Solar Photovoltaic Forecast Methodology

Version 2.0

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Table of Contents

List of Tables

List of Equations

Abbreviations and Acronyms

AC	Alternating Current
AEF	Average emission factor
AVERT	Avoided Emissions and generation Tool
CO2	Carbon dioxide
CH4	Methane
DC	Direct Current
deg	Degrees (angle)
EF	Emission factor
eGRID	Emissions & Generation Resource Integrated Database
EPA	United States Environmental Protection Agency
FMU	Forecasted Mitigation Unit
GHG	Greenhouse gas
kW	Kilowatt
lb/MWh	Pound per megawatt-hour
LID	Light-induced degradation
MEF	Marginal emission factor
N2O	Nitrous oxide
NREL	National Renewable Energy Laboratory
PV	Photovoltaic
Reserve	Climate Action Reserve
RPS	Renewable portfolio standard
SSR	Source, sink, and reservoir
STC	Standard test conditions
t	Metric ton (or tonne)

1 Introduction

The Climate Action Reserve (Reserve) is an environmental nonprofit organization that promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. Based in Los Angeles, the Reserve is the foremost carbon offset registry in North America with internationally recognized expertise in project-level GHG accounting. The Reserve establishes regulatory-quality standards for the development and quantification of GHG emission reduction projects; issues GHG emission reduction credits for use in compliance and voluntary carbon programs; and tracks the transaction of credits over time in transparent, publicly-accessible systems. Adherence to the Reserve's standards ensures that emission reductions associated with projects are real, permanent, and additional, thereby instilling confidence in the environmental benefit, credibility, and efficiency of carbon markets.

Climate Forward, a greenhouse gas mitigation program of the Climate Action Reserve, provides a practical solution to companies and organizations seeking cost-effective mitigation of anticipated (i.e., future) operational and/or project-related GHG emissions. Climate Forward facilitates investments in GHG reduction[1] activities that are practical, scientifically-sound, transparent, and aligned with forward-looking mitigation needs such as the California Environmental Quality Act (CEQA). Climate Forward will drive forward-looking investment into actions expected to result in GHG reductions, with a goal of expanding the scope and scale of feasible emission reduction project types.

Climate Forward is designed to provide companies, organizations, developers, and other entities with a conservative, robust, and methodologically rigorous option to mitigate an estimate of expected GHG emissions, on a voluntary or compliance basis, using FMUs generated from mitigation projects under this program. Climate Forward fundamentally differs from existing carbon credit programs through its focus on projecting and crediting estimated emission reductions on an *ex ante* basis. Under Climate Forward, estimated GHG reductions from the mitigation project are recognized as Forecasted Mitigation Units (FMUs), which are each equal to one metric ton of carbon dioxide equivalent (CO_2e) expected to be reduced or sequestered. FMUs can be retired for multiple purposes, including for CEQA mitigation or for other voluntary mitigation purposes.

The Climate Forward Solar Photovoltaic Forecast Methodology provides guidance to account for, report, and confirm forecasted (i.e., *ex ante*) greenhouse gas (GHG) emission reductions associated with renewable power generation realized by installing grid-connected solar photovoltaic (PV) systems ("solar PV project" or "project"). Project proponents that initiate solar PV projects use this document to quantify and register forecasted GHG emission reductions with Climate Forward on an *ex ante* basis. The methodology provides eligibility rules and methods to calculate expected reductions, performance-monitoring instructions, and procedures for reporting project information to Climate Forward. Additionally, a Project Implementation Report will receive independent confirmation by a Reserve-approved confirmation body selected by the project proponent. Guidance for confirmation bodies to confirm reductions is provided in the Climate Forward Confirmation Manual and Section 8 of this methodology.

[1] Throughout this document, the term "reduction" is intended to address both GHG emission reductions that are the result of activities designed to reduce or avoid emissions, and GHG removals, which are those activities aimed at removing atmospheric CO_2 at rates that exceed business as usual sequestration.

This methodology is designed to ensure the complete, consistent, transparent, accurate, and conservative *ex ante* quantification and confirmation of GHG emission reductions associated with solar PV projects.

2 The GHG Reduction Project

2.1 Project Definition

For the purpose of this methodology, the project is defined as the installation and operation of a grid-connected solar PV system (a "PV installation") that will produce electricity for use on or off site, offsetting electricity generation from the electrical grid.

One solar PV installation location constitutes one "installation site". Sites that are eligible to host a PV project under this methodology must fall within disadvantaged communities and must meet the eligibility requirements set out in Section 3. Refer to *Box 1.1 GHG Reductions in Capped Sectors* of the Climate Forward Program Manual for the criteria to define a disadvantaged community.

The baseline scenario is the continued generation of electricity at the current marginal emissions rate from the grid (Section 5.1). The project scenario is the installation of a grid-connected PV system and use of solar energy to meet electricity demand (Section 5.2). Quantification of emission reductions from a solar PV project is described in Section 5 and is based on the amount of displaced grid energy generation via grid-connected solar energy generation and forecasted grid emission factors, accounting for increasing renewable electricity in future years. Eligible PV systems, along with default parameters and emission factors required for the quantification of emission reductions under this methodology, are listed in a separate Solar Photovoltaic Forecast Methodology Parameters document.[2]

A project may consist of one solar PV installation or a group of installations, collectively referred to as a "batch". Each installation site in a batch must meet the project definitions set forth in this section and the eligibility rules set forth in Section 3. Similarly, the emissions benefits for the solar PV system at each installation site must be quantified separately, as described in Section 5, with the resulting emission reductions from all installation sites summed together for total project emission reductions.

To be eligible, projects must meet the following criteria:

1. Solar PV systems must be new installations, (i.e., this methodology is not applicable to existing, previously installed solar PV systems);
2. Solar panel systems, components, and installation parameters must fit within the constraints of the calculation model PVWatts® (described further in Section 5.3), or an alternative quantification methodology that has been accepted by the Reserve; and,
3. Projects must meet the other eligibility criteria described in Section 3.

2.2 The Project Proponent

The "project proponent" is an entity that has an active account on the Climate Forward registry, submits a project for listing and registration with Climate Forward, and is ultimately responsible for all project reporting and confirmation. In all cases, the project proponent must attest to the Reserve that they have exclusive claim to the GHG reductions resulting from the project. At the time a project is confirmed, the project proponent must attest that no other entities are reporting or claiming (e.g., for voluntary reporting or regulatory compliance purposes) the GHG reductions

[2] The most current version of the Solar Photovoltaic Project Forecast Methodology Parameters file may be downloaded from https://climateforward.org/program/methodologies/solar-photovoltaic/.

caused by the project.[3] The Reserve will not issue Forecasted Mitigation Units (FMUs) for GHG reductions that are reported or claimed by entities other than the project proponent.

2.3 Project Parameters

All Reserve-approved quantification parameters for this methodology are listed in the Solar Photovoltaic Project Forecast Methodology Parameters document.[4] The project proponent may propose additions or changes to all parameters by demonstrating the appropriateness of such changes to the Reserve, though the values for all parameters must be approved by the Reserve before a project can be listed and the parameter values can be employed in the calculation of emission reductions. The project proponent must provide the Reserve with robust evidence demonstrating to the Reserve's satisfaction that proposed parameter values are reasonable and conservative. Examples of evidence that may satisfy this requirement include independent baseline studies conducted within 10 years of the project start date, literature reviews or independent expert testimony.

Confirmation bodies must confirm the correct parameter values (as published in the most recent version of the Solar Photovoltaic Project Forecast Methodology Parameters document) have been used, however, the confirmation body will not need to review materials provided in support of the use of such parameters (i.e., reference documents).

[3] A standard form for this attestation will be posted on the Climate Forward website at http://www.climateactionreserve.org/climate-forward/program-and-project-forms/.

[4] The most current version of the Solar Photovoltaic Project Forecast Methodology Parameters file may be downloaded from https://climateforward.org/program/methodologies/solar-photovoltaic/.

3 Eligibility Rules

Projects must fully satisfy the following eligibility rules in order to be registered with Climate Forward. The criteria only apply to projects that meet the definition of a GHG reduction project (Section 2.1).

Eligibility Rule I:	Location	⟶	Regions able to be modeled with PVWatts® or an alternative quantification methodology that has been accepted by the Reserve
Eligibility Rule II:	Start Date and Crediting Period	⟶ ⟶	Submitted within one year of start date; confirmed within two Project-specific expected useful lifetime of the PV system(s)
Eligibility Rule III:	Additionality	⟶ ⟶	Meet performance standard Exceed regulatory requirements
Eligibility Rule IV:	Environmental and Social Safeguards	⟶	No negative environmental and social impacts
Eligibility Rule V:	Regulatory Compliance	⟶	Comply with all applicable laws
Eligibility Rule VI:	Ownership and Double Counting	⟶	Must not receive credits from more than one program, where GHG boundaries overlap
Eligibility Rule VII:	Project Resilience Measures	⟶	Project must address risks of failure to reach expectations
Eligibility Rule VIII:	Market Expansion Objective	⟶	Expand opportunities for GHG mitigation
Eligibility Rule IX:	Demonstration of *Ex Ante* Suitability	⟶	Project activity must be suitable for *ex ante* crediting

3.1 Location

Only solar PV installations located in regions able to be modeled by the PV Watts® Calculator, or another quantification methodology or tool that has been approved by the Reserve, are eligible to register FMUs with Climate Forward under this methodology.[5] The project proponent must demonstrate the project's installation site(s) are wholly included in the geographic scope of the PVWatts® tool, or alternative method approved by the Reserve, at the time of project submittal.

3.2 Project Start Date and Crediting Period

The emission reductions will begin at the date of initial operation and active generation of grid-connected solar electricity at each installation site, to the extent that this may be different from

[5] As of this writing, the PVWatts® Calculator (Version 6) can forecast electricity generated by solar PV systems through "the Americas including Hawaii between about 21 degrees South latitude (about 300 km North of Sao Paolo, Brazil) to about 60 degrees North (about 200 km south of Anchorage, Alaska), and the Indian subcontinent and parts of Central Asia" NREL. 2018. *Welcome to the new PVWatts®!* Available at https://pvwatts.nrel.gov/version_6.php. Accessed: August 2018.

the date of equipment installation. For projects that include a batch of installation sites, the project start date is defined as the earliest date of initial operation and active generation of electricity across all installation sites in the batch. The project proponent must provide evidence of the date(s) the solar PV installation(s) became operational (e.g., jurisdictional/utility inspection results, notices of permission to operate (PTO), etc.). To be eligible for inclusion in a project, the solar PV system at each installation site must be delivering useful electricity prior to the initiation of confirmation activities for that project.

The project must be submitted to Climate Forward no more than one year after the project start date, and the confirmation must be completed no later than two years after the project start date. Projects may always be submitted prior to the project start date.

All projects that pass the eligibility requirements set forth in this methodology as of the project start date are eligible to register FMUs with Climate Forward for the duration of the project's crediting period. A crediting period is the length of time over which GHG emission reductions are quantified and forecast. Emission reductions for each project will be calculated as the sum of the forecasted maximum emission reductions realized by each installation site over the lifetime of the project PV systems. Crediting periods representative of the expected useful lifetime of a PV system will be determined on a case-by-case basis, depending on the system information provided by the project proponent (e.g., operations and maintenance contracts and warranty start dates and periods) for each installation site. For projects consisting of a batch of installations sites, each installation site may have its own unique crediting period, depending on the individual PV systems. System crediting periods are proposed upon project submittal and established upon successful completion of project confirmation. The project proponent must also provide evidence that operations and maintenance will be undertaken to maintain the solar PV panels for the duration of the crediting period.

3.3 Additionality

Climate Forward registers only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of the project.

Projects must satisfy the following tests to be considered additional:

1. The performance standard test
2. The legal requirement test

3.3.1 The Performance Standard Test

Projects pass the performance standard test by meeting a methodology-wide performance threshold – i.e., a standard of performance applicable to all prospective projects, established on an *ex ante* basis. The performance standard threshold represents "better than business as usual" energy consumption and/or generation. If the project meets the threshold, then it exceeds what would happen under the "business as usual" scenario and generates additional GHG reductions. This methodology uses a technology-specific threshold: the installation of a solar PV system.

A project passes the performance standard test for additionality if the project installs a solar PV system or systems, and at the time of installation the host site was considered to be in a disadvantaged community (see Section 2.1 for further details regarding demonstrating the project is in a disadvantaged community) and:

- (i) The system is installed on an existing residential rooftop; or

- (ii) the system is installed at commercial, public, industrial or agricultural premises, it must be demonstrated (e.g., through contractual commitments) that at least 70% of the expected power produced is intended to be consumed by the project within the given disadvantaged community by existing consumers, and that less than 30% of expected generation is exported to the grid.

The Solar Photovoltaic Project Forecast Methodology Parameters document includes a list of regions for where it has been demonstrated to the satisfaction of the Reserve that the performance threshold has been met, as well as reference materials used to demonstrate additionality, and the specific parameters and emission factors for such regions. If a proposed project is located in a region not currently included in the *Parameters* document, prior to submittal, the project proponent shall demonstrate to the Reserve's satisfaction that the technology-specific threshold is met for the region in which each project is implemented. Documentation to support such assertions may include surveys of market penetration rates, analyses of other incentives, assessments of barriers to implementation, and other evaluations to justify why solar PV installations in the region(s) of the installation sites pass the performance standard test for additionality. An example of such an assessment for existing buildings in the State of California is provided in Appendix A.

The performance standard test is applied at the time of the project's start date. All projects that pass this test at the project's start date are eligible to register FMUs with Climate Forward for the duration of the project's crediting period, even if the performance standard changes after the project's start date. Each installation site in a batch must pass the performance standard test to be eligible for inclusion in the project.

3.3.2 The Legal Requirement Test

All projects are subject to a legal requirement test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to any law (including any rules, regulations, or other legally binding mandates) issued by any authority with jurisdiction over the project. A project passes the legal requirement test when there are no such legal requirements for the installation of solar PV in the project grid region. For example, at the time of this writing, there is no state-wide rule, regulation, or requirement for *existing* commercial, residential, and industrial buildings in California to install solar PV systems. However, on May 8, 2018, the California Energy Commission adopted building standards that require solar PV systems on new construction of residential buildings, beginning January 1, 2020.[6] As such, solar PV installations at newly constructed residential buildings in California do not pass the legal requirement test for additionality. Each installation site in a batch must pass the legal requirement test to be eligible for inclusion in the project. The project proponent must also demonstrate that the project was not established or implemented and was not operated at any time prior to the start date, in anticipation of, or to avoid or satisfy the anticipated requirements of any law.

The Solar Photovoltaic Project Forecast Methodology Parameters document includes a list of regions for where it has been demonstrated to the satisfaction of the Reserve that the legal requirement test has been passed, as well as reference materials used to demonstrate additionality. The Reserve expects the project proponent to perform a review of existing and pending regulations, including local agency ordinances or rulings, to identify any specific

[6] Additional information regarding California's 2019 Title 24, Part 6, Building Energy Efficiency Standards may be found online at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency

regulatory requirements that would mandate the installation of [electricity generation from] grid-connected solar PV systems.

The legal requirement test is applied at the time of a project's start date. Each installation site in a batch must pass the legal requirement test at the time of their respective start dates to be eligible for inclusion in the project. To satisfy the legal requirement test, project proponents must submit a signed Attestation of Legal Additionality form prior to the commencement of confirmation activities. In addition to the attestation, the Project Implementation Report must include procedures that the project proponent will follow to ascertain and demonstrate that the project passes the legal requirement test at the time of a project's start date. All projects that pass this test at the project's start date are eligible to register reductions with Climate Forward for the duration of the crediting period, even if legal requirements change or new legal requirements are enacted during that period. The project proponent should include documentation to justify that the project passes the legal requirement test. The confirmation body must confirm the Attestation of Legal Additionality by reviewing evidence provided by the project proponent, and any other evidence they feel is necessary such as literature reviews, independent expert testimony, or letters from relevant government agency representatives, or other means.

3.4 Environmental and Social Safeguards

The project proponent must attest that the project will not materially undermine progress on environmental and social issues such as air and water quality, endangered species and natural resource protection, and environmental justice. The project proponent must provide applicable authorizations, permits, and certifications from the appropriate authorities required for project operations to the confirmation body at the commencement of confirmation activities. Given the environmentally non-intensive nature of solar PV installations, there are not likely any appreciable, negative environmental or social impacts. Projects with the proper permits, certifications, and regulatory approvals for the installation of the solar PV systems will be deemed in conformance with the environmental and social safeguard requirements of this section.

Furthermore, the Reserve encourages the project proponent to include information in the Project Implementation Report regarding any non-GHG benefits of the project activities to the environment or society. This may include discussion of how the project aligns with the United Nations' Sustainable Development Goals,[7] as well as additional quantification of any non-GHG benefits (such quantification is not specified by this methodology).

3.5 Regulatory Compliance

The project proponent must sign an Attestation of Regulatory Compliance prior to the commencement of project confirmation activities, attesting that no laws have been broken in the implementation of each project, and provide an assessment of any aspects of the project which may present a risk of future regulatory violations. Where such risks are identified, the project proponent shall describe measures undertaken to reduce and/or mitigate these risks. The confirmation body shall endeavor to confirm that the project implementation did not result in any regulatory noncompliance, and also that appropriate measures have been implemented to avoid potential future noncompliance during the project crediting period.

[7] Additional information regarding the Sustainable Development Goals may be found online at https://sustainabledevelopment.un.org/.

3.6 Ownership and Double Counting

The project proponent must attest that the project is not being submitted for emission reductions credit under any other carbon crediting program, world-wide. By signing the Attestation of Title, the project proponent attests that the FMUs have not and will not be registered with, reported in, held, transferred or retired via any emissions registry or inventory other than the Climate Forward registry, or registered with Climate Forward under a different project title or location. Evidence of transfer of rights of all GHG emission reductions to the project proponent is required and must be confirmed by the confirmation body. The project proponent must provide a signed Attestation of Title document for each project, attesting to their ownership of all GHG emission reductions generated by the project. This signed attestation, and any necessary supporting evidence, must be provided to the confirmation body. In addition to the Attestation of Title, confirmation bodies may wish to review relevant contracts, agreements, and/or supporting documentation between project proponents, end users, utilities (e.g., utility sign offs), and other parties that may have a claim to the FMUs generated by the project.

The project proponent must attest that the project is not being submitted for emission reduction credits under any other carbon crediting program. The project proponent must also attest and provide clear documentation demonstrating that the project is permanently retaining, contractually retiring, or retiring in an electronic tracking system, the Renewable Energy Certificates (RECs) or environmental attributes associated with production for which FMUs are issued. Confirmation bodies must review contracts, purchase agreements, or tracking system reports as necessary.

Confirmation that there is no double counting shall be verified from the unique identity of the PV systems and installation sites using unique serial numbers and detailed location descriptions (e.g., street address of the solar PV system plus a description of the installation site, such as “south eastern corner of rooftop”), including GPS coordinates. That the PV systems are not part of any other carbon crediting project or program shall be confirmed by reviewing public sources of data made available by other carbon crediting programs.

3.7 Project Resilience Measures

Project Resilience Measures are to be implemented by the project to address the risks of project abandonment, underperformance, and/or failure. In addition to the requirements for establishing the project start date and crediting period (Section 3.2), measures to reduce and/or mitigate potential future noncompliance (Section 3.5), project-specific adjustments to PV system losses (Section 5.3), and estimating solar PV performance decline (Section 5.4), the Solar Photovoltaic Project Forecast Methodology requires long-term service contracts for continued system monitoring and maintenance and periodic inspections.

Another optional resilience measure which projects are encouraged to implement would be evidence that the building itself will continue to be occupied for the lifetime of the system(s). For residential buildings, this could be economic or housing data showing that the building is sited in a stable community. For commercial and industrial buildings, this could be evidence that the building owner(s) and/or tenant(s) could reasonably be expected to remain stable for the lifetime of the system(s).

3.8 Market Expansion Objective

Solar PV projects submitted under the Solar Photovoltaic Project Forecast Methodology encourage actions leading to GHG reductions that are generally not feasible under existing

GHG crediting or incentive programs. Firstly, the carbon offset market in the United States has minimal opportunity for carbon credits for renewable energy projects that displace consumption of grid electricity. With emission reductions occurring at grid facilities not owned or controlled by project developers, it can be difficult to establish ownership for the reductions and the reductions may be prone to double counting. Furthermore, with an emission cap in place for the power sector in the State of California, it is not possible to issue offset credits for renewable energy projects that affect emissions at capped power plants because doing so would result in the double counting of emission reductions. Secondly, in establishing the methodology's technology-specific performance threshold (Section 3.3.1), after careful evaluation of industry practice and drivers and barriers to the adoption of solar PV installation in the State of California, where the majority of solar installations in the United States occur (exceeding the next closest State by ~20,000 MW in installed solar electric capacity[8]), it was determined the installation of solar PV systems at existing buildings in California exceeds common practice and is additional. Despite significant opportunity and existing incentives for PV systems (see Appendix A), there are substantial barriers to installing and operating solar PV systems, including the high upfront costs of installation, preventing them from being common practice. Despite a number of existing incentive programs, including net energy metering (NEM), property assessed clean energy (PACE) financing, and power purchase agreements (PPAs), there is an opportunity to install far greater numbers of solar PV at existing buildings (e.g., only roughly four to six percent of a viable 90 percent of existing rooftops in California have solar PV installations). The existing incentive programs are insufficient to significantly scale up installations and additional incentives could help close the gap between demand and affordability, leading to installations that otherwise may not have occurred.

Nationwide, while incentives also exist for the installation of solar PV systems, they are insufficient to drive large scale adoption. Existing incentives are also generally subject to political forces which cause great uncertainty. The carbon market does not currently provide a significant incentive for solar PV installations in the regions able to be modeled by the PV Watts® Calculator.

3.9 Demonstration of *Ex Ante* Suitability

The Solar Photovoltaic Project Forecast Methodology is suitable for *ex ante* crediting as it provides for the complete, consistent, transparent, accurate, and conservative quantification and confirmation of forecasted GHG emission reductions from the installation of and electricity generation from solar PV systems, while providing sufficient safeguards to ensure the activities continue for the duration of the crediting period.

The PVWatts® Calculator for calculating solar electricity generation is appropriately conservative and accounts for uncertainty and variation of production over the course of a year. System inputs and losses in PVWatts® are also adjusted based on project-specific information and age to improve the accuracy of the estimated solar electricity generation. As demonstrated in Section 5.1.1, grid-electricity emission factors can also be projected into the future. Specific safeguards to ensure projected emission reductions are realized throughout the crediting period; these include the Project Resilience Measures (Section 3.7), estimates of solar PV performance decline (Section 5.4), and requirements for evidence of continued implementation (Section 8.3.4).

[8] SEIA Top 10 Solar States 2018.

Solar PV panels and their components are also well-suited for a forward-looking approach. The panels are built to last, with highly durable components and few, if any, moving parts, and are often warrantied for 25 or even 30 years. Additionally, even after the end of their warranty period, solar panels continue to produce electricity, albeit with slightly lower efficiency over time. According to a study undertaken by the National Renewable Energy Laboratory (NREL),[9] which looked at the 'photovoltaic degradation' rates of approximately 2,000 solar installations, the average solar panel loses about half of a percentage point (0.5 percent) of efficiency per year,[10] this means that a panel at the end of its 25-year crediting period should still be operating at about 88 percent of its original capacity. However, not every panel will even see degradation rates as high as 0.5 percent. While the solar panels themselves are highly durable, the inverter (which converts the DC from the panels into AC for feeding into the grid) may need replacement sooner. The average inverter warranty ranges from 10 to 15 years. Unlike the PV panels themselves, inverters tend to simply fail at a point in time, rather than slowly degrade in performance. However, as systems transition from central inverters (which handle the output of all panels) to the use of 'micro-inverters' (which are installed or included with each panel), the durability of this component is expected to match that of the panels.[11]

High initial implementation costs continue to be an important barrier to solar PV installation. However, once installed, solar PV systems have relatively low ongoing maintenance, upkeep, and operation costs. Thus, the incentive from FMUs can help overcome the main barrier to solar PV installation and use.

[9] Jordan, Dirk C. and Sarah R. Kurtz. *Photovoltaic Degradation Rates — An Analytical Review.* National Renewable Energy Laboratory (NREL). Available at https://www.nrel.gov/docs/fy12osti/51664.pdf. Accessed April 2019.

[10] The same degradation rates are included in the quantification of emission reductions to estimate performance decline (Section 5.5).

[11] Cost of Solar, 2015. *How Long Do Solar Panels Last?* Available at http://www.costofsolar.com/how-long-do-solar-panels-last/. Accessed April 2019.

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs[12] (SSRs) that must be assessed by project proponents in order to determine the net change in emissions caused by installing solar PV panels. This methodology's assessment boundary captures sources from utility emissions due to the project's installation.

After their construction, solar PV panels are zero emission devices. Therefore, the only GHG SSRs included in the GHG Assessment Boundary are from reduced CO_2 emissions due to displacing grid-delivered electricity or fossil fuel use. All CO_2 emissions associated with this project are from anthropogenic sources (as opposed to biogenic).

Figure 4.1 below provides a general illustration of the GHG Assessment Boundary, indicating which SSRs are included and excluded from the project boundary. Table 4.1 provides a comprehensive list of the SSRs relevant to solar PV projects, and their reasons for inclusion or exclusion in the project boundary.

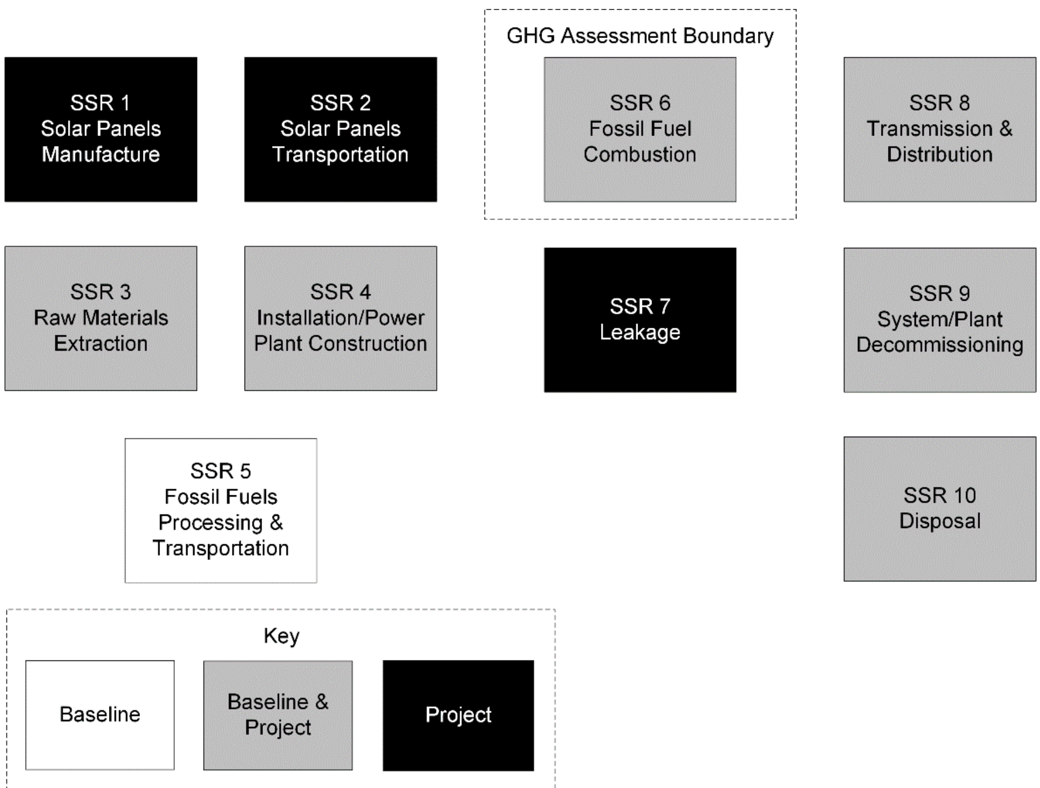

Figure 4.1. General Illustration of the GHG Assessment Boundary

[12] The definition and assessment of SSRs is consistent with ISO 14064-2 guidance.

Table 4.1 Description of all Sources, Sinks, and Reservoirs

SSR	GHG Source	Gas	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Justification/Explanation
1	Emissions from the manufacture of solar panels	CO_2 CH_4 N_2O	P	Excluded	Minor, one-time emission sources equivalent to or less than emissions from the manufacture of construction materials in the baseline.
2	Emissions from the transport of solar panels to the installation site	CO_2 CH_4 N_2O	P	Excluded	Minor, one-time emission sources equivalent to or less than emissions from the transport of fossil fuels in the baseline.
3	Emissions from raw materials extraction	CO_2 CH_4 N_2O	B, P	Excluded	One-time emission sources comparable in the project and baseline.
4	Emissions from installation/power plant construction	CO_2 CH_4 N_2O	B, P	Excluded	Minor, one-time emission sources significantly less for the project than for the baseline.
5	Emissions from processing and transport of fossil fuels	CO_2 CH_4 N_2O	B	Excluded	This source does not increase in the project scenario, thus exclusion is conservative.
6	Emissions from local utility's combustion of fossil fuels	CO_2	B, P	Included	Reduced CO_2 emissions from displaced electricity generation in fossil fuel-fired power plants due to the project activity are the main source of emissions under this methodology.
		CH_4 N_2O	B, P	Excluded	Minor emission sources anticipated to decrease from the baseline scenario.
7	Emissions from leakage	CO_2 CH_4 N_2O	P	Excluded	Negligible source of emissions; it is not anticipated that the project activity will materially cause an increase in GHG emissions at operations outside the project boundary.
8	Emissions from electricity transmission and distribution	CO_2 CH_4 N_2O	B, P	Excluded	Minor emission sources that may or may not be embedded in a region's emission factors; anticipated to decrease from the baseline scenario.
9	Emissions from system/plant decommissioning	CO_2 CH_4 N_2O	B, P	Excluded	Downstream emission sources difficult to quantify and likely greater in the baseline than for the project.

10	Emissions from disposal	CO_2	B, P	Excluded	Downstream emission sources difficult to quantify and likely greater in the baseline than for the project.
		CH_4			
		N_2O			

5 Quantifying GHG Emission Reductions

GHG emission reductions from each project are quantified by comparing modeled baseline emissions to project emissions at each installation site. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary that would have occurred in the absence of the solar PV project. Project emissions are GHG emissions that are expected to occur at sources within the GHG Assessment Boundary during the crediting period. Project emissions are then subtracted from the baseline emissions to quantify the project's total net GHG emission reductions. Emission reductions must be quantified independently for each installation site in the project and summed together to totalize the number of emission reductions from the batch, as shown in Equation 5.1.

Equation 5.1. Calculating GHG Emission Reductions

$$ER = BE - PE$$

Where,			<u>Units</u>
ER	=	Total emission reductions from the project	tCO_2e
BE	=	Lifetime baseline emissions of the project summed for the crediting period	tCO_2e
PE	=	Lifetime project emissions of the project summed for the crediting period, equal to zero for solar PV projects	tCO_2e

GHG emission reductions for FMU issuance in Climate Forward are quantified and awarded on an *ex ante* basis based on application of this methodology and confirmation of project implementation. Baseline emissions are calculated through modeling of the annual electricity output of the system and the application of an emission factor, while project emissions are expected to be zero, given that solar PV panels do not generate GHG emissions during operation, and any other potential sources are excluded from the GHG Assessment Boundary.

5.1 Estimating Baseline Emissions

Under this methodology, it is assumed that in the absence of the project (i.e., the installation and use of a grid-connected solar PV system), the baseline scenario would be the continued operations of existing electricity generation plants from a local utility. Therefore, baseline emissions are equivalent to the emissions associated with the amount of electricity that would have been generated and supplied by the installation site's local utility, likely from generation facilities on the margin, that is now being produced by the solar PV system in the project. Thus, baseline emissions are directly proportional to the amount of electricity generated by individual installation site's solar PV systems, as calculated by PVWatts®, multiplied by the appropriate GHG emission factor, as shown in Equation 5.2.

Equation 5.2. Calculating Baseline Emissions

$$BE = \sum_{i=1}^{n} \left(\sum_{y} EG_{PV,i,y} \times EF_{r,y} \right)$$

Where,			Units
BE	=	Lifetime baseline emissions of the project summed for the crediting period	tCO_2e
$EG_{PV,i,y}$	=	Estimated annual energy generation of solar PV installation, *i*, for year, *y*, of the crediting period, as determined using PVWatts® (Section 5.3)	MWh/year
$EF_{i,y}$	=	Annual region-specific grid emission factor for region *r*, for year *y*, of the crediting period	tCO_2e/MWh
y	=	Index for each year of the crediting period	
i	=	Index for each installation in the project	
n	=	The total number of installations in the project	
r	=	Index for the region of the installation site	

The emission factor (EF) refers to the amount of GHGs per unit of electricity produced by the grid. Selection of the appropriate EF is described in Section 5.1.1 below. To smooth hourly and seasonal variations in energy generation and usage, annual PVWatts® output, as described in Section 5.3 and Section 5.3.1, and annual EFs are used. The lifetime baseline emissions for each installation site are based on the same years of each installation site's crediting period (Section 3.2).

5.1.1 Emission Factor Selection

Emission factors in this methodology represent the amount of GHG emissions released to the atmosphere per unit of electricity generated for a given region over the course of a single year. The selection of the most appropriate emission factors for use in the quantification of GHG savings from a project depends on the project's location, scale, and data availability. The specific emission factors to be used for a given project will be determined and approved prior to the submittal of the project, based on supporting literature provided to the Reserve by the project proponent. In general, preference is given to emission factors with greater geographic-specificity than those with wider applicability. Reserve-approved emission factors are listed in the Solar Photovoltaic Project Forecast Methodology Parameters document.[13]

Solar-generated electricity generally replaces electricity that otherwise would be generated and supplied by the local utility's electricity grid, likely from marginal, rather than baseload, generating facilities that are operated coincident with peak demands. These units are the first to shut off when demand is reduced, and therefore better estimate the emissions benefits of

[13] The most current version of the Solar Photovoltaic Project Forecast Methodology Parameters file may be downloaded from https://climateforward.org/program/methodologies/solar-photovoltaic/.

reductions in grid-supplied electricity use. Thus, emission reductions from projects under this methodology are reductions from marginal emitting generating facilities on the grid due to the installation and operation of the solar PV systems at the installation sites. Given the small output of rooftop PV systems (as compared to baseload generating stations), marginal emission factors (MEFs) that represent the power generation sources at the time of the solar electricity production are the most reasonable metrics for assessing the avoided grid GHG emissions due to projects implemented under this methodology. Therefore, when available, utility-specific MEFs *must* be used.

In addition to selecting the most appropriate emission factors, the project proponent must also provide a method for how to forecast changes to the annual emission factors going forward for each year of the project crediting period. The implication embedded in this methodology is that each kilowatt-hour of electricity produced by solar panels from projects in this methodology will result in a lower reduction in future years, based on the assumption that the electricity it replaces will become less carbon-intensive over time. Regional annual energy outlook reports or renewable electricity mandates may be useful resources in determining the appropriate emission factor adjustment.[14] Both the selected starting emission factors and future adjustments must be approved by the Reserve prior to their use (i.e., at listing). The project proponent may also propose changes to any of the currently-approved emission factors contained in the *Parameters* document by demonstrating the appropriateness of such changes.

Calculating MEFs requires detailed information related to system load and demand for the utility serving a project and projected forward for the years of the project crediting period. As such, utility-specific MEFs may be difficult to obtain (or unavailable) and forecast into the future. If this is the case, the project proponent may propose alternative emission factors (e.g., utility-specific average emission factors, region-specific EPA eGRID non-baseload output emission rates or region-specific EPA AVERT emission factors) to use as a proxy for a utility-specific MEF and select the most conservative one available for the project's location. The project proponent must also demonstrate the challenges associated with the MEFs and the reasonableness of using the proposed alternative emission factors to the Reserve's satisfaction. For reference, Box 5.1 provides an example of how emission factors were selected and forecasted for projects located in Southern California.

Box 5.1. Selecting and Forecasting Emission Factors in Southern California

The Reserve-approved factors for use in this methodology for projects located in Southern California are utility-specific annual average forecasted grid electricity emission factors (AEFs). These factors were approved after it was sufficiently justified that MEFs could not be readily obtained and forecasted into the future. In California, utilities report their emissions per unit power distributed and the proportion of the electricity sourced from eligible renewables; these data are available in reports such as Corporate Sustainability Reports or through The Climate Registry. Each utility has a unique power mix, such that the emissions per unit of power delivered may vary substantially from one location to another within California. State-wide Renewable Portfolio Standard (RPS) targets are used to project how the electricity intensity factors will decrease in future target years, and linear interpolations are used to estimate annual average emission factors for intervening years.

For example, for the year 2016, Southern California Edison (SCE) reported 28.3 percent total energy from renewables, and the RPS targets for 2020, 2030, and 2045 are 33, 60, 100 percent in accordance with Senate Bill

[14] The Energy Information Administration produces the Annual Energy Outlook, which contains projections of regional electricity production and emissions, allowing for comparison of GHG intensity on an annual basis into the future. https://www.eia.gov/outlooks/aeo/ (accessed 5/31/2019).

(SB) 100, respectively. The non-renewable AEF per total energy delivered is calculated as the SCE-specific AEF divided by the SCE-specific non-renewable fraction (for example, 529 lb/MWh as reported in 2016 by SCE at 28.3 percent renewables equates to a non-renewable AEF of 738 lb/MWh). To estimate the 2020 AEF, the 2016 non-renewable AEF is multiplied by the 2020 non-renewable fraction (67%) which equates to a 494 lb/MWh. To interpolate the AEF for 2025, the 2020 AEF is interpolated with the 2030 AEF (738 lb/MWh multiplied by 40% = 295 lb/MWh), to arrive at 395 lb/MWh.

The types of fuels representing the non-renewable fraction are assumed to be constant during the project crediting period. The AEFs are based on a historical mix of electricity from non-RPS-eligible sources used as a basis for the projections and will be utility-specific. Projections of changes in the mix are not made, although it is recognized that variations will occur year-to-year depending on conditions (e.g., drought) because at this time, forecast of the projected fuel mix could not be completed with available data. However, the change in the fraction of RPS-eligible renewables in future years has been accounted for in the AEFs.

5.2 Estimating Project Emissions

The project scenario is the installation of a solar PV system and generation of solar energy. The amount of solar energy generated by the PV system, which displaces an equivalent amount of existing electricity generation from the local utility in the baseline, is a zero-emissions source of energy. As such, project emissions under this methodology are zero, as shown in Equation 5.3.

Equation 5.3. Project Emissions

THIS EQUATION IS FOR INFORMATIONAL PURPOSES ONLY. THERE ARE NO PROJECT EMISSIONS FOR SOLAR PV PROJECTS.

$$PE = \sum_{i=1}^{n} \left(\sum_{y} EG_{PV,i,y} \times EF_{PV,i,y} \right) = 0$$

Where,			<u>Units</u>
BE	=	Lifetime project emissions of the project summed for the crediting period	tCO_2e
EGPV,i ,y	=	Estimated annual energy generation of solar PV installation, i, for year, y, of the crediting period	MWh/year
EFi,y	=	Annual emission factor from solar PV energy generation for solar PV installation, i, for year, y, of the crediting period = 0	tCO_2e/MWh
y	=	Index for each year of the crediting period	
i	=	Index for each installation in the project	
n	=	Index for the number of installations in the project	

5.3 Estimating Solar PV Power Generation

The Solar Photovoltaic Project Forecast Methodology evaluates the electricity production of a grid-connected roof-or ground-mounted PV system using the PVWatts® Calculator developed by the National Renewable Energy Lab (NREL). This online calculator performs hourly simulations of a solar panel's operations over a single year to estimate its monthly and annual energy generation. PVWatts® gathers solar insolation data from several hundred meteorological stations across the world and takes user-specified PV system information to accurately model the electricity generated from the system. PVWatts® uses a set of assumptions that are appropriate for flat-plate PV systems with typical crystalline silicon or thin-film modules; it is not appropriate for systems using some types of thin-film modules, concentrating collectors, or for modules using novel cell technologies or module designs. Please see the PVWatts® Manual[15] for more details about the model.

To represent the system's physical characteristics, PVWatts® requires values for six basic and three advanced inputs as described below. When available, project-specific information must always be used for the six basic inputs in place of defaults, as outlined below. The default values for each parameter are justified in the PVWatts® Manual. A summary of the PVWatts® input parameters is also found below in Table 5.2.

The project proponent must run PVWatts® independently for each year of the crediting period, making the required System Losses adjustments, to estimate the annual solar electricity generation for each year of the crediting period.

The basic inputs required by PVWatts® include:

1. **DC system size (kW)**: The DC (direct current) power rating of the PV array in kilowatts (kW) at standard test conditions (STC). PVWatts® can model any size of a PV array. Historical utility data are commonly used to determine the appropriate size of the solar PV system. As such, system size must be project specific; a default value is not acceptable for use in this methodology.

2. **Module type**: The module type describes the PV modules in the array. PVWatts® includes three module types (see Table 5.1 below). The default value is a “Standard” module type, which represents typical poly-or mono-crystalline silicon modules. If project-specific information of the module type is unknown or unavailable, the default value may be used in this methodology.

Table 5.1. Module Type Options in PVWatts®

PVWatts® Module Type	Cell Material	Approximate Nominal Efficiency	Module Cover	Temperature Coefficient of Power
Standard	Crystalline silicon	15%	Glass	-0.47 %/°C
Premium	Crystalline silicon	19%	Glass with anti-reflective coating	-0.35 %/°C
Thin Film	Thin film	10%	Glass	-0.20 %/°C

3. **Array type**: The array type describes whether the PV modules in the array are fixed or track sun movement with one or two axes of rotation. The default value is for a fixed (open rack) array, which is appropriate for ground-mounted systems with no sun tracking. The typical residential installation is a fixed (roof mount) array. Other options that can be selected for a specific project include 1-axis, backtracked 1-axis, and 2-axis. The project proponent must select the array type(s) most appropriate for the system(s) in their project.

[15] PVWatts® Version 6 is the current version of the PVWatts® Calculator, however, the algorithms used to calculate energy output are the same as in Version 5. The PVWatts® Version 5 Manual remains the most current version of the manual. Users should refer to the most current version of the calculator and the manual, unless otherwise directed by the Reserve.

4. **System losses**: The system losses account for performance losses expected in a real system that are not explicitly calculated by the PVWatts® model equations. The default value is 14 percent based on the following categories: soil/shade/snow blocking the panels, mismatch, wiring, connections, light-induced degradation (LID) nameplate rating, age, and availability. The system loss categories of LID and age must be adjusted for each year of the crediting period, based on the guidance in Section 5.4. Soiling, shading, and snow must each be adjusted based on project-specific information appropriate and relevant for the location of each installation site in the project, provided by the project proponent and confirmed by the confirmation body.[16] The other categories may be adjusted based on project-specific information as well, otherwise the default values for the other system loss categories in the "Systems Losses (%) Loss Calculator" on PVWatts® must be used.

5. **Array tilt angle (deg)**: The tilt angle is the angle from horizontal of the PV modules in the array. For a fixed array, the tilt angle is the angle from horizontal of the array where 0° = horizontal, and 90° = vertical. For arrays with one-axis tracking, the tilt angle is the angle from horizontal of the tracking axis. The tilt angle does not apply to arrays with two-axis tracking. The PVWatts® default value for the tilt angle depends on the array type: for a fixed array, the default value is 20 degrees, and for one-axis tracking the default value is zero. If project-specific information of the tilt angle is unknown or unavailable, the default value for the project-specific array type may be used in this methodology.

6. **Array azimuth angle (deg)**: The azimuth angle is the angle clockwise from true north (fixed) or from true north of the axis of rotation (one-axis), describing the direction that the array faces (180° for south- and 0° for north-facing array). The azimuth angle does not apply to arrays with two-axis tracking. The default value is an azimuth angle of 180° (south-facing) for locations in the northern hemisphere and 0° (north-facing) for locations in the southern hemisphere. If project-specific information of the azimuth angle is unknown or unavailable, the default value for the project-specific array type may be used in this methodology.

The system design assumptions can be refined using three optional advanced inputs:

1. **DC to AC size ratio**: The DC to AC size ratio is the ratio of the inverter's AC rated size to the array's DC rated size. The default value is 1.1, which means that a 4-kW system size would be for an array with a 4 DC kW nameplate size at STC and an inverter with a 3.63 AC kW nameplate size.

2. **Inverter efficiency**: The inverter's nominal rated DC-to-AC conversion efficiency, defined as the inverter's rated AC power output divided by its rated DC power output. The default value is 96 percent. PVWatts® calculates the inverter's hourly operating

[16] This should be informed by the results of any onsite soiling, shading, and/or snow analyses, where relevant, completed prior to and/or during installation. For example, it would be anticipated that the factor for soiling may be greater than the PVWatts® default values for arid regions that receive below average annual rainfall; for shading, greater for systems installed below crown height for mature trees in the area; and for snow, greater for colder regions that receive regular snowfall each year. The tabulated results and/or maps from Appendix A and Appendix B in NREL's report *Integration, Validation, and Application of a PV Snow Coverage Model in SAM* (August 2017) may be used to inform the system losses due to snow cover for a project's given location. Available at https://www.nrel.gov/docs/fy17osti/68705.pdf.

efficiency based on the nominal efficiency. The DC-to-AC conversion derate factor was chosen to be in line with common practice in the industry.

3. **Ground coverage ratio**: The ground coverage ratio (GCR) is the ratio of module surface area to the area of the ground or roof occupied by the array. In PVWatts®, the GCR applies only to arrays with one-axis tracking and is used to calculate self-shading losses caused by shading of neighboring rows of modules in the array. A GCR of 0.5 corresponds to horizontal and would decrease with narrower spacing to a GCR of 1 (no space between modules). The default value is 0.4. For fixed and two-axis arrays, PVWatts® ignores the GCR input, so there is no need to set it to a particular value or change the default value.

The advanced parameters are assumptions that can be changed when additional information about the system is available. For most analyses default values are sufficient for the advanced inputs.

Table 5.2 Summary of PVWatts® Input Parameters

Model Inputs	Default Value	Prefer Project-Specific Value?	Value Changes Over Time?
BASIC INPUTS			
DC system size (kW)	NONE	Yes	No
Module type	Standard	Yes	No
Array type	Fixed (open rack)	Yes	No
System losses	14%[17]	Yes	Yes
Array tilt angle (deg)	20° (fixed) or 0° (1-axis tracking)	Yes	No
Array azimuth angle (deg)	180° (northern hemisphere) or 0˚ (southern hemisphere)	Yes	No
ADVANCED INPUTS			
DC to AC size ratio	1.1	Yes	No
Inverter efficiency	96%	Yes	No
Ground coverage ratio	0.4	Yes	No

[17] System losses are a composite of several factors affecting system performance. Project proponents should use project-specific values for the underlying parameters, some of which must be adjusted over time, as specified in Section 5.4.

5.3.1 Using the PVWatts® Calculator

PVWatts® is an online calculator.[18] The project proponent must adhere to the following steps to calculate the annual electricity production for each year of the crediting period, for each solar PV installation in the project.

1. On the PVWatts® homepage, enter the street address, zip code, or latitude and longitude of the installation site location in the "Get Started" box, and click "GO".
    a. PVWatts® uses this information to automatically identify solar resource data available at or near the system location.
2. On the "Solar Resource Data" page, confirm the latitude and longitude of the solar resource data site are appropriate (i.e., are within close proximity of) for the installation site, and click "Go to system info".
3. On the "System Info" page, modify the basic parameters for the solar PV installation based on project-specific information and defaults, where permissible, as stipulated in Section5.3. Once completed, click "Go to PVWatts® results".
    a. The advanced parameters can be modified provided the project proponent has the necessary additional information about the system.
    b. The "Retail Electricity Rate" section can be ignored.
4. The Results page displays the annual energy production estimate in kilowatt-hours (kWh) at the top of the page and the monthly energy production estimates in an underlying table. The estimated annual energy production (kWh) at the top of the page is the amount to be used as the annual energy generation of solar PV installation ($EG_{PV,i,y}$) in Equation 5.2.
5. Run the PVWatts® Calculator for each year of the crediting period, modifying the "System Losses" input as stipulated in Section 5.4, to compute an estimated solar PV output ($EG_{PV,i,y}$) for each year of the crediting period.
    a. The system loss categories can be modified by selecting the "Loss Calculator" next to the "System Losses (%)" on the "System Info" page.
6. Repeat the above steps for each solar PV installation in the project.

Further assistance can be found in the PVWatts® Manual and on the PVWatts® web application itself.

5.4 Estimating Performance Decline

Performance decline over the lifetime of each solar PV installation in the project is accounted for by making mandatory adjustments to two of the System Loss categories in the PVWatts® Calculator "System Losses (%) Loss Calculator" as follows:

- **Light-induced degradation (LID)**: LID is a phenomenon in which the power output of a module decreases when it is exposed to sunlight for the first time. After this initial period, the module power stabilizes and subsequently follows typical long-term degradation over the lifetime of the installation (~ 0.5%/year). The default LID loss of 1.5 percent is a typical value based on measurements of losses in different module types.
    - The LID must be 1.5 percent in year 1 of the project's crediting period and adjusted to 0.5 percent in all subsequent years

- **Age**: Effect of weathering of the PV modules on the array's performance over time. The default value is zero.

[18] As of this writing, the calculator is accessible at the following address: https://pvwatts.nrel.gov/index.php.

  - Age must be 0 percent in year 1 of the project's crediting period and increased by 0.5 percent per year based on the age, starting at 1.5 percent in year 2. For example, the aging factors are 1.5 percent for year 2, 2.0 percent for year 3, 2.5 percent for year 4, 3.0 percent for year 5, and so on.

These figures can be specified in the PVWatts® Calculator system info, in the "System Losses (%) Loss Calculator".

5.5 Estimating Abandonment Rates

Given the high upfront implementation costs, significant infrastructural changes, contractual obligations, and financial incentives for continued use of the solar PV systems, project abandonment is not anticipated over the crediting period and is thus not accounted for in this methodology. Confirmation bodies must still confirm evidence of continued implementation (Section 8.3.4) is sufficient.

5.6 Leakage Accounting

Leakage for solar PV projects implemented under this methodology is considered to be negligible and is excluded from the GHG calculations. Solar energy generation reduces generation demands from more GHG-emission intense sources, however, it does not reduce the overall amount of energy generated. Therefore, it is not anticipated that the installation and operation of solar PV systems in the project will materially cause external third parties outside of the project to install operations to generate additional energy from potentially more GHG-emission intense sources, which would cause an increase in GHG emissions at their operations.

6 Project Implementation and Monitoring

Climate Forward requires a Project Implementation Report to be established for all implementation and reporting activities associated with the project. The Project Implementation Report will serve as the basis for the confirmation body to confirm that the implementation and reporting requirements in this methodology have been met. The Project Implementation Report must cover all aspects of implementation and reporting contained in this methodology and must specify how data for all relevant parameters have been collected and recorded.

At a minimum, the Project Implementation Report shall include the frequency of data acquisition, parameter values, a record keeping plan, and the role of individuals performing each specific monitoring activity. The Project Implementation Report must also include procedures that the project proponent has followed to ascertain and demonstrate that the project passed the legal requirement test and will remain in regulatory compliance.

For this methodology, documentation required in the Project Implementation Report includes the following:

- PVWatts® inputs for each installation site for each year of the crediting period and supporting project-specific information
- PVWatts® output for each installation site (including multiple runs if a single site has panels with parameters that vary, such as tilt angle) for each year of the crediting period
- Documentation to justify the emission factors, including their projections to future years (e.g., annotated tables with references)
- Emission reductions calculations
- Historical electricity data used for solar PV system size (kW) determination
- Evidence of completed installation and date operational activity commenced
- Evidence of operational activity (e.g., metered performance)
- Plans for operations and maintenance
- Warranties and/or contracts for maintenance of solar PV panels and other system components over the crediting period

Project proponents are responsible for ensuring that all implementation and reporting requirements of this methodology have been met.

6.1 Quantification Parameters

Each project must include the prescribed implementation parameters necessary to calculate emission reductions. These must be shown in a table, such as below in Table 6.1. The project proponent must provide the Reserve robust evidence demonstrating to the Reserve's satisfaction that proposed parameter values are reasonable and conservative. Confirmation bodies will also review all parameter values to ensure their use in the given project is appropriate.

Table 6.1. Solar PV Implementation Parameters

Parameter	Description	Data Unit	Applicable	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Comment
ER	Total emission reductions of project	tCO_2e	Project	c	Sum of emission reductions of all installation sites in the project
BE	Lifetime baseline emissions of the project	tCO_2e	Project	c	
PE	Lifetime project emissions of the project	tCO_2e	Project	c	
$EG_{PV,i,y}$	Estimated annual energy generation of solar PV installation, *i*, for year, *y*, of the crediting period	MWh	Installation site	c, r	PVWatts® output
System size	The DC (direct current) power rating of the PV array in kilowatts (kW) at standard test conditions (STC).	kW	Installation site	o	PVWatts® input; Must be project-specific (i.e., defaults not allowed); commonly determined using historical data.
Module type	The type of solar PV panel(s) installed.	Standard; Premium; Thin film	Installation site	o, r	PVWatts® input
System losses	Performance losses expected in a real system that are not explicitly calculated by the PVWatts® Calculator.	%	Installation site	c	PVWatts® input. Includes the following categories: soil/shade/snow blocking the panels, mismatch, wiring, connections, light-induced degradation (LID) nameplate rating, availability, age, and availability
LID	Phenomenon whereby the power output of a module decreases following exposure to sunlight.	%	Installation site	c	PVWatts® input; Must be adjusted for each year of the crediting period
Age	Effect of weathering of the PV modules on the array's performance over time.	%	Installation site	c	PVWatts® input; Must be adjusted for each year of the crediting period
Array type	Describes whether the PV modules in the array are fixed or track sun movement with one or two axes of rotation.	Fixed (open rack); Fixed (roof mount); 1-Axis; Backtracked 1-Axis;	Installation site	o, r	PVWatts® input

		2-Axis			
Tilt angle	The tilt angle is the angle from horizontal of the PV modules in the array.	deg	Installation site	o, r	PVWatts® input
Azimuth angle	The angle clockwise from true north (fixed) or from true north of the axis of rotation (one-axis), describing the direction that the array faces.	deg	Installation site	o, r	PVWatts® input
DC/AC ratio (optional)	The ratio of the inverter's AC rated size to the array's DC rated size.	Ratio	Installation site	o, r	PVWatts® input
Inverter efficiency (optional)	The inverter's nominal rated DC-to-AC conversion efficiency, defined as the inverter's rated AC power output divided by its rated DC power output.	%	Installation site	o, r	PVWatts® input
GCR (optional)	Ground coverage ratio – the ratio of module surface area to the area of the ground or roof occupied by the array.	fraction	Installation site	o, r	PVWatts® input
$EF_{r,y}$	Annual region-specific grid emission factor for region, *r*, for year, *y*, of the crediting period.	tCO_2e/MWh	Installation site	c, r	Contained in *Parameters* document

6.2 Voluntary Ongoing Monitoring Incentive

Each Climate Forward methodology is designed to ensure the quantification of emission reductions over the crediting period is conservative. It may be possible to have additional FMUs issued following *ex post* verification, using data collected by the project through ongoing monitoring of actual electricity production from the project systems. For this methodology, *ex ante* risk related to performance decline during the full crediting period is accounted for in Section 5.4. In order to conduct a successful *ex post* project verification, and generate additional FMUs from the solar PV project, the project proponent shall conduct ongoing monitoring of the kWh output of each project system. If data from each year of the crediting period are submitted in a Project Monitoring Report, and successfully verified, the Reserve may approve the issuance of further FMUs. *Ex post* FMUs may only be issued for systems for which ongoing monitoring and data collection has occurred. A site visit is required during *ex post* verification, per the requirements in Section 8.3.3.

7 Reporting and Record Keeping

This section provides requirements and guidance on reporting rules and procedures. A priority of Climate Forward is to facilitate consistent and transparent information disclosure among project proponents. Project proponents must submit an emission reduction report as part of the Project Implementation Report to Climate Forward.

7.1 Project Submittal and Confirmation Documentation

Project proponents must provide the following documentation for project listing and confirmation with Climate Forward:

- Project Submission form
- Signed Attestation of Title form
- Signed Attestation of Legal Additionality form
- Signed Attestation of Regulatory Compliance form
- Project Implementation Report (not public)
- Confirmation Report
- Confirmation Statement
- Confirmation List of Findings

The above project documentation will be available to the public via the Climate Forward online registry, unless otherwise noted. Further disclosure and other documentation may be made available on a voluntary basis through the Climate Forward registry.[19]

7.2 Record Keeping

For purposes of independent confirmation and historical documentation, project proponents are required to keep all information outlined in this methodology for a period equal to either the project crediting period or seven years after the information is generated, whichever is greater. This information will not be publicly available, but may be requested by the confirmation body or the Reserve. Records must be kept in both hard copy and digital format, where possible.

Examples of information the project proponent must retain includes:

- All data inputs for the calculation of project emission reductions, including all required sampled data
- Copies of all permits, formal notices of regulatory violations, and any relevant administrative or legal consent orders dating back at least 3 years prior to the implementation of the first project system
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Legal Additionality forms
- Results of emission reduction calculations
- Confirmation records and results
- All evidence relating to continued implementation
- Emission factor projections
- Records for proper installation and start date of operational activity

[19] Climate Forward documents and forms are available at https://climateforward.org/program/program-and-project-forms/.

Climate Forward also requires that the following project-related records be retained by the confirmation body for a period equal to either the project crediting period or seven years after the completion of confirmation activities, whichever is greater. It must be noted that some records may be subject to fiscal or other legal requirements that are longer than Climate Forward's mandated period.

Confirmation bodies shall retain electronic copies, as applicable, of:

- The Project Implementation Report
- The project proponent's SSR and/or project activity data as well as evidence cited
- The confirmation plan
- The sampling plan
- The Confirmation Report
- The List of Findings
- The Confirmation Statement

Each confirmation body must have an easily accessible record-keeping system, preferably electronic, that provides readily available access to project information. Copies of the original activity and source data records shall be maintained within the record-keeping system. Records must be kept in both hard copy and digital format, where possible. The Reserve may at any time request access to the record-keeping system or any supporting documentation for oversight or auditing purposes.

7.3 Reporting and Confirmation Period

Project proponents must report forecasted GHG emission reductions from the project for the entire crediting period. A confirmation period is the period of time over which forecasted GHG reductions are confirmed. The confirmation period begins with the project start date and ends with the submission of the final Confirmation Report to Climate Forward. The end date of any confirmation period may not extend past the project crediting end date.

Confirmation activities cannot commence until the project is submitted and approved by the Reserve, and the PV systems, including at least one system in a batch, have been operational for at least three months. As stipulated in Section 3.2, to be eligible for inclusion in a project, the solar PV system at an installation site must be delivering useful electricity prior to the initiation of confirmation activities for that project. Confirmation must conclude, and a Confirmation Statement must be issued, no later than two years after the project start date. The confirmation period for solar PV projects may range from three to twenty-four months after the project start date. Successful confirmation fixes the start and end dates of the project crediting period for the duration of the mitigation project.

7.4 *Ex Post* Verification

Ex post issuance may be possible for solar PV projects if data from each year of the crediting period are submitted in a Project Monitoring Report, and verified at the conclusion of the crediting period. A site visit is required during an *ex post* verification. The verifier may, at their discretion, request evidence of continued operation for systems for which ongoing monitoring data are *not* submitted for *ex post* verification, in order to avoid "cherry-picking" of successful systems for *ex post* verification. This methodology does not prescribe detailed *ex post* verification procedures, so guidance must be sought from the Reserve prior to the commencement of *ex post* verification.

8 Confirmation Guidance

This section provides confirmation bodies with guidance on confirming GHG emission reductions associated with solar PV projects. This confirmation guidance supplements the Climate Forward Confirmation Manual and describes confirmation activities specifically related to solar PV projects listed or registered under this methodology.

Confirmation bodies trained to confirm solar PV projects must be familiar with the latest versions of the following resources:

- Climate Forward Program Manual
- Climate Forward Confirmation Manual
- Solar Photovoltaic Project Forecast Methodology (this document)
- PVWatts® Calculator
- PVWatts® Manual

The Climate Forward Program Manual, Climate Forward Confirmation Manual, and Climate Forward methodologies are designed to be compatible with each other and are posted on the Climate Forward website at http://www.climateforward.org.

In cases where the Climate Forward Program Manual or Climate Forward Confirmation Manual differs from the guidance in this methodology, this methodology takes precedent.

Only confirmation bodies trained and accredited by the Reserve are eligible to confirm solar PV project reports. Information about confirmation body accreditation and Climate Forward project confirmation training can be found on the Climate Forward website at http://www.climateforward.org/program/confirmation/.

8.1 Standard of Confirmation

The standard of confirmation for solar PV projects is the Climate Forward Solar Photovoltaic Project Forecast Methodology (this document), the Climate Forward Program Manual, and the Climate Forward Confirmation Manual. To confirm solar PV project reports, confirmation bodies apply the guidance in the Climate Forward Confirmation Manual and this section of the methodology to the standards described in Sections 2 through 7 of this methodology.

While there is no requirement for *ex post* verification of this project under Climate Forward, there is a requirement for an accredited confirmation body to confirm the project has been implemented as described in this methodology and that the estimated emission reductions have been calculated accurately. The confirmation process incorporates both a desktop documentation review and a site visit assessment of the mitigation project.

Beyond criteria for the confirmation of mitigation project implementation, the confirmation body also confirms any provisions specified in this methodology that are to be undertaken to ensure the continued implementation of the solar PV project for the duration of its crediting period. The confirmation body assesses whether such measures have been appropriately implemented.

8.2 Confirming the Project Implementation Report

The Project Implementation Report serves as the basis for confirmation bodies to confirm that the implementation and reporting requirements have been met. Confirmation bodies shall confirm that the Project Implementation Report covers all aspects of implementation and reporting contained in this methodology and specifies how data for all relevant parameters were collected and recorded.

When assessing the Project Implementation Report, the confirmation body shall:

a) Assess the compliance of the Project Implementation Report with the requirements of this methodology, Climate Forward Program Manual, and Climate Forward Confirmation Manual.

b) Identify the list of parameters required by the methodology and confirm that the Project Implementation Report accounts for all necessary parameters.

c) Assess the means of implementation of the project data capture, including data management and quality assurance and quality control procedures, and determine whether these are sufficient to ensure the accuracy of forecasted GHG emission reductions to be achieved by the project.

Where the project proponent has applied a sampling approach to determine data and parameters, the confirmation body shall assess the proposed sampling plan in accordance with sampling requirements in section 4.3.3 of ISO 14064-3.

8.3 Core Confirmation Activities

The Climate Forward Confirmation Manual describes the core confirmation activities that shall be performed by confirmation bodies for all project confirmations. They are summarized below in the context of a solar PV project, but confirmation bodies must also follow the general guidance in the Climate Forward Confirmation Manual.

Confirmation is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The core confirmation activities are:

1. Reviewing GHG management systems and estimation methodologies
2. Confirming emission reduction estimates
3. Undertaking site visits
4. Confirming implementation of Project Resilience Measures

8.3.1 Reviewing GHG Management Systems and Estimation Methodologies

The confirmation body reviews and assesses the appropriateness of the methodologies and management systems that the project proponent uses to gather data and calculate baseline and project emissions.

8.3.2 Confirming Emission Reduction Estimates

The confirmation body further investigates areas that have the greatest potential for material misstatements and then confirms whether material misstatements have occurred. In addition, the confirmation body recalculates a representative sample of the estimated performance and emissions data for comparison with data reported by the project proponent in order to verify the GHG emission reduction calculations.

8.3.3 Undertaking Site Visits

In addition to undertaking a desk review, confirmation bodies shall conduct one or more site visits to confirm project activities. At a minimum, the confirmation body must visit a random sample of 25 percent of all installation sites in the project, rounding up to the nearest whole number. The confirmation body should also undertake a risk-based assessment of the project installations to determine whether additional site visits are warranted. The specific itinerary for a site visit, including the specific installation sites to be visited, and the activities to be confirmed will be determined by the confirmation body, following an assessment of project risk. It is the responsibility of the project proponent to ensure the confirmation body has the proper access and information needed to conduct the site visit(s).

During field site visits, at a minimum the confirmation body will:

1. Inspect the installation sites to establish whether reported existence and use of PV systems, including the reasonableness of the PVWatts® system loss inputs, is as recorded in the Project Implementation Report.
2. Review and discuss with the project proponent evidence of Project Resilience Measures (Section 3.7) and of continued implementation (Section 8.3.4).

8.3.4 Confirming Implementation of Project Resilience Measures

The project proponent must also provide evidence of implementation of the required Project Resilience Measures, including:

- Long-term service contracts for continued system monitoring, operations and/or maintenance and periodic inspections, as necessary
- Evidence of warranty coverage for the solar PV system
- Measures undertaken to reduce and/or mitigate risks of regulatory noncompliance, as necessary
- Project-specific adjustments to solar PV system losses (e.g., soiling, shading, snow)
- Where applicable, written procedures to ensure timely removal of snow and/or dust from the panel surfaces
- Evidence of continued building occupancy (*optional*)

8.4 Confirmation Items

Confirmation bodies are expected to use their professional judgment to confirm that methodology requirements have been met in instances where the methodology does not provide sufficiently prescriptive guidance. For more information on Climate Forward's confirmation process and professional judgment, please see the Climate Forward Confirmation Manual.

8.4.1 Project Eligibility and Credit Issuance

Table 8.1 lists the set of eligibility criteria that confirmation bodies must confirm during the confirmation process to determine that a project is eligible under the Solar Photovoltaic Project Forecast Methodology. These requirements determine if a project is eligible to register with Climate Forward and/or have credits issued. If any requirement is not met, the project may be determined ineligible.

Table 8.1. Eligibility Confirmation Items

Methodology Section	Eligibility Qualification Item	Apply Professional Judgment?
2.1	Confirm the PV system is newly installed and not pre-existing.	No
2.1	Confirm the solar panel systems, components, and installation parameters fit within the constraints of the calculation model PVWatts®.	No
3.1	Location – confirm projects are located in geographic regions suitable for use in PVWatts®.	No
3.2	Project start date – confirm the start date is appropriately chosen and that the project was submitted to Climate Forward within one calendar year of the project start date.	Yes
3.2	Crediting period - confirm the crediting period is appropriate based on the project information provided by the project proponent to demonstrate the expected useful lifetime of the solar PV system at each installation site.	Yes
3.3.1	Additionality – performance standard test – confirm the project is located within a disadvantaged community. For projects at residential premises, confirm the system is installed on an existing residential rooftop. For projects at commercial, public, industrial or agricultural premises: confirm that at least 70% of the expected power produced is intended to be consumed by the project within the given disadvantaged community, and that less than 30% of expected generation is going to be exported to the grid.	No
3.3.2	Additionality – legal requirement test – confirm the project was not mandated by any laws and that the project was submitted with a project start date prior to any relevant laws being adopted and/or promulgated.	No
3.4	Environmental and social safeguards – confirm the project is not expected to cause adverse environmental, social or economic impacts. Confirm appropriate mitigation measures are in place to guard against such risks.	Yes
3.5	Regulatory compliance – confirm no laws have been broken in the implementation of the project. Confirm appropriate mitigation measures are in place to guard against such risks.	Yes
3.6	Double counting – confirm no other GHG mitigation credits have been issued for the project or will be during the crediting period. Confirm projects are not and will not be generating and selling RECs. Confirm relevant contracts, agreements, and/or supporting documentation between project proponents and other parties that may have a claim to the FMUs generated by the project are in place.	No
3.7	Project Resilience Measures – confirm Project Resilience Measures have been implemented as described, including during site visit.	Yes
3.8	Market expansion objective – confirm project leads to GHG reductions that are generally not feasible under existing GHG crediting or incentive programs.	No
3.9	Demonstration of *ex ante* suitability – confirm the project activity is suitable for *ex ante* crediting.	No

8.4.2 Quantification

Table 8.2 lists the items that confirmation bodies shall include in their risk assessment and recalculation of the project's GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project's GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before FMUs are issued.

Table 8.2. Quantification Confirmation Items

Methodology Section	Quantification Item	Apply Professional Judgment?
5	Confirm that emission reductions are properly aggregated.	No
5	Confirm that the appropriate inputs were used in PVWatts®, as applicable.	No
5	Confirm that the project proponent correctly performed baseline and project scenario calculations using PVWatts®, as applicable.	No
5	Confirm that the project proponent correctly calculated the projected emission factors, as applicable.	No
5	Confirm that the project proponent correctly adjusted the system losses in PVWatts® to account for performance decline over time.	No

The confirmation body will confirm the validity of all parameters utilized in estimating claimed emissions reductions, including but not limited to:

- Current and projected emission factors
- PVWatts® inputs
  - Confirm proper values based on project-specific information and defaults, where permissible, were input and adjusted in PVWatts® for the following values:
    - DC system size (kW)
    - Module type
    - Array type
    - System losses
      - LID
      - Age
    - Array tilt angle (deg)
    - Array azimuth angle (deg)
- PVWatts® output

In assessing the appropriateness of parameter values, the confirmation body shall:

a) Confirm approval was given by the Reserve for use of such values. All Reserve-approved parameters are found in the Solar Photovoltaic Project Forecast Methodology Parameters document

b) Determine whether all *ex ante* data sources and assumptions are appropriate and calculations are correct, as applicable under the methodology, and results in an accurate and conservative estimate of the forecasted emission reductions;

c) Determine whether all *ex post* data sources and assumptions are appropriate and calculations are correct. Whether these data, with respect to specific parameters defined, are replicable to a reasonable and logical extent.

8.4.3 Risk Assessment

Table 8.3 provides a list of items confirmation bodies will review to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.3. Risk Assessment Confirmation Items

Methodology Section	Item that Informs Risk Assessment	Apply Professional Judgment?
3.7	Confirm sufficient Project Resilience Measures are in place.	Yes
6	Confirm that the Project Implementation Report is sufficiently rigorous to support the requirements of the methodology and proper operation and maintenance of the project.	Yes
6	Confirm that the solar PV systems are properly installed, operated and maintained according to manufacturer specifications.	No
6	Confirm that the individual or team responsible for managing and reporting project activities are qualified to perform this function.	Yes
6	Confirm that appropriate training was provided to personnel assigned to greenhouse gas reporting duties.	Yes
6	Confirm that all contractors are qualified for managing and reporting greenhouse gas emissions if relied upon by the project developer. Confirm that there is internal oversight to assure the quality of the contractor's work.	Yes
7.2	Confirm that all required records have been retained by the project proponent.	No
8.3.4	Confirm evidence of continued implementation is appropriate.	Yes

8.5 Completing Confirmation

The Climate Forward Confirmation Manual provides detailed information and instructions for confirmation bodies to finalize the confirmation process. It describes completing a Confirmation Report, preparing a Confirmation Statement, submitting the necessary documents to Climate Forward, and notifying the Reserve of the project's confirmed status.

9 Glossary of Terms

Additionality	Project activities that are above and beyond “business as usual” operation, exceed the baseline characterization, and are not mandated by regulation.
Age	Effect of weathering of the photovoltaic modules on the array's performance over time.
Alternating current (AC)	An electric current that periodically reverses direction; in contrast with direct current (DC). Solar photovoltaic cells generate DC electricity, which must be converted to AC electricity, before the electricity can be supplied to and used by the grid.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e., fossil fuel destruction, de-forestation, etc.).
Array	A series of PV modules; the PV modules in the array may be fixed or move to track the movement of the sun across the sky with one or two axes of rotation.
Azimuth angle	For a fixed array, the azimuth angle is the angle clockwise from true north describing the direction that the array faces. An azimuth angle of 180° is for a south-facing array, and an azimuth angle of zero degrees is for a north-facing array. For an array with one-axis tracking, the azimuth angle is the angle clockwise from true north of the axis of rotation. The azimuth angle does not apply to arrays with two-axis tracking.
Batch	The implementation of the same activity at multiple sites over a finite period of time. In the case of solar PV projects, a batch consists of multiple solar PV systems. The project proponent may designate multiple batches in a single project.
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the Carbon Cycle, as opposed to anthropogenic emissions.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Confirmation	The process used to ensure that a given participant’s GHG emissions or emission reductions have met the minimum quality standard and complied with Climate Forward’s procedures and methodologies for calculating and reporting GHG emissions and emission reductions.
Confirmation body	An organization or company that has been ISO-accredited and approved by the Reserve to perform GHG confirmation activities for specific forecast methodologies.
Crediting period	The length of time over which GHG emission reductions are quantified and forecast.
Direct current (DC)	An electric current that flows only in one direction; Solar photovoltaic cells generate DC electricity, which must be converted to AC electricity, before the electricity can be supplied to and used by the grid.

Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.
GHG source	A physical unit or process that releases GHG into the atmosphere.
Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Inverter	An electrical converter that converts the direct current (DC) output of a solar photovoltaic system into an alternating current (AC) that can be fed into an electricity grid.
Light-induced degradation (LID)	Effect of the reduction in the array's power during the first few months of its operation caused by light-induced degradation of photovoltaic cells.
Marginal emission factor (MEF)	The average annual amount of GHG emissions per unit of electricity generated from a given region's marginal generating facilities that would have been dispatched to meet demand above and beyond baseload generation.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
Module	A single photovoltaic panel that is an assembly of connected solar cells; also called "solar panels".
Photovoltaic (PV)	The conversion of sunlight into electricity using semiconducting materials.
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project proponent	An entity that undertakes a GHG project, as identified in Section 2.1 of this methodology.
PVWatts® Calculator	A web application developed by the National Renewable Energy Laboratory (NREL) that estimates the annual and monthly electricity production of a grid-connected roof- or ground-mounted photovoltaic system based on a system's location and basic design parameters.
System losses	Performance losses you would expect in a real system that are not explicitly calculated by the PVWatts® model equations. Categories include soiling/shading/snow, mismatch, wiring, connections, light-induced degradation (LID), nameplate rating, age and availability.
System size (kW)	The DC (direct current) power rating of the photovoltaic array in kilowatts (kW) at standard test conditions (STC).
Tilt angle (deg)	The angle from horizontal of the photovoltaic modules in the array. For a fixed array, the tilt angle is the angle from horizontal of the array where 0° = horizontal, and 90° = vertical. For arrays with one-axis tracking, the tilt

	angle is the angle from horizontal of the tracking axis. The tilt angle does not apply to arrays with two-axis tracking.
Utility-specific average emission factor (AEF)	The average annual amount of GHG emissions per unit of electricity generated for a given region's utility.

Appendix A Solar PV Performance Standard

A.1 Developing the Performance Standard

Climate Forward only registers projects that generate additional GHG emission reductions, that is, GHG emission reductions beyond what would otherwise have occurred in the absence of the project. As part of this analysis, projects must satisfy the performance standard test. Described in Section 3.3.1, the performance standard test begins by examining factors contributing to baseline GHG emission levels in the "business as usual" context. This includes identifying prevailing practices in the industries and jurisdictions in question, as well as researching drivers and barriers to the adoption of the project. The Reserve then establishes a threshold representing a level of performance in GHG emission reduction exceeding that of common practice.

For this methodology, after a careful consideration of industry practice and the drivers and barriers to the adoption of solar PV installation, the Reserve used a technology-specific threshold: buildings with solar PV installations represent a "better than business as usual" building electricity GHG intensity scenario and go beyond common practice. The "business as usual" building electricity GHG intensity scenario envisions grid-connected buildings with no solar PV installations that rely on utility-generated electricity. By installing eligible solar PV on existing buildings, a project proponent meets and exceeds this performance standard threshold passes the performance standard test for additionality.

In setting the performance standard, the Reserve was informed by the following publicly-available, independent, and authoritative sources, explained in more detail below.

A.2 Analysis to Inform Methodology Development

An extensive review was conducted of available and relevant studies, reports, and other data sets to evaluate and determine a performance standard. The review focused on a collection of authoritative market data that provides information pertinent to the opportunities for solar PV installation in California, the market penetration of solar PV installations in California, and barriers to widespread distribution of solar PV installations on existing buildings in California preventing greater market penetration to capitalize on the significant opportunity presented.

A.2.1 Market Penetration Rates of Solar PV Installation at Existing Buildings

A.2.1.1 National Renewable Energy Laboratory: The Open PV Project[20]

In the Open PV Project, the National Renewable Energy Laboratory (NREL) provides the real time status of the solar PV market in the United States with rankings of each state by cost, system count, and capacity. Because of highly favorable geographic and climate conditions, California is ranked first in number of installations, with over 626,000 installations as of August 2018. This is seven times more installations than the second ranking state of Arizona with over 89,000 installations. "Installations" include any sector: residential, commercial, governmental, etc. The Open PV Project is based on open source data that is voluntarily disclosed (limited validation). The NREL Open PV Project demonstrates the highly favorable conditions existing within the state of California for solar PV installations.

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[20] National Renewable Energy Laboratory. 2018. *The Open PV Project*. Available at https://openpv.nrel.gov/rankings.

A.2.1.2 NREL: Rooftop Solar PV Technical Potential in the U.S.: A Detailed Assessment[21]

The NREL technical report sought to quantify the potential of solar PV installations on rooftops in the United States. Based on 2013 data, the report found that the majority of annual electricity generation sales in California, 74.2 percent, *could* be generated by rooftop solar PV on all buildings. Rooftop solar PV on small buildings could comprise 43.6 percent of these annual generation sales, and medium and large buildings could comprise 30.6 percent. Thus, California could generate a significant percentage of its electricity from solar PV installations, but the lack of widespread solar PV installations on buildings has so far prevented California from reaching this potential.

A.2.1.3 Google: Project Sunroof Data Explorer[22]

Google used its expansive mapping data and computing resources to calculate solar viability in the United States with their Project Sunroof Data Explorer. The Project found 91 percent of 8.6 million rooftops (164,000 MW DC capacity and 243,000,000 MWh AC per year electricity generation) in California are viable for solar PV based on 3D modeling accounting for rooftop obstacles, shading, rooftop size, and solar insolation. This figure indicates that there is opportunity beyond the Google estimate of 332,000 existing solar installations in California. The existing homes estimate was based on interpretation of imagery data collected from July 2009 to April 2017. Given the difference in time and methodology, we recognize that this value does not correspond to the existing solar PV installations value reported by NREL Open PV for 2018 (above). Despite this discrepancy in these estimates, the order of magnitude shown in this data (between approximately 300,000 and 630,000) supports the conclusion in this appendix that despite massive and favorable opportunity for solar PV installations in California, adoption of such technology on existing buildings is not widespread or common practice.

A.2.1.4 Solar Energy Industries Association: California Solar[23]

Solar Energy Industries Association (SEIA) is a national trade association for the United States solar industry. Based on data current through the second quarter of 2018, 5,976,729 homes in California could be powered by solar (assumed to be based on cumulative solar capacity[24] though further detail on the derivation of this statistic is not publicly available). Additionally, SEIA projects 14,037 MW in solar power growth through both utility installation and *new* home installations over the next five years. SEIA's data is further evidence of the opportunity for solar PV installations in California, but notably neglects to project significant increases in solar power generation from existing building solar PV installations.

A.2.2 Low Adoption Rates of Solar PV Installations at Existing Buildings

The following sources and data sets establish that despite the favorable conditions and significant opportunity for solar PV installation at existing buildings in California, there are significant barriers and insufficient existing incentives to installing such systems which are preventing them from being the common practice.

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[21] National Renewable Energy Laboratory. 2016. *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment.* January. Technical Report NREL/TP-6A20-65298. Accessed at https://www.nrel.gov/docs/fy16osti/65298.pdf.

[22] Google. 2018. *Project Sunroof Data Explorer*. May. Accessed at https://www.google.com/get/sunroof/data-explorer/.

[23] Solar Energy Industries Association. 2018. *California Solar*. Q2 2018. Accessed at https://www.seia.org/state-solar-policy/california-solar.

[24] Solar Energy Industries Association. 2019. *What's in a Megawatt?* Accessed at https://www.seia.org/initiatives/whats-megawatt.

A.2.2.1 Lumidyne Consulting, LLC: The Residential Solar Retrofit Market in California White Paper[25]

Lumidyne Consulting, LLC's white paper indicates that in 2017, for the first time in 10 years, there was a *decline* in residential solar PV installations in California in the retrofit market (as differentiated from the new construction market). According to the white paper, a variety of hypotheses have been put forth regarding the cause, and speculation abounds about whether it is a temporary phenomenon, or whether a resurgence will occur. In drafting the white paper, Lumidyne used a model (SPIDERTM) that forecasts retrofit installation of solar PV. The model showed a current pattern of decline in the retrofit market and predicted a continued decline in the number of installations over the next six years. Despite a decade of explosive growth, the white paper noted only six percent of housing units in California have a PV system installed.[26] It also noted significant obstacles to retrofit residential solar PV:

1. Despite favorable climatic conditions for solar PV power generation, not all existing residential housing is structurally or technically suitable for large solar PV installation due to roof orientation, shading, and other factors (though 90 percent of homes in California have at least one plane suitable for a solar system greater than 1.5 kW).

2. Homes that are not owner occupied (i.e., rentals) account for 46 percent of housing units (single- and multi-family units) in California.

3. Many homeowners lack the discretionary funds to install solar PV.

This white paper's findings illustrate that additional incentives could benefit home owners in overcoming barriers to solar PV retrofits on existing buildings.

A.2.2.2 Energy Solutions Company: California Distributed Generation Statistics[27]

California Distributed Generation Statistics (CA DG) is the official public reporting site of the California Solar Initiative (CSI), presented jointly by the CSI Program Administrators, GRID Alternatives, the California Investor Owned Utilities, and the California Public Utilities Commission (CPUC). CA DG is built and maintained by Energy Solutions Company, a consulting firm focused on large-scale environmental impacts. CA DG reports that there are several arrangements and initiatives that bridge the gap between demand for solar PV installations and affordability.

Net Energy Metering (NEM) is a special billing arrangement that provides credit to customers with distributed generation systems such as solar PV for generation of excess electricity. NEM covers 768,369 residential and 22,752 non-residential (75 percent commercial, with the remainder educational, military, non-profit, other government, and industrial) cumulative solar installations approved since 1993 as of November 12, 2018, with capacity in 2018 of 4,200 MW and 2,400 MW, respectively. CSI has a general market incentive overseen by CPUC and

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[25] Lumidyne Consulting LLC. 2018. *The Residential Solar Retrofit Market in California is Beginning to Saturate: The New Construction Market Can Help Mitigate the Decline*. Accessed at https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5ab1826ecefb7701f5ba89d6_Lumidyne%20Consulting%2C%20March%202018%20White%20Paper%20-%20Residential%20Solar%20in%20California%20R3%20(Updated%203-20-2018).pdf.

[26] The three investor owned utilities (IOUs) – Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric – in California have about 690,000 residential solar PV systems installed (through December 31, 2017), which represents 5.8 percent of the 11,900,000 housing units within their service territories.

[27] Energy Solutions Company. 2018. *California Distributed Generation Statistics*. Accessed at https://www.californiadgstats.ca.gov/charts/.

administered by PG&E, SCE, and CSE. A total of 136,308 residential and 6,895 non-residential projects used this general market incentive. CSI also funds solar PV installations for single- and multi-family affordable housing units. This CSI incentive program has assisted in 865 projects with a total capacity of 5.4 MW in 2018 as of November 12, 2018. GRID Alternatives is a non-profit organization which seeks to make solar energy and jobs accessible to low-income communities through the California Single-Family Affordable Solar Homes (SASH) program and the solar portion of the Low-Income Weatherization Program (LIWP).

The above demonstrates arrangements and initiatives already implemented to close the gap between demand for solar PV installations and affordability. However, despite these programs, as Section A.2.1 demonstrates, there is an opportunity to install far greater numbers of solar PV at existing buildings. The existing incentive programs are insufficient to take advantage of this significant opportunity and close the gap between demand and affordability. Additional incentives, including those associated with GHG reductions, could lead to installations that otherwise may not have occurred.

A.3 Findings

The analysis to inform the methodology development found that California provides climatic conditions highly suitable for solar PV installations. Nearly 75 percent of annual electricity sales in California could be generated by rooftop solar PV at existing buildings. Approximately 90 percent of existing rooftops may be viable for such solar PV installations, however, only approximately four to six percent of rooftops (depending on which figure is used) have a solar PV system. Additionally, only 2.8 percent of total housing units in California currently have solar PV installations. Even lower percentages of buildings have solar PV installations in states outside of California, although many residential rooftops could have solar PV installed.

An important barrier to installation is the expense of installing solar PV. GRID Alternatives and other income-based programs highlight opportunities for solar PV installation at existing buildings in California, but these incentives have proven insufficient to meaningfully close the gap between solar PV installation demand or opportunity and affordability. Further, there is no legal requirement to install solar panels on existing roofs in California at a state-wide level.[28] Other incentives for residential solar PV installation exist as discussed further in this methodology, however, these are not requirements. Additional incentives would not preclude existing buildings without solar PV from being further incentivized by GHG reduction credits contemplated by this methodology.

A.4 Setting the Performance Threshold

The above analysis sufficiently demonstrates to the Reserve that the common practice or “business as usual” scenario at existing buildings in California is to rely upon the grid for electricity despite significant opportunity and existing incentives for solar PV installation. The performance threshold, therefore, is the installation of solar PV on existing buildings that do not currently have a solar PV system. The installation of a solar PV system will result in additional reductions in electricity-related GHG emissions, and thereby exceeds common practice and is “better than business as usual” when compared to common practice or “business as usual.” By installing eligible solar PV systems on existing buildings, a project proponent meets and

[28] This is not to be confused with California’s new legal requirement for newly constructed homes. On May 8, 2018, the California Energy Commission adopted building standards that require solar photovoltaic systems on new construction of residential buildings starting in 2020. Accessed at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency.

exceeds this performance standard threshold, passes the performance standard test, and satisfies additionality.

Appendix B PVWatts® Calculator Highlighted Internal Calculations

PVWatts® is an online calculator that calculates the amount of electricity produced by a grid-connected PV system with crystalline silicon or thin film modules. It consists of a set of component models to represent the different parts of a PV system, and performs hourly simulations to calculate the electricity produced by the system over a single year. The calculator combines a number of sub-models to predict overall system performance, and includes several built-in parameters that are hidden from the user. Major components of the PVWatts® internal calculations include the following:

- Sun tracking is based on geographic location, angle of incidence, time of year. Geographic location determines plane-of-array beam, sky diffuse, and ground-reflected diffuse irradiance components.
- Reflection and transmission off an array are estimated with either a single-slab or two-slab model depending on array type, geographic location, angle of incidence, and time of year.
- Solar cell performance is temperature dependent, so PVWatts® includes a thermal model based on first-principles to predict efficiency losses. Inputs to this sub-model include meteorological data such as wind speed and dry bulb temperature along with irradiance data. The array efficiency is linearly and inversely correlated with temperature, as governed by a temperature coefficient.
- System losses (such as those due to soil/shade/snow blocking the panels and LID) are taken into account to produce a total system loss parameter.
- An inverter model is based on the California Energy Commission (CEC) performance data and a quadratic loss model from literature.[29]
- LID slowly lowers solar panel efficiency over time. In the first year, typical arrays experience a 1.5 percent decrease in efficiency. After this initial period, LID reduces to a 0.5 percent annual decrease. These figures can be specified in the PVWatts® Calculator input. This figure is substantiated by previous NREL studies and measurements of LID in different module types.[30,31]
- To account for aging of the solar array, an aging factor is included to represent cumulative panel degradation and efficiency losses over the course of the project lifetime. [32]

For more details about the model, please see the PVWatts® Manual.[33]

[29] *PVWatts® Version 5 Manual*. See Section 12: Inverter Model.

[30] Jordan, Dick and Sarah Kurtz. June 2012. *Photovoltaic Degradation Rates — An Analytical Review*. Available at https://www.nrel.gov/docs/fy12osti/51664.pdf. Accessed September 2017.

[31] *PVWatts® Version 5 Manual*. See Section 11: System Losses.

[32] Jordan, Dirk C. and Sarah R. Kurtz. *Photovoltaic Degradation Rates — An Analytical Review.* National Renewable Energy Laboratory (NREL). Available at https://www.nrel.gov/docs/fy12osti/51664.pdf. Accessed April 2019.

[33] Dobos, Aron. September 2014. *PVWatts® Version 5 Manual*. Available at https://www.nrel.gov/docs/fy14osti/62641.pdf. Accessed September 2017.