DRAFT FOR PUBLIC COMMENT

Draft Specifications for the application of the United Nations Framework Classification for Resources to Solar Energy

Prepared by the Solar Energy Sub-group of the Renewable Energy Working Group of the Expert Group on Resource Management

Summary

This document provides Specifications for the application of the United Nations Framework Classification for Resources (UNFC) to Solar Energy (aka Solar Specifications). The intended use of this document is in conjunction with UNFC and the Specifications for the Application of UNFC to Renewable Energy Resources (Renewables Specifications). The Renewables Specifications represent rules of application of UNFC to renewable energy resources, while this document represents rules of application of UNFC to solar resources via the Renewables Specifications. Growing awareness and interest in renewable energy resources, including solar resources, has highlighted a need to normalize how renewable energy potential is reported. It is hoped that the inclusion of Solar Specifications within UNFC will facilitate the appreciation of the potential role that solar energy specifically, and renewable energy in general, must play as part of a rapidly changing energy sector.

Preface

Over the last decade, the renewable energy industry has rapidly grown in scale and matured into an ever more important part of the current and future energy mix. The growing importance of renewable energy resources, including solar, has raised questions around standardised reporting of energy resources estimates for projects and at national and international levels.

Work on an international framework classification for resources started in 1994, with the United Nations International Framework Classification for Reserves/Resources published in 1997. Following this, and in recognition of the need for comparable energy and other data, the Ad Hoc Group of Experts on Harmonization of Fossil Energy and Mineral Resources Terminology was established in November 2001, and later became the Expert Group on Resource Classification. As part of its work, the Expert Group revised the United Nations Framework Classification for Resources (UNFC), which was approved by the United Nations Economic Commission for Europe (ECE) Committee on Sustainable Energy at its Eighteenth Session. The Expert Group is

currently responsible for the promotion and further development of UNFC, including the application of UNFC to renewable energy.

As a result of industry and ECE interest in renewable energy resource classifications, the Task Force on Application of UNFC to Renewable Energy Resources was established in June 2013. Phase 1 of the Task Force's work was the production of generic Renewables Specifications for the application of the UNFC to renewable energy. The Task Force is now in Phase 2 of its work and has five working groups, responsible for specifications for the application of the UNFC to geothermal, bioenergy, solar, wind and hydro-marine energy resources.

The Solar Working Group was established by the Task Force in July 2016, as per the ECE Expert Group on Resource Classification Work Plan for 2016–2017. In July and August 2016, there was a call for volunteers interested in joining a Working Group to draft Specifications for the Application of the United Nations Framework Classifications to Solar Energy (aka Solar Specifications). The Solar Working Group began its work in August 2016. The Solar Working Group was charged with preparing the Solar Specifications to improve the consistency and interpretation of reported solar resources estimates while at the same time facilitating comparisons with other energy sources. In April 2017, the Solar Working Group and Renewables Tasks Force had their names changed to the Solar Subgroup and Renewables Working Group (RWG) respectively.

While working on the Solar Specifications, the Solar Subgroup noted that the Specifications not only support the classification of solar resources but also help identify the steps that solar projects and sites need to go through before solar energy can be utilised. Utilisation starts with the identification of potential solar resources and a series of stages towards realising commercial resources at project sites where energy is either sold to a market or used directly. The Solar Specifications are designed to support the classification of solar energy data in a way that follows a solar energy project cycle while at the same time allowing comparison with other energy sources.

Acknowledgements

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Contents

I. Introduction

1. The purpose of this document is to provide the means to classify *solar resource*s (e.g. electricity or heat) using an internationally accepted United Nations Framework Classification system (UNFC). As UNFC is a project maturity-based system, it provides a common classification for the effective management of resources anticipated to be put into production over time. It can be applied both for corporate assessment and national/regional inventories.

2. UNFC is a generic, principle-based system in which quantities are classified using three fundamental criteria: economic, environmental and social viability (E), field project status and feasibility (F), level of project knowledge and confidence in the potential recoverability of the quantities (G).

3. The fundamental principles are project maturity (as expressed by the E- and F-axis) and project confidence (G-axis). Classes of project maturity and project confidence can be represented as in Table 1. The class names Non-Commercial, Potentially Commercial and Commercial denote increasing levels of maturity of the project.

Table 1: Abbreviated version of UNFC showing classes and subclasses relevant to solar projects and confidence levels.

Confidence in estimated quantity (G axis)

Class	Description applicable to solar energy[1]	Subclass	Resource confidence		
			High	Moderate	Low
Commercial Projects	Development of the *solar resource* is economically, environmentally and socially viable[2]. Technical feasibility has been confirmed.	On Production			
		Approved for Development			
		Justified for Development			
Potentially Commercial Projects	Development of the *solar resource* is expected to become economically, environmentally and socially viable in the foreseeable future. Technical feasibility has not yet been confirmed.	Development Pending			
		Development on Hold			
Non-Commercial Projects	Development of the *solar resource* is not expected to become socially, environmentally and economically viable in the foreseeable future or evaluation is at too early a stage to determine social, environmental and economic viability. Technical feasibility has not yet been confirmed.	Development Unclarified			
		Development Not Viable			
Potential Projects	Developments associated with the investigation of one or more potential *solar sites*. No development project has yet been identified.	NA			
Additional quantities associated with known and potential resource sources	Quantities of *solar irradiation* that will not be developed. Some of these may become recoverable in the future as technological developments occur. Some or all of these quantities may never be utilised.	NA			

Increasing Project Maturity (E and F axes)

[1] The descriptions are of the minimum requirements for a class. A project which meets some, but not all, requirements of a higher class would be classified in the lower class.

[2] Environmental and social viability is determined by the positive and negative environmental and social impact of the project. In order for a project to be viable, the impacts have been assessed, and there is appropriate regulatory and community license or acceptance for the development.

4. This document is to be used in conjunction with the United Nations Framework Classification (UNFC) and its Specifications to Renewable Energy Resources (Renewable Energy Specification), as set out in ECE Energy Series No. 42, ECE/ENERGY/94. The Renewable Energy Specification represents rules of application of UNFC that are to be applied to all Renewable Energy Resources, while this document represents rules of application of both UNFC and the Renewable Energy Specification to *solar resource*s. To assist in the application, relevant text from UNFC and the Renewable Energy Specifications is quoted in this document and is highlighted for clarity.

5. Until now, there has been no internationally accepted framework for reporting solar energy in this way. As such, the Solar Specifications address an important gap. Potential applications of the Solar Specifications include energy resource and project management by companies and support of national energy assessments by governments and international energy studies. These national energy assessments can be used to inform national and international energy policies and agreements as well as natural resources management. Furthermore, there is an opportunity for the Solar Specifications to be used for public reporting or as a template for solar project reporting when seeking investors or project finance and assist in capital allocation. Intended users for the Solar Specifications include governments, businesses and others interested in solar energy.

6. It should be noted that this is not the first time solar energy, or other renewable energy resources, have been classified using frameworks that allow comparison between all energy sources. In 1989, the United States Department of Energy (DOE) assessed renewable and non-renewable energy sources (see Annex I). Further efforts to establish renewable energy definitions were published by NREL (Maxwell and Renné, 1994). In the report, the authors contrasted depletable reserves (typically fossil and nuclear fuels) as depicted under the classic McKelvey Diagram (USGS 1976) with renewable reserves that are not depletable (e.g. solar and wind energy, and other renewable resources). To date, the classification of renewable energy has been restricted to ad hoc classification exercises. Previous classification systems have used a top-down approach, whereas UNFC uses a project approach. This enables the maturity of developments to be assessed and brings clarity to how much energy will be extracted for use from the solar irradiation and the expected lifetime of the solar installation.

7. With the growing importance of solar energy, government and intergovernmental organisations have been providing more guidance on issues of solar energy projects including potential resources, technologies, risk management and financial arrangements. This guidance comes through the establishment of the International Renewable Energy Agency (which develops assessments of national solar potentials) as well as work already underway at the International Energy Agency (e.g. Future Scenarios for Renewables and the World Energy Outlooks), the World Bank (e.g. Global Solar Atlas), the European Commission (e.g. Solar Bankability) and through work at research institutions around the world (e.g. the United States National Renewable Energy Laboratory or PBL Netherland's Environment Agency). As noted by DOE in 1989, there is a range of delineations, definitions and assumptions that can be used to frame or classify solar energy and related projects. The World Energy Council (1994), for example, delineated renewable energy into "theoretical potential", "geographic potential", "technical potential" and "economic potential" (see Annex 2). The Solar Specifications draws upon existing work by these organizations and takes the "economic potential" as applied to solar (Köberle et al. 2015) further delineating it into commercial and other *solar resource*s using the latest version of UNFC.

8. It is anticipated that the classification of solar resources using the Solar Specifications will become an important source of information for investors, project developers and energy-related authorities and government. It helps facilitate the monitoring of solar energy portfolios, investment opportunities and in doing so, support decision making. Also, the Solar Specifications provide terms, concepts and definitions important for classification of solar energy. It is expected that an evaluator could take the Solar Specifications and work out how to classify solar projects based on the data and information they have.

9. It should be noted that the Solar Specifications does not provide step-by-step guidance on how to develop solar resources as there are too many business models, technologies and applications for this to be possible in a single document. Instead, the Solar Specifications focuses on concepts and definitions required to classify solar resources, leaving issues of data sources, estimation methods and guidance of application for future documents. However, the Solar Specifications does describe how it may be applied by businesses to projects as well as by governmental to national and regional assessments.

II. Definitions

A. Solar Energy Sources, Products and Resources

1. Solar Energy Source (Solar irradiation)

10. The solar energy source (equivalent to the generic term Renewable Energy Source as defined in the Renewable Energy Specifications) is the total solar irradiation being received by the solar collector. Total solar irradiation consists of three components: direct beam irradiation directly from the sun, diffuse irradiation from clouds and sky, and ground reflected irradiation. Standard practice is to measure or calculate solar irradiation on a horizontal surface, represented as the sum of the direct and diffuse components, typically in units of $w\text{-}m^{-2}\text{-}hr^{-1}$ or equivalent, and then convert this value to the irradiation received by the solar collector, regardless of its orientation or type. Flat plate collectors or concentrating collectors are typically oriented in positions other than a horizontal surface to take maximum advantage of the sun's rays. In such cases, ground reflected radiation may also be part of the irradiation received at the collector, even though concentrating collectors respond only to the direct beam radiation from the sun. Therefore, for purposes of these Solar Specifications, the total solar irradiation source represents the total amount of solar irradiation (direct, diffuse, and reflected) received by a solar collector, regardless of its orientation. Data on total solar irradiation are derived either from actual ground measurements or from models using weather satellite imagery (and occasionally from numerical weather prediction models) and are available through both public and private sources. In cases where the data sources represent irradiation reaching a horizontal surface (which is common practice), the data must then be converted to indicate the total solar irradiation reaching specific collector orientations or types.

2. Solar Energy Product

11. A *solar energy product* is the energy commodity produced by the project that can either be sold or can be used for economic benefit. This would include direct domestic, industrial or business use of energy produced by a solar installation. Note that energy consumed during production (parasitic loss) is not considered part of the commercial production and is categorized separately (see Table 4).

12. Electricity and heat (e.g. steam) are *solar energy product*s. Also, a project may identify another product as a *solar energy product* provided; it meets the requirements in paragraph 11. The identification of a product, other than electricity or heat, as an energy product, shall be justified with supporting evidence.

13. *Solar irradiation* may also be used to produce non-energy products, for example, photocatalytic water detoxification. These can be of considerable benefit but do not meet the criteria for *solar energy product.*

14. Where a project has associated production of non-energy co-products, the economic value accruing to the project as a result of such production may be considered within the assessment of the project's economic viability. However, per the Energy Product definition, such production shall not be included in the quantities classified as solar energy resources.

3. Solar resources

15. The *solar resource* (equivalent to the generic term Renewable Energy Resource as defined in the Renewable Energy Specifications) is the cumulative quantities of *solar energy products* that will be generated from the *solar irradiation* via a project from the effective date of the evaluation forward until the end of the project lifetime/limit, measured or evaluated at the *reference point* (see paragraph 26).

B. Solar Project and Reference Point

16. For *solar irradiation* at a site to be utilised and be converted to a *solar energy product* requires a project implementing some form of technology (Figure 1). For example, *solar irradiation* can be used to generate electricity through the photovoltaic conversion of sunlight into electricity (i.e. solar PV) or through conversion to heat to drive turbines (e.g. CSP).

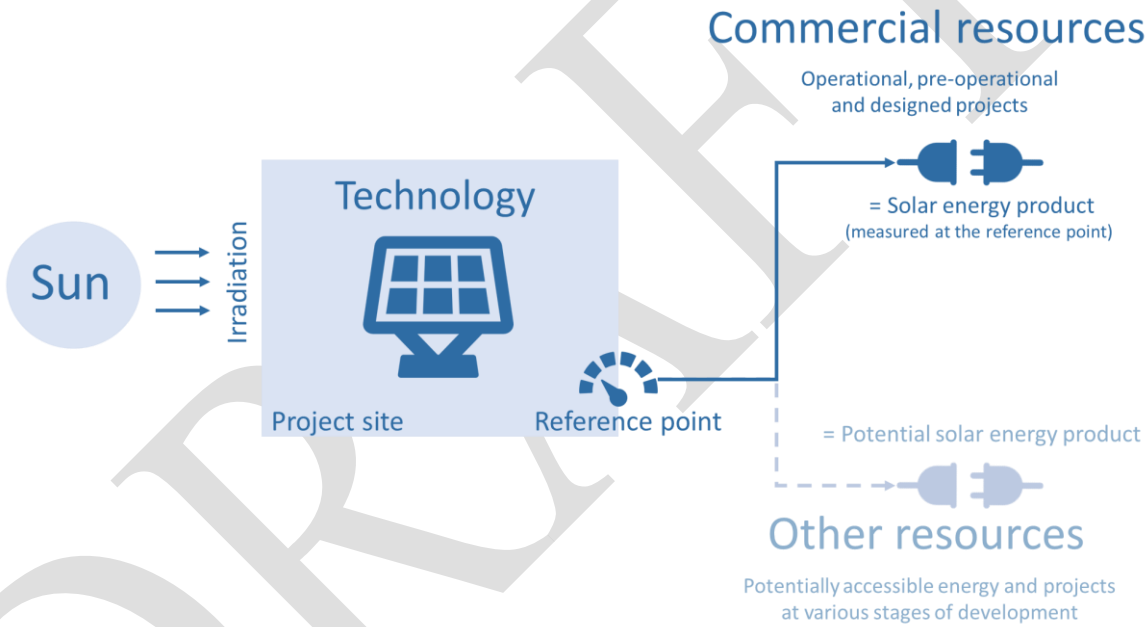

Figure 1: Schematic representation of how solar irradiation at a site coupled with technology can generate a solar energy product, in this case, using a solar PV panel and other necessary technologies. Importantly, the solar energy product is measured at the reference point. (For some projects, there may be more than one energy type or more than one reference point.)

17. The project is the link between the solar *energy source* (i.e. irradiance from the sun) and quantities of *solar resources* and provides the basis for economic evaluation and decision making.

18. In the framework of definitions underpinning UNFC and Renewable Energy Specifications, the *solar resource* estimation and classification process are integrally tied to the definition of a project, or projects, which is the basis for both the amount and class of *solar resources* per the criteria defined by the E, F and G categories in UNFC.

19. A *solar project* consists of the site(s), technologies and activities over which decisions are made to derive energy from *solar irradiation*. A *solar site* is a location with access to *solar irradiation*. *Solar sites* have varying levels of access to *solar irradiation* depending on latitude, climate, topography and other characteristics. *Solar technologies* are the devices and practices that utilise energy from *solar irradiation*. *Solar technologies* only convert a fraction of the energy

contained in *solar irradiation*, and as such, the *solar resource* from a *project site* will always be less than the energy contained in *solar irradiation* at the *project site*.

20. In the context of solar energy, the project includes all the systems and equipment connecting the solar energy source to the reference point(s) where the *solar energy product* is sold, used, transferred or disposed of. The project shall include all equipment and systems required for the conversion of energy, including, for example, solar panels, power transmission equipment and any necessary ancillary equipment. In the early stages of evaluation, a project might be defined only in conceptual terms, whereas more mature projects will be defined in much more detail.

21. There is no size limit to a project although it may not be practical to apply the Solar Specifications to an individual project at the household scale, for example. In some cases, multiple household projects might be classified and aggregated using the Solar Specifications. The aggregated projects could then be compared with other energy projects.

22. National solar resource quantification and classification or equivalent (regional) studies are often not project based as projects may not exist yet or it is premature to provide a sufficiently detailed definition of a project. Hence, for national resource reporting, the creation of notional or generic projects (using notional solar product capacities for a given area and a notional project lifetime) may allow an estimate and classification of all the national or regional *solar resource*s, including those not yet linked to defined projects. These notional projects could be appropriately classified as, e.g. Potential solar resource projects (E3, F3.3, G4), see Table 2.

23. Another key component of the project definition is the identification of the *reference point* as the point at which the cumulative quantities of *solar energy products* are measured or estimated, and the quality of the *solar energy product* follows the appropriate specification. The reference point will typically be either the point of sale to third parties where measurement using appropriately calibrated custody transfer metrology equipment occurs or where custody is transferred. The specific custody transfer point will depend on the legal structure and contract terms of the specific project being evaluated. If a project has more than one type of *solar energy product* (e.g. both heat and electricity), then there may be more than one *reference point*, for example, one for each type of *solar energy product*.

C. Project Lifetime

24. The estimated *solar resource* for a project is constrained by the lifetime or limits of a project. Generically, the lifetime of a project could be constrained by technical, economic, regulatory or other permit/license cut-offs. As stated in the Renewable Energy Specifications, a significant difference with non-renewable energy projects is that the economic limit will often not be an appropriate basis for the resource assessment because renewable energy is normally replenished at an equal or higher rate than consumed, and thus other project limitations, such as the technical (or design) limit or permit limit may become relevant before the economic limit is reached.

25. Generally, it will be necessary to limit the resources to the defined project lifetime even if the solar source is limitless. Solar sources are limitless over long or unlimited periods of time, but solar resources are limited over any given period of time, for example, the project lifetime. This project lifetime has no correlation to the solar source and thus can be determined from the design basis of the facilities or critical components of those facilities or based on industry practice or benchmarks for similar projects.

26. Routine maintenance requirements do not constrain the project lifetime as it is likely that solar projects will be maintained as long as it is technically and commercially feasible, which could be indefinite. New projects may replace previous projects and thus if significant capital re-investment, requiring a new project investment decision and/or regulatory approval, is required, then the re-investment may constitute a separate, less mature project with its separate resource estimate and classification.

27. In some cases, a *project lifetime* might become constrained by an *economic limit*, which is a point in time when the anticipated cumulative net operating cash flows from the project are expected to be negative. The likelihood of this happening is low for many *solar projects* due to their low operating expenditures. However, this can happen when key contractual arrangements are modified or are about to expire and need to be renegotiated, or policies and regulations are changed. Important contractual arrangements include off-take agreements and leases related to *solar sites*; meanwhile, institutional risks can affect access to markets, permissible contractual arrangements and prices paid for energy.

28. Entitlement (see Section D) to the *solar resources* may also be limited in time and, if of lesser duration than the design life of the facilities and the economic limit, will be the constraining factor for the entity's resource reporting.

D. Entitlement

29. Entitlement defines the quantities of *solar resources* that accrue to project participants.

30. A reporting entity's entitlement to *solar resource*s is governed by applicable contracts. Key elements that provide the basis for the ability of the entity to recognize and report resources are: (i) access to the *solar energy source*; (ii) exposure to risks in the conversion of *solar irradiance* to the *solar energy product*; and (iii) the opportunity for reward through the subsequent sales of the *solar energy product*.

Access to Source

31. Consistent with the Specifications for the application of UNFC to Renewable Energy Resources, a reporting entity needs to consider the degree of access to the solar energy source, both in terms of quantities available and the level of confidence in accessing those quantities.

32. When using the Specifications for disclosure purposes, the reporting entity shall demonstrate that it has sufficient entitlement to the solar energy source. A reporting entity gains and secures access to a solar energy source through licenses and permits, or other similar contracts, generally issued by the applicable government authorities. These licenses and permits typically allow the reporting entity, subject to applicable regulations, to develop and operate a project or projects to deliver *solar energy product*s into the market.

Access to Conversion Process and Market

33. Consistent with the Specifications for the application of UNFC to Renewable Energy Resources, a reporting entity must demonstrate that it has:

i. Sufficient access and entitlement both to the conversion/processing asset to produce the *solar energy product*;

ii. The opportunity for a benefit through the subsequent sales of the *solar energy product*;

iii. Sufficient existing or planned infrastructure and/or logistics with sufficient capacity to transport or otherwise transfer the energy product to the necessary markets and/or end users for sale.

34. The access to the market is a key project maturity criterion which will be used in the selection of the appropriate socio-economic viability category (E-axis, refer to Table 3).

35. The sufficient access, entitlement and opportunity for reward are typically defined by the selected business and owner/operator models. Ownership models are, for example, equity ownership, joint venture (JV) ownership comprising a set of stakeholders, or government ownership; the operator can be either the equity owner, a designated partner in a JV, a government body, an electricity utility or otherwise selected third-party contractor.

36. In case the solar project owner does not own the utility to which the *solar energy product* is sold, then a Power Purchase Agreement (PPA) or equivalent will be required between the solar

project owner (seller) and the purchaser (buyer) of the solar energy product which could be a utility, large power buyer/trader or even building occupant, school, business etc. A PPA describes the commercial arrangement under which the energy product, e.g. electricity, is sold. The PPA provides the means whereby the reporting entity of the *solar resource*s accesses the electricity market. The existence of a PPA is another project maturity criterion, which needs to be considered for the appropriate socio-economic viability (E category) assessment. (A PPA, or equivalent, is not necessarily required when the *solar energy product* will be for use but not for sale.)

37. Legal agreements vary, but key terms and conditions to consider when classifying solar resources for solar projects include: pricing; delivery incentives; penalties; energy quality and quantity conditions including an allowance for variations; and, stipulations concerning the duration and termination, extension and renewal of an agreement. Requirements necessary to secure financing for a project may also have a bearing on the socio-economic viability and project feasibility.

38. The price and margin risk should be considered when estimating and classifying solar resources. Solar projects witch have power purchase agreements and can provide firm capacity typically have higher entitlement, and as such, higher socio-economic viability and project feasibility. The *solar resources* from solar projects without power purchase agreements should be classified based on assumptions consistent with current market conditions and expectations around prices and contracts. A solar project, which has a track record of lower than expected capacity factors, cost overruns, or receiving low energy prices for the *solar energy product* sold to other parties, will need to ensure that these risks are appropriately considered when estimating and classifying *solar resources*.

39. Consideration of possible project extensions or new projects at existing solar sites should include how likely it is that entitlements will be extended. Supporting evidence shall be given if it is assumed that permits, land-lease agreements, and off-take agreements will be extended. Assessments should take into account the previous track record and capacity of those undertaking the solar project. (Also note comments in paragraph 28 on project extension versus new projects.)

E. Variable Production, including downtime and curtailment

40. *Solar projects* typically have variable energy flows through *reference point*(s). This variability can be due to a multitude of factors and occur over a range of timespans or frequencies. For example, the diurnal variation in solar irradiance results in no production overnight in the case of solar PV. There is also a seasonal variation, and in given years, cyclical climate events such as El Niño and La Niña cloud cover impacts on solar irradiance that will affect *solar resource* quantities.

41. An estimate of a solar project's resources will typically require the preparation of a future production forecast/scenario(s) or annual average power output of the delivered energy and any solar irradiance variability shall be appropriately considered within that assessment. Assumptions that impact the overall estimate of cumulative energy generated from solar energy projects must also be expressed via appropriate confidence limits (G-axis) and supported by appropriate evidence (e.g. measurement data, engineering assumptions). This includes:

- estimates for downtime due to planned or unplanned maintenance
- estimated energy transfer losses
- loss of grid connection
- curtailment of the power generated due to electrical grid issues beyond the reference point.

42. If a proportion of the *solar resource* will not give economic benefit, e.g. sold at zero or negative prices, such as what occurs under *curtailment*, then this shall be appropriately factored

into the estimated resources and assessment of the economic viability of the solar project and documented accordingly.

43. NREL defines *curtailment* "as a reduction in the output of a generator from what it could otherwise produce given available resources (e.g., wind or sunlight), typically on an involuntary basis." (page 1, Bird et al. 2014).

44. As *curtailment* becomes of greater concern to energy producers, contract terms are evolving to include provisions addressing the use of *curtailment* hours, including the sharing of risk between the project and *solar energy product* off-taker. Some studies (Sterling et al. 2016) have shown that curtailed *solar resources* can provide *ancillary services* to aid in system operations, e.g. providing both up and down regulation reserves for the balancing area.

45. In most cases, force majeure events or unforeseen operational issues are not considered when making *solar resource* estimates. However, if such an event does occur and impacts *solar resource* quantities, then the project classification should be reviewed based on revised expectations. For example, a resource report can be prepared, which assesses the likelihood of utilising previously anticipated *solar resource* quantities.

46. *Solar resources* may be stored before use or sale, e.g. as an alternative to curtailment. This can be included in the classification, e.g. where there is a commercial agreement to sell stored quantities then this can be categorised as E1; where no agreement exists, it may be E2 or E3. However, care shall be taken to avoid double counting, e.g. electricity received for storage from another project shall not be counted as part of the project resources.

F. Projects with multiple energy types

47. Some *solar projects* may produce two or more types of *solar energy product*, e.g. both heat and electricity. In this case, *solar resource*s shall be estimated and classified separately. Consistent with UNFC Part IV.D, estimated quantities should be reported separately for each commodity or significant product type that will be sold, used, transferred or disposed of separately. Where estimates for different commodities or product types have been aggregated for reporting purposes, and separate estimates are not provided, the aggregated estimates shall be accompanied by a statement clarifying which commodities or product types have been aggregated and identifying the conversion factor(s) used to render them equivalent for aggregation.

G. National/Regional versus Corporate Classification and Reporting

48. UNFC is geared towards classifying the energy resources associated with single or multiple projects. For reporting of corporate or national *solar resource*s, the estimated quantities of the 'single' projects may need to be aggregated. UNFC, Part II, section IV and section VI.K provide guidance on the issues of national resource reporting and aggregation of estimated quantities.

49. For national resource reporting, the aggregation of known projects from commercial, non-commercial and/or governmental organizations may not cover the total national *solar resource*. This is because national or global resource quantification and classifications are often not based on defined projects and estimate a total solar energy potential (expressed as installed power output) rather than finite, project-based *solar resource*s (expressed as a fixed energy amount for the project lifetime).

50. The UNFC and Solar Specifications can be used for national, regional or global *solar resource* quantification and classification by taking into consideration the defined projects and defining notional projects with a notional reference point and project duration to estimate the full solar resource. Immature or notional projects shall be classified accordingly, using the E and F category definitions. If it is assumed that the notional project lifetime will be extended by reinvestment or like-for-like replacements, then such assumptions need to be stated and relevant costs incorporated in the economic analysis. Initial solar projects are likely to be extended or

replaced by new projects in their place, often utilizing better technology and generating a larger *solar resource*.

51. If solar energy potentials are used for notional projects, then the associated *solar resource* is the multiplication of the solar energy potential (expressed in installed power or energy delivered per year) and the assumed project duration (years). The uncertainty relating to the potential and thus ultimately, *solar resource* shall be assessed using G categories and all assumptions shall be documented.

H. Effective date

52. Reported estimates of remaining *solar resources* are as at the Effective Date of the evaluation. The Effective Date shall be clearly stated in conjunction with the estimate. The evaluation should take into account all data and information available to the evaluator prior to the Effective Date. If information becomes available subsequent to the Effective Date, but prior to reporting, that could have significantly changed the estimated quantities as at the Effective Date, the likely effect of this information shall be included in the report.

I. Evaluators

53. Evaluators are the people that estimate the quantity of *solar resources* from a project and classify *solar resource*s. Evaluators must possess an appropriate level of expertise and relevant experience in the estimation and classification of *solar energy resources*.

III. Definitions of UNFC classes, categories and supporting explanations

A. The UNFC

54. As explained in the Introduction, UNFC is a generic principle-based system in which quantities are classified using three fundamental criteria:

- Economic, environmental and social viability (E)
- field project status and feasibility (F)
- level of project knowledge and confidence in the potential recoverability of the quantities (G).

55. The fundamental principles are project maturity (as expressed by the E- and F-axis) and project uncertainty (G-axis).

56. Using a numerical coding system, combinations of these criteria create a three-dimensional classification shown in Figure 2. Categories (e.g., E1, E2, E3) and, in some cases, sub-categories (e.g., E1.1), are defined for each of the three criteria as presented and defined in Annexes I and II of the Generic Specifications.

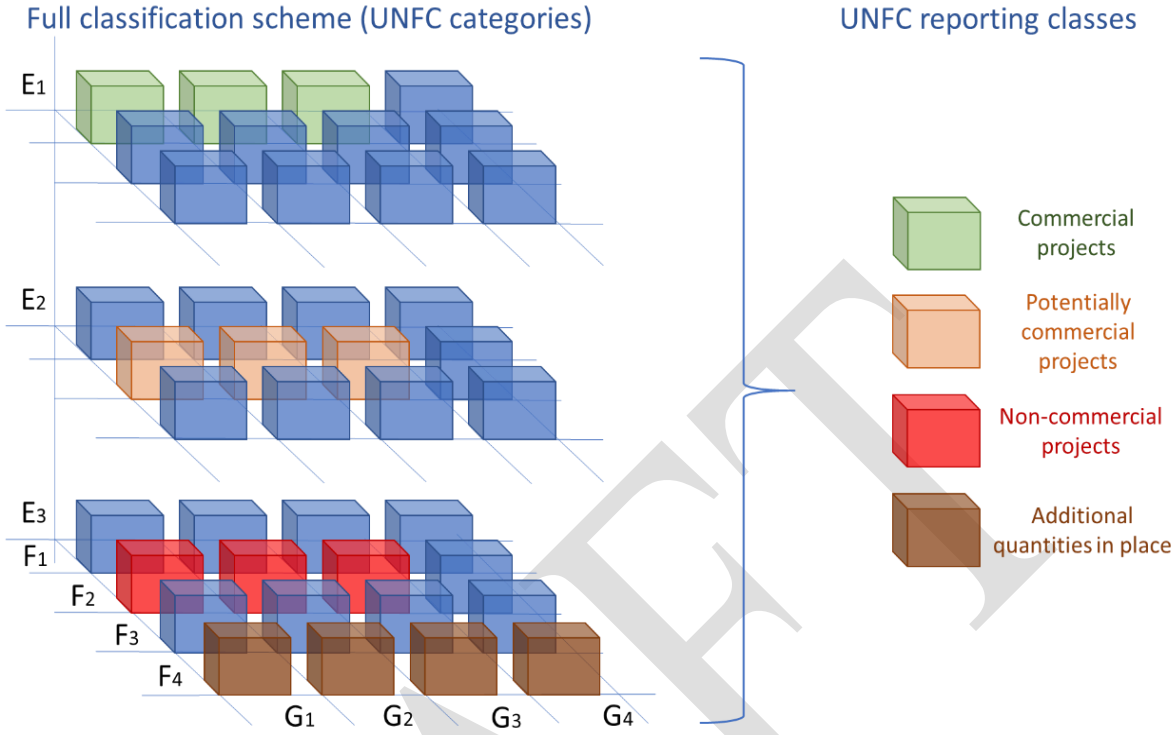

Figure 2: UNFC classification categories and UNFC classes for reporting.

57. Sub-classes are defined to provide additional clarity and granularity, Table 2. Their use is optional.

Table 2: Abbreviated version of UNFC adapted to solar showing classes and subclasses.

Class	Description	Subclass	Resource confidence		
			High	Moderate	Low
			(UNFC minimum resource categories[3])		
Commercial *solar resource* projects	Development of the *solar resource* is economically, environmentally and socially viable[2], and technical feasibility has been confirmed.	On Production	(E1, F1.1, G1)	(E1, F1.1, G2)	(E1, F1.1, G3)
		Approved for Development	(E1, F1.2, G1)	(E1, F1.2, G2)	(E1, F1.2, G3)
		Justified for Development	(E1, F1.3, G1)	(E1, F1.3, G2)	(E1, F1.3, G3)
Potentially commercial *solar resource* projects	Development of the *solar resource* is expected to become economically, environmentally and socially viable in the foreseeable future and/or technical feasibility has not yet been confirmed.	Development Pending	(E2, F2.1, G1)	(E2, F2.1, G2)	(E2, F2.1, G3)
		Development on Hold	(E2, F2.2, G1)	(E2, F2.2, G2)	(E2, F2.2, G3)
Non-commercial *solar resource* projects	Development of the *solar resource* is not expected to become socially, environmentally and economically viable in the foreseeable future or evaluation is at too early a stage to determine social, environmental and economic viability. Technical feasibility has not yet been confirmed.	Development Unclarified	(E3.2, F2.2, G1)	(E3.2, F2.2, G2)	(E3.2, F2.2, G3)
		Development Not Viable	(E3.3, F2.3, G1)	(E3.3, F2.3, G2)	(E3.3, F2.3, G3)
Potential *solar resource* projects	Developments associated with the investigation of one or more potential *solar sites*. No development project has yet been identified.		(E3, F3, G4)		
Additional quantities of *solar resources*	Quantities of *solar irradiation* that will not be developed. Some of these may become recoverable in the future as technological developments occur. Some or all of these quantities may never be utilised.		(E3, F4, G1)	(E3, F4, G2)	(E3, F4, G3)

58. Additional requirements and explanations are provided below for the application of UNFC to *solar resources*.

B. E Axis Categories – Establishing Socio-Economic Viability

59. The E-axis encompasses all non-technical issues that could directly impact the viability of a project, including energy prices, operating costs, legal, fiscal and regulatory framework, environmental regulations and known environmental or social impediments or barriers.

[3] The E and F categories and subcategories shown in Table 2 are the minimum required for the subclass. A project which meets some, but not all, requirements of a higher subclass would be classified in the lower subclass. A project which is categorized as E2, F1.3 would be classified as Development Pending.

60. Environmental and social viability is determined by the positive and negative environmental and social impacts of the project. For a project to be viable, the impacts have been assessed, and there is appropriate regulatory and community license or acceptance for the development.

61. Table 3 presents the E-axis categories E1 to E3, including UNFC definitions and explanations. Alongside are interpretations and explanations for solar Specifications. Solar Specification definitions and explanations are based on UNFC definitions and explanations but using solar energy terms presented earlier in this document. Similarly, Table 4 presents the revised UNFC E-axis subcategories E1.1 through to E3.3, including revised UNFC definitions alongside the solar energy interpretations.

62. In accordance with the definitions of E1, E2, and E3, economic assumptions shall be based on current market conditions and realistic assumptions of future market conditions. Except where constrained by regulation, assumptions of future market conditions should reflect the view of either: (1) the organization responsible for the evaluation; (2) the view of a competent person or evaluator; or, (3) an externally published independent view, which is considered to be a reasonable forecast of future market conditions. All assumptions shall be disclosed.

63. Current market conditions and realistic assumptions of future market conditions should include policy support mechanisms (if applicable) for solar energy but shall not assume that such mechanisms will become more beneficial in the future unless already specified in the regulation.

64. There are three key terms used for the E axis: *reasonable expectations, reasonable time frame and foreseeable future*.

Reasonable Expectations

65. The term reasonable expectations is used within the E1 classification. Reasonable expectations concern the likelihood of obtaining necessary regulatory approvals, permits and contracts necessary to implement the solar project and require objective supporting evidence.

66. For the condition of reasonable expectations to apply in the case of governmental approvals or permits, the application or submission shall have been made together with supporting information. Aside from minor additional information requests or clarifications, there should be justification to expect that the application will be approved within a period that is typical for applications of that type in the jurisdiction concerned. The condition of *reasonable expectations* can also apply in circumstances when the application is still to be made or to be fully completed so long as there is a demonstrated track record of obtaining such approvals.

67. For the condition of *reasonable expectations* to apply to commercial/financing contracts or agreements, negotiations shall be underway, with the specific justification that agreement will be achieved within a time period that would be typical for such contracts or agreements. The conditions of *reasonable expectations* can also apply in the circumstance when negotiations have not commenced, provided there is a demonstrated track record of negotiating similar contracts/agreements.

Reasonable Time Frame

68. The term *reasonable time frame* concerns the time frame within which all approvals, permits and contracts necessary to implement the *solar project* are to be obtained. This should be the time generally accepted as the typical period required to obtain approval, permits or contracts.

Foreseeable Future

69. The *foreseeable future* is the period of time that a *solar project* can make a reasonable projection of future market conditions, events or other conditions that determine the economic viability or other factors of a *solar project*.

Table 3: UNFC E-axis category definitions and application to solar energy.

UNFC Categories	*UNFC definition*	*UNFC explanation*	*Solar interpretation*	*Solar explanation*
E1	Development is confirmed to be socially, environmentally and economically viable.	Development is socially, environmentally and economically viable on the basis of current market conditions and realistic assumptions of future market conditions. All necessary conditions have been met, or there are reasonable expectations that all necessary conditions will be met within a reasonable timeframe and there are no impediments to the delivery of the raw material or energy to a market. Social, environmental and economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.	Development of *solar resources* has been confirmed to be economically socially and environmentally viable.	Development of *solar resources* is socially, environmentally and economically viable on the basis of current market conditions and realistic assumptions of future market conditions. All necessary conditions have been met, or there are reasonable expectations that all necessary conditions will be met within a reasonable timeframe and there are no impediments to the delivery of the raw material or energy to a market. Social, environmental and economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.
E2	Development is expected to become socially, environmentally and economically viable in the *foreseeable future*.	Development is not yet confirmed to be socially, environmentally and economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for social, environmental and economic viability in the *foreseeable future.*	Development of *solar resources* is expected to become socially, environmentally and economically viable in the *foreseeable future*.	Development of *solar resources* is not yet confirmed to be socially, environmentally and economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for social, environmental and economic viability in the *foreseeable future.*
E3	Development is not expected to become socially, environmentally and economically viable in the *foreseeable future* or evaluation is at too early a stage to determine social, environmental and economic viability	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for social, environmental and economic viability in the *foreseeable future*; or, economic viability of extraction cannot yet be determined due to insufficient information. Also included are estimates associated with projects that are forecast to be developed, but which will not be available for sale	Development of *solar resources* is not expected to become socially, environmentally and economically viable in the *foreseeable future* or evaluation is at too early a stage to determine social, environmental and economic viability.	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for social, environmental and economic viability of the development of *solar resources* in the *foreseeable future*; or, economic viability of extraction cannot yet be determined due to insufficient information. Also included are estimates associated with projects that are forecast to be developed., but which will not be available for sale or use for economic benefit. This includes quantities consumed in production (parasitic loss) and other losses.

Table 4 UNFC E-axis subcategory definitions and application to solar energy

UNFC categories	*UNFC sub-categories*	*UNFC definition*	*Solar interpretation*
E1	E1.1	Development is socially, environmentally and economically viable on the basis of current conditions and realistic assumptions of future conditions.	The production of *solar resources* via a new or existing project is viable, and it can be demonstrated that all the following conditions are in place or there are *reasonable expectations* that the elements will be put in place in a *reasonable time frame*: • Access to source: land lease/ownership of the site (on or offshore) for the project • Access to market: required power purchase agreement (or equivalent), whereby the *solar energy product* can be sold for the project lifetime or until the end of the contract, or economic limit has been reached. A power purchase agreement, or equivalent, is not necessarily required when the solar energy product will be for use but not for sale. • Authorization/entitlement: permits to build and operate the project • Economic case: the project is economically viable over the project lifetime based on current, anticipated or contractually agreed on prices, costs, tax incentives and taxes • Social and environmental considerations: local communities, government agencies and/or non-governmental agencies support the project, and there are no counter-indications that pose a risk to the viability of the project.
	E1.2	Development is not socially, environmentally and economically viable on the basis of current conditions and realistic assumptions of future conditions, but is made viable through government subsidies and/or other considerations.	In addition to the requirements for E1.1 as listed above, the calculation of economic viability is dependent on regulatory or policy support, typically in the forms of tax and/or price incentives. This includes any regulatory support and/or grants or subsidies needed to make the current project economically viable. Policy support mechanisms are typically phased out over time, and the economic case shall reflect this. Support shall not be assumed to become more beneficial in the future unless already so specified in the regulations.
E2	n/a	Not all economic, social and environmental contingencies have been resolved, but there is a high probability that they will be resolved within the *foreseeable future*.	One or more of the economic, legal, social and environmental contingencies are not yet in place, but the missing elements are expected to be in place in the *foreseeable future*. • Access to source: land lease/ownership of the site for the project lifetime • Access to market: required power purchase agreement (or equivalent contract) with suitable buyers(s) have been negotiated or terms defined. A power purchase agreement, or equivalent, is not necessarily required when the solar energy product will be for use but not for sale. • Authorization/entitlement: permits to build and operate the project have been identified, the applications process and timelines are clear, or the process may have started. • Economic case: the project is economically viable over the expected project lifetime using anticipated prices, costs, tax incentives and taxes. • Social and environmental considerations: issues relating to local communities, government agencies and/or non-governmental agencies who may oppose the project have been identified, a mitigation and stakeholder engagement plan is in place, thereby making any potential risks manageable.

E3	E3.1	Estimate of raw materials or energy that are forecast to be developed, but which will not be available for sale.	*Solar resource* quantities that are forecast to be produced but not available for sale or use for economic benefit. This includes quantities consumed in production (parasitic loss) and other losses.
	E3.2	Economic, social and environmental viability cannot yet be determined due to insufficient information.	The project is not viable because one or more of the economic, legal, social and environmental contingencies are insufficiently defined and/or inadequately assessed due to insufficient information. • Access to the source: land lease/ownership requirements for the project site are not known, unlikely to be obtained and/or the timeframe to obtain access to the source not known. The solar source assessment is insufficient or not available. Regulatory requirements may not be known. • Access to market: the required power purchase agreement (or equivalent contract) with suitable buyers(s) have not been identified and/or terms have not been negotiated with buyers. A power purchase agreement, or equivalent, is not necessarily required when the solar energy product will be for use but not for sale. • Authorization/entitlement: required permits to build and operate the project are not known or unlikely to be obtained in the foreseeable future. • Economic case: the project is economically not viable, or viability cannot be assessed due to lack of knowledge of likely prices and costs over the project lifetime. • Social and environmental considerations: issues relating to local communities, government agencies, non-governmental agencies who may oppose the project have not been identified, and the extent of managing social and environmental risks to the project is not known.
	E3.3	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for social, environmental and economic viability in the *foreseeable future*.	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for social, environmental and economic viability of the development of *solar resources* in the *foreseeable future*.

C. F Axis Categories – Establishing Field Project Status and Feasibility

70. The F axis designates the maturity of studies and commitments necessary to implement solar projects. These extend from early exploration or evaluation of a Solar Resource through to a project that is extracting/producing and selling Energy Product(s) and reflects standard value chain management principles. The assessment of maturity covers both the technical feasibility of the project and the level of commitment by the project sponsors to proceed with the project and its maturation stages prior to operation.

71. In order to assign a *solar resource* to any class, except for category F4, a development plan needs to be defined consisting of one or more projects. The level of detail appropriate for such a plan may vary according to the maturity of the project and may also be specified by regulation.

72. It is important to note that the F axis is intended to capture both the technical feasibility and the maturity of a project, and in doing so, represents the level of risk in the technology as well as the level of commitment by the project sponsor, the classifying entity, joint venture partners, and/or financial partners. Generally, F1 projects do not require significant technical refinements prior to implementation and commitment of capital funds, or the project sponsor does not require

any further technical studies prior to the decision to commit capital. F2 projects are still in the development process and require further technical definition prior to a decision to commit capital funds, while F3 projects do not have sufficient information to quantify the Energy Products that may be extracted. Category F4 may be utilized by Evaluators where there is an identifiable solar resource site, but a project to extract the Energy Product has not been defined.

73. Table 5 presents the F-axis categories F1 to F4, including revised UNFC definitions and explanations. Alongside these are solar interpretations and explanations. The solar interpretations and explanations use solar terms presented earlier in the solar specifications. Following the same logic, Table 6 presents the UNFC E-axis subcategories F.1.1 through to F.4.3, including revised UNFC definitions alongside solar interpretations.

Table 5 UNFC F-axis category definitions and application to solar energy

UNFC Category	*UNFC definition*	*UNFC explanation*	*Solar interpretation*	*Solar explanation*
F1	Feasibility of a development project has been confirmed.	Development is completed or currently taking place or, sufficiently detailed studies have been completed to demonstrate the feasibility of development.	Feasibility of development of *solar resources* has been confirmed.	Development of a solar energy project is completed or currently taking place or, sufficiently detailed studies have been completed to demonstrate the feasibility of development.
F2	Feasibility of a development project is subject to further evaluation.	Preliminary studies of a defined project provide sufficient evidence of the potential for development that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.	Feasibility of development of *solar resources* is subject to further evaluation.	Preliminary studies of a defined solar energy project provide sufficient evidence of the potential for development that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.
F3	Feasibility of a development project cannot be evaluated due to limited technical data.	Very preliminary studies of a defined (at least in conceptual terms) project or potential project, indicate the need for further data acquisition or study in order to evaluate the potential feasibility of development.	Feasibility of development of *solar resources* cannot be evaluated due to limited technical data.	Scoping studies of a defined (at least in conceptual terms*) solar energy* project or potential project, indicate the need for further data acquisition or study in order to evaluate the potential feasibility of development.
F4	No development project has been identified.	Remaining quantities of commodity not developed by any project or potential project.	No solar project has been identified	*Solar irradiation* will not be utilised by any currently defined solar project or technology.

Table 6 UNFC F-axis subcategory definitions and application to solar energy

UNFC categories	*UNFC sub-categories*	*UNFC definition*	*Solar interpretation*
F1	F1.1	Development is currently taking place.	Development of the solar energy project is currently taking place.
	F.1.2	Capital funds have been committed, and implementation of the development is underway.	Capital funds have been committed, and implementation of the solar project is underway.
	F1.3	Studies have been completed to demonstrate the feasibility of development.	Sufficiently detailed studies have been completed to demonstrate the feasibility of developing *solar resources*.
F2	F2.1	Project activities are ongoing to justify development in the *foreseeable future*.	Project activities are ongoing to justify development in the *foreseeable future*.
	F2.2	Project activities are on hold and/or where justification as a commercial development may be subject to significant delay.	Project activities are on hold or where justification as a commercial development may be subject to significant delay.
	F2.3	There are no current plans to develop or to acquire additional data at the time due to limited potential.	There are no current plans to develop or to acquire additional data at the time due to limited potential.
F3	F3.1	Where site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	Where site-specific studies have identified a potential solar energy development with sufficient confidence to warrant further testing.
	F3.2	Where local studies indicate the potential for development in a specific area but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing.	Where local studies indicate the potential for solar energy development in a specific area but require more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing.
	F3.3	At the earliest stage of studies, where favourable conditions for the potential development in an area may be inferred from regional studies.	At the earliest stage of studies, where favourable conditions for the potential solar energy development in an area may be inferred from regional studies.
F4	F4.1	The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project or potential project.	The technology necessary is under active solar energy development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project or potential project.
	F4.2	The technology necessary is being researched, but no successful pilot studies have yet been completed.	The technology necessary is being researched, but no successful pilot studies have yet been completed.
	F4.3	The technology is not currently under research or development.	The technology is not currently under research or development.

D. G Axis Categories – Delineating Uncertainty

74. The G axis reflects the level of confidence in the estimated quantities of *solar resources*. Table 7 shows the category definitions and explanations of the application to *solar resources*.

75. The G-axis categories are intended to reflect all significant uncertainties impacting the estimated *solar resource* quantities that are forecast to be produced by the Project. Uncertainties include specific quantity and variability of the solar source, the efficiency of the extraction and conversion methodology, planned and unplanned maintenance, and how much will be produced.

76. There are three established approaches to determining appropriate estimates for G1, G2 and G3; two of which are based on the assessment of a range of uncertainty for quantities associated with a project and the other reflecting different levels of confidence. The terms used within these specifications are as follows:

i. The "incremental" approach, which is based on estimates for discrete portions of the *solar source* and/or the project, where each estimate is assigned on the basis of its level of confidence (high, moderate and low), reflecting available knowledge regarding potential recoverability;

ii. The "scenario" approach, which is based on three discrete scenarios that are designed to reflect the range of uncertainty in the possible outcomes (low, best, and high estimates) of the project producing energy from the *solar source* as a whole;

iii. The "probabilistic" approach, where multiple possible scenarios are generated (e.g., by Monte Carlo analysis) from input distributions of parameter uncertainty associated with the project producing energy from the *solar source* as a whole. Three specific outcomes are then selected from the output probability distribution as representative of the range of uncertainty (P90, P50 and P10 values are equated to low, best and high estimates respectively, where P90 means there is 90% probability of exceeding that quantity).

77. Any of the three approaches is permissible. The assessment shall state which approach is being used; however, it is anticipated that the "scenario" or "probabilistic" approaches will be the most relevant.

78. Where the "scenario" or "probabilistic" approaches are used, the low (or P90) estimate is classified as G1, the best (or P50) estimate is classified as G1+G2, and the high (or P10) estimate is classified as G1+G2+G3.

79. In all cases, due consideration shall be given to possible dependencies between input parameters. Further, whichever approach is used, all three categories (G1, G2 and G3) should be reported to provide an indication of the range of uncertainty in the estimate.

80. Irrespective of the approach, the basis of the uncertainty assessment and/or assumptions shall be provided.

81. Where a project's long-term financial or operating plan is being used to provide an estimate of a project's solar resources, then that plan/projection shall typically be considered as a best (or P50) estimate, that is, a G1+G2 classification.

82. G4 applies to sites where no development project has yet been defined or where no direct measurements exist to quantify the solar source. Subcategories of G4 are defined in UNFC, denoting different levels of confidence. This additional level of detail is not considered useful for solar.

Table 7 UNFC G-axis category definitions and application to solar energy

Category	*UNFC definition*	*UNFC explanation*	*Solar interpretation*
G1	Estimates associated with a project that can be estimated with a high level of confidence.	Estimates may be categorized discretely as G1, G2 and/or G3 (along with the appropriate E and F categories), based on the level of confidence in the estimates (high, moderate and low confidence, respectively) based on direct evidence. Alternatively, estimates may be categorized as a range of uncertainty as reflected by either (i) three specific deterministic scenarios (low, best and high cases) or (ii) a probabilistic analysis from which three outcomes (e.g. P90, P50 and P10)[4] are selected. In both methodologies (the "scenario" and "probabilistic" approaches), the estimates are then classified on the G Axis as G1, G1+G2 and G1+G2+G3 respectively. In all cases, the estimates are those associated with a defined project. Additional Comments The G axis reflects the level of confidence in the estimates of raw material or energy. Thus, the G axis categories are intended to reflect all significant uncertainties impacting the estimated forecast for the project. Uncertainties include both variability and the efficiency of the development (where relevant). Typically, the various uncertainties will combine to provide a full range of possible outcomes. In such cases, categorization should reflect three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.	Typically, the various uncertainties will combine to provide a full range of possible outcomes. In such cases, categorization should reflect three scenarios or outcomes that are equivalent to G1 (low case or P90), G1+G2 (best estimate or P50) and G1+G2+G3 (high case or P10). Uncertainties include both variability in the *solar irradiation*, the efficiency of the extraction and conversion methodology, and how much will be produced.
G2	Estimates associated with a project that can be estimated with a moderate level of confidence.		
G3	Estimates associated with a project that can be estimated with a low level of confidence.		
G4	Estimates associated with a potential project based primarily on indirect evidence.	A potential project is one where the existence of developable solar energy is based primarily on indirect evidence and has not yet been confirmed. Further data acquisition and evaluation would be required for confirmation. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty of the potential project or projects. In addition, it is recommended that the chance of success (probability) that the potential project will progress to a Commercial Project is assessed and documented.	A potential project is one where the existence of developable solar energy is based primarily on indirect evidence and has not yet been confirmed. Further data acquisition and evaluation would be required for confirmation. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty of the potential project or projects. In addition, it is recommended that the chance of success (probability) that the potential project will progress to a Commercial Project is assessed and documented.

[4] Where P90 means that there is a 90 per cent probability that the actual outcome will exceed this estimate. Similarly, P50 and P10 reflect 50 per cent and 10 per cent probability respectively, that the actual outcome will exceed the estimate.

IV. Applying the Solar Specifications

A. Workflow for estimating and classifying solar projects

83. The classification of projects is one step within a wider information cycle (Figure 3). Steps leading up to the classification of solar resources consist of:

Step 1. Collecting data on projects or possible project sites; and,

Step 2. Calculating the *solar resource* from each project or possible project site should take into account expectations around energy prices, costs, and the economics of solar projects.

Step 3 is the classification of projects. This involves reviewing the data collected on projects, and possible projects, and then determining which category a project or potential project belongs in, based on the definitions provide in this document.

84. After classifying projects, there are a series of other steps consisting of:

Step 4. Compiling *solar resource* estimates in the same UNFC classes and subclasses and calculating totals for each class and subclass;

Step 5. Controlling for data quality, e.g. checking calculations and the classification of projects;

Step 6. Reporting of information to decision makers typically in reports, but also through business information systems, finance/loan applications and governmental surveys.

85. Data classified as "UNFC" can serve as an input to decisions either by business leaders, government agencies or others, on issues of whether to progress projects or make new investments. The implementation of these decisions then leads to changes which are captured in updated solar resources classification exercises, e.g. as projects go from *development pending* to *development justified*, *potentially commercial resources* are reclassified as *commercial resources*.

B. Consideration of Risk

86. The robustness of classification is impacted by project risk. Key risks to development shall be disclosed by the evaluator or reporting entity.

87. There is a growing range of technologies, applications and business models for utilising *solar energy products*. These include: utility-scale solar PV electricity supplying the grid or large energy users; utility-scale concentrating solar power electricity generation for the grid or large energy users; solar electricity generation for an independent micro-grid, solar electricity generation for own use; household solar PV electricity generation with a feed-in tariff or some form of net metering benefit; household solar water heating, solar space heating, community and shared solar; solar rechargeable devices, and more. When taking into account the financing, power purchase agreements and other arrangements, these business models and their risks quickly multiply in combination and number.

88. Irrespective of the business or contractual model used, the *project* should be able to demonstrate that it has considered: possible risks impacting the socio-economic viability and project feasibility; possible technical risks to the project; and, *entitlement* to benefit from utilising the *solar energy products*. Annex III provides a list of typical technical risks related to solar energy projects.

89. Important risks to consider include technical, social, environmental, financial and business issues. These are assessed in classifying the project status (E and F axes) and managed to mature and execute the project. Note that technical uncertainties, such as yield estimates and downtime impact the estimated quantities, rather than project maturity, and are reflected on the G axis.

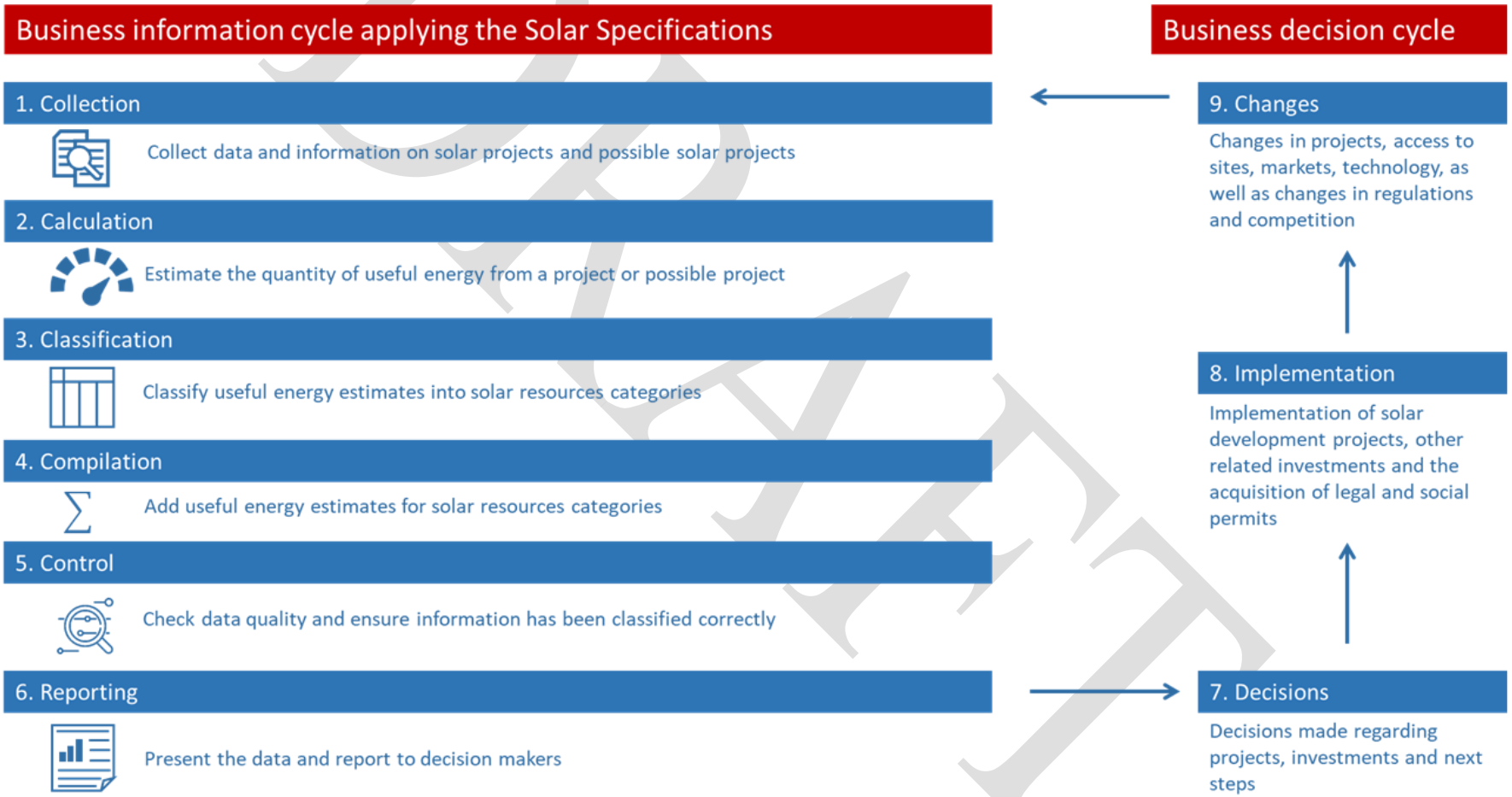

Figure 3: Process for identifying estimating, classifying and reporting solar energy project resources using the UNFC.

C. National and Regional estimates

90. In addition to corporations and investors, the UNFC can also be used by governments and institutions to assess or monitor solar energy potentials and projects, for example at national and regional levels. Government agencies may have an interest in *solar resource*s within the territories over which they have jurisdiction. This might include an interest in understanding: *solar resource*s being utilised; *solar resource*s that are at various stages of development or are expected to be commercially viable in the foreseeable future; and, *solar resource*s currently inaccessible including the reasons why these resources are currently inaccessible. Furthermore, the UNFC creates the opportunity for governments to compare *solar resource* estimates with other energy resource estimates.

91. National and Regional assessments can support energy statistics and policy. In turn, policies will impact project viability and maturity, and the estimated quantities of solar energy products and solar resources.

92. Importantly the International Recommendations for Energy Statistics note that energy resources classified using the UNFC are within the scope of energy statistics (IRES 2018). In principle, solar resources should be included in environmental and economic accounts and in a national system of energy statistics.

93. The government information cycle is similar to the business information cycle (Figure 4). Key differences include data collection methods and sources, compilation methods and gap filling, as well as the types of decisions the information is used for.

94. Data collection by the government can include project data from its own investments, as well as project data collected from administrative sources (e.g. data collected as part of permitting processes), surveys of projects, industry associations as well as research organisations including universities. To get a complete picture of *solar resource*s, during the calculation stage governments will usually fill gaps in data on solar resources through an analysis of theoretical, geographic, technical and economic potentials using Geographic Information Systems (GIS) and related models. These models take into account infrastructure, energy demand, technologies, and regulations (see Section II.D. Solar resources estimates).

95. After data checking and quality control, national *solar resource* estimates are published and shared with government decision makers and the public, including business, civil society and researchers. In many instances, there will be an additional analysis of *solar resource*s, for example, to assess progress against policy targets and objectives, or to understand issues or create policy options for consideration by government leaders. Governments might also use the classification of solar resources to monitor their solar energy projects.

96. Government decisions generally regard policies including legislation, regulations, taxes and subsidies, as well as projects and energy-related investments. These decisions not only direct government interventions but also influence business enterprises, establishments and their economic activities, including solar energy projects. As such, government decision can spur many changes, and these are, in turn, are monitored through successive rounds of data collection.

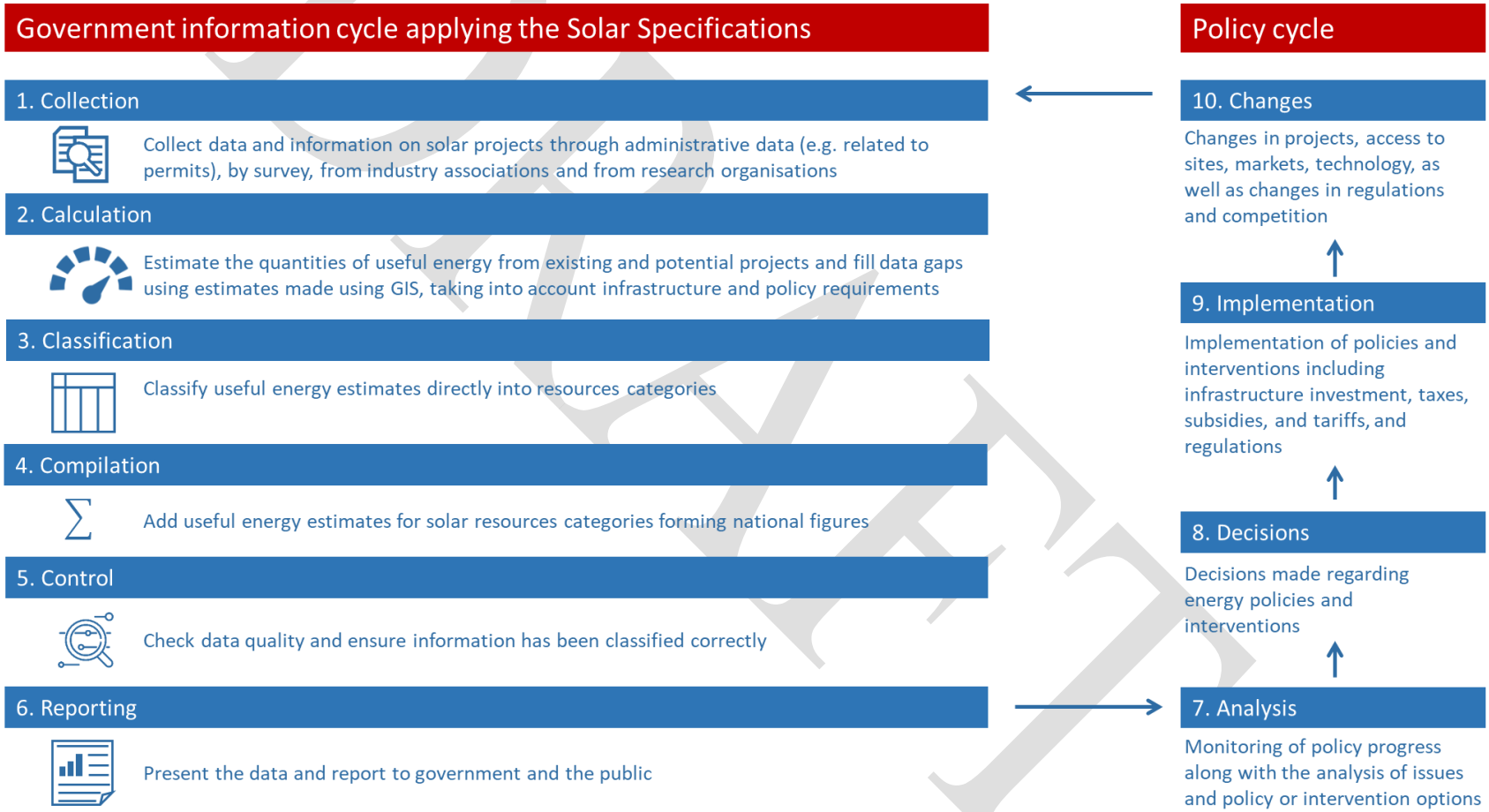

Figure 4: Process of organising solar energy reserves and resources data for input to government energy analysis and decision making

D. Solar project information users

97. Figure 5 illustrates the information-audience model for solar resources data. On the left side, it shows that information for solar classification is gathered and assessed by evaluators, assurers and analysts. The resultant classification is then used by internal managers and internal and external decision makers. This includes an information pyramid with detailed information on *solar projects* and possible project *sites* (e.g. in GIS or a database) at the base. Information is successively aggregated, or estimated, forming summary information toward the top of the pyramid. The right side shows that for each layer of information, there are different users. For the most detailed information, users consist of a few *evaluators* that estimate the *solar resources* and classify these estimates. Above the evaluators are analysts who review the work and use it to support business analyses. Externally reported information would typically have the largest and widest audience including investors, developers, regulators and others. In between, there are managers, executives and directors, for example, who receive and use internally reported resource data and analyses to support their decision-making.

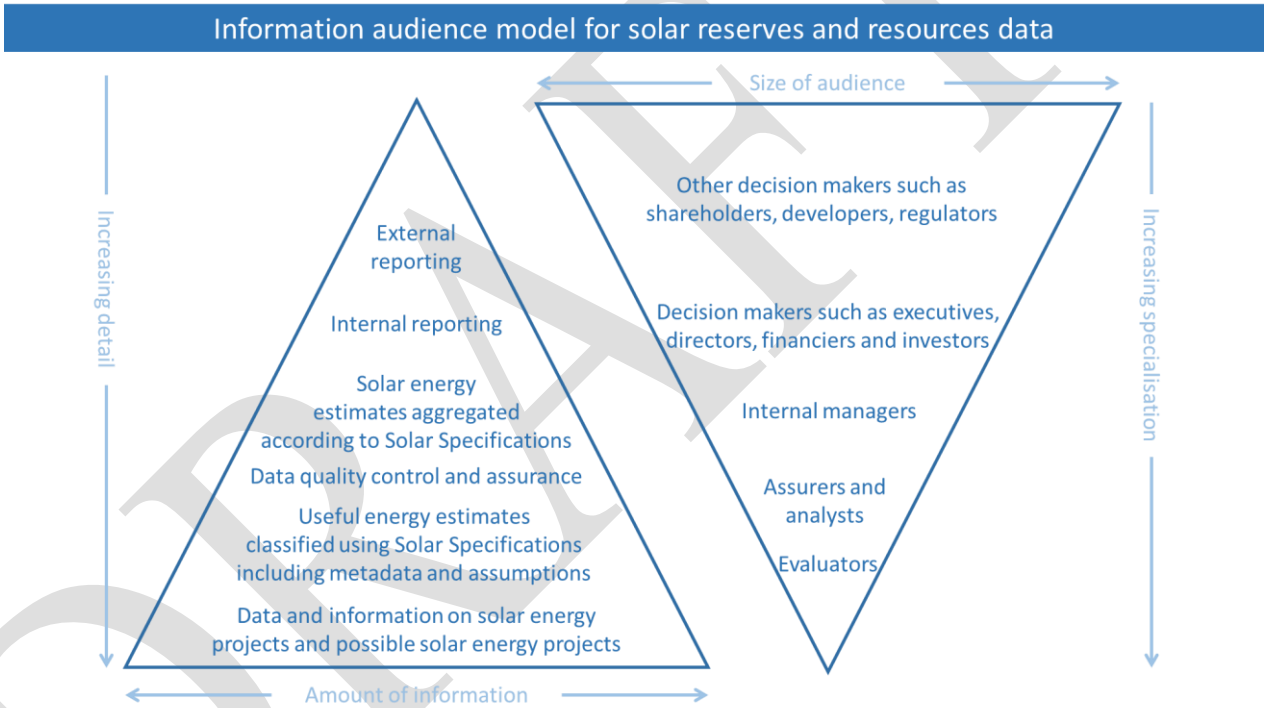

Figure 5: Information audience model for solar energy resource estimates classified using the UNFC.

V. References

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Glossary

Additional solar energy: Solar energy that may become recoverable in the future as technological developments occur; however, some or all of these quantities may never be utilised.

Additional quantities (associated with known and potential resource sources): Energy that may become recoverable in the future as technological developments occur. Some or all of these quantities may never be utilised.

Ancillary services: Services that assist the grid operator in maintaining system balance.

Commercial solar resource projects: Development of the solar resource is economically, environmentally and socially viable, and technical feasibility has been confirmed.

Curtailment: A reduction in the output of a generator from what it could otherwise produce given available resources (e.g., total solar irradiation), typically on an involuntary basis.

Direct beam irradiation: the total energy directly from the sun coming along a straight line perpendicular to the sun, over a specified time period, typically expressed in units of W-hr-m^{-2}-day^{-1} or equivalent.

Diffuse irradiation: The total energy from the sky other than the sun, including the scattered irradiation from both clouds and clear sky, over a specified time period, typically expressed in units of W-hr-m^{-2}-day^{-1} or equivalent.

Economic limit: A point in time when the anticipated cumulative net operating cash flows from the project are expected to be negative.

Effective date: the date for which the assessment is made.

Entitlement: The quantity of *solar resource* that is legally and practically accessible to a *project*. A project's *entitlement* to *solar resource* may be limited by regulatory, contractual or other conditions.

Establishment: An enterprise or part of an enterprise that is situated in a single location and in which (a) only a single productive activity is carried out or (b) the principal productive activity accounts for most of the value added.

Foreseeable future: The period of time that a *solar project* can make reasonable projections of future market conditions, events or other conditions that determine the economic viability or other factors of a *solar project*.

Ground reflected irradiation: The total energy from the sun that has been reflected upward from the ground over a specified time period, typically expressed in units of W-hr-m^{-2}-day^{-1} or equivalent.

Non-commercial solar resource project: Development of the solar resource is not expected to become socially, environmentally and economically viable in the foreseeable future or evaluation is at too early a stage to determine social, environmental and economic viability. Technical feasibility has not yet been confirmed.

Potentially commercial solar resource project: Development of the solar resource is expected to become economically, environmentally and socially viable in the foreseeable future and/or technical feasibility has not yet been confirmed. Consequently, not all Potentially Commercial Projects may be developed.

Potential solar resource projects: Projects associated with the investigation of one or more potential solar sites.

Project lifetime: the remaining period of time that a project is expected to operate, constrained by technical, economic, regulatory or other permit/license cut-offs.

Reasonable expectations: The likelihood of obtaining necessary regulatory approvals, permits and contracts necessary to implement the *solar project*. It requires objective supporting evidence.

Reasonable time frame: The time frame within which all approvals, permits and contracts necessary to implement the *solar project* are to be obtained. This should be the time generally accepted as the typical period required to obtain approval, permits or contracts.

Reference point: The point at which the cumulative quantities of solar energy products are measured or estimated.

Solar irradiation: The sum of the direct and diffuse irradiance components, plus any reflected irradiation, falling on a flat plate or concentrating solar collector, regardless of its orientation relative to a horizontal surface, typically expressed in units of W-hr-m-2-day-1 or equivalent.

Solar resources being explored: Quantities of *solar energy product* under investigation.

Solar site: a location with access to *solar irradiation*.

Solar technologies: The devices and practices that utilise energy from *solar irradiation*.

Solar energy product: The energy commodity produced by the project that can either be sold or can be used for economic benefit. This would include direct domestic, industrial or business use of energy produced by a solar installation. Note that energy consumed during production (parasitic loss) is not considered part of the commercial production and is categorized separately.

Solar source: The total solar irradiation being received by the solar collector, regardless of its type and orientation.

Solar project: the site(s), technologies and activities over which decisions are made to derive energy from *solar irradiation*.

Solar resource: The cumulative quantities of *solar energy products* that will be generated from the solar irradiation via a project from the *effective date* of the evaluation forward until the end of the project lifetime/limit, measured or evaluated at the *reference point*

Annex I: United States Energy Resources 1989

1. The "Characterization of US Energy Resources and Reserves" published by the United States Department of Energy (DOE) in 1989 assessed energy resources from a variety of renewable and non-renewable energy sources (Table 8).

Table 8: Energy sources assessed in the characterisation of US energy resources and reserves.

Renewable energy sources	*Non-renewable energy sources*
Geothermal	Coal
Hydropower	Natural gas
Photoconversion (consisting of solar and bioenergy)	Peat
Wind	Petroleum
	Shale oil
	Uranium

2. Resources were classified using three simplified categories drawing from the McKelvey diagram (Figure 6). The McKelvey diagram provided a two-dimensional framework for classifying energy sources according to the degree of physical assurance (i.e. geological assurance for energy minerals and petroleum) on the horizontal axis, and the degree of economic feasibility on the vertical axis. The three simplified categories drawn from the McKelvey diagram consisted of: reserves, accessible resources and total resource base.

3. Reserves had the greatest physical assurance and economic feasibility and were defined as "a subset of the accessible resource which is identified and can be economically and legally extracted using the current technology to yield useful solar energy." (page 1, DOE 1989). Accessible resources were defined as "The portion of the total resource base, without regard to current economics, that can be captured, mined, or extracted using current technology or technology that will soon be available or economically extracted." (page 1, DOE 1989). Accessible resources were the portion of the total resource base that had been identified (see Figure 7). The total resource base was defined as the "Total physically available energy that encompasses both identified and undiscovered resources, regardless of whether or not they can be practically or economically extracted." (page 1, DOE 1989). The total resource base included both identified and undiscovered energy sources.

4. The DOE made estimates of the reserves, accessible resources and total resource base for the energy sources in Table 10 and presented the results graphically (see Figure 7 and 8). Figure 7 presented the total energy reserves and illustrated the relative proportions. Figure 8 presents the results for each type of energy source.

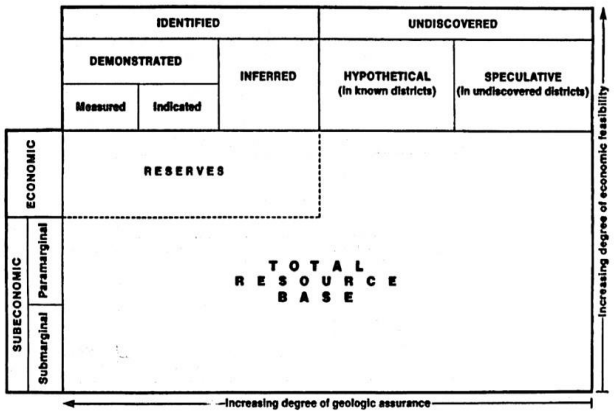


Figure 6: McKelvey diagram

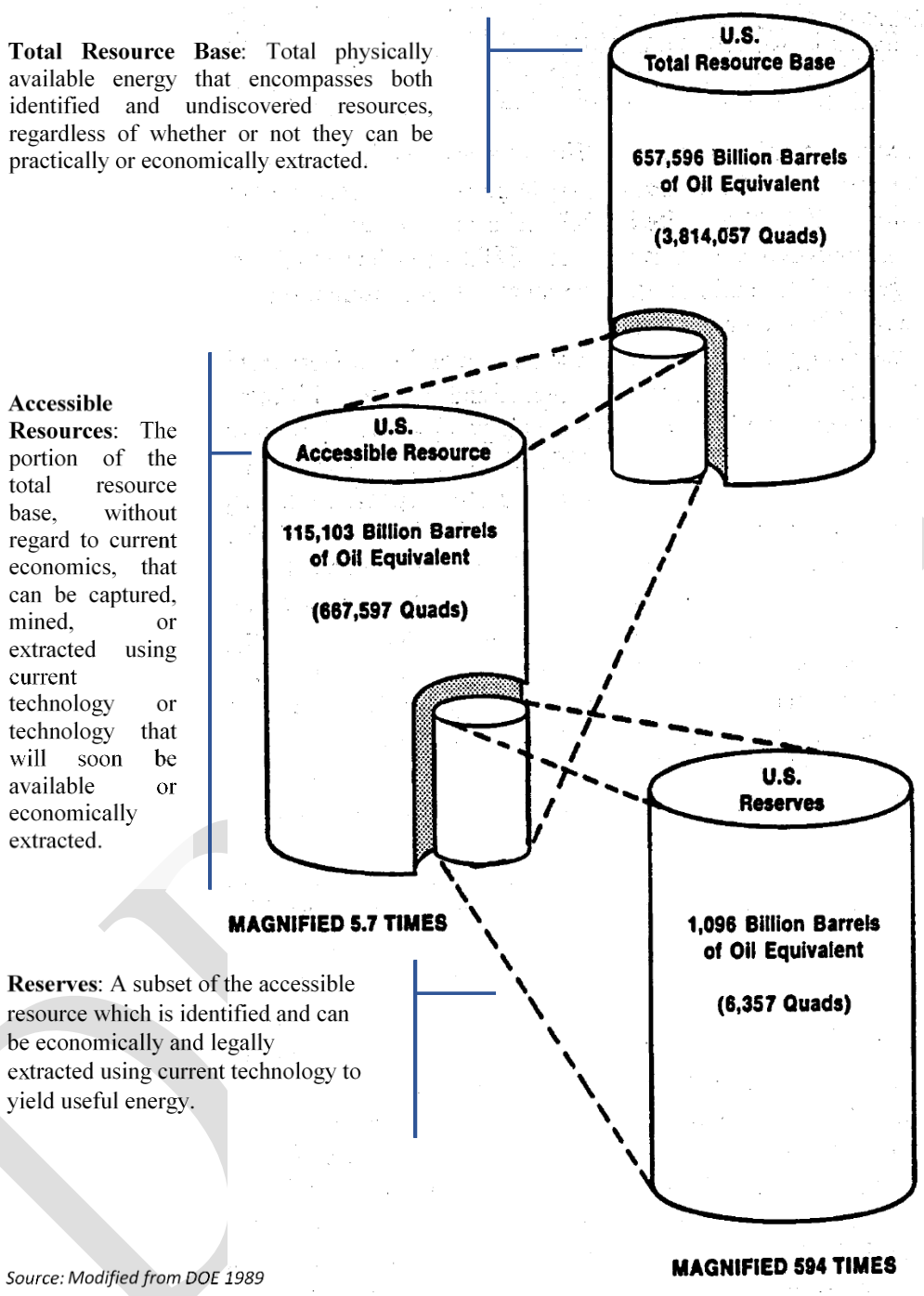
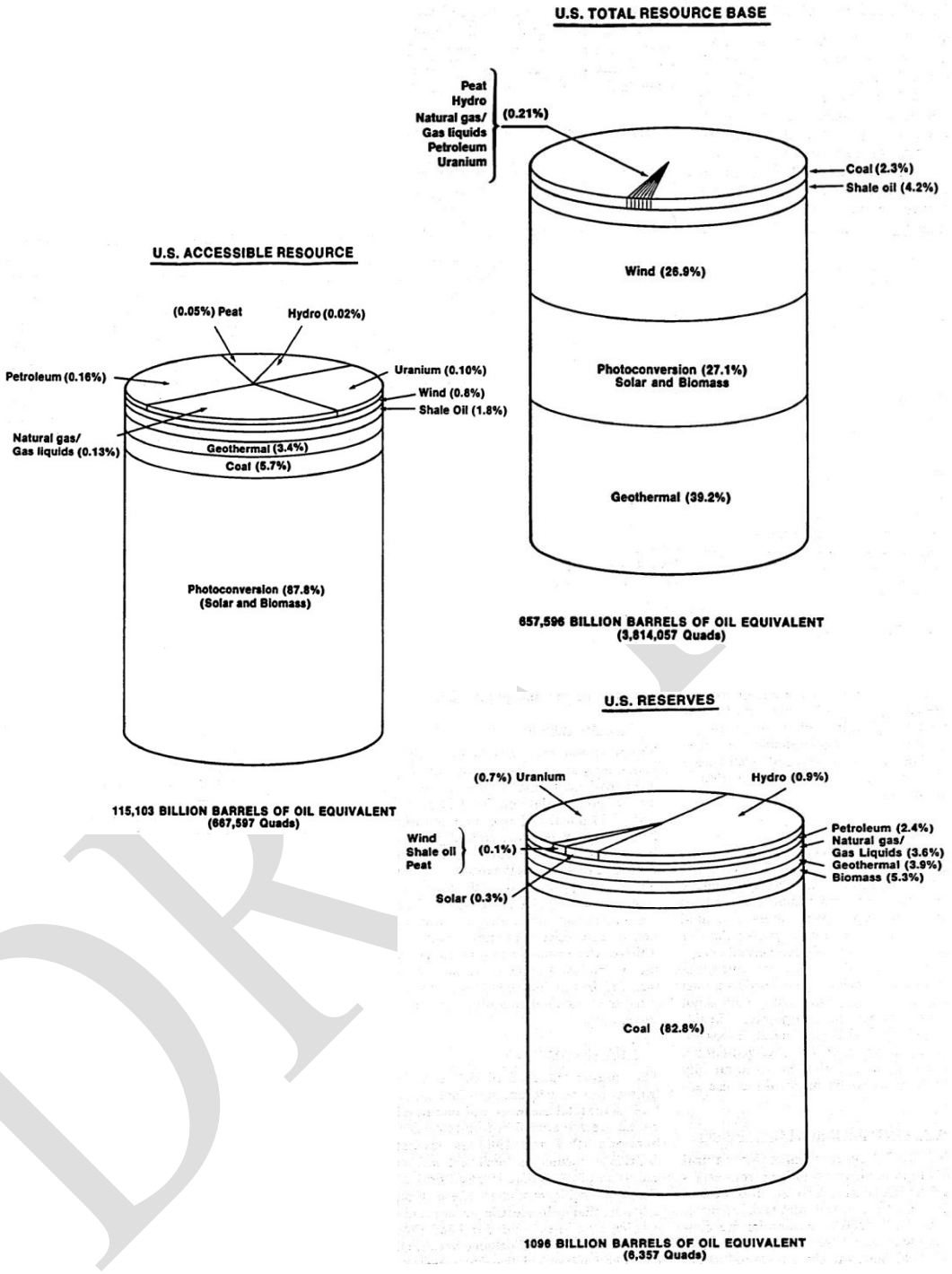


Figure 7: United States total energy reserves, accessible resources and resource base estimates from 1989



Source: DOE 1989

Figure 8: United States total energy reserves, accessible resources and resource base estimates from 1989.

Annex II: Similar Resource Classifications and Methodologies

1. The World Energy Council (WEC) in its report from 1994, titled "New Renewable Energy Resources - a guide to the future" used 4 categories from van Wijk and Coelingh (1993) for assessing renewable energy. The four categories consisted of theoretical potential, geographic potential, technical potential and economic potential. These categories are important because they reflect a methodology for progressively estimating the *solar resources* (i.e. economic potential) using GIS (e.g. Hermann 2014).

When applied to solar energy:

(a) Theoretical potential can be defined as "the total primary solar energy flux hitting the Earth's surface suitable for PV and CSP" (page 2, Köberle et al. 2015) in the case where PV and CSP are being assessed.

(b) Geographic potential can be defined as "the primary energy flux in suitable and available geographic areas of the globe" (page 2, Köberle et al. 2015).

(c) Technical potential can be defined as "the geographic potential after any efficiency losses of the primary to secondary conversion process are accounted for" (page 2, Köberle et al. 2015) when applied to the generation of electricity for example.

(d) Economic potential can be defined as "the economically feasible technical potential" (page 2, Köberle et al. 2015).

2. Figure 7 represents the four categories of potential from the WEC (1994) and Köberle et al. (2015) with the titles on the left-hand side of the diagram. The economic potential is a portion of the technical potential, which is a portion of the geographic potential, which in turn is a portion of the theoretical potential. Solar resources divide the economic potential into two parts with the darkest part being commercial solar resources and the slightly lighter part being other solar resources.

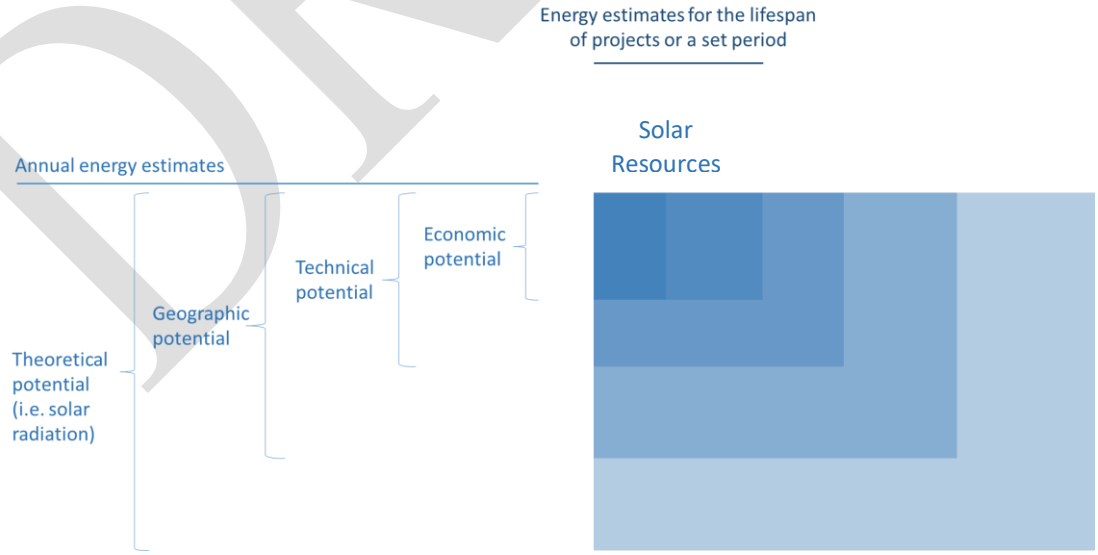
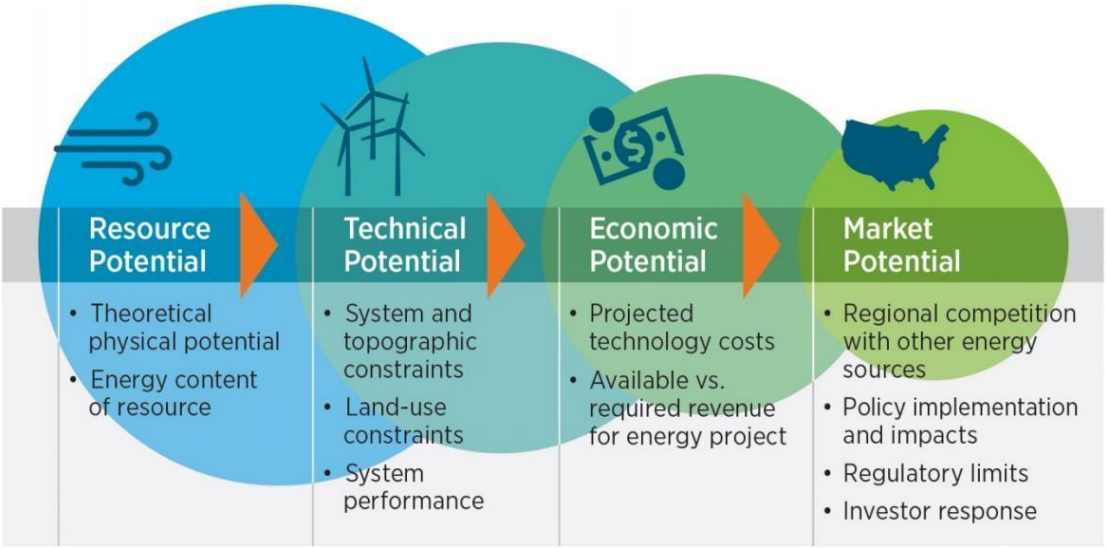


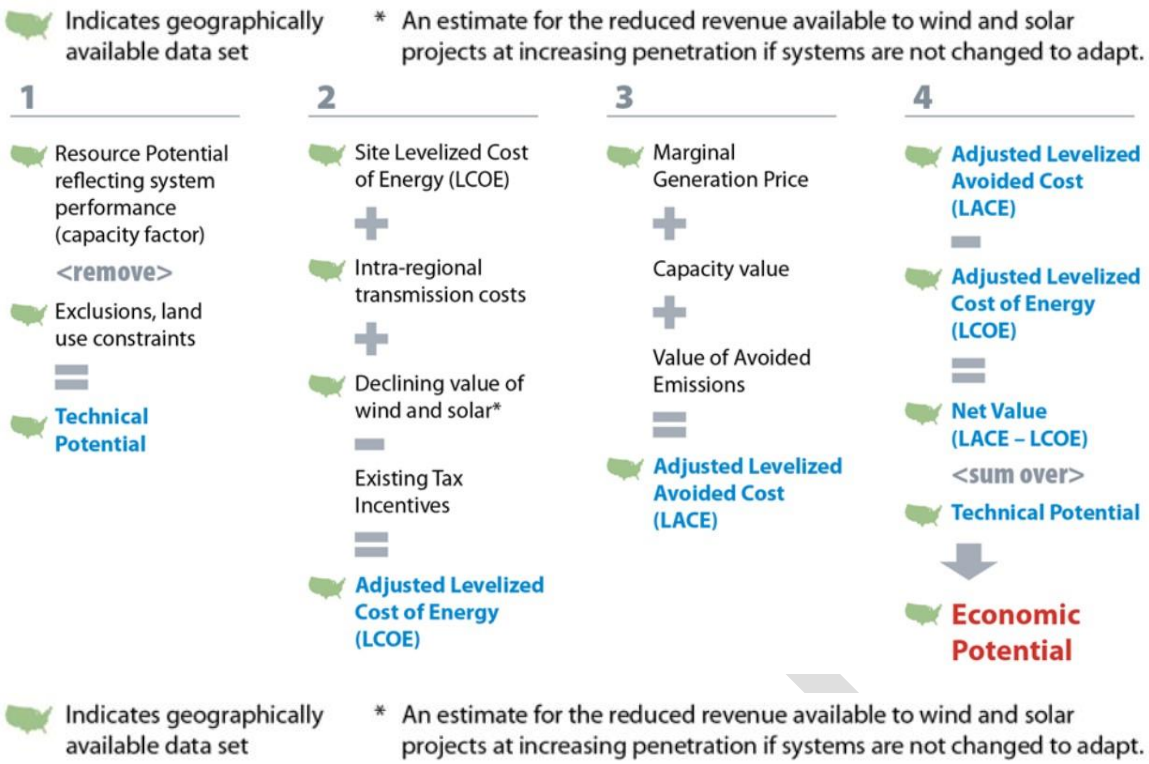
Figure 9: Potential defined by the World Energy Council and used by IRENA, in relation to solar resources.



Source: Brown et al., 2016.

Figure 10: Types of renewable electricity generation potential identified by NREL.

3. The United States National Renewable Energy Laboratory (NREL) also made renewable energy assessments using a methodology similar to WEC and others. This includes assessments made by Lopez et al. (2012) and Brown et al. (2016). These studies identified a set of potentials (Figure 8). "Resource potential" consisted of the theoretical energy content from a source, which in the case of solar was irradiation. The "technical potential" limits the quantity energy by taking into account land use and topographic constraints as well as system performance including, for example, the capacity factors likely to be achieved. The "economic potential" took into account energy costs, including the Levelised Cost of Energy (LCOE) for renewable energy at a site (or area) and the Levelised Avoided Cost of Energy (LACE) which was the cost of energy from some other source. If LACE – LCOE was positive, then the renewable energy at the site (or area) was considered economic and the theoretical potential for the site (or area) was included in the economic energy estimate (Figure 9). The "market potential" included policies such as tax incentives or avoided costs related to health or climate change, for example. More information on the methodology used can be found in Brown et al. 2016.



Source: Brown et al., 2016.

Figure 11: Generalized NREL method for calculating the economic potential of renewable energy sources based on high geospatial resolution data.

Annex III: Technical Risks

Table 9: Indicative list of technical risks for solar PV projects.

Stage	Activity	Risks
On production (i.e. operational)	Maintenance	Module cleaning missing or frequency too low.
		Missing or inadequate maintenance of the monitoring system.
	Day to day operations	Incorrect or missing specification for collecting data for availability evaluations: incorrect measurement sensor specification, incorrect irradiance threshold to define time window of operation for availability calculation.
		Missing guaranteed key performance indicators (availability or energy yield).
		Inadequate or absence of devices for visual inspection to catch invisible defects/faults.
		The selected monitoring system is not capable of advanced fault detection and identification.
Commercial operation date		Technology does not perform or last as long expected; construction is faulty.
Pre-operational	Securing acceptance (performance testing)	Incorrect or missing specification for collecting data for availability evaluations: incorrect measurement sensor specification, incorrect irradiance threshold to define time window of operation for availability calculation.
		Missing final performance check and guaranteed performance.
		Missing short-term performance check at provisional acceptance test, including proper correction for temperature and other losses.
		Inadequate protocol or equipment for plant acceptance visual inspection.
	Installation	Missing intermediate construction monitoring.
		Inadequate quality procedures in component un-packaging and handling during construction by workers.
	Transport	Absence of standardised transportation and handling protocol post the Reference Point, which creates uncertainty of the *solar resource(s)* delivery.
Financial close		Market conditions change, for example, due to regulations or false assumptions.
Designed or under development	Solar energy product estimation	Incorrect availability assumption to calculate the initial yield for project investment financial model.
		Incorrect degradation rate and behaviour over time assumed in the yield estimation.
		The effect of long-term trends in solar resource is not fully accounted for.
	Technology selection and testing	Absence of adequate independent product delivery acceptance test and criteria.
		Inadequate component testing to check for product manufacturing deviations.
		Insufficient technical specifications to ensure that selected components are suitable for use in the specific plant environment of the application.

Source: Modified and adapted from Tjengdrawira et al. 2017