Accurate Solar Forecasting -- A Key Enabler in Meeting the Goals of the SunShot Initiative

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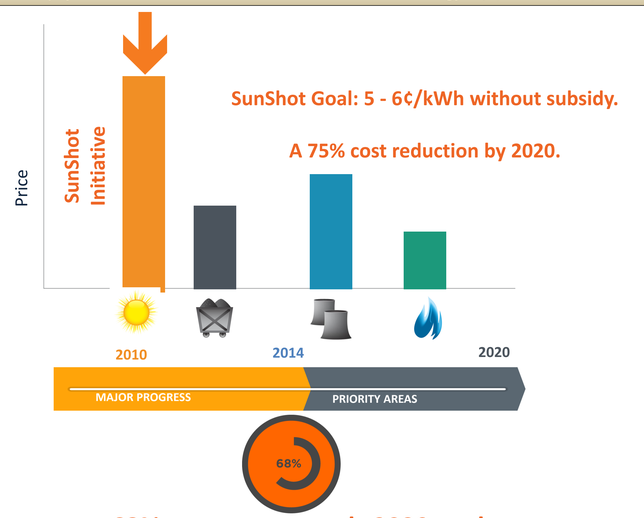
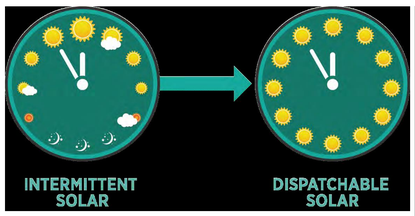
What is the SunShot Initiative?

The SunShot Initiative was launched in 2011 by former U.S. Energy Secretary, Dr. Steven Chu to reduce the total cost of solar energy systems by about 75% to make them cost competitive with other forms of energy (without subsidies) by 2020. This translates to a total cost of installed solar energy at $1/Watt or $0.06/kWh.

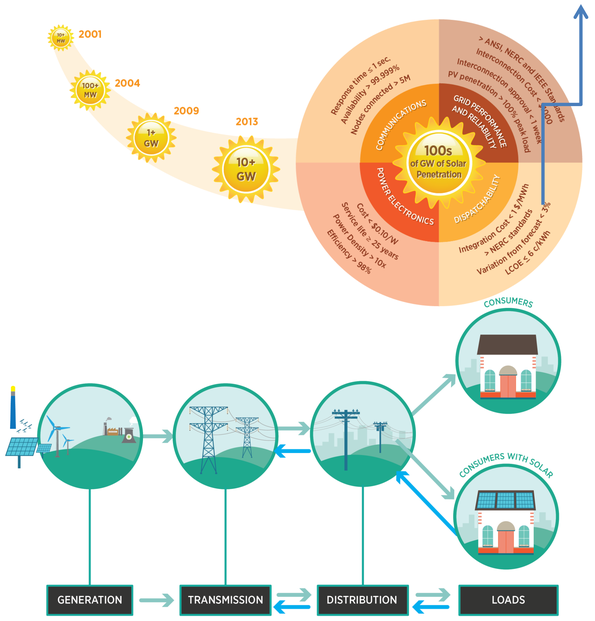


Solar Forecasting In The Context Of The SunShot Initiative

In the past four years, the SunShot Initiative has catalyzed revolutionary advancements in solar technologies, stimulating significant growth and accelerating deployment of solar energy systems. However, as solar deployment increases, integrating solar energy into the utility grid poses difficult challenges due to the intermittent nature of solar energy and the impact of clouds and aerosols on surface irradiance. Accurate forecasting of solar resource and its variability at high temporal and spatial resolution at least a day ahead is crucial to large scale integration of solar energy into the utility grid.



To meet the goals of the SunShot Initiative, solar energy has to be dispatchable on demand and accurately forecast such that the utility operators can match the load and generation on the utility grid. This requires a forecast uncertainty of **less than 3%** by using a combination of strategies to improve forecasting and energy storage.



Acknowledgements

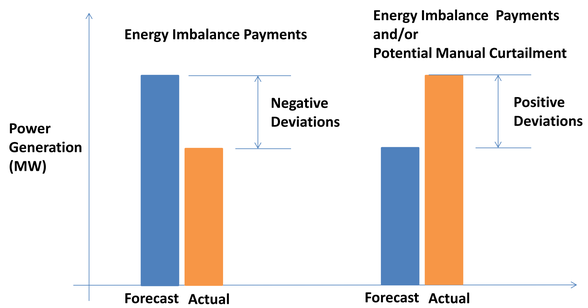
The authors greatly appreciate the efforts of the SunShot communications team in providing graphics used in this presentation.

Brief Overview of Solar Forecasting

Although solar energy is abundantly available in most parts of the world, accurate forecasting of solar irradiance is vital to integrate solar energy into the utility grid, and for the efficient operation of solar thermal power plants and energy markets. The most challenging aspect of utilizing solar radiation for meeting our energy needs is the intermittent nature of solar irradiance and the difficulty in accurately forecasting the variance in power output due to variations in surface irradiance. Currently, satellite based irradiance data and Numerical Weather Prediction (NWP) are the best tools for hour ahead (HA) and day ahead (DA) forecasts, respectively. However, the resolution and accuracy of satellite derived and NWP based surface irradiance forecasts are not sufficient to meet the needs of the SunShot initiative, especially at high penetration of solar.

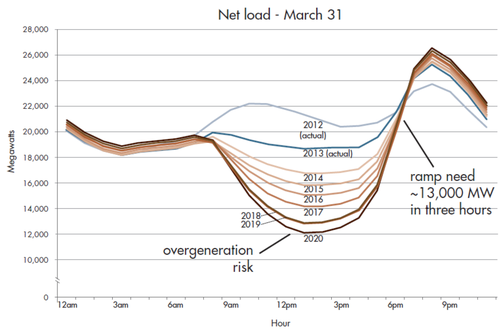
While accurate forecasts of the Global Horizontal Irradiance (GHI) is sufficient for photovoltaic (PV) based solar production, accurate forecasting of Direct Normal Irradiance (DNI) is necessary for Concentrating Solar Power (CSP) plants. This compounds the challenge since accurate DNI forecasts require accurate representation of cirrus clouds, and aerosols such as soot and dust particles that can reduce DNI by up to 30% on otherwise cloud-free days.

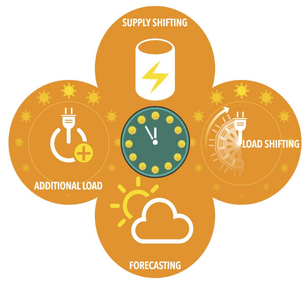
Need For Accurate Solar Forecasting



Power producers submit a day-ahead schedule to the electric system operator. If there are any deviations from that schedule, (subject to a "tolerance band" for renewables in recognition of their variable nature) the power producer could be subject to penalties and replacement power costs levied by the electric system operator.

Over the last couple of decades the proliferation of rooftop and distributed solar energy systems has been significant. Additionally, due to the reduction in cost of solar technologies, widespread adoption of state renewable portfolio standards (RPS), and growing concerns about climate change, utility-scale solar generation now includes a rapidly expanding number of large scale Photovoltaic (PV) and Concentrating Solar Power (CSP) power plants that are being interconnected to the transmission system. The number of transmission-connected systems above 20MW in size is expected to increase dramatically in the near future and will need to be integrated into electric power system planning and operations processes





Solar Forecasting Research Under Current SunShot Awards

In 2012, the DOE SunShot Initiative launched a Funding Opportunity Announcement (FOA) to improve solar forecasting. The FOA required applicants to address all of the following types of forecasts in their application:

1) Intra-hour ramp forecasts - 15 minute, 30 minute, 60 minute, and 180 minute ramps
2) Short-term forecasts - 15 minute, 30 minute, and 1 to 6 hours ahead
3) Day-ahead forecasts - 12 to 24-hours ahead

As a result of the solicitation, DOE announced $8 million to fund NCAR and IBM to advance research on solar forecasting through the following projects.

NCAR – NCAR is working with several universities, national labs, utility companies and NOAA to make significant improvement in solar forecasting through improved parametrization of clouds and aerosols, NWP improvements and observations (primarily Total Sky Imagers). The team is working to advance methods for solar radiation measurement and cloud observation and tracking techniques; methods to quantify and track aerosols that affect cloud formation and radiative transfer, including the prediction of aerosols, haze, and contrails; short-term prediction of cloud properties based on observations; and nowcasting techniques.

WRF- SOLAR: A new tool developed through NCAR-NOAA collaboration to improve GHI and DNI forecasts of surface irradiance.

IBM – IBM is working with several national labs, solar companies and utilities to develop models for improving forecasting, especially nowcasting through advanced ensemble modeling.

Similar to the recently demonstrated Watson computer system, the proposed technology leverages deep machine learning and self-adjusting voting algorithms to decide between various forecasting models and expert systems. The approach yields improved forecasts and continuously adjusts as the system operates and evolves.

SunShot Funded Resources at the National Renewable Energy Laboratory

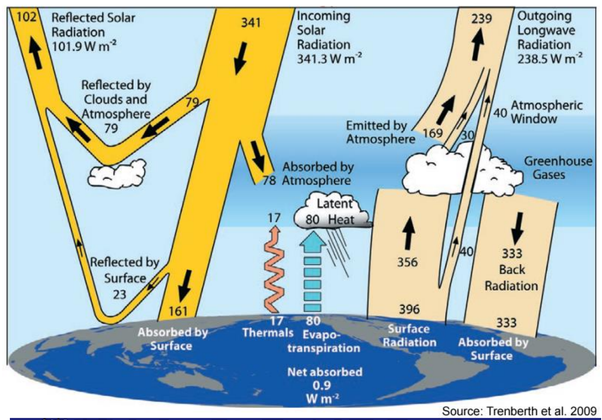
The National Renewable Energy Laboratory (NREL) develops clean energy and energy efficiency technologies and practices, advances related science and engineering, and provides knowledge and innovations to integrate energy systems at all scales. NREL's resource assessment and forecasting research supports industry, government, and academia by providing renewable energy resource measurements, models, maps, and support services. The following NREL products are specifically useful for solar energy development.

Solar Resource Database (NSRDB): The National Solar Radiation Data Base 1961-1990 (NSRDB) contains 30 years of solar radiation and supplementary meteorological data from 237 NWS sites in the U.S., plus sites in Guam and Puerto Rico. The updated 1991-2010 National Solar Radiation Database holds solar and meteorological data for 1,454 locations in the United States and its territories. The National Solar Radiation Database 2005-2012 update comprises 30-minute solar and meteorological data for approximately 1.4 million 0.038 degree latitude by 0.038 degree longitude surface pixels (nominally 4 km2) by merging data from GOES-East and GOES-West.

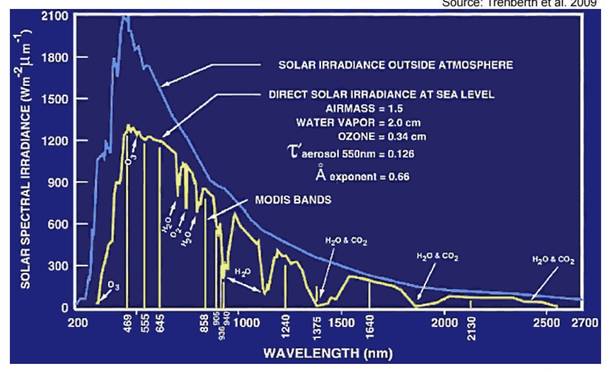
System Advisor Model (SAM): The System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry. SAM includes several libraries of performance data and coefficients that describe the characteristics of system components such as photovoltaic modules and inverters, parabolic trough receivers and collectors, wind turbines, and biopower combustion systems.

Solar Prospector: The Prospector is a mapping tool developed for the Solar Power industry. This tool is designed to help developers site large-scale solar plants by providing easy access to solar resource datasets and other data relevant to utility-scale solar power projects.

Earth's Energy Balance



Source: Trenberth et al. 2009



Source: NASA JPL

The earth's atmosphere is complex and radiative transfer is a challenging problem to tackle. Most advances in atmospheric science are aimed at improving weather forecasts and column radiation balance for better understanding of climate change. Improving surface irradiance for solar forecasting is one component of the puzzle but requires an innovative approach to meet the goals of the SunShot Initiative in the near future. Although storage solutions can provide some resolution to the solar variability problem, advances in solar forecasting are an essential part of the solution.

Solar Forecasting Research Needs and Feedback Request

The goal to achieve high accuracy solar forecasts for high penetration of solar is a challenging problem that needs to be addressed for meeting the goals of the SunShot Initiative. While the limits of predictability and the complexity of the atmosphere can make it extremely challenging to provide irradiance forecasts with accuracy of 3%, dramatic improvements in surface irradiance forecasts will be necessary for making solar energy dispatchable (available on demand) and cost competitive with other conventional forms of energy.

While improving understanding of basic atmospheric physics is the best way to improve deterministic forecasts, a combination of deterministic and statistical forecasting approaches through advanced machine learning and other statistical methods may provide the best solution. Your input and feedback is highly appreciated and welcome.

QUESTIONS?
Please feel free to email me at Subhashree.Mishra@ee.doe.gov