverters used in this portfolio are the Solivia string inverters ranging in size from 3.8kW to 7.6kW. They are 600Vdc input, single phase inverters ideally suited for the residential market. They also can produce power at 208 Vac making them applicable to the commercial market.

DNV has reviewed Delta and its solar inverters in detail and considers Delta to be an acceptable supplier of inverters due to its long history of designing and manufacturing power supply solutions, combined with its growing families of PV and energy storage inverters.

3.4 Metering and communication equipment

DNV understands that metering and communication equipment is not tracked in the Portfolio system information. As previously reviewed in Q2, 2020 [5] the RSIP states that the contractor and/or system owner and homeowner is responsible for installing a Sponsor approved revenue grade performance monitoring meter and for maintaining a working connection over the useful life of the PV system. For all RSIP projects, system performance data shall be made available to the Sponsor for incentive payments and REC monetization. For PBI projects, incentive payments are made quarterly over six years based on actual production data.

3.4.1 Metering and communication equipment conclusions

The meter hardware in use is for a low-cost revenue-grade energy metering with adequate accuracy. The revenue grade meters have not been evaluated by DNV regarding reliability and useful life; however, the technology in use should provide adequate reliability. Typically, the primary issue with metering is getting the initial settings correct and current transformers properly installed. Once the equipment is operating properly, the reliability of the communications equipment affects the availability of the data, while the revenue grade meters continue to log energy data, with or without functioning communications. RSIP began requiring all meters to communicate using a cellular connection (since it was more reliable in the majority of cases). This requirement was put in place 8 August 2015: Starting with Step 8, which began 8 August 2015, Revenue-Grade Meters were required to be cellular and include a five-year cellular plan provided to the customer incorporated into the price of the meter. The Green Bank covers the cost of the cellular plans after the 5-year period [3].

3.5 Racking

Though DNV has not reviewed racking used by individual installers in this Portfolio, DNV has reviewed all leading residential racking products in the past. DNV considers residential roof racking commonly installed to be a low risk item. Most residential roof racking systems consist of extruded aluminum rails to support modules, spanning between aluminum or steel mounting standoffs which are bolted to the existing roof structure. The systems are inherently simple, with relatively simple wind loading and structural analysis required. With the adoption of NBC 2018 and ASCE 7-16 building codes and standards, residential racking loads are fully characterized, and the risks of projects being insufficiently designed are low. Issues related to residential racking tend to be related to installation errors rather than problems with the racking design. In addition, the relative risk of a structural failure of a roof due to the installation of solar PV module racking is considered by DNV to be low. This is due to the relatively low weight of the PV system (typically 3 or 4 psf) in comparison to typical code required design live loads (16 to 20 psf) which are effectively replaced when solar is installed. Therefore, DNV considers residential roof racking to represent low project risk if appropriately designed, installed, and maintained.

4 SHREC PRODUCTION FORECASTING PROCEDURES REVIEW

4.1 Review methodology

DNV has reviewed the procedure by which the Sponsor generates energy production forecasts for each PV system with the purpose of evaluating the long-term accuracy of these forecasts and their usefulness for predicting the Portfolio's revenue from energy production, and thereby the Portfolio's ability to generate SHRECs. The review has focused on the following areas:

- Quality of data used to establish long-term irradiation and temperature
- Method employed to determine irradiation on the collector plane
- Simulation of physical plant
- Reasonableness of loss factor assumptions.

This section provides a qualitative review of the Sponsor's energy production forecasting procedure, whereas Section 5 provides a comparison between the Sponsor's forecasts and the actual production data.

4.2 Energy simulation

Since 2006, PowerClerk has acted as the proposal and system reporting portal for all Sponsor systems, as well as supporting the Sponsor's incentive program. The Sponsor's process requires system information be initially entered in PowerClerk, however, for SHREC forecasting purposes, the Sponsor relies on a parallel calculation in Clean Power Research's (CPR) SolarAnywhere Fleetview. The only difference between PowerClerk and SolarAnywhere Fleetview is the choice of weather data used in the simulation. PowerClerk relies on National Solar Radiation Database (NSRDB) Typical Meteorological Year 3 (TMY3) weather files whereas the CPR SolarAnywhere Fleetview estimate is based on SolarAnywhere typical global horizontal irradiation year (TGY) weather files. All PowerClerk system entries are transferred to CPR SolarAnywhere Fleetview automatically and the underlying PVForm code is the same between PowerClerk and SolarAnywhere Fleetview. The remainder of this section and report focuses on SolarAnywhere Fleetview as the SHREC forecast source.

SolarAnywhere Fleetview is able to access Clean Power Research's (CPR) SolarAnywhere irradiance data through a web-based RESTful API to calculate solar energy production. CPR's SolarAnywhere Fleetview tool incorporates a modified version of Sandia National Labs PVForm Power Output Model. NREL's PVWatts is also based on PVForm, but the SolarAnywhere Fleetview API implements the model differently in several ways. DNV understands some of the major differences include reference cell temperature, PV module temperature equations, radiation transmitted though module covers, and module nonlinearity. DNV does not have access to the underlying API code and therefore has not independently verified the SolarAnywhere Fleetview API model. DNV requested access to PowerClerk and SolarAnywhere Fleetview to validate a number of sample systems.

The inputs into PowerClerk and later transferred to SolarAnywhere Fleetview include the following system parameters:

- Location
- Number of arrays, inverters per array
- PV module manufacturer, model, quantity, and cost
- Inverter manufacturer, model, quantity, and cost
- Fixed tilt or tracking array type
- Azimuth and tilt for each array
- Solar obstruction (shading) angles or monthly (solar access) percentages for each array.

4.2.1 Calculation procedure for the continental United States

The Sponsor uses PVForm code to produce an hourly production time series and SolarAnywhere Fleetview sums the hourly simulation results to output year 1 monthly energy estimates that can be summed to an annual value.

The following is a description of the calculation procedure after drawings are completed:

1 CPR SolarAnwhere Fleetview maintains a database of satellite irradiation data. Address, zip code, and state are used to find the irradiance tile over the site.

2 The inputs entered into PowerClerk are transferred to SolarAnywhere Fleetview and are translated into the PVForm-required inputs of dc rating, array type, array tilt, and array azimuth.

3 The Perez irradiance model is used and plane of array calculations are performed based on the PV array orientation parameters input by the user.

4 A shading model is applied based on the shading obstruction angles or monthly (solar access) percentages input by the user. DNV notes that the shade loss is calculated based on the percent of shaded area which is not directly correlated to actual module shade losses. Actual shading losses depend on system variables such as module architecture (e.g., bypass diodes) and orientation, string configuration, and severity of shade. As shown in various studies [22], this assumption underestimates the impact of shading losses on the string of modules for string inverters.

5 The PVForm Power Output Model is used to calculate production from irradiance, based on the inverter and module specifications of the system. PowerClerk has a drop down of inverter and module models selected by the user and can look up hardware specifications including inverter efficiency values from the California Energy Commission (CEC). These specifications are transferred to SolarAnywhere Fleetview for use in the PVForm Power Output Model.

6 The Sponsor uses a fixed 10% de-rate factor, with the exception of inverter and PV module specifications as noted above. A comparison of the Sponsor's de-rate factor vs. DNV's recommended values for Connecticut are provided in Table 4-1 below.

7 The hourly production time series is summed by SolarAnywhere Fleetview to obtain year 1 monthly energy estimates and an annual energy estimate.

8 The Sponsor applies a 0.5% annual degradation to the year 1 energy estimates. DNV comments on portfolio degradation in Section 5.6.3.

4.3 Commentary on the Sponsor's residential methodology

The below commentary regarding the Sponsor's methodology for generating production estimates provides context to the forecast accuracy discussion in Section 6, where estimates are compared to Portfolio production data.

4.3.1 Accuracy and reliability of meteorological data

The Sponsor uses CPR SolarAnywhere TGY data at the site location as the irradiation data input to the energy estimate simulation. Irradiation inputs are a high impact variable within a solar energy production assessment and have the potential to significantly impact the production results. DNV discusses the effect of weather data selection throughout this section.

CPR SolarAnywhere data is derived from the SolarAnywhere satellite imagery collected from geosynchronous satellite networks and is applied to 10 x 10 km mesh grids. The data spans 1998 – 2017. DNV has reviewed discussions of uncertainty supplied by CPR and has found them insufficient to provide a clear picture of the spatial and temporal uncertainty of this dataset. DNV considers the data to be acceptable for use in solar energy estimate production estimates based on endorsements from NREL and the data's general agreement with other, peer reviewed datasets. Also, production index analysis produces correction factors that can compensate for bias error in the weather data among other sources of bias.

DNV considers the CPR SolarAnywhere data sets to be suitable for use in PVForm model simulations assuming the localized 10x10 km gridded data is selected as the weather file. DNV recommends comparing nearby irradiance resource files to lower the risk of outliers, especially in climatically diverse zones such as coastal or mountainous regions. DNV expects the localized 10 x 10 km gridded data from SolarAnywhere to be reasonable, especially given the nature of the spatial coverage needed for residential energy estimates.

Given the background with CPR SolarAnywhere data, DNV considers the uncertainty of the Sponsor's solar radiation to be relatively high and higher than a well-calibrated ground measurement station. Nonetheless, DNV considers such an approach to be among the best available methods for residential solar applications given the need to have rapid and algorithmic energy estimates. Other meteorological data could potentially have a lower uncertainty if it were site-specific, well-calibrated, well-maintained and consistent between all sites, however the cost of such an approach makes it impractical in most cases with such a large number of systems and the time required to record the measurements. DNV considers the use of CPR SolarAnywhere data as a meteorological source to be acceptable for use in the Sponsor's energy forecasts.

4.3.2 Accuracy and reliability of energy simulation process

DNV has reviewed SolarAnywhere PV Simulation Product Documentation [23] to inform its understanding of the modifications performed to the PVForm Power Output Model, as discussed in Section 4.2. This document provides a comparison of the PVForm model used by PVWatts and SolarAnywhere for a representative system in Boulder, CO, using the same weather data in the simulation. The difference in AC power is 6% with the largest source of discrepancy being the PTC versus STC reference temperature. The full list of discrepancies are summarized within the document.

While this comparison is useful for highlighting the differences between the two PVForm-based models it does not provide information on the accuracy of the model's energy estimates. The PVWatts v5 Manual [24] lists the PVForm-based energy estimate error as high as +/- 10% on an annual basis. DNV does not have access to the underlying API code and therefore has not independently verified the SolarAnywhere Fleetview API model.

As an engine for generating energy production forecasts, SolarAnywhere Fleetview is able to achieve usability and speed and adequately provides meteorological data spatially and geographically for the various systems considered in this portfolio. Therefore, DNV considers the use of SolarAnywhere Fleetview to be a reliable method and the selection of such a tool seems appropriate given the Sponsor's business model. Aggregating a large number of PV systems into a portfolio results in a portfolio-wide uncertainty that is lower than the uncertainty for a given rooftop PV system, an effect that is discussed in further detail in Section 5.6.

4.3.3 Accuracy and reliability of energy loss factor assumptions

Table 4-1 below summarizes the losses used to determine DNV 's standard loss assumptions compared to SolarAnywhere Fleetview's default loss value.

Table 4-1 Default loss factors

Component loss factors	Sponsor default loss factors	DNV recommended values in CT
Soiling + Snow		3.5%
Shading	Defined per system outside of this value	Defined per system
Mismatch		1%
Wiring		2%
Connections		0%
Light-induced degradation		2%
Nameplate rating		0%
Age		0%
Availability		2%
Total loss factor	**10%**	**10%**

While DNV does not have information on the breakdown of the 10% loss factor applied in SolarAnywhere Fleetview, DNV finds the 10% loss factor reasonable for this specific Portfolio of systems based on regional weather and assuming aggregation of many thousands of systems. Recommended loss values for each component loss factor are presented herein. DNV notes that in SolarAnywhere Fleetview, shade losses are considered outside of the 10% loss factor and DNV agrees with this approach. DNV notes that the shade loss is calculated based on the percent of shaded area and may underestimate the impact of shading losses on the string of modules for systems using string inverters. DNV notes that actual soiling losses can change based on the geographical region and environment and recommends regional dust and snow soiling losses be calculated. A standard loss factor in all regions would not account for this variability. DNV calculated typical snow loss factors in Connecticut since the regional distribution of this Portfolio is small.

A discussion of selected loss factor assumptions follows:

- **PV module nameplate dc rating:** Nameplate variation (also referred to as module binning tolerances) is listed as 0%/+3% (or -0 W to +5 W) on most PV module datasheets. DNV also accounts for MPPT non-ideality with an additional 0.5% loss. When considering all module nameplate power losses, DNV recommends a value of 0% be used for this loss.
- **Inverter and Transformer:** The inverter efficiency is obtained from a look-up table which is updated using values published by the CEC. DNV finds this approach reasonable.
- **Mismatch:** The electrical losses resulting from the performance variation of individual electrically-connected modules. DNV recommends a 1% loss for default residential systems using string inverters. DNV notes that this loss is lower when using dc optimizer or microinverters.
- **DC and AC wiring:** DNV recommends a 2.0% loss for dc wiring loss and ac wiring loss for generic systems. DNV notes that for string inverter systems dc wiring losses will be higher than for module-level microinverters. The opposite is true of ac wiring losses when comparing string and microinverter systems. In total, dc and ac wiring losses are typically 1.5% to 2.5% for most residential systems. DNV notes that the Sponsor can control this loss by altering the system design and wire selection.
- **LID:** Most conventional silicon modules stabilize with a 1-3% loss within the first few hours/days of exposure.
- **Shading:** As part of the design process, installers must take either manual or satellite-based shade measurements. The shade obstruction angles or monthly solar access percentages are entered into PowerClerk (and subsequently transferred to SolarAnywhere Fleetview) and incorporated into the production estimate. DNV notes that the shade

loss is calculated based on the percent of shaded area and may underestimate the impact of shading losses on the string of modules for string inverters.

- **Soiling/Snow:** DNV notes that actual soiling/snow losses can change based on the geographical region and environment. DNV independently calculated soiling/snow losses using precipitation data and snowfall data for a generic residential system in CT and determined that 3.5% is a reasonable estimate of soiling/snow losses as presented in Table 4-1. In order to account for potential error caused by soiling/snow losses, DNV considers variance in production expectations in the uncertainty analysis as presented in Section 5.6.
- **System Availability:** DNV notes that, to some extent, the Sponsor has visibility into the downtime of systems by monitoring system production data. The Sponsor is able to inform third-party owners and installers when systems are down so that those systems can be brought back online. For project monitoring issues that are not addressable by owners and installers, the Green Bank will rely on SunSystem Technology (SST) to assist with troubleshooting and repair.

  DNV notes that industry-wide practices for controlling system downtime include employing good monitoring techniques, active maintenance, and responsive repairs. DNV generally considers a portfolio-wide availability 98% as an achievable target for a well-maintained residential system portfolio of thousands of systems. An estimate of the Sponsor's Portfolio availability is provided in Section 5.3.4.

To obtain an estimate of PV system degradation, DNV has relied on its review of the Jordan and Kurtz 2016 Compendium of photovoltaic degradation rates [25]. DNV notes that degradation rates used in non-recourse project finance transactions for PV systems are typically in the range of 0.5-0.75% per annum. This range is supported by extensive industry literature [25]. Based on DNV's review of available studies, the median system-level degradation rate is reported to be 0.64%, and the interquartile range (P25-P75) is 0.2%-1.2% per annum.

4.3.4 Uncertainty calculations

Uncertainty analyses are not typically performed or considered on individual residential system energy estimates. Therefore, no project level uncertainly calculations were provided for review by the Sponsor. However, DNV has used the production data set to draw conclusions regarding the uncertainty of the Sponsor's Portfolio production forecasts. These results are provided in Section 5.6.

4.3.5 Validating Sponsor energy estimate process consistency

DNV has attempted to replicate the Sponsor's energy forecasting process by manually entering PV system specifications directly into SolarAnywhere Fleetview for 20 systems randomly selected by DNV. The inputs used were determined from system drawings and shading reports provided by the Sponsor.

The estimate made by DNV for each system was then compared to the annual as-built production estimate provided by the Sponsor for that system. The summary of the validation results including model inputs are provided in Appendix B, as well as in Table 4-2 below. DNV notes continued process consistency from the results of these validations.

Table 4-2 Methodology validation summary

System	Capacity (kWp)	Installer	Module	Inverter	Estimated Deviation (%)
RPV-07683	6.12	SolarCity	Canadian Solar	SolarEdge	NA[1]
RPV-32529	8.70	PosiGen	Silfab	SolarEdge	2.20%

System	Capacity (kWp)	Installer	Module	Inverter	Estimated Deviation (%)
RPV-32540	14.70	SunPower Capital	SunPower	SunPower	0.00%
RPV-34357	9.36	SunPower Capital	SunPower	SunPower	0.00%
RPV-36853	6.20	Vivint Solar	Hanwha	SolarEdge	0.00%
RPV-34389	6.49	Trinity Solar	Hanwha	SolarEdge	0.00%
RPV-38804	5.12	PosiGen	Silfab	SolarEdge	0.00%
RPV-39966	5.67	Momentum Solar	Hanwha	Enphase	0.00%
RPV-39980	2.64	Sunrun	LG Electronics	SolarEdge	0.00%
RPV-40122	10.08	Sunlight Solar Energy	LG Electronics	SolarEdge	0.00%
RPV-41114	4.13	Trinity Solar	Hanwha	SolarEdge	0.00%
RPV-41191	7.46	C-TEC Solar	Solaria	Enphase	0.00%
RPV-41227	20.44	EcoSmart Home Services	LG Electronics	Enphase	0.00%
RPV-41651	5.80	Sunrun	REC Solar	SolarEdge	0.00%
RPV-42057	5.27	PosiGen	Silfab	SolarEdge	0.00%
RPV-42360	10.72	Sun-Wind Solutions	LG Electronics	Enphase	0.00%
RPV-42422	9.60	PosiGen	Hanwha	SolarEdge	0.00%
RPV-42425	2.24	Trinity Solar	Hanwha	Enphase	0.00%
RPV-44212	3.77	Sunrun	REC Solar	SolarEdge	0.00%
RPV-45786	4.41	Trinity Solar	Hanwha	SolarEdge	0.00%

[1]Energy estimate is not available in FleetView

For validation, DNV attempts to replicate the Sponsor's energy estimates to a ±1% threshold based upon initial data provided by the Sponsor. If DNV 's initial validation efforts result in agreement with the Sponsor's estimate outside of the ±1% range, DNV requests further details on the Sponsor's inputs to reconcile the deviation.

DNV notes that the energy estimate for system RPV-07683 is not available in FleetView and that of the energy estimates, only one system (RPV-32529) exceeds the threshold range. DNV also notes that although the other energy estimates do not exceed the threshold range the following systems' electrical drawings differ from the specifications used in SolarAnywhere FleetView:

- <u>System RPV – 07683</u>: Shading specifications are missing in SolarAnywhere FleetView, and therefore the energy estimate is not available for comparison with the energy estimate provided by the Sponsor.
- <u>System RPV – 32529</u>: The energy estimate comparison exceeds the threshold range, which DNV believes is due to incorrect shading profiles being used in SolarAnywhere FleetView – more specifically it appears that the shading profiles for array two and array four have been erroneously swapped.
- <u>System RPV – 41114</u>: System drawings indicate one array with a tilt angle of 18 degrees. System details within SolarAnywhere FleetView indicate a tilt angle of 16 degrees. DNV considers this discrepancy to have a negligible impact on the energy estimate.
- <u>System RPV – 42360</u>: System drawings indicate that the three arrays all have an azimuth angle of 138 degrees. System details within SolarAnywhere FleetView indicate an azimuth angle of 140 degrees. DNV considers this discrepancy to have a negligible impact on the energy estimate.

- System RPV – 47586: System drawings indicate one array with a tilt angle of 29 degrees. System details within SolarAnywhere FleetView indicate a tilt angle of 27 degrees. DNV considers this discrepancy to have a negligible impact on the energy estimate.

Of the 20 systems reviewed, DNV independently validated 18 of the 20 systems to within ±1%. The systems with specification discrepancies were examined by the Sponsor who confirmed that the discrepancies were all within their margin of error. The uncertainty in the portfolio forecast is dependent on sufficient information being provided by the Sponsor.

5 PRODUCTION ANALYSIS

5.1 Summary

DNV has analyzed the available production data from the Sponsor's Portfolio of deployed systems in order to confirm the accuracy of the Sponsor's energy production estimates as well as the overall performance of the Portfolio.

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary findings
0	**Production data set:** The Sponsor supplied DNV with annual production and forecast data for 6,957 systems.
5.3	**Production analysis methodology:** DNV performed a QA/QC procedure on the Tranche 4 Data. DNV calculated the extent to which over/under production in a region can be attributed to differences between the irradiance during the operational period relative to the long-term irradiance for that region and applied irradiance adjustment factors. DNV calculated a Performance Index for each system by taking the ratio of the summed irradiance-adjusted annual actuals to the summed annual estimates.
5.4	**Production analysis results:** The Production Sample systems have overperformed their estimates by 2.0% on average. DNV compared the performance of the Production Sample by Installer, PTO date, module manufacturer, and inverter manufacturer.
5.6	**Uncertainty:** DNV has calculated a P50 Portfolio forecast of 97.1% of the Sponsor's first-year energy estimate. DNV has calculated a P99 Portfolio forecast of 90.1% of the Sponsor's first-year energy estimate.

5.2 Description of the datasets

DNV received a dataset in January 2021 ("Tranche 4 Data") containing production data for 6,957 systems [26]. These systems represent the Tranche 4 Portfolio with estimated and actual energy produced between January 2015 and December 2020. The Sponsor has provided system information for the systems in the Portfolio, including location, system size, estimated monthly production, installer, and inverter and module information. DNV understands from the Sponsor that all Year-1 monthly estimates were generated using SolarAnywhere FleetView, a solar forecasting service from Clean Power Research which is the Sponsor's current energy estimate methodology, and that a future portfolio of systems would be expected to have their energy estimates generated using the same methodology.

5.3 Production analysis methodology

DNV has analyzed the Sponsor's operational data. This process involved the following steps:

- Clean the production data to remove erroneous values
- Adjust system production to be more representative of the long-term period
- Derive performance indexes based on the past accuracy of the Sponsor's forecasts.

DNV assessed all PV systems with available historical data to gain insight on the performance of the Sponsor's entire operational Portfolio. Each of these steps is described in detail in the following sections.

5.3.1 Data cleaning and processing

The analysis of the systems in the Tranche 4 Data first began with a data QA/QC procedure. The data QA/QC procedure consisted of the following steps:

1. Any months where the meter was running but the system had not begun to produce electricity have been removed from the data set. For each system, the first month of non-zero production was removed to account for typical issues associated with project startup.
2. Any system with a monthly energy estimate of zero, or more than three summer months with production greater than 200% of the energy estimate, were classified as erroneous due to sizing problem and were removed from the analysis. 21 systems have been removed as a result of this qualification.
3. DNV has identified data surges where normal production months are followed by unrealistically high production months. These data surges are defined as any month where the measured production is more than 500 kWh overestimated or more than 200% greater than estimated. These months have been removed from the analysis.
4. Systems in the Portfolio are occasionally unable to communicate production data due to communication errors. In such cases, the meter will continue registering production while it is offline and sync data with the server when the communication is corrected, and the meter is back online. When such a communication error spans multiple months, data spikes result, where a month of low or zero production is followed by an unrealistically high measurement for the month. DNV has identified such data spikes, including the preceding months of zero production, and removed these months from the analysis.
5. DNV identified 351 systems without any actual data reported. These systems were removed from the analysis.
6. Systems without 12 months or more of production data with at least one valid data point for each calendar month have been removed from the analysis.

DNV finds the Portfolio data set supplied to be reasonable and to contain a low proportion of erroneous data. Table 5-1 summarizes the results of the QA/QC process, finding 6,051 systems (the "Production Sample") as valid for the analysis. The Production Sample forms the basis of the rest of the analysis.

Table 5-1 Data QA/QC Summary

Tranche 4 Portfolio Systems	**6,957**
Systems with sizing problem or missing estimates	(21)
Systems without any actual data	(351)
Systems without 12 months of valid production data	(534)
Production Sample Systems	**6,051**

5.3.2 Solar resource comparison to long-term irradiation

To adjust production data for differences caused by irradiance above or below long-term average, the Sponsor has provided DNV with monthly ratios of historical GHI to long-term average GHI for each of the systems in the Portfolio [27]. These ratios were calculated for each system using SolarAnywhere data from a tile located near the system. DNV has used these ratios to adjust the production data to what would have occurred in long-term average irradiance conditions.

5.3.3 Additional weather considerations

DNV acknowledges that, in addition to GHI, other meteorological variability can impact the production of a PV system; however, in this case, only irradiance variability was considered in this analysis.

DNV understands that, in general, the East Coast received higher-than-average amounts of snowfall in 2015. This suggests that the production of the Sponsor's systems in the Northeast may have been negatively impacted during these winter months and is therefore not necessarily reflective of average long-term production. DNV has not reviewed snowfall levels during the period of operation of the Production Sample systems. DNV also notes that the number of systems operational starting in 2015 is relatively small, and therefore the impacts of this higher-than-average snowfall in 2015 is likely relatively minimal on the portfolio level.

While DNV is of the view that adjusting the production data for variation in historical solar resource compared to long term solar resource results in more certain forecasts, it does not completely consider all weather events that may cause the average observed performance of the Portfolio to deviate from long-term average behavior.

5.3.4 System availability

For purposes of assessing availability, DNV defines availability as system downtime where production losses are attributable to a downtime event. DNV employs the following approach to assessing Portfolio availability:

- DNV estimates lost production by comparing the actual production to the expected production for each month of operation for each system.
- Any month where the ratio of actual to expected production is less than 50% (including zero production months) is flagged as a potential downtime event and lost production is approximated as the difference between expected and actual.
- System availability is calculated as the ratio of the total actual production to the sum of the total actual production and the total lost production.

This analysis showed that the production data set system availability has been moderate, with approximately 61.4% of systems having less than 0.5% downtime. DNV has calculated the average availability of the Production Sample to be 93.4%. Table 5-2 summarizes the distribution of system availability for the Production Sample.

Table 5-2 System availability frequency distribution

Availability Bin Floor	% of Total	Availability Bin Floor	% of Total
0.995	61.4%	0.865	0.9%
0.985	2.2%	0.855	1.0%
0.975	2.9%	0.845	0.8%
0.965	2.4%	0.835	0.8%
0.955	2.6%	0.825	0.6%
0.945	2.5%	0.815	0.6%
0.935	2.3%	0.805	0.5%
0.925	1.8%	0.795	0.5%
0.915	1.6%	0.785	0.5%
0.905	1.5%	0.775	0.4%
0.895	1.2%	0.765	0.5%
0.885	1.3%	0.755	0.4%
0.875	0.9%	<0.755	7.7%

5.4 Production analysis results

DNV has analyzed the available production data from the Sponsor's Portfolio of deployed systems in order to confirm the accuracy of the Sponsor's energy production estimates as well as the overall performance of the Portfolio. The results are presented as the Performance Index ("PI") which is the ratio of the sum of monthly means of actuals to sum of monthly means of estimates.

5.4.1 Sponsor energy estimation accuracy

Figure 5-1 below summarizes key attributes of the Production Sample, and Figure 5-2 summarizes key statistics. The Sponsor's operating systems have overperformed their current modeled as-built estimates on average by 2.0%. The Performance Index standard deviation is 20.1%.

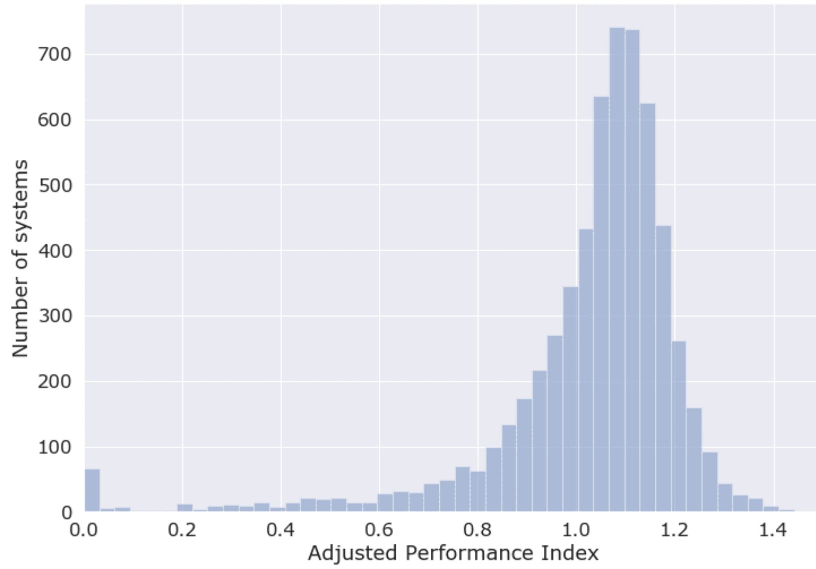

Figure 5-1 Production Sample Performance Index summary

Table 5-3 Summary statistics of energy production of the Production Sample

Statistic	Summary
System Count	6,051
Average Performance index	1.02
Median Performance index	1.07
Performance index Standard Deviation	20.1%
Minimum Performance index	<0.01
Maximum Performance index	1.57
Performance index < 0.95	21.1%

5.4.2 Accuracy by Installer

DNV has presented system performance for the top ten installer companies that appear in the Portfolio, as summarized in Figure 5-2.

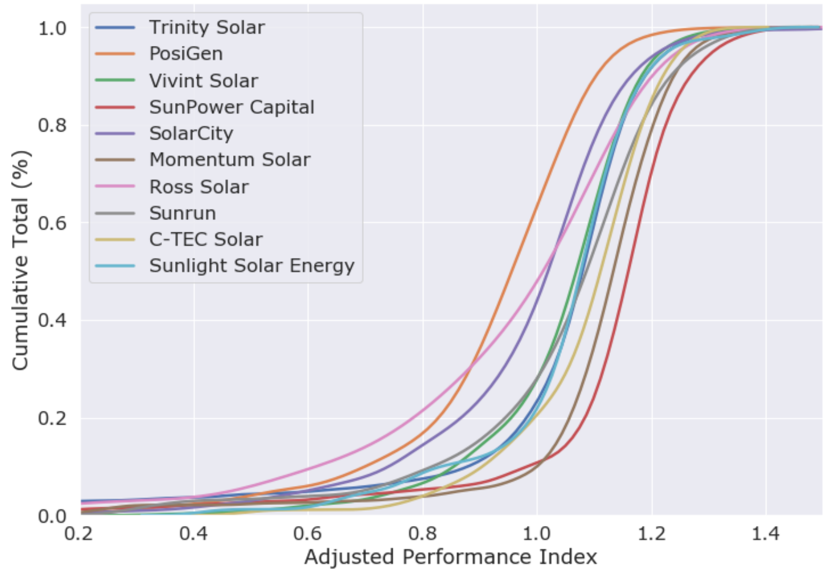

Figure 5-2 Cumulative distribution functions of performance index by Installer

Table 5-4 Summary statistics for energy production by Installer

Installer	Count	Mean	Standard Deviation	Minimum	Maximum
Trinity Solar	2,449	1.03	21.7%	0.00	1.57
PosiGen	885	0.92	19.4%	0.05	1.56
Vivint Solar	613	1.04	13.8%	0.31	1.39
SunPower Capital	547	1.12	17.1%	0.00	1.42
SolarCity	376	0.98	19.0%	0.19	1.53
Momentum Solar	238	1.11	15.0%	0.19	1.37
Ross Solar	96	0.95	25.2%	0.06	1.29
Sunrun	126	1.05	18.5%	0.27	1.35
C-TEC Solar	89	1.08	12.1%	0.49	1.30
Sunlight Solar Energy	81	1.05	14.4%	0.41	1.39

5.4.3 Accuracy by system age

Figure 5-3 illustrates the cumulative distribution of the PI by the age of the system. Each curve represents systems of various ages in years.

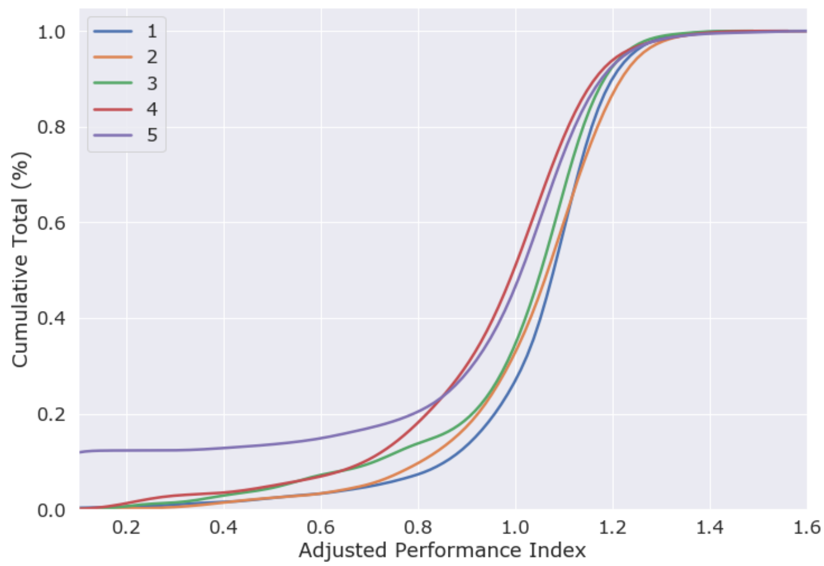

Figure 5-3 Cumulative distribution functions of Performance Index by Age of the system calculated based on PTO date

Table 5-5 Summary statistics of energy production by system age

Age [Years]	1	2	3	4	5
Systems	4,579	682	153	126	511
Average PI	1.04	1.03	1.00	0.95	0.89
Maximum PI	1.56	1.57	1.36	1.37	1.53
PI Std. Deviation	17.0%	17.6%	20.6%	22.2%	40.7%
Minimum PI	<0.01	0.08	0.19	0.21	<0.01

The PI is seen to generally decrease after one year of operation, from an average of 1.04 for systems one year old to an average of 0.89 for systems five years old. However, the sample size for systems for ages 3, 4, and 5 is generally low and may not necessarily be representative of longer operating systems. DNV notes that the Portfolio is primarily composed of relatively new systems under 2 years and that performance over time will be monitored by the Sponsor to be described in Section 4.3.3. DNV notes the performance difference between systems one, two, and three years old may be attributed to factors outside of the analyzed irradiance variability, such as installation quality, prior energy estimation versions, equipment, etc.

5.4.4 Accuracy by module manufacturer

DNV has presented system performance for the top ten module manufacturers that appear in the Portfolio, as summarized in Figure 5-4.

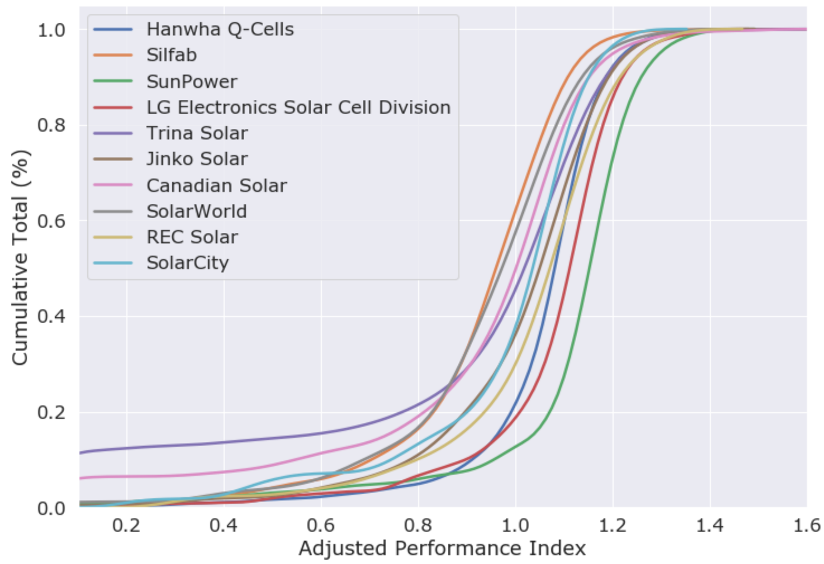

Figure 5-4 Cumulative distribution functions of Performance Index by module manufacturer

Table 5-6 Summary statistics of energy production by module manufacturer

Module manufacturer	Count	Mean	Standard deviation	Minimum	Maximum
Hanwha Q-Cells	2,584	1.05	14%	<0.01	1.57
Silfab	841	0.93	20%	0.05	1.56
SunPower	695	1.11	18%	<0.01	1.42
LG Electronics Solar Cell Division	589	1.08	16%	0.04	1.40
Trina Solar	403	0.89	41%	0.01	1.53
Jinko Solar	252	1.01	18%	0.08	1.36
Canadian Solar	216	0.92	32%	<0.01	1.50
SolarWorld	84	0.94	21%	0.01	1.29
REC Solar	83	1.03	18%	0.27	1.32
SolarCity	56	0.98	20%	0.19	1.21

Within these results, systems with Trina Solar modules present the lowest average PI at 0.89. Systems with SunPower modules outperformed the estimated production with an average PI of 1.11.

5.4.5 Accuracy by inverter manufacturer

Figure 5-5 presents a summary of system performance for the Production Sample binned by inverter manufacturer.

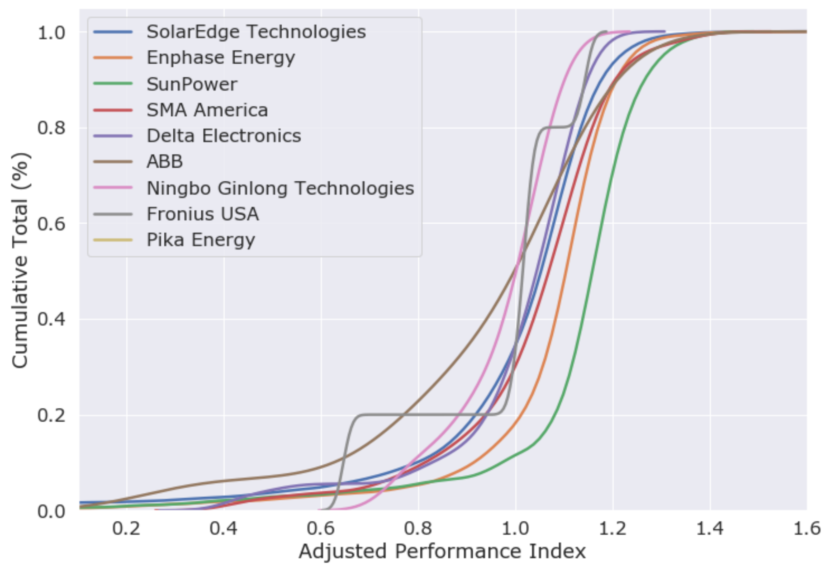

Figure 5-5 Cumulative distribution function of Performance Index by inverter manufacturer

Table 5-7 Summary statistics for energy production by inverter manufacturer

Inverter manufacturer	Count	Mean	Standard deviation	Minimum	Maximum
SolarEdge Technologies	4,351	1.00	21%	<0.01	1.56
Enphase Energy	872	1.07	16%	0.01	1.57
SunPower	610	1.12	17%	<0.01	1.42
SMA America	105	1.04	17%	0.40	1.39
Delta Electronics	54	1.00	16%	0.40	1.17
ABB	45	0.94	26%	0.21	1.27
Ningbo Ginlong Technologies	8	0.98	11%	0.75	1.08
Fronius USA	5	0.97	19%	0.65	1.14
Pika Energy	1	0.33	-	0.33	0.33

Among the manufacturers that represented more than 1% of the Portfolio, SolarEdge Technologies had the lowest PI, but still performed on par with estimates. SunPower had the highest PI, performing 12.0% above estimates.

5.5 SHREC production analysis

5.5.1 SHREC minting process summary

As described in the SHREC Creation and Minting Process Standard Operating Procedure (the "SOP") and email correspondence to changes in the procedure provided to DNV in June 2019, the Sponsor creates and mints SHRECs from qualified projects [28].

A summary of the procedure is as follows:

- Obtain net production in kWh from the Locus monitoring data platform;
- Adjust the production data with the CPR solar resource ratio;
- Compare adjusted measured production to the energy estimate for each system;
- If the adjusted measured production exceeds 200% of the estimated production, the Customer assumes the value to be erroneous due to communication errors or back fed generation. Measured production is then limited to the 200% cap;
- 1 MWh equates 1 unit SHREC.

In order to understand future performance of the Portfolio in terms of the SHREC asset class, DNV has analyzed past performance of the Portfolio and converted the past performance of SHREC estimates using the processes described in the SOP. DNV understands that historically minted SHREC production is largely unavailable, as the Sponsor was granted permission in 2015 to mint SHRECs beginning with 2017.

5.5.2 Performance Index of estimated SHREC production

DNV has analyzed historical production and processes described in the Section 5.5.1 to develop a synthetic dataset of past SHREC performance. This is done due to the differences in comparisons between the metered production and SHREC forecast estimate, and the SHREC minting process. DNV has assumed that all MWhs estimated convert to units of SHREC in the Sponsor's SHREC estimate.

DNV has approached the analysis by considering the following:

- Utilize the cleaned dataset arrived after data quality management described in Section 5.3.1
- Adjust the measured production on a monthly basis using the steps described in Section 5.5.1 to created the SHREC Production Sample
- Produce SHREC Performance Index utilizing the method described in Section 5.3

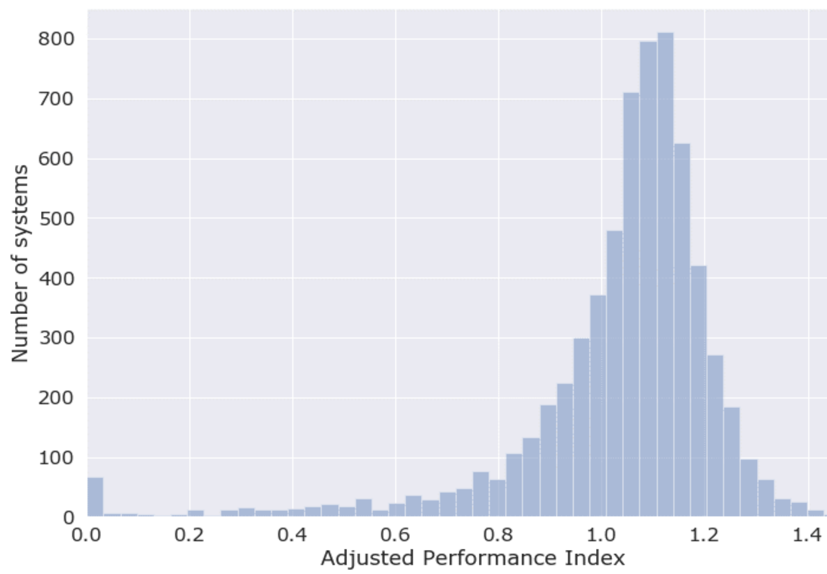

Figure 5-6 SHREC Performance Index distribution of the Portfolio

Table 5-8 Summary statistics of synthetic SHREC Production

Statistic	Summary
System Count	6,455
Mean PI	1.03
Median PI	1.08
Standard deviation	19.9%
Minimum PI	<0.01
Maximum PI	1.62
PI< 0.950	19.8%

DNV notes that the mean production is increased by 1.0% after comparing these results to those presented in Section 5.4.1. The increase in PI from the Production Sample to the SHREC Production Sample is likely due to the addition of months with high production being capped at 200% of the adjusted estimated production rather than excluded from the analysis completely as they were from the Production Sample.

5.6 Forecast and uncertainty calculations

DNV has completed an uncertainty analysis specific to the Portfolio results presented above. This uncertainty analysis is utilized for Portfolio forecasting as presented in Section 5.6.4, below.

An ensemble of PV systems represents a lower uncertainty relative to the sum of individual systems—this is referred to as the “portfolio effect.” DNV has estimated the uncertainty in its production forecast by the method described below.

5.6.1 Sources of uncertainty

The sources of uncertainty in the forecast of energy production can be categorized as two types: (1) those due to uncertainties in the historical data and analysis methodology; and (2) those due to the future variability of the solar resource and production loss factors. The portfolio effect arises due to the statistical independence of the contributing sources of uncertainty, which are described in the following subsections.

5.6.1.1 Historical uncertainty

- **Sample representation:**
  - **Production Index:** DNV 's forecast is an adjustment to the Sponsor's forecast, which is assumed to follow the empirical distributions provided in Section 5.6.1. It is observed that regions with larger quantities of PV systems generally have lower production index uncertainty as defined by the law of large numbers.
  - **Technology:** For Portfolio systems whose specifications are as yet undefined, or whose technology (e.g., model type) is not analyzed in the available sample of production data, uncertainty has been assigned to account for any potential deviation in production. Here, the portfolio is used to forecast for itself. Hence, there is no added uncertainty from a technology perspective.
- **Analysis process:**
  - **Sunniness:** The uncertainty associated with production data's period of record. This uncertainty is calculated by considering the region's inter-annual variability and reducing this value by the square root of the period of record of the production data. This uncertainty value represents the possible deviation in solar radiation and thus energy production, as compared to the long-term solar radiation of the region.
  - **Adjustment to long-term reference:** The uncertainty associated with an adjustment from the historical production data to a long-term solar radiation source. This adjustment process can determine and correct for above or below average solar radiation over the production data period of record.
  - **General:** The uncertainty associated with the general analysis process is taken into consideration. This accounts for factors such as the number of systems being forecasted versus the number of systems with production data in the portfolio, the consistency of the energy assessment forecasting methodology within the portfolio, and other portfolio-specific factors that may need to be accounted for. DNV notes that this portfolio has a typical level of general uncertainty.
  - **Measurement/Data Reliability:** The accuracy of the production data, including the accuracy of the production metering hardware and validation results.

DNV 's uncertainty expectation and methodology is set forth in the Table 5-9 below for each of the uncertainty factors. These values are blended to represent the Portfolio and consider the composition of the Portfolio and the Production Sample in terms of methodology used, the availability of production data, and the definition of system details.

Table 5-9 Uncertainty in the Correction Factor

Production Sample Representation	Analysis Process	Measurement and Data Reliability	Historical Uncertainty
1.0%	1.8%	1.2%	2.4%

5.6.1.2 Future variables

- **Interannual Variability (IAV):** In any given year, Portfolio production may be higher or lower as a result of variability in the incident solar radiation; and

- **Availability:** The variability of the future energy production due to availability.

Table 5-10 Future uncertainty

Inter-Annual Variability 1-Year	Availability	Future Uncertainty 1-Year
1.7%	1.0%	3.1%

5.6.2 Portfolio mean and uncertainty

DNV presents correction factors for the Sponsor's Portfolio first-year energy estimates based on historical data and future uncertainty. Table 5-11 summarizes the estimated correction factors along with the corresponding uncertainty. DNV 's annual forecast for future years for the Portfolio is provided below in Section 5.6.4.

Table 5-11 Correction factors for Year-1 and uncertainties

Correction Factor	Total Uncertainty 1-Year
1.02	3.1%

Combining the model uncertainty found using the principal values described in Section 5.6.1 with the solar resource and availability uncertainty for the 1-year future period case yields overall Portfolio uncertainty of 3.1%.

5.6.3 Degradation

For an individual system utilizing standard crystalline modules, DNV utilizes an asymmetric degradation distribution with a mean of 0.81% and a P90 of 1.8% [29]. For an individual system utilizing SunPower E-series or X-series modules, DNV utilizes a normal degradation distribution with a mean of 0.25% and a standard deviation of 0.7%. For large portfolios of systems consisting of a variety of module models, some independent behavior with regards to degradation is expected. This independence reduces the overall Portfolio-level degradation uncertainty when compared to the individual system uncertainties.

To calculate the Portfolio-level degradation uncertainty, DNV performed a Monte Carlo simulation on the Portfolio systems. This simulation was run with the assumption that each module model behaves independently. DNV notes that other factors can create either correlation or independence in degradation; however, little data is available to inform how these factors behave. In each iteration of the simulation, the model sampled a degradation rate from the appropriate distribution for each module model, and the Portfolio-level degradation rate was then calculated by taking the energy estimate-weighted average of the degradation rates. The results of 10,000 simulations of the Portfolio are presented in Table 5-12.

Table 5-12 Portfolio degradation rates

Percentile	Degradation rate
P50	-0.70%
P75	-0.95%
P90	-1.22%
P95	-1.47%
P99	-1.99%

When calculating annual forecasts, DNV combines the degradation rates with the Year 1 model uncertainties and variabilities assuming an independent relationship. This results in a further reduction of the apparent degradation rate observed when a degraded forecast is compared with the Year 1 forecast for any of the downside scenarios.

5.6.4 Annual forecasts

Based on the observations above, DNV has developed an expectation of the annual production for the Portfolio at various probabilities of exceedance. The annual forecasts are the combination of the uncertainties reported in Section 5.6.2, the degradation uncertainty described in Section 5.6.3, and reductions in availability during the years when inverters are expected to be replaced.

Table 5-13 displays the downtime due to inverter replacements as estimated by DNV.

Table 5-13 Estimated availability due to inverter replacements

Year	Availability due to inverter replacements
1	99.91%
2	99.90%
3	99.89%
4	99.84%
5	99.77%
6	99.58%
7	99.38%
8	99.03%
9	98.53%
10	98.14%
11	98.66%
12	99.17%
13	99.52%
14	99.82%
15	99.79%

The annual forecasts for various probabilities of exceedance for 1-year and 15-year periods are presented below in the tables below with Year 1 representing 01 January 2021 to 31 December 2021. These forecasts are expressed as a percentage of the Sponsor's contractual first year production estimate [30] and in production in MWh. DNV notes that the relative production forecasts shown will change if the final Portfolio composition differs materially from the Portfolio analyzed.

Table 5-14 Confidence limits for the Portfolio, 1-year period

Year	p(50)	p(75)	p(90)	p(95)	p(99)
1	97.1%	95.1%	93.2%	92.1%	90.1%
2	96.4%	94.4%	92.5%	91.4%	89.3%
3	95.7%	93.6%	91.7%	90.5%	88.3%
4	95.0%	92.9%	90.9%	89.6%	87.0%
5	94.3%	92.0%	89.9%	88.5%	85.6%
6	93.4%	91.1%	88.8%	87.2%	84.0%
7	92.6%	90.1%	87.7%	85.9%	82.3%
8	91.6%	88.9%	86.3%	84.4%	80.4%
9	90.4%	87.7%	84.9%	82.8%	78.4%
10	89.4%	86.5%	83.5%	81.2%	76.4%
11	89.2%	86.1%	82.9%	80.3%	75.0%
12	89.0%	85.7%	82.2%	79.5%	73.6%
13	88.7%	85.1%	81.4%	78.4%	72.1%
14	88.2%	84.5%	80.6%	77.3%	70.5%
15	87.5%	83.6%	79.4%	75.9%	68.7%

Table 5-15 Confidence limits for the Portfolio, production in MWh, 1-year period

Year	p(50)	p(75)	p(90)	p(95)	p(99)
1	58,550	57,316	56,206	55,541	54,294
2	58,136	56,893	55,772	55,093	53,814
3	57,716	56,448	55,294	54,576	53,202
4	57,285	55,976	54,768	53,988	52,467
5	56,833	55,469	54,191	53,329	51,622
6	56,317	54,886	53,525	52,568	50,647
7	55,802	54,294	52,838	51,775	49,619
8	55,200	53,609	52,049	50,875	48,473
9	54,517	52,837	51,170	49,881	47,229
10	53,902	52,126	50,344	48,936	46,024
11	53,785	51,891	49,972	48,427	45,224
12	53,657	51,640	49,578	47,893	44,391
13	53,438	51,296	49,091	47,265	43,465
14	53,191	50,921	48,569	46,602	42,500
15	52,770	50,375	47,882	45,778	41,385

6 MAJOR AGREEMENT REVIEW

In Q4, 2018 [31] DNV reviewed the Master Purchase Agreement (MPA) for SHRECs between Connecticut Green Bank and The Connecticut Light and Power Company (dba "Eversource Energy") and The United Illuminating Company ("UI"). The MPA covers buying and selling SHRECs and is the sole offtake agreement. DNV also presents the solar incentive structure relevant to SHREC generation. Review of installer EPC agreements was not included; the CT Green Bank's procedures for qualifying installers are discussed in Section 2.

6.1 Master Purchase Agreement

6.1.1 Summary

In Q4, 2018 DNV reviewed the executed agreements (collectively, "MPAs"), both dated 7 February 2017 with Eversource Energy [32] and UI [33].

SHREC sales to Eversource Energy and UI are provided for using a Master Purchase Agreement (MPA).

The MPAs provide for the Sponsor to sell SHRECs at firm pricing ($50 per MWh for the first tranche, $49 per MWh for tranche two, $48 per MWh for tranche three, and $47 per MWh for tranche four) for 15 years. The Buyer, either Eversource Energy or UI, is obligated to purchase those SHRECs in a tranche associated with the energy generated by the projects assuming the pre-requisites have been met and continue to be met through the term. The main difference between the MPAs provided is the Buyer's Percentage Entitlement ("BPE"). Eversource Energy having a BPE of 80% and UI having a BPE of 20%. DNV has not identified other meaningful differences between the individual MPAs.

While the Buyer is obligated to purchase all SHRECs from a qualifying tranche, there is not a SHREC guaranty or other performance-based terms that require a minimum amount of electricity be produced from a tranche.

A summary of the primary findings and/or risks identified is provided in the following table.

Section	Primary Findings

6.1.1	**Parties and contract status:**
	- Buyer of SHRECs:
	  o Eversource Energy (80%)
	  o UI (20%)
	- Contract status: Executed 7 February 2017 (MPA) / 15 July 2020 (Tranche 4 Transaction Confirmation)

6.1.2	**Term:** The tranche delivery term starts on 1 January of a tranche year and continues for 15 years. The Buyer's obligation to purchase tranche SHRECs will end no later than the earlier of when Sponsor achieves deployment of 305.4 MWdc of qualifying residential solar PV installations or 31 December 2022, meaning the final tranche start date would begin 1 January 2022.
6.1.3	**Sale of SHRECs:** The purchase price of each SHREC is $50.00 in the MPAs for Tranche 1, $49 for Tranche 2, $48 for Tranche 3, and $47 for Tranche 4. The Sponsor establishes the price of each tranche in accordance with Connecticut General Statutes. An SHREC is equal to one megawatt hour (MWh) of electricity generated from a qualifying residential solar photovoltaic system. The Buyer is obligated to purchase all SHRECs generated by SHREC projects in a tranche. SHRECs are invoiced quarterly.
6.1.4	**Obligations of Sponsor**: The Sponsor is responsible for ensuring energy generation has begun prior to tranche delivery start date, providing the tranche purchase price and project details, ensuring the SHREC projects qualify as residential solar PV system, executed the tranche confirmation (Exhibit B), and completing delivery of SHRECs to Buyer.

Section	Primary Findings
6.1.5	**Obligations of Buyer:** The Buyer is responsible for ensuring it has received regulatory and corporate approval and has received tranche detail and executed the confirmation (Exhibit B).
6.1.6	**Energy generation and metering:** SHREC projects must be located behind a qualifying utility revenue meter and must have a separate meter dedicated to measurement of SHREC project's energy output. The meter shall be installed, operated, maintained, and testing to meet applicable requirements and standards of the utility and electric system operator.

6.1.2 Term and termination

The agreement term begins upon execution and, unless terminated earlier, continues for 15 years from the final tranche start date. The Buyer's obligation to purchase tranche SHRECs will end no later than the earlier of when Sponsor achieves deployment of 305.4 MWdc of qualifying residential solar PV installations or 31 December 2022, meaning the final tranche start date would begin no later than 1 January 2022.

The tranche delivery term starts on 1 January of a tranche year and continues for 15 years.

6.1.3 Sale of SHRECs

The purchase price of each SHREC is set by the Sponsor in accordance with the Connecticut General Statutes, currently not more than $50.00 (the price for each SHREC in Tranche 1), $49 (the price for each SHREC in Tranche 2), $48 (the price for each SHREC in Tranche 3), and $47 (the price for each SHREC in Tranche 4). A SHREC is equal to one megawatt hour (MWh) of electricity generated from a qualifying residential solar PV system. The Buyer is obligated to purchase all SHRECs generated by SHREC projects in a particular tranche, irrespective of any delays in REC deliveries, whether or not due to one or more force majeure events. Upon transfer and receipt, Buyer receives titles to all the SHRECs and Environmental Attributes.

Assuming all obligations are meet, SHRECs are bought and delivered within 90 days after tranche delivery term start date. For each contract year of the tranche term, SHRECs are delivered equal to the electricity produced by projects in the applicable tranche. Payment for any SHRECs are invoiced quarterly, with payment due by the last business day of the month following the month during which SHRECs were delivered.

6.1.4 General obligations

The Sponsor is responsible for providing notice to the Buyer certifying:

- Details of the tranche project's and their system size, tranche delivery term start date, and purchase price has been provided in Exhibit B and has been executed between both parties for each tranche.
- Energy generation has begun prior to tranche delivery start date
- The tranche purchase price
- The SHREC projects, as constructed, meet all of the requirements of a qualifying residential solar photovoltaic system pursuant to the Energy Act, which means the project:
  - Receives funding from the Connecticut Green Bank
  - Certified by the authority as a Class I renewable source (e.g. electricity generated from solar power)
  - Emits no pollutants,
  - Located on the customer-side of the review meter of a one-to-four family home,
  - Serves the distribution system of the electric distribution company

- Capable of producing SHRECs

- Has satisfied all obligations in the MPAs to complete the delivery of the SHRECs to Buyer

6.1.5 Buyer's general obligations

The Buyer agrees to the following general obligations:

- Has received regulatory and corporate approvals
- Details of the tranche project's and their system size, tranche delivery term start date, and purchase price has been provided in Exhibit B and has been executed between both parties for each tranche.

6.1.6 Metering and interconnection

SHREC projects must be located behind a qualifying Connecticut electric system's revenue meter. The MPAs do not allow for a SHREC project to be interconnected to the utility electric system. The project must have a separate meter dedicated to measurement of the SHREC project's energy output. The meter shall be installed, operated, maintained, and tested to meet applicable requirements and standards of the utility and electric system operator.

6.1.7 Liability limits

In the MPAs reviewed by DNV, the Sponsor nor the Buyer is liable to the other party for any damages or otherwise.

6.2 Solar incentive structure

The following describes the current residential solar incentives as per the residential solar investment program website [34] which provides both current [35] and historical incentive levels [36]. As the program is structured as a declining incentive block structure, projects in Tranche 4 will have received various incentive levels:

- When purchasing a solar PV system for your home, the EPBB incentive is calculated at $0.358/watt up to 10 kW for utility consumption equaling the last 12 months of electricity usage and $0.207/watt from previous utility consumption for systems up to 20 kW. Systems that have a calculated design factor less than 75% receive a discounted incentive. Systems with a design factor less than 60% are not eligible to receive a Connecticut Green Bank EPBB.
- For PV systems that are leased, the PBI is calculated at $0.03/kWh for system up to 20 kW. The PBI is paid quarterly over six years upon validation of system generation. Systems with a design factor less than 60% are not eligible to receive a Connecticut Green Bank PBI.

6.3 O&M Agreement

DNV understands that the Sponsor does not have direct responsibility for O&M costs for the Portfolio, as the Sponsor's role is as an asset program administrator. As such, DNV has not reviewed either O&M cost estimates or inverter replacement cost projections.

7 OPERATING SYSTEM REVIEW

7.1 Summary

DNV has completed an electrical design audit for a sample of 20 systems within the Sponsor's Portfolio for the purpose of confirming consistency with the Sponsor's agreed processes and identifying any specific issues or risks.

Sample systems were selected from within the Portfolio from top 10 installation partners from across the state of Connetticut. The systems were independently selected by DNV to be representative of the Portfolio as a whole.

A summary of the primary findings identified is provided in the following table.

Section	Primary findings
7.2.1	**Electrical audit:** DNV considers the 20 sampled systems to exhibit standard electrical design quality which is consistent with typical practices in the residential market.
7.2.2	**Structural audit:** The Sponsor does not require installers to submit structural design drawings as part of project completion. As such, DNV was not able to inspect a sample of structural designs for the Portfolio.
7.3.6.1	**Electrical inspection findings:** Inspectors from IBTS performed site inspections on behalf of DNV, and DNV reviewed IBTS site inspection reports. Common issues across most sites are inadequate wire management (low criticality in the short-term but high for long-term reliability) and improper labeling. Labeling issues should be corrected whenever service personnel are called to the site for other service needs. A review of NEC required labels during the design stage may help alleviate improper labeling, especially with the use of inverter integrated solar modules.
7.3.6.2	**Structural inspection findings:** Inspectors from IBTS performed site inspections on behalf of DNV, and DNV reviewed IBTS site inspection reports. Among the structural issues noted in the inspection reports, none represent a high criticality. The most prevalent issues noted were improperly fastened module clamps or lag bolts, which represents a low criticality in isolated incidents. Criticality would increase if systemic, as multiple instances represent a medium risk to production and life safety if panels become dislodged during heavy winds or snow. Inspection reports also noted improper conduit flashing, which represent a low criticality based on DNV's assessment of the photos and location. The module damage from an apparent falling object cannot be confirmed to be due to installation..

7.2 Design audit review

The detailed findings from the electrical audit review are presented in Appendix D and a summary of the audit systems is shown in Table 7-1..

Table 7-1 Design review system summary

System	Size [kWdc]	Partner firm	PIS Date
RPV-40786	5.22	Sunrun	5/31/2019
RPV-40789	10.71	Trinity Solar	6/17/2019
RPV-41075	5.12	PosiGen	8/14/2019

System	Size [kWdc]	Partner firm	PIS Date
RPV-41389	9.765	PosiGen	8/8/2019
RPV-41476	7.2	Palmetto Solar	8/14/2019
RPV-41479	7.54	Sunrun	8/20/2019
RPV-41489	5.67	Vivint Solar	7/24/2019
RPV-41848	7.705	Momentum Solar	8/19/2019
RPV-41856	9	SunPower Capital	6/12/2019
RPV-42230	4.725	Trinity Solar	9/3/2019
RPV-42365	6.03	Momentum Solar	10/16/2019
RPV-42507	4.8	Trinity Solar	7/29/2019
RPV-42508	8.375	Momentum Solar	9/18/2019
RPV-42535	5.4	Sunrun	7/24/2019
RPV-42539	6.09	Sunrun	8/21/2019
RPV-44146	14.4	SunPower Capital	10/29/2019
RPV-44150	8.04	Momentum Solar	10/24/2019
RPV-44234	7.35	Earthlight Technologies	11/5/2019
RPV-44776	5.04	Trinity Solar	11/4/2019
RPV-45413	8.505	Trinity Solar	12/5/2019

7.2.1 Electrical design

DNV reviewed the electrical design drawing package provided by the Sponsor for each sample system as well as site installation photos of the PV system. The electrical design packages have varying degrees of consistency and completeness.

DNV notes the following observations:

- Eleven systems had missing NEC labels in the design package. Photos of the systems appear to show PV equipment correctly labeled but not all labels were visible.
- The interconnection at System 42539 violated NEC 705.12(B)(2)(3)(b) as the interconnection circuit breaker is rated above the maximum allowed value for the rating of the interconnection panelboard.

DNV considers the sampled systems to exhibit standard electrical design quality compared with typical practices in the residential market. Plan sets provide the necessary details, conductors and over current protective devise (OCPD) are sized appropriately, and equipment is rated for its intended usage. DNV does not expect that the PV systems in the Fleet to have undue risk of electrical issues. Normal or typical issues arise over the long term include fading of equipment labels or loose hanging wires from broken or worn zip ties.

7.2.2 Structural design

The Sponsor does not require installers to submit structural design drawings as part of project completion. As such, DNV was not able to inspect a sample of structural designs for the Portfolio. Site visit inspection results are summarized in Section 7.3 in lieu of a structural design audit sample review.

7.2.3 RSIP inspection report review

DNV reviewed self-inspection reports and third party-inspection reports, if available, provided by the Sponsor for twenty systems in the design audit review sample shown in Table 7-1. Prior to receiving an incentive, passing inspection documentation is required to be submitted. Therefore, all systems reviewed were deemed to have passed by the Sponsor. DNV has reviewed the inspection reports for completeness and any inconsistencies in the reports. DNV notes the following observations:

- For all systems, the inspection forms were complete or missing items that were deemed to be low risk. The most prevalent low risk deficiency was failure to complete the performance data section and provide solar reporting device information;
- For system 41856, there were missing passing checks for overcurrent protection despite the project utilizing circuit breakers and fuses. DNV was not able to confirm ratings via photos; and
- For system 42539, passing checks were noted for interconnection despite the project violating NEC 705.12(B)(2)(3)(b). Unfamiliarity with this by the inspector leads to low confidence that other issues would be found on this system or in this jurisdiction.

7.3 2021 site inspection results

7.3.1 Site visit sample

Fifteen PV systems were scheduled for inspection between February 2021 and March 2021. 14 inspections have been completed at time of reporting. The 15th system was not inspected due to the inspector not having access to the Homeowner’s roof at time of inspection.

7.3.2 Sampling considerations

Candidate systems were selected for inspections by DNV and provided to Connecticut Green Bank and IBTS for site visit scheduling. Sites inspected were determined by scheduling logistics organized between IBTS and the Homeowner.

The systems inspected were placed in service in 2018 and 2019. The inspected systems are presented in Appendix D and below.

Table 7-2 2021 Site visit sample by installer

System ID	Installer
RPV-32438	Trinity Solar
RPV-39338	Vivint Solar
RPV-31202	Trinity Solar
RPV-38204	SunRun Inc.
RPV-35581	SolarCity
RPV-28888	PosiGen
RPV-39345	Vivint Solar
RPV-36386	SolarCity
RPV-28669	PosiGen
RPV-32557	Trinity Solar
RPV-35669	SolarCity
RPV-28899	PosiGen
RPV-29719	PosiGen
RPV-28225	PosiGen
RPV-29723	PosiGen

7.3.3 Inspection methodology

DNV employed IBTS as its sub-contractor for purposes of inspecting deployed systems. Typically, IBTS inspectors are on site for approximately 1 hour. The inspection has five major sections, which include site and safety, point of interconnection, inverter, electrical, and mechanical. IBTS site visit reports are internally quality reviewed prior to delivery to DNV.

DNV has reviewed the IBTS summary reports as well as individual inspection reports and photo documentation for each inspected system. DNV 's summary of the 2021 site visit results, with particular focus on structural and electrical issues, is presented in the following sub-section.

7.3.4 Electrical inspection findings

Table 7-3 summarizes the incidence rate for electrical issues across the 14 inspected Portfolio systems.

Table 7-3 Incidence of electrical issues at Portfolio site visits

Issue	Fails	% of systems with an issue
Wiring and wire management	10	71%
Conductors loose/low beneath array	*6*	*42%*
Conductors exposed	*4*	*28%*
Conduit / junction box supports	2	14%
Equipment not rated for location	2	14%

Of the electrical inspection categories, wire management is a commonly identified issue, with a 71% prevalence. Some of the wire management issues if not remediated could lead to system failure due to damaged conductors. Several NEC code violations were noted in these inspections.

IBTS has identified and applied a “criticality” designation to the following issues:

- **Wiring and wire management** – Four instances were found where array circuit conductors were in contact with the roof surface or hanging loose, which over time due to roof abrasion could damage the PV wire and will lead to conductor failure. Other issues noted are less serious and include loose, improperly secured conductors, and tight bend radiuses of PV wire. The criticality is low in the short-term but high for long-term reliability.
- **Conduit / junction box supports** – Two of the 14 systems in the site inspection sample were found to have conduit / junction box support issues. Improperly secured blocks may dislodge or degrade over time, allowing the conduit to sag or contact the roof surface. Conduit in contact with the roof can cause increased heating of the conductors resulting in premature conduit failure.
- **PV system labeling** – Missing or improper labeling was noted at all of the sites. Interpretation and enforcement of PV labeling requirements varies by jurisdiction, and DNV does not view these issues as a material risk to the Green Bank or the Portfolio. Issues brought up during the inspection in one state may not have been flagged in another state. Labeling issues should be corrected whenever service personnel are called to the site for other service needs.

7.3.5 Structural inspection findings

Table 7-4 summarizes the incidence rate for structural issues across the 14 completed inspected systems.

Table 7-4 Incidence of structural issues at site visits

Issue	Fails	% of systems with an issue
Racking & module installation	3	21%
Flashing and additional penetrations	2	14%
Roof conditions	1	7%
Mounting of other components	0	0%
PV array layout	0	0%

Of the structural inspection categories, Racking and Module Installation has the highest issue prevalence, at 21% of systems inspected having one occurrence of this category (however only two failures can be confirmed to be installation).

Major findings, per inspection category, include:

- **Racking & module installation** – Three systems were found to have one or more incidences of racking and module installation issues. For one system, a lag bolt for a mounting foot appeared to be not fully tightened down. A second system had one module clamp not fully seated on the module. A third system contained a broken module, appearing to be an impact from a falling object, but it was not clear that this occurred during installation. The International Building Code (IBC) Section 1510.7.3 has requirements for attachment of PV modules in accordance with the manufacturer’s directions.
- **Flashing and additional penetrations** – This category typically includes flashing of racking mounting feet and penetrations for conduits. Two systems failed this category, with photos of a conduit penetration in a wall. The penetration appeared to have sealant based on the photo; it was not clear nor stated why exactly the system failed. Flashing of the mounting system feet was not identified as a failure for any systems. Improper flashing of penetrations can result in roof leaks, which may result in increased O&M costs if repairs are required under warranty, however the conduit failure observed appears to be a side wall. The International Residential Code (IRC) Section R903 and R905.2.8 has requirements for flashing of roof penetrations, but not side wall penetrations.

- **Roof conditions** — Roof conditions overall were found to be in good or average condition at all sites, with one exception. This system included a photo that appeared to show some worn shingles, however it is not clear if the shingles were previously worn or occurred as a result of traffic during installation. It does not appear that the inspectors entered the attic to inspect the roof framing or positive attachment of the racking system due to COVID-19 safety restrictions.

7.3.6 Discussion

DNV has assessed all the issues presented by IBTS and has assigned a DNV criticality index (low, med, high) rather than relying on the "criticality" designation provided by IBTS.

7.3.6.1 Electrical

DNV notes that the majority of the issues identified are inadequate wire management and improper labeling, which is typical of residential systems. A review of NEC required labels during the design stage may help alleviate improper labeling, especially with the use of inverter integrated solar modules.

A complete list of the electrical issues and a detailed assessment/criticality assignment for each issue is included in Appendix D.

The high criticality designation has been assigned to the following electrical issues, which DNV recommends the asset owner remediate:

- Wire management with respect to long term reliability (system RPV39338, RPV38204, RPV35581, RPV28888, RPV39345, RPV28899)
- Improper grounding terminations (system RPV32557, RPV29719, RPV35581)

7.3.6.2 Structural

A complete list of the structural issues and a detailed assessment/criticality assignment for each issue is included in Appendix D.

For the structural issues noted, none of the items noted represent a high criticality. The most prevalent issues noted were improperly fastened module clamps or lag bolts, which represents a low criticality in isolated incidents. Criticality would increase if systemic, as multiple instances represent a medium risk to production and life safety if panels become dislodged during heavy winds or snow. The flashing of the conduits represent a low criticality based on DNV's assessment of the photo and location. The module damage cannot be confirmed to be due to installation.

8 FINANCIAL MODEL TECHNICAL INPUT REVIEW

DNV has not received a project specific financial model for review. DNV 's review of technical inputs relevant for revenue generation as well as O&M considerations and stress case considerations follows.

8.1 Revenue

8.1.1 Correction factors

As discussed in Section 5 and summarized in Section 5.5, using the synthetic SHREC production generated from the production data of the Portfolio, DNV has calculated a P50 value of 1.08 which is intended to be applied to the Sponsor's first-year energy estimates for the Portfolio. When adjusting the correction factor for age and inverter availability, the P50 Year 1 annual forecast, 01 January 2021 to 31 December 2021, is 0.971 and is intended to be applied to the Sponsor's first-year energy estimates for the Portfolio.

8.1.2 Degradation

Recommended Portfolio degradation rates are described in Section 5.6.3, and re-presented in Table 8-1 below.

Table 8-1 Portfolio degradation rates

Percentile	Degradation rate
P50	-0.70%
P75	-0.95%
P90	-1.22%
P95	-1.47%
P99	-1.99%

When calculating annual forecasts, DNV combines the degradation rates with the Year 1 model uncertainties and variabilities assuming an independent relationship. This results in a further reduction of the apparent degradation rate observed when a degraded forecast is compared with the Year 1 forecast for any of the downside scenarios.

8.1.3 Useful life

DNV expects well-designed, properly installed, and well-maintained PV systems to perform in line with expectations for 25–30 years. While DNV views system performance and maintenance requirements as increasingly uncertain beyond Year 30, as equipment replacement rates are expected to increase, DNV considers that well-funded and maintained systems could achieve an operational life beyond their designed service life and up to 35 years or longer. Given the broad equipment list and installer base, and given the varying care with which homeowners will care for systems, the actual achieved lifetime for the PV systems is expected to vary within the Portfolio.

8.2 O&M

DNV understands that the Sponsor does not have direct responsibility for O&M costs for the Portfolio, as the Sponsor's role is as an asset program administrator. As such, DNV has not reviewed either projected Performance Guarantee payout liabilities or inverter replacement cost projections.

8.3 Stress cases

The stress cases outline below are intended to illustrate potential risks to the Portfolio. DNV considers lower-than-expected Project performance and limited or absent operational monitoring and PV system maintenance risks to Portfolio economics.

8.3.1 Production stress cases

DNV 's correction factors for P75, P90, P95, and P99 production stress cases are presented in Section 5.6.4, above.

8.3.2 Installer bankruptcy / market exit

DNV has considered the case that an installer is no longer able to service its systems. This would have potential deleterious impacts on SHREC production.

The Sponsor has taken steps to mitigate against this risk. As noted in Section 2.1.1, the Sponsor has contracted with Locus Energy, an AlsoEnergy Company, for Portfolio monitoring, and the Sponsor has contracted with SunSystem Technology as a third-party US residential O&M provider. DNV views this as an appropriate risk mitigation step.

In addition, DNV further notes the emergence of market depth in the form of specialized firms able to step in as O&M service providers for residential portfolio. In alphabetical order, Energy Expert Services, IndaSpec, and Omnidian are three such firms.

DNV can evaluate other stress cases upon request.

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APPENDIX A – PRODUCTION ANALYSIS – TECHNICAL APPENDIX

A.1 Portfolio effect across regions

An assessment of the expected portfolio effect requires a determination of the statistical level of independence between projects and groups of projects for each source of uncertainty identified. From the assumption that the correlations between projects is linear, the level of independence is typically determined through a correlation analysis where the resulting Pearson coefficient, r, defines the level of dependency. Once established, the combination of uncertainties to estimate the overall level is defined as:

$$\text{Variance – Covariance matrix} = \begin{pmatrix} \sigma_1^2 & r_{12}\sigma_1\sigma_2 & \dots & r_{1j}\sigma_1\sigma_j & r_{1m}\sigma_1\sigma_m \\ r_{21}\sigma_2\sigma_1 & \dots & & & \\ \dots & & \sigma_i^2 & & \\ r_{i1}\sigma_i\sigma_1 & & & \dots & \\ r_{m1}\sigma_m\sigma_1 & & & & \sigma_m^2 \end{pmatrix} \text{[Eqn 1]}$$

Where σ_i and σ_j are the standard errors for a given source of uncertainty for Project *i* and *j*.
Since the Pearson coefficient is symmetric $r_{ij} = r_{ji}$, a simplification which can be made for its implementation is to reduce the above matrix to the form below:

$$\text{Variance – Covariance matrix} = \begin{pmatrix} \sigma_1^2 & 2*r_{12}\sigma_1\sigma_2 & \dots & 2*r_{1j}\sigma_1\sigma_j & 2*r_{1m}\sigma_1\sigma_m \\ 0 & \dots & & & \\ 0 & & \sigma_i^2 & & \\ \dots & & & \dots & \\ 0 & 0 & \dots & & \sigma_m^2 \end{pmatrix} \text{[Eqn 2]}$$

Given that the Pearson coefficient has a range of -1 < *r* < +1 where +1 represents perfectly linear dependent while a value of 0 represents complete independence, the case of negative dependency—where there is some inverse relationship between the variables—has not been considered in this analysis.

It is noted that in the case of all uncertainties with the exception of solar resource variability, the level of independence cannot easily be estimated analytically. A higher level experienced-based assessment of the “model” uncertainty, which includes an analysis of the independence between process, “other”, and availability and degradation uncertainty, has therefore been undertaken.

A.2 Solar resource uncertainty at the portfolio level

The analysis of the level of independence between regional solar resource regimes is ideally undertaken based on an assessment of the correlation of on-site sources of consistent, long-term irradiance for each of the PV systems. Given the PV systems in question, however, regional SolarAnywhere data with a period of at least 11.0 years were used.

Since the periods of available data are relatively short for the purposes of determining dependence, the investigation has focused on the correlation of monthly global horizontal irradiance (GHI) as a proxy for determining the level of correlation. The use of monthly data, however, is recognized to introduce the potential for autocorrelation due to the seasonality inherent in most solar regimes. In order to avoid such artifices, the seasonal pattern of GHI was estimated from the available data and used to normalize the individual monthly GHI. The use of annual mean GHI for determining the correlation would be ideal since this effect would be removed; however, as mentioned before, the amount of annual data available is limited and therefore it was not practical to follow this route for the analysis reported here.

A correlation of concurrent normalized monthly GHI was undertaken between each combination of region pairs and the resulting Pearson coefficient established. As discussed above, the Pearson coefficient is a measure of the level of dependency; however, the 'raw' resulting values indicated some dependency, albeit small, between most solar resource regimes. Consequently, a review of the statistical significance of the Pearson coefficient, which is function of both the value of the Pearson coefficient, r, and the number of data pairs, n, was undertaken. The upper and lower limits of the 95% confidence interval were established as follows:

$$r_{upper,lower} = \frac{1}{2}\ln\left(\frac{1+r}{1-r}\right) \pm 1.96\left(\frac{1}{\sqrt{n-3}}\right) \qquad \text{[Eqn 3]}$$

A review of the confidence limits, in particular the lower 95% confidence limit, was then undertaken. Where the estimated lower limit was negative, it was observed that the values rarely indicated a strong negative correlation and were generally close to zero. Consequently, for such cases the resulting Pearson coefficient values were set to zero, indicating complete independence of the solar regimes, in order to avoid the introduction of potential statistical artificial influences into the analysis. While the choice of confidence interval for the review and setting those values with negative lower limits to zero is somewhat subjective, sensitivity to the choice of method was reviewed and found to be relatively insensitive to this assumption.

To draw conclusions about the *r* correlation coefficient—that is, to calculate its confidence interval—it is necessary to assume that the data are independent and normally distributed.

In order to demonstrate the above two factors of the data series, normal distribution and autocorrelation tests have been performed for each series. In those series where a normal distribution was not fully achieved, symmetry has been demonstrated.

Based on the above correlation analysis and adjustment of the resulting Pearson coefficients as described, a correlation matrix describing the inter-dependency of solar resource regimes between all regions was defined. From this, the covariance matrices describing each of the terms in [Eqn 2] for the 1-year and 20-year future solar resource inter-annual variability were developed based on the individual regions' inter-annual variability.

APPENDIX B – SUNPOWER SYSTEM DEGRADATION SUMMARY

DNV has reviewed sufficient data and literature to conclude that most long-term system degradation rates for solar photovoltaic power systems constructed using standard silicon technology range from 0.2%-1.2% annually. DNV agrees that SunPower's module technology is unique, with features that may inhibit the degradation mechanisms that characterize conventional Si photovoltaic technologies.

SunPower has invited DNV to review an extended abstract summarizing their recent findings on degradation. This work was slated to be presented at the IEEE Photovoltaic Specialists Conference (PVSC) in June 2017. The paper was being co-authored with subject matter experts based at the National Renewable Energy Laboratory (NREL).

The joint SunPower/NREL study describes several refinements over existing methods of extracting degradation rate information. The new method is applied to hundreds of privately-held, SunPower-managed systems. The key features of this method include:

- a focus on evaluating clear sky and non-inverter-limited performance data in quality control
- record-by-record normalization of power using modeled clear-sky estimates
- robust (median) aggregation to weekly summaries
- comparison of summaries from successive years to identify performance changes.

These are improvements that allow the evaluation to focus on ac revenue meter data. These data have the lowest uncertainty of any item measured on PV power generating systems. This approach avoids calibration drift/soiling change issues that are common with irradiance sensors. Furthermore, periods of clipping, where true dc degradation is "hidden" because of the maxed-out ac power limit, can also be identified and removed from this type of degradation analysis. The conclusion of the study is that systems built with SunPower's interdigitated-back-contact (IBC) technology show median annual degradation rates of -0.20%/year, though this is surrounded by a very large standard deviation of ±0.22%/year. The system ages ranged from 5 to 8 years for the systems using IBC modules, periods which are considered brief but satisfactory for identifying long-term trends.

DNV also requested supplemental access to review the detailed year-over-year degradation rate values that the above abstract is based on, as well as raw 15-minute data for a sample of systems, along with a white paper describing the data reduction algorithms with key sample analysis code. This review confirmed the above-reported median values to within 0.05%/yr. However, it is characteristic of this year-over-year analysis approach that the raw data exhibit large magnitude changes (usually within ±30% for year-over-year changes in this data) due to transient effects on performance. To counteract this volatility, robust median statistics are used to extract the desired "typical" results. This process is sensitive to the data that was used, so DNV used a separate bootstrap method to estimate a 95% confidence interval for the median estimated from this sample. The result of this separate analysis for 216 systems, including 6,199 sets of six consecutive years of slopes, was a very similar -0.25%/yr±0.05%/yr. The standard deviation of ±0.05%/yr is only used to confirm the median and is not to be used as the uncertainty of the system-level degradation uncertainty. When we examined shorter periods of contiguous years of data we obtained values near -0.20%/yr, but such data are also more likely to be affected by early-life reduced availability so we prefer the results based on longer time periods. This additional analysis confirms the -0.25%/yr rate that SunPower typically utilizes when contracting residential systems.

While this estimate may closely represent the true median degradation rate, it is not suited for use in financial stress tests, which are more appropriately represented by the distribution of per-system degradation rates. Any one of these estimates could stand in for the apparent long-term performance trend in a particular PV system such as this one, and the standard deviation of those rates is 0.7%/yr. This issue of high uncertainty is intrinsic to the degradation problem in general, and is not specific to SunPower or this project.

APPENDIX C – Validation of Production Estimates

DNV has attempted to replicate the Sponsor's energy forecasting process. System specifications and validation results are listed below.

Table C-1 SolarAnywhere Fleetview inputs for audits 1 to 5

Audit #	1	2	3	4	5
ID	RPV-07683	RPV-32529	RPV-32540	RPV-34357	RPV-36853
City	Storrs Mansfield	Waterbury	Woodbridge	Middletown	Fairfield
State	CT	CT	CT	CT	CT
ZIP Code	6268	6704	6525	6457	6825
PTO Date	42170	43448	43322	43388	43490
PV Module Manufacturer	Canadian Solar	Silfab	SunPower	SunPower	Hanwha
PV Module Model	CS6P-255PX	SLA 290-M	SPR-X21-350-BLK-D-AC	SPR-X22-360-D-AC	Q.PEAK DUO BLK-G5 310
Module Pmax (W)	255	290	350	360	310
DC Power (kWp)	6.12	8.7	14.7	9.36	6.2
Inverter Manufacturer	SolarEdge	SolarEdge	SunPower	SunPower	SolarEdge
Inverter Model	SE5000A-US	SE7600H-US	SPR-X21-350-BLK-D-AC	SPR-X22-360-D-AC	SE7600H-US
No. of Inverters	1	1	42	26	1
Array 1 - DC Power (kWp)	6.12	3.48	14.7	1.44	6.2
Array 1 - Tilt (°)	18	18	16	33	40
Array 1 - Azimuth (°)	242	87	153	353	221
Array 1 - Average Shading Loss (%)	78%	96%	73%	85%	77%
Array 2 - DC Power (kWp)		2.9		6.12	
Array 2 - Tilt (°)		18		33	
Array 2 - Azimuth (°)		267		173	
Array 2 - Average Shading Loss (%)		79%		80%	
Array 3 - DC Power (kWp)		1.16		1.8	
Array 3 - Tilt (°)		18		33	
Array 3 - Azimuth (°)		177		263	
Array 3 - Average Shading Loss (%)		99%		66%	

Audit #	1	2	3	4	5
Array 4 - DC Power (kWp)		1.16			
Array 4 - Tilt (°)		18			
Array 4 - Azimuth (°)		357			
Array 4 - Average Shading Loss (%)		97%			

Table C-2 SolarAnywhere Fleetview inputs for audits 6 to 10

Audit #	6	7	8	9	10
ID	RPV-34389	RPV-38804	RPV-39966	RPV-39980	RPV-40122
City	Waterford	Bridgeport	Trumbull	Stamford	Stratford
State	CT	CT	CT	CT	CT
ZIP Code	6385	6604	6611	6902	6615
PTO Date	43399	43707	43637	43608	43706
PV Module Manufacturer	Hanwha	Silfab	Hanwha	LG Electronics	LG Electronics
PV Module Model	Q.PEAK-BLK G4.1 295	SLA 320-M	Q.PEAK DUO BLK-G5 315	LG330N1C-A5	LG360Q1C-A5
Module Pmax (W)	295	320	315	330	360
DC Power (kWp)	6.49	5.12	5.67	2.64	10.08
Inverter Manufacturer	SolarEdge	SolarEdge	Enphase	SolarEdge	SolarEdge
Inverter Model	SE5000H-US	SE3800H-US	IQ7-60-2-US	SE3000H-US	SE10000H-US
No. of Inverters	1	1	18	1	1
Array 1 - DC Power (kWp)	6.49	5.12	4.725	2.64	10.08
Array 1 - Tilt (°)	27	40	21	21	23
Array 1 - Azimuth (°)	226	155	130	201	187
Array 1 - Average Shading Loss (%)	71%	99%	89%	81%	91%
Array 2 - DC Power (kWp)			0.945		
Array 2 - Tilt (°)			40		
Array 2 - Azimuth (°)			221		
Array 2 - Average Shading Loss (%)			80%		

Table C-3 SolarAnywhere Fleetview inputs for audits 11 to 15

Audit #	11	12	13	14	15
ID	RPV-41114	RPV-41191	RPV-41227	RPV-41651	RPV-42057
City	Windsor	West Granby	Oxford	East Haven	Meriden
State	CT	CT	CT	CT	CT
ZIP Code	6095	6090	6478	6512	6451
PTO Date	43615	43664	43628	43691	43773
PV Module Manufacturer	Hanwha	Solaria	LG Electronics	REC Solar	Silfab
PV Module Model	Q.PEAK BLK-G4.1 295	POWERXT-355R-PD	LG365Q1C-A5	REC290TP2 BLK	SLA310M
Module Pmax (W)	295	355	365	290	310
DC Power (kWp)	4.13	7.455	20.44	5.8	5.27
Inverter Manufacturer	SolarEdge	Enphase	Enphase	SolarEdge	SolarEdge
Inverter Model	SE3800H-US	IQ7PLUS-72-US	IQ7PLUS	SE5000H-US	SE3800H-US
No. of Inverters	1	21	56	1	1
Array 1 - DC Power (kWp)	4.13	7.455	8.76	5.8	3.1
Array 1 - Tilt (°)	18	45	34	23	16
Array 1 - Azimuth (°)	178	128	184	208	111
Array 1 - Average Shading Loss (%)	70%	52%	95%	77%	95%
Array 2 - DC Power (kWp)			1.46		2.17
Array 2 - Tilt (°)			34		39
Array 2 - Azimuth (°)			184		111
Array 2 - Average Shading Loss (%)			97%		89%
Array 3 - DC Power (kWp)			1.46		
Array 3 - Tilt (°)			34		
Array 3 - Azimuth (°)			184		
Array 3 - Average Shading Loss (%)			91%		
Array 4 - DC Power (kWp)			2.555		
Array 4 - Tilt (°)			28		
Array 4 - Azimuth (°)			275		
Array 4 - Average Shading Loss (%)			97%		

Audit #	11	12	13	14	15
Array 5 - DC Power (kWp)			3.65		
Array 5 - Tilt (°)			34		
Array 5 - Azimuth (°)			184		
Array 5 - Average Shading Loss (%)			88%		
Array 6 - DC Power (kWp)			3.65		
Array 6 - Tilt (°)			34		
Array 6 - Azimuth (°)			184		
Array 6 - Average Shading Loss (%)			75%		

Table C-4 SolarAnywhere Fleetview inputs for audits 16 to 20

Audit #	16	17	18	19	20
ID	RPV-42360	RPV-42422	RPV-42425	RPV-44212	RPV-45786
City	Fairfield	Avon	Branford	Windham	Wolcott
State	CT	CT	CT	CT	CT
ZIP Code	6824	6001	6405	6280	6716
PTO Date	43814	43684	43686	43733	43781
PV Module Manufacturer	LG Electronics	Hanwha	Hanwha	REC Solar	Hanwha
PV Module Model	LG335N1C-A5	Q.PEAK DUO-G5 320	Q.PEAK DUO BLK-G5 320	REC290TP2 BLK	Q.PEAK DUO BLK-G5 315
Module Pmax (W)	335	320	320	290	315
DC Power (kWp)	10.72	9.6	2.24	3.77	4.41
Inverter Manufacturer	Enphase	SolarEdge	Enphase	SolarEdge	SolarEdge
Inverter Model	IQ7-60-2-US	SE7600H-US	IQ7PLUS-72-2-US	SE3800H-US	SE3800H-US
No. of Inverters	32	1	7	1	1
Array 1 - DC Power (kWp)	4.02	9.6	0.96	3.77	4.41
Array 1 - Tilt (°)	27	27	34	18	29
Array 1 - Azimuth (°)	138	181	148	255	185
Array 1 - Average Shading Loss (%)	97%	76%	84%	66%	94%
Array 2 - DC Power (kWp)	5.36		1.28		
Array 2 - Tilt (°)	10		40		

Audit #	16	17	18	19	20
Array 2 - Azimuth (°)	138		238		
Array 2 - Average Shading Loss (%)	96%		87%		
Array 3 - DC Power (kWp)	1.34				
Array 3 - Tilt (°)	27				
Array 3 - Azimuth (°)	138				
Array 3 - Average Shading Loss (%)	99%				

Table C-5 SolarAnywhere Fleetview results for audits 1 to 5

Audit #	1	2	3	4	5
ID	RPV-07683	RPV-32529	RPV-32540	RPV-34357	RPV-36853
As-built expected first year production [kWh]	6,344	8,785	14,348	8,698	6,350
DNV Prediction from SolarAnywhere FleetView [kWh/year]	-	8,595	14,348	8,698	6,350
Deviation [%]	-	2.20%	0.00%	0.00%	0.00%

Table C-6 SolarAnywhere Fleetview results for audits 6 to 10

Audit #	6	7	8	9	10
ID	RPV-34389	RPV-38804	RPV-39966	RPV-39980	RPV-40122
As-built expected first year production [kWh]	6,352	6,748	6,208	2,996	12,292
DNV Prediction from SolarAnywhere Fleetview [kWh/year]	6,352	6,748	6,208	2,996	12,292
Deviation [%]	0.00%	0.00%	0.00%	0.00%	0.00%

Table C-7 SolarAnywhere Fleetview results for audits 11 to 15

Audit #	11	12	13	14	15
ID	RPV-41114	RPV-41191	RPV-41227	RPV-41651	RPV-42057
As-built expected first year production [kWh]	3,919	4,238	24,157	6,037	5,649
DNV Prediction from SolarAnywhere Fleetview [kWh/year]	3,919	4,238	24,158	6,037	5,650
Deviation [%]	0.00%	0.00%	0.00%	0.00%	0.00%

Table C-8 SolarAnywhere Fleetview results for audits 16 to 20

Audit #	16	17	18	19	20
ID	RPV-42360	RPV-42422	RPV-42425	RPV-44212	RPV-45786
As-built expected first year production [kWh]	13,182	10,059	2,387	2,991	5,496
DNV Prediction from SolarAnywhere Fleetview [kWh/year]	13,182	10,059	2,387	2,991	5,496
Deviation [%]	0.00%	0.00%	0.00%	0.00%	0.00%

APPENDIX D – DNV Inspection Summary

See attached file "10271931 CT Green Bank – DNV Inspection Summary"

About DNV

We are the independent expert in assurance and risk management. Driven by our purpose, to safeguard life, property and the environment, we empower our customers and their stakeholders with facts and reliable insights so that critical decisions can be made with confidence. As a trusted voice for many of the world's most successful organizations, we use our knowledge to advance safety and performance, set industry benchmarks, and inspire and invent solutions to tackle global transformations.