

UNDERSTANDING

THE VITALS OF PFS, FS, AND DPR FOR SOLAR ENERGY PROJECTS

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Introduction

Solar energy projects are almost similar to other technical projects. These require sound planning and coordination outlook and are often constrained by budgetary allocations. They demand enunciation of a clear set of objectives, so that the most suitable feasibility approach is selected. Success of any project undertaken depends on the quality of the pre-feasibility study

(PFS), feasibility study (FS), and finally the detailed project report (DPR) preparation.

Understanding the vitals of these three types of studies for solar energy projects can be summarized in the following few strategies.

- Finding the best locations for new solar energy systems
- Reducing the time and cost of pre-feasibility solar studies
- Securing success of solar development

- Increasing the efficiency and effectiveness of policy development

At the time of investigating the solar resource within a given land area, several approaches are available for use. The preferred approach will depend on the objectives of the solar energy programme and on previous experiences with solar resource assessment. Therefore, adopting effective and efficient solar development



projects with accompanying goals and issues must be defined in the framework of articulating the obstacles for solar development along with specific measures to remove them. In fact, two of the most important vitals have to do with the risk factors and economic limitations.

Solar energy is an unlimited energy resource, set to become increasingly important in the long run, for providing electricity and heat energy on a large scale. It is an energy resource that could be used in large, centralized power generation plants; smaller distributed heat and power plants; or scaled down, at the individual consumer level. Solar energy technology is technically well proven and draws on an inexhaustible primary energy resource.

Definition and purpose of FS, PFS, and DPR

PFS examines solar energy options for electricity generation in a given location. It can be argued at this stage as to which solar energy technology is preferred. There are two major alternatives—solar photovoltaic (SPV) and solar thermal energy technologies. Solar PV technology collects and converts solar radiation directly into electricity. Solar thermal generation systems collect solar energy to generate steam for use in an otherwise conventional thermal electricity generating plant (steam turbine). Low intensity solar energy is used for water heating and, less commonly, for air/space heating, solar ponds, and solar chimneys. However, it is high temperature solar systems that seem to be the most appropriate for large-scale power generation. These require solar radiation to be concentrated so as to achieve temperatures high enough to be thermodynamically useful, and are also known as Concentrating Solar Thermal (CST) systems. CST is best suited for relatively large generation plants, which are different from the smaller household rooftop PV systems.

The PFS study examines solar electricity generation technologies, undertakes a brief analysis of those that could be considered suitable, and identifies a preferred technology for further techno-economic evaluation.



The review and selection of a preferred technology includes the following.

- An assessment of the technology
- Consideration of the practical status of the technology and commercial experience
- Consideration of the solar resource in the location
- Cost and risk investigation

A solar FS study, however, is defined as an evaluation or analysis of the potential impact of a proposed solar project or programme. It is basically conducted to assist decision-makers in determining whether or not to implement a particular solar project or programme. The feasibility study for solar projects is based on extensive research on both the current practices and the proposed project/programme, along with its impact on the proposed project. This study will deal with extensive data related to financial and operational impact, advantages and disadvantages of both the current situation, and the proposed plan of the solar project.

Goal of the FS

FS report is prepared to support the investment proposal. Feasibilities related to various technical, commercial, and financial aspects are examined in detail by the experts designated for the purpose. FS report is normally termed as a techno-

economic FS. It is the primary report for the formulation of the investment proposal. Investment decisions are taken based on the details incorporated in the study. Thus, feasibility is prepared only for the formulation and investment decision-making. The first step in FS is the need-based analysis. The purpose is to define the overall objectives of the system proposed to be designed. The second and perhaps the most important thing is system identification. This is referred to as activity analysis of the following nature.

- Project justification
- Resource identification for project development
- Technology selection
- Capacity determination
- Process description and layout plans
- Infrastructure availability
- Evaluation of available facilities
- Capital cost assessment
- Profitability analysis
- Project schedule and implementation plan
- Design and flow diagrams

Following the preparation of a FS report, it should be subjected to a thorough scrutiny by the subject area experts. Modifications, if any, must be carried out based on their opinions.



Preparation of DPR

Preparation of a DPR is the next logical step in firming up a project proposal. It is appropriate to firm up the capital cost once an investment proposal has been approved on the basis of a functional report. Key elements of DPR may include the following.

- Technology assessment
- Technology detailing
- Broad technical specifications
- Evaluation of the existing resources
- Schedule plan
- General layout
- Volume of work

Hence, these reports are to be made before investing in any project. Thus, formulation of investment is based on the studies initiated. These can be considered as pre-investment decisions. Detailed project report is not only for the investment specific decision-making approval, but also for the execution of the project and preparation of the plan. DPR, additionally, includes the following.

- Project description
- Planning and implementation of the project
- Specifications
- Layouts and flow diagrams

As per the above paragraphs, DPR will be a complete document for investment decision-making, approval, and planning.

Thus, while FS report is a base document for investment decision-making, DPR is a base document for planning and implementing the project.

Defining successful solar design

In defining a successful solar design, achieving of targets set through the three stages of studies must be optimized and the obstacles noted. The few obstacles, which hinder successful solar energy project development are as follows.

- additional (unexpected) administrative expenses
- long, non-transparent, and costly permission procedures
- uncertainty about successful application / failed projects
- high market-entry barriers
- potential changes in future regulation
- risky market environments
- uncertainties regarding the direction and effect of technology development (lock-in)
- industrial bottlenecks and limited growth

Solar energy resource

The evaluation of the solar resource for a specific project requires an understanding of the basic principles of solar radiation. Every part of the earth gets sunlight, at least for some part of the year. However, the amount of sunlight reaching the earth varies according to geographical location, time of the day, and season.

Factors are responsible for variations in the amount and quality of sunlight that the earth receives are as follows.

- The shape of the earth
- The earth revolves around the sun in an elliptical orbit
- The earth rotates on a tilted axis

Since the earth is round, the sun strikes the surface at different angles ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Since the earth is round, the frigid polar region never gets

a high sun. Because of the tilted axis of rotation, these areas get no sunlight for some part of the year. Because the earth revolves around the sun in an elliptical orbit, it is nearer to the sun during most parts of the year. When the sun is nearer to the earth, the earth's surface receives more solar energy. The earth is close to the sun when it is summer in the southern hemisphere and winter in the northern hemisphere. However, the presence of vast oceans moderates the hotter summers and colder winters.

Nature and use of solar radiation

The amount of sunlight falling on specific locations at various times of the year is usually measured to estimate the amount of sunlight falling on regions at the same latitude with similar climates. Measurements of solar energy are typically expressed as total radiation on a horizontal surface. Radiation data for photovoltaic (PV) systems, which produce electricity, are often represented as kilowatt-hours per square metre (kWh/m²). The sun is a reliable source of energy and the earth receives this on its surface as relatively diffuse energy. It has a maximum flux of about 1 kW/sq m in Australia compared to India's 4–7 kWh/ sq m. There is a variable daily cycle with seasonal variation and may be intermittent, influenced heavily by meteorological conditions, such as cloud. Solar energy, being radiant energy, cannot be stored directly.

Solar insolation or the total amount of solar radiation received at a given point on the earth, is made up of two components—direct and diffuse insolation. Calculating the amount of sunlight available for a solar energy system is complex and challenging. Atmospheric conditions, the changing position of the sun, and the local terrain interact to moderate the solar resources at a given time and place. Historical data about weather, climate, and air pollution are vital for designing a solar energy system for a specific site. The sun's position throughout the year must be considered. Also, care must be taken to use published information about solar radiation that applies to tilted, south-

facing collectors. And there must be basic understanding on how seasonal weather patterns affect sunlight, and also how they affect solar energy system requirements. Whether sunlight is direct or diffuse can significantly affect solar energy system performance. Solar electric systems require direct sunlight.

Collectors for solar heating systems, including passive solar buildings, capture both direct and diffuse solar radiation. In some areas, solar energy systems will capture significant amount of sunlight reflected from nearby white surfaces such as light-coloured sand. We need to account for the surface reflection where they exist.

Direct radiation

This type of solar radiation is received directly from the orbit of the sun and is of interest for solar concentrators used in CPV and solar thermal systems. Direct estimates of solar energy may also be expressed as watts per square metre (W/sq m). Radiation data for active and passive solar energy systems, which produce heat, are usually represented in British thermal units per square foot (Btu/sq ft).

The following equation can be used to convert from one system of measurement to the other.

$$317 \text{ Btu/ft}^2 = 1 \text{ kWh/m}^2.$$

Diffuse radiation

Solar radiation, which get scattered while passing through the earth's atmosphere is referred to as diffuse radiation and includes reflected solar radiation and solar radiation re-reflected from the earth. Assessing climate helps define system requirements for solar projects. Seasonal weather patterns affect heating and cooling requirements as well as the solar resource. During winters, heat loss is affected by the outdoor, or ambient temperature. The colder it is outside, the faster a solar collector will lose heat, thus reducing its efficiency. Low temperatures also increase heat loss from the buildings. Lower the daily average outdoor temperature, higher the heating requirement will be. Winter heating requirements usually increase

when there is less solar energy available. For this reason, it is better to design solar-based projects to capture the maximum amount of energy from the winter sun. Then the principles of climatic design can be applied to keep the system from producing too much heat during summer. Figure 1 shows the radiation network in India.

Global radiation

Global radiation comprises both the direct and diffuse components and is of interest for flat-panel and tracking PV power generation systems. The amount of solar radiation of all types received is influenced by the location of the receptor on the earth's surface and by its orientation. Fixed receptors oriented toward the sun collect less solar energy than those that track the sun. It is important to note that concentrating

systems use the direct beam component of global (total) solar radiation and as with many renewable energy solutions, weather conditions, such as cloud, haze, and fog, play an integral role in system performance. Direct or normal beam radiation data is, in general, less readily available than other solar energy data. The most common type of PV system in India is the flat-panel collector or module, which is typically inclined at a latitude angle. This usually is the best compromise between minimizing cost and maximizing annual energy collection. The same is true for a solar hot water collector. An alternative form of installation is sun tracking, where the solar collector panel is mounted in a mechanism that tracks the sun. This can be on one or two axes and results in higher energy collection for the same size solar collector, but comes at a higher

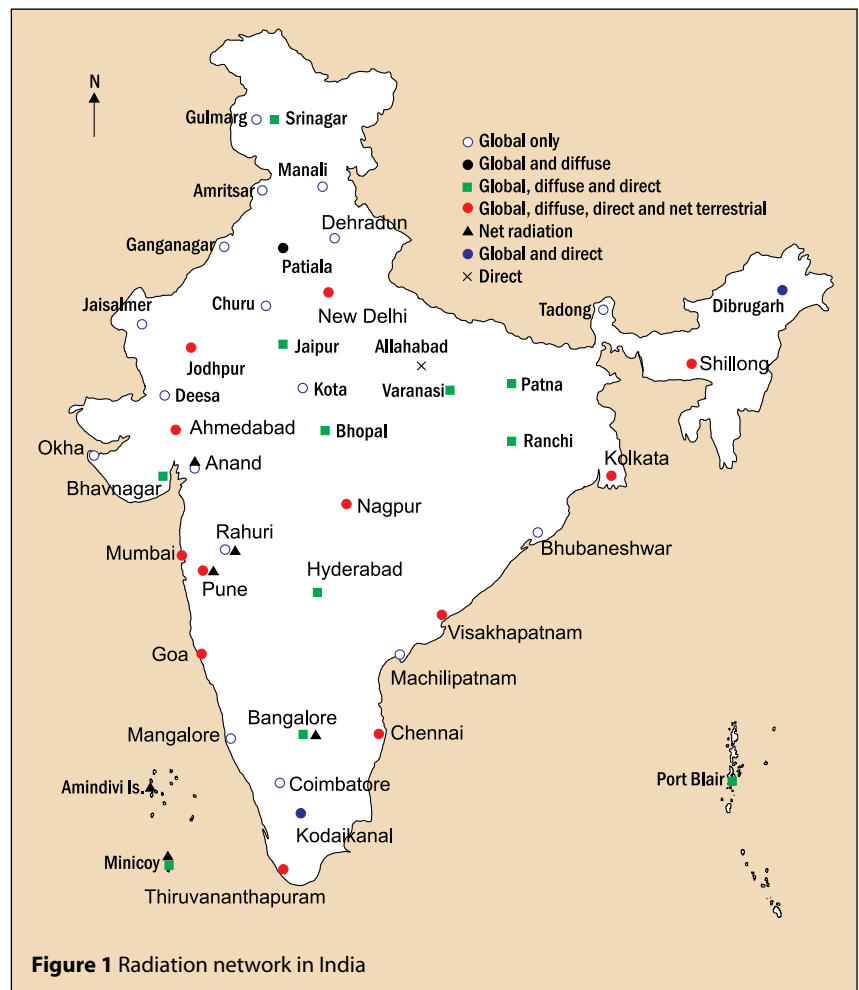


Figure 1 Radiation network in India

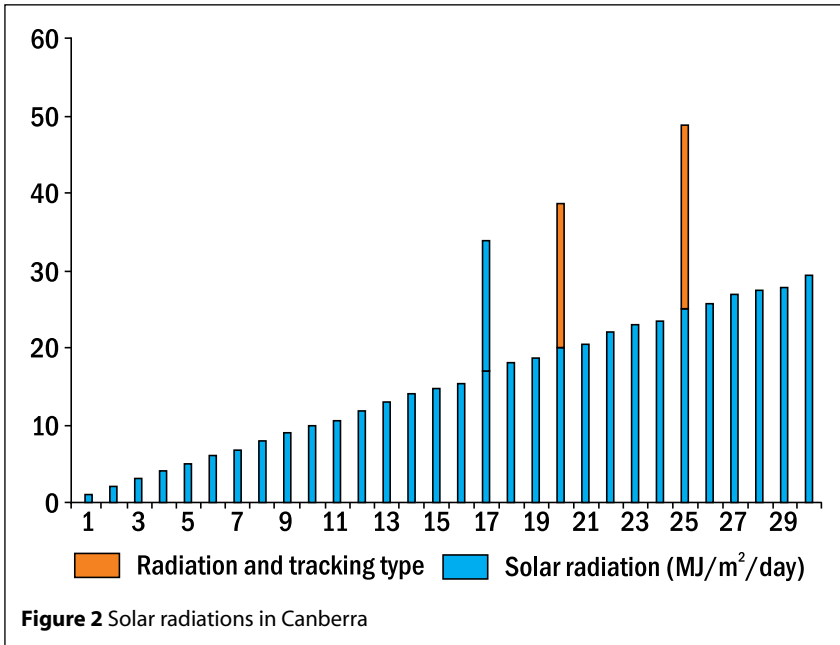


Figure 2 Solar radiations in Canberra

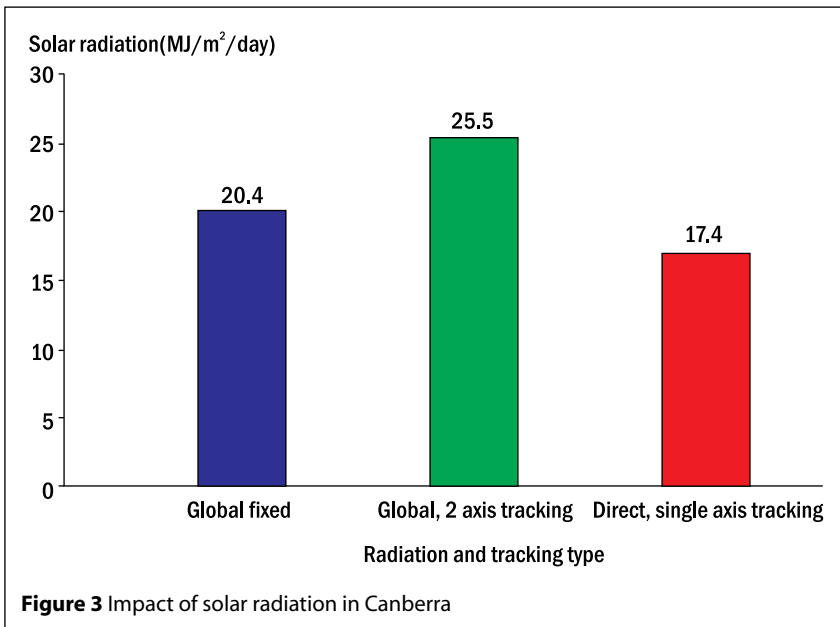


Figure 3 Impact of solar radiation in Canberra

cost. The impact of tracking on energy collection is illustrated in Figure 2, Figure 3, and Figure 8 and Figure 10.

Solar concentrating systems are usually of a sun tracking type.

Estimation of average daily global radiation

Angstrom proposed the following empirical correlation for computing

the average daily global radiation on a horizontal surface.

$$\frac{\bar{H}}{\bar{H}_o} = \hat{a} + \bar{H}_c \hat{S}_a / S_p \quad (1)$$

where

\bar{H} = monthly average daily radiation on a horizontal surface

\bar{H}_c = average clear sky daily radiation for the location and month in question

\hat{a}, \bar{H}_c = empirical constants

\hat{S}_a = monthly average daily actual hours of sunshine

S_p = monthly average daily possible sunshine hours

There is an ambiguity in defining clear day and hence, to get \bar{H}_c , the above formula was modified using extraterrestrial solar radiation, \bar{H}_o .

$$\bar{H} / \bar{H}_o = a + b \hat{S}_a / S_p \quad (2)$$

where

\bar{H}_o is the extraterrestrial solar radiation on a horizontal surface and can be calculated as

$$\bar{H}_o = 12 \times 3600 / \Pi \times I_{sc} [1 + 0.033 \cos(360/365)n][\cos L \cos \delta \sin W_s + \Pi W_s / 180 (\sin L \sin \delta)] \quad (3)$$

where

W_s is the sunset hour angle in degrees, n is the average day for the whole month, and Π is in radians

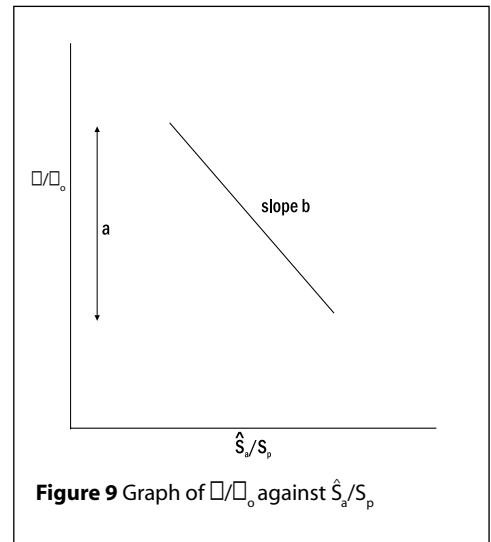
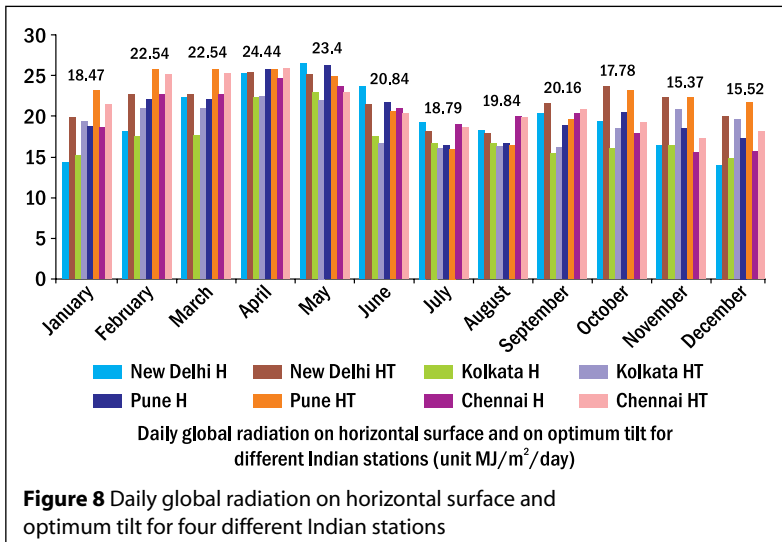
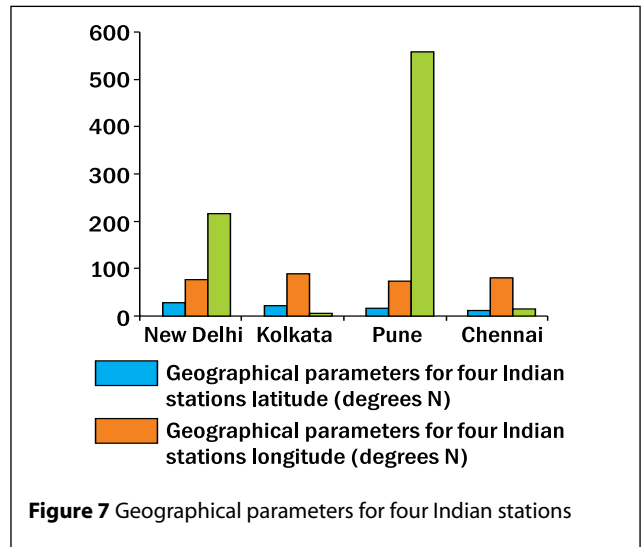
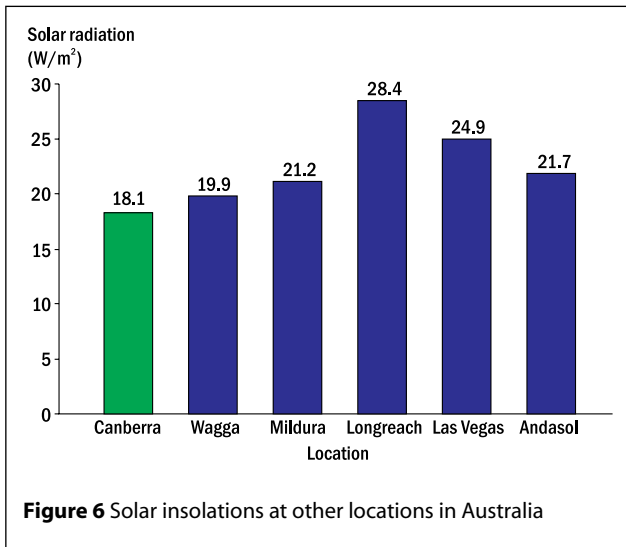
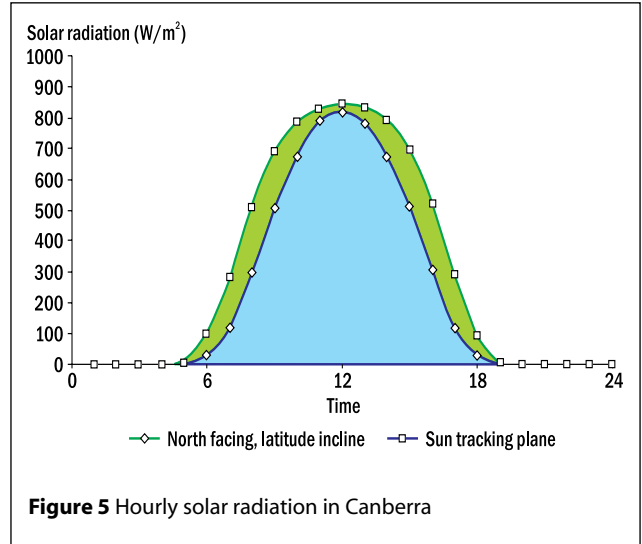
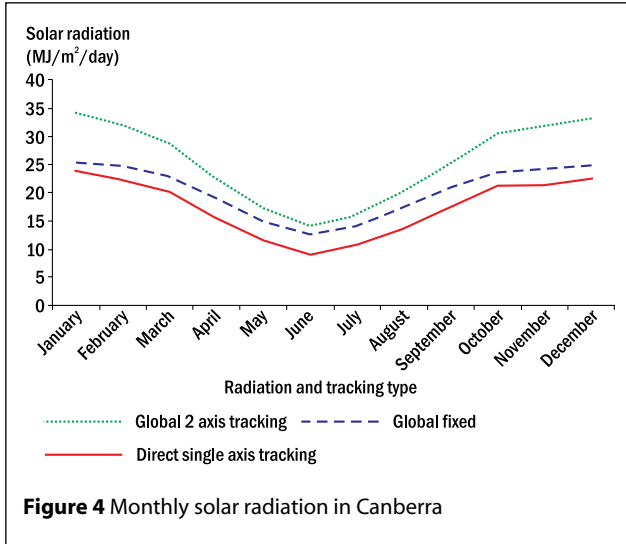
\hat{S}_a is measured value of actual sunshine hours and can be calculated for any place from this relation

$$S_p = 2W_s / 15 = 2/15 \cos^{-1}(-\tan L \tan \delta) \quad (4)$$

Equation (2) can be used for calculating average daily global radiation at a location when data on actual sunshine hours, \hat{S}_a , possible sunshine hours, S_p , extraterrestrial solar radiation, \bar{H}_o , and values of a and b are known for a place, is found out by plotting a graph between known values of \bar{H} / \bar{H}_o and \hat{S}_a / S_p , as shown in Figure 9. This figure shows the estimation of average daily global radiation.

Reliability and measurement of solar radiation

Global solar radiation data is readily available and reliable for all locations. The same is not true in case of direct radiation specific data. Data is available on direct solar radiation in Delhi, and the extent to which the available data has been verified is very clear. The success of a solar thermal project depends heavily on the quantity and quality of the resource data. It is recommended that site specific monitoring be carried out at one or more potential sites. There are a few organizations with the capability to



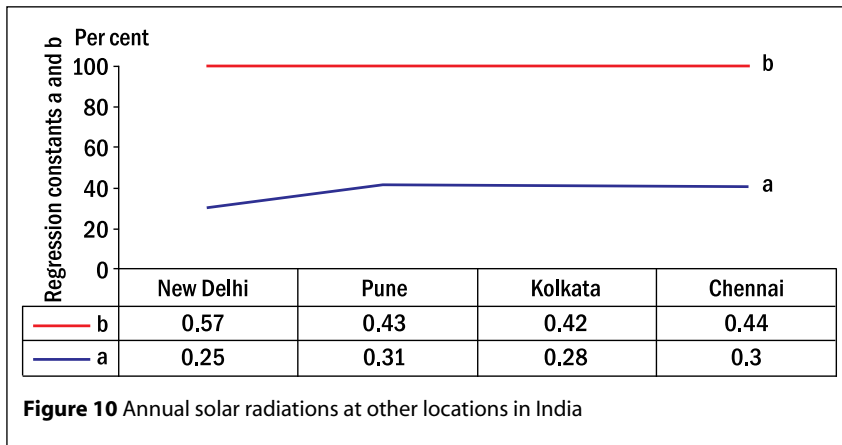


Figure 10 Annual solar radiations at other locations in India

measure, record, and verify direct solar radiation and to correlate it with existing stations.

In India, such capability is probably limited to a few organizations such as the India Meteorology Department (IMD), Solar Energy Centre (SEC) of the Ministry of New and Renewable Energy, (MNRE), Indian Institute of Tropical Meteorology, and so on. It is often necessary to recommend that discussions be held with these organizations with a key objective of scoping and costing a monitoring and data verification programme. There is also a need for correlating this with other direct radiation data from the weather monitoring stations put up at the aviation centres. Until a programme of work is fixed, it is inappropriate to establish the cost of an associated measuring and verification programme. This scope of work should include the identification of the differences that exist among the sites in the same region. For instance, the existence of local conditions like dust, cloud, or haze could significantly affect the quantum of available solar energy. This, in turn, would impact the power output available from a solar energy system.

System requirements and climate

A good project designing takes into account climate specifications and prevents over heating during the summer months. Such issues should be considered during the PFS. Obtaining specific data on the solar resources in any area will help design the most effective solar PV system.

Climates can play an important role at the following four stages in the solar energy system design process.

- The evaluation of the solar resource
- The definition of system requirements, including the impact of climate-related factors on system project design
- The analysis of existing site-specific micro climates
- The design of systems, buildings, and landscapes to maximize performance.

Until recently, solar projects involved series of complex calculations to determine the size of the solar resource, figuring out heating and cooling requirements in different parts of the country at various times of the year, and deciding the optimal size and orientation of a solar heating or electric system. Once this information is obtained, integration of the various plans for a new solar project or building and the landscape can be done. Today, the design process is made easier because of the number of resources available on the Internet or on CD-ROM. However, accurate prediction of latitude and longitude with a detailed analysis of local solar resources along with information on long-term weather patterns can be very useful.

Other resources for climate and design, which are vital during the studies include the following.

- Green design checklists
- Strategies for finding the best locations for new solar energy systems
- Strategies for reducing the time and cost of PFS

- An easy-to-use method for estimating the performance of PV systems connected to the power grid
- A programme that calculates the location of the sun in the sky—any place, any day, any time

Detailed assessment of risk factors and potential administrative barriers

Solar power behaves quite differently than conventional power generation. If solar and other renewable power sources are to be integrated rather than simply added to conventional power systems, then procedures need to be developed to analyse their risk contributions that are part of their unique characteristics.

The deterministic approach for allocating operating reserve based on the loss of the largest operating unit does not recognize the inherent probabilistic nature of system behaviour and component failures and therefore, cannot estimate the system operating risk appropriately.

Categorization of risk factors

Infrastructure projects, such as solar projects, require capital on a large scale and a long congestion period is involved. Development of infrastructure projects is vital for the economic growth of any country. These projects provide forward and backward linkages to the industry. Development of solar projects is capital intensive due to the technological requirements and gestation period is high owing to its constant unavailability.

Return on capital in case of solar projects is small as well as slow. Hence, investors are shy to invest capital in solar projects, unless some special incentives and privileges are provided.

Technical risk

Under the technical risk, it is examined whether the design and technology used in the project are viable to the country or not, coupled with the following.

- Volume of fuel input
- Investment costs
- Operation and maintenance costs

- Plant availability
- Expected plant lifetime

Political risk

Political and regulatory risks are inherent in doing business. They affect all aspects of a project, from site selection and construction through completion, operations, and marketing.

- New market designs
- Changes in subsidy structure
- Changes in taxation
- Building plan approvals

Market risk

Economic risk of the project is to examine whether the projects' expected cash inflows will have the positive net present value, and how much time the project will take to recover the initial cash outflow, issues concerning policies, and regulatory frameworks. Amongst these the following are vital.

- Electricity price
- Competition
- Input fuel price are vital

$$\text{REVENUE} = \text{Technological risk} + \text{Political risk} + \text{Market risk}$$

Risk perception

Like most technical projects, solar energy projects require planning and coordination and are constrained by budget and schedule limitations. These projects demand a clear set of objectives, so the best feasibility approach is selected. Through the various stages of studies carried out, it will be easy to have an overview of the impending dangers or risk. These can be detailed under the survey report submitted to the prospective client for consideration.

Technical factors

Technical performance risk arises because of the operating conditions of the project, whether the project will bring desired revenue or not.

- Investment
- Production
- Availability
- Lifetime
- Operations and maintenance

Market factors

Financial risk arises based on how the projects are funded—the capital structure of the project. The capital structure directly affects the market value of the project. Risks related to foreign currency arises when the project is sponsored by some foreign company. Fluctuations in forex rate affects the profitability of the parent company along with the following factors.

- Exchange rates
- Interest rates
- Electricity prices

Political factors

Political factors include politically-motivated embargo or boycott of a project, debt repayments, or shipment of product, which may reflect the foreign policy of the country. Political factors also consider circumstances where the host country cannot permit transfer of funds for debt service because of its own economic problems, which include the following

- Production support
- Investment support
- Building permission

Mitigation measures

Improved efficiency lowers cost, which in turn increases demand. To ensure that

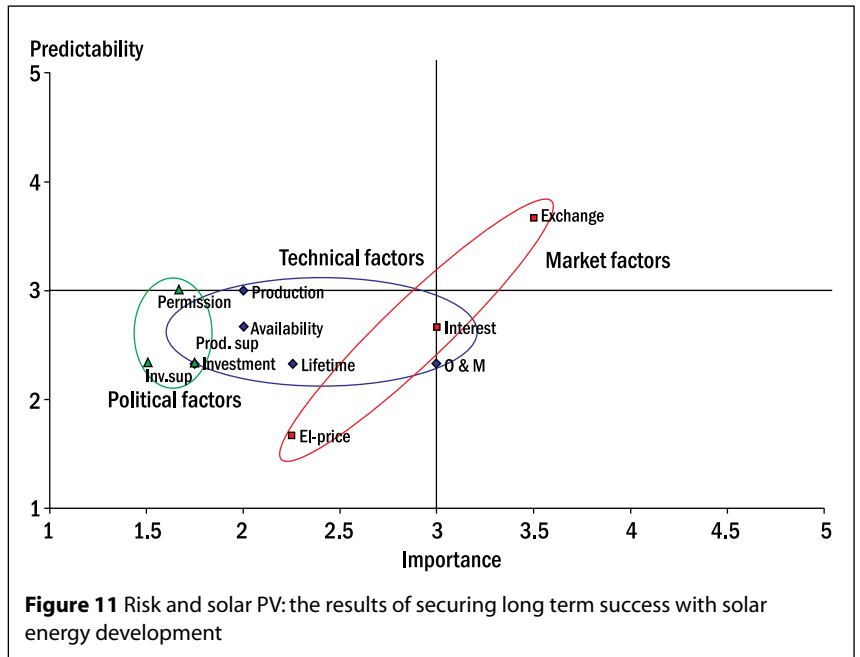
increase in efficiency actually reduces energy use, a tax must be imposed to remove any cost savings from improved efficiency. Energy conservation is the practice of increasing the efficiency of the use of energy, in order to achieve higher output for the same energy consumption. This may result in increasing the environmental value.

Environmental Due Diligence (EDD) is the collection and assessment of data, relative to environmental conditions or impacts, prior to a transaction to identify and quantify environment related financial, legal, and reputation risks.

The general intention of a due diligence review is to ensure that a projected investment does not carry financial, legal, or environmental liabilities beyond those that are clearly defined in an investment proposal as presented during the course of the FS.

Risk mitigation: measure I

There is a growing realization in energy and environmental policy and research circles that procedures for renewable energy technologies (RETs) are poorly defined and financiers must often adopt ad hoc procedures for environmental review. Although, most RETs are environmentally sound in theory, all of



them can have negative impacts on the environment, if poorly planned.

Technological risk

- Facilitate technological development
- Obligated minimum quality standards
- Training and qualification measures

Market risk

- Policy measures and instruments (FiT)
- Investors' specific risk strategies (hedging)
- Facilitate strategy development
- Round tables and workshops with banks, investors, developers, and policy-makers
- Knowledge exchange, trainings, and accompanying/complementary research (scientific/academic)

Risk mitigation: measures II

Risk management measures may be identified through industrial or sectoral best practices, and international or other widely used/accepted standards. When the mitigation measures have been determined, the next step is to estimate the cost of the risks and their management. This includes both the real cost of the mitigation measure itself, as well as the potential costs associated with non-compliance (increased charges, fines and other penalties, the closure of an operation by environmental authorities, project delays due to permitting requirements, and so on). Estimating such costs is important even if the financial institution or investor may not be directly responsible for them. First, any unforeseen institution could be held liable under certain liability regimes.

Political risk

Political factors will continue to be important, however, we should also remember that predictability generates trust and reduces risk perception.

- Essential: binding, long-term political commitments

- Proven willingness to share risks (by facilitating priority dispatching and guaranteed connection to the grid)
- Transparency and rationality in policy- and decision-making processes:
- Policy design
- Implementation / administration
- Monitoring / adjustment
- Investors / developers: coordinated formation of common opinions / positions regarding

Conclusions and recommendations

A wide range of parameters are involved in arriving at the techno-economic viability, or otherwise, of any renewable energy project. Policy-cum-regulatory framework is quite essential to push forth such projects, which do entail some risk perception as well. A case in point is that of biomass gasifier projects at selected locations in the southern regions, whose feedstock availability prices appreciated heavily following the plant installation. Solar projects do not depend on the fuel price in any way, but bank upon a slew of financial and fiscal incentives from the

designated government agencies. The risk sharing and risk mitigation strategies are quite vital along the following few considerations. No less important is putting in place a crystal clear and user-friendly regulatory structure.

Essential risk sharing and risk mitigation strategies.

- Guaranteed market access
- Minimization of political risk by long-term binding governmental commitments
- Ensuring long-term adequacy of policy measures by regular monitoring adjustment

Transparent and simple regulation

- Reduced administrative burden; lower transaction cost
- Less failed planning efforts and targeted actions due to predictable and transparent procedures
- Lower risk perception and transaction cost leading to reduction in needed revenues and increase in efficiency and effectiveness of policy.

