Solar Photovoltaics

Market Outlook

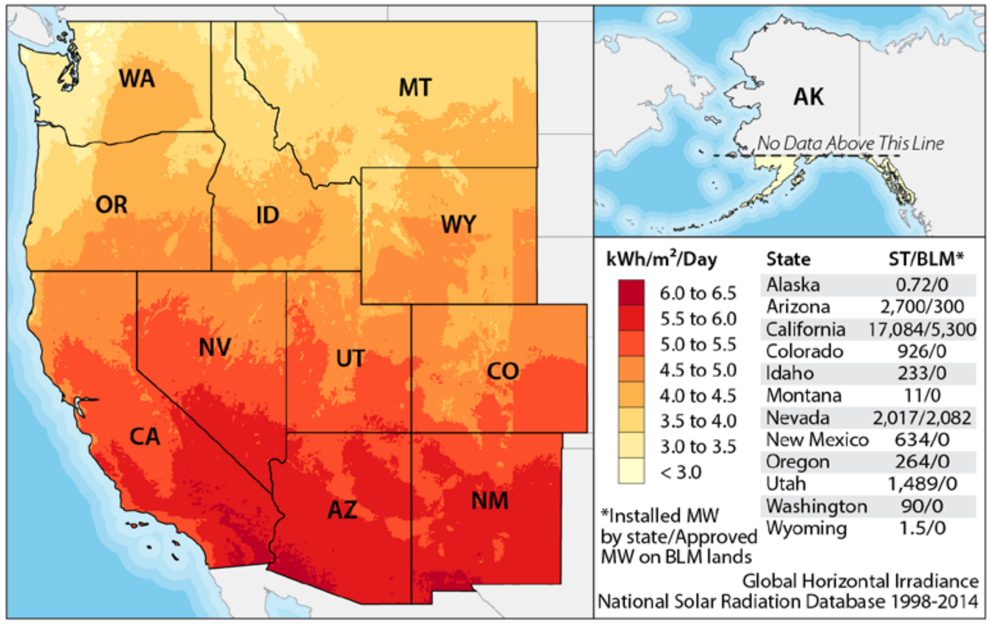
In 2016, Solar PV grew 97% over 2015, representing the largest new source of electricity generating capacity.

Although solar PV does require a large land area, there are relatively few environmental impacts. Solar costs continue to decline, and the extension of the Investment Tax Credit (ITC) is likely to drive continued growth in the near term.

Proximity and availability of interconnection remains a key consideration for utility-scale PV.

Key U.S. Technology Statistics

- Total Solar Capacity: **42.4 GW**[2]
- Recent Capacity Additions:
  - 2013: **4,762 MW**
  - 2014: **6,251 MW**
  - 2015: **7,501 MW**
  - 2016: **14,762 MW**
- 2016 utility-scale capacity factor: **27.26%** (100 MW≈240,000 MWh/yr)[4]
- 2015 PPA price range: ($35-60/MWh)[3]
- ITC Extended
  - Present – 2019: **30%**
  - 2020: **26%**
  - 2021: **22%**
  - 2022 onward: **10%** commercial **0%** residential
- YOY installed cost reduction of **20%** for utility-scale systems[2]
- BLM Projects: [3]
  - Approved: **7,682 MW**
  - Installed: **1,170 MW**



Technology Basics

A solar photovoltaic (PV) system consists of three basic subsystems: solar PV modules, power electronics (combiner boxes and inverters), and structural and wiring hardware, commonly referred to as balance of system (BOS). PV module technology falls into two major technology groups, crystalline silicon and thin film. The silicon is produced in such a way that an internal electric field is created in the wafer, and positive and negative electrical connections are added to form a cell. The circuit is completed for each cell and multiple cells are then linked and encapsulated to form modules. In contrast, thin film PV is deposited directly onto a rigid or flexible substrate. Thin-film PV may use any of several different substances and various deposition methods can be used on a variety of substrates.

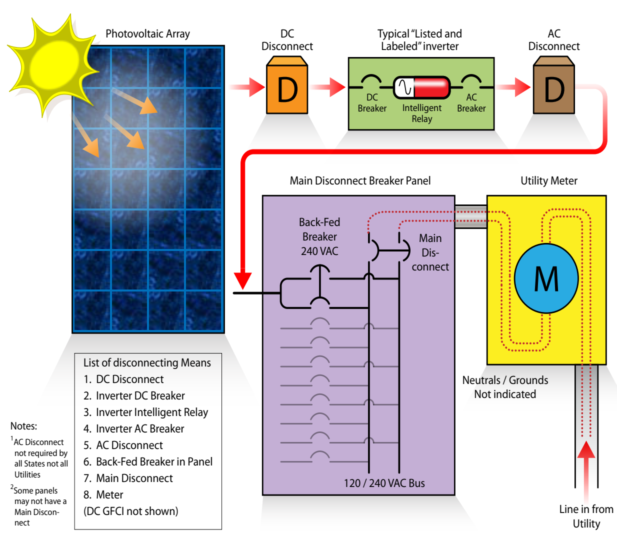


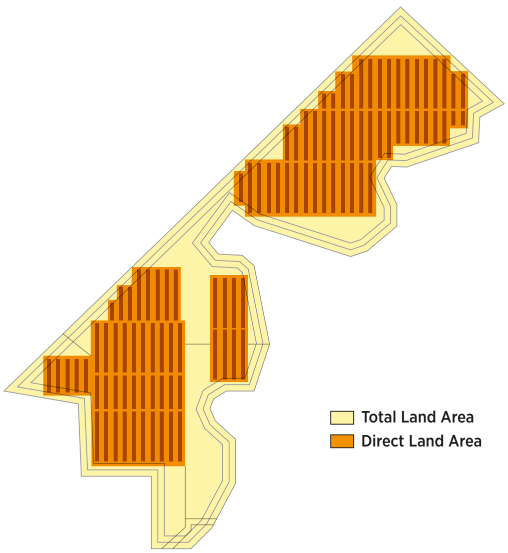
Image Credit: Coddington et. al. (2008)[9] Illustration by Alfred Hicks, NREL

The power electronics are an essential part of the PV system, in particular, an inverter converts direct current (DC) to alternating current (AC), and a transformer steps the electricity up to the appropriate voltage. Finally, the remaining components and procedures required to produce a complete PV system—mounting and wiring hardware, installation, etc. —constitute the BOS. Solar PV systems can be fixed in position, often tilted toward the south (in the northern hemisphere), or mounted on a tracker to better capture sunlight throughout the day.

Typical Project Requirements & Specifications

Site Requirements (Typ.)	
Land Slope	<5%
Water Use (non-cooling)[5]	26 gal/ MWh
Land Use[6]	5 acres/MW
Typical Capacity Factor[2]	14% to 27.2%
Interconnection Proximity	<1-10 miles (typical for all technologies)
Contiguous Land	Yes
O&M Cost[1]	$18/kW/year
Setback Distance	County-dependent, up to 50 feet (Noise from inverters)
Insolation Requirements (GHI)	Dependent on economics, > 5.0 kWh/m²/day, typical for BLM lands in Southwestern US

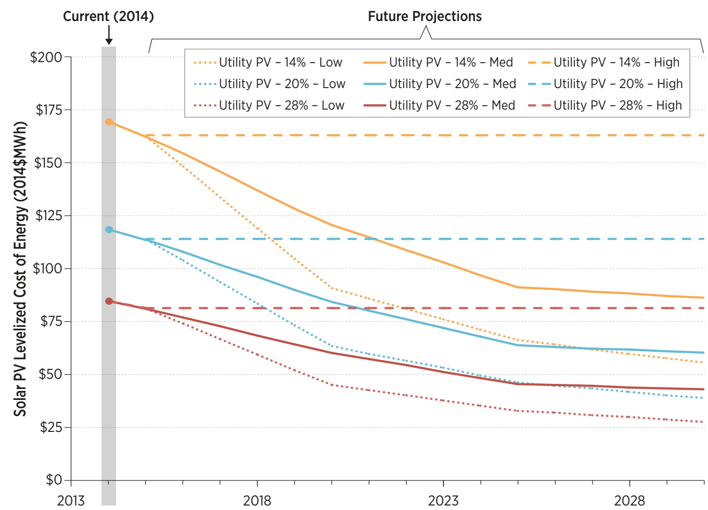
Lithium-Ion Battery Storage	
MW installed in U.S.	383.8 MW
Grid Storage installed cost[7]	$500/kWh, $1,100-$1,200/kW
Storage Round-trip Efficiency[8]	DC-DC (83%), AC-AC (76%)
Value of energy storage for grid services[7]	Energy Arbitrage: $0-100/kW-yr Regulation Reserves: $20-200/kW-yr Resource Adequacy: $60-160/kW-yr



In addition to the area covered by the PV array, additional land area is required for setbacks, access roads, fencing, and a possible substation.

Example of total vs. direct land use in a ground-mount PV system[6]

Technology LCOE Cost Curve



Depicts the impact on LCOE at various capacity factors (14-28%) and cost reduction trajectories (Low-High)[1]

Resources

1. NREL Draft ATB 2016. *http://www.nrel.gov/analysis/data_tech_baseline.html?print*

2. GTM 2016 Solar Year in Review "GTM Research/SEIA U.S. Solar Market Insight®." *http://www.seia.org/research-resources/us-solar-market-insight*

3. Bolinger, Mark, and Joachim Seel. Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States., 2016. *https://emp.lbl.gov/publications/utility-scale-solar-2015-empirical*

4. US Energy Information Administration. "Electric Power Monthly: Data for February 2016". 4/28/2016. *https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b*

5. Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies: A Review of Existing Literature. Article No. 045802. Environmental Research Letters, 7(4), 10 pp. *http://www.nrel.gov/docs/fy11osti/50900.pdf*

6. Ong, S., C. Campbell, P. Denholm, R. Margolis, and G. Heath (2013). Land-Use Requirements for Solar Power Plants in the United States. *http://www.nrel.gov/docs/fy13osti/56290.pdf*

7. The Economics of Battery Energy Storage. Rocky Mountain Institute, September 2015. *http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf*

8. Performance Assessment of the PNM Prosperity Electricity Storage Project(No. SAND2014-2883). Sandia National Laboratories (SNL-NM), Albuquerque, NM (United States).*http://www.sandia.gov/ess/publications/SAND2014-2883.pdf*

9. Utility-Interconnected Photovoltaic Systems: Evaluating the Rationale for the Utility-Accessible External Disconnect Switch (Poster). *http://www.nrel.gov/docs/fy08osti/43295.pdf*.

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Prepared by the National Renewable Energy Laboratory (NREL), a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; NREL is operated by the Alliance for Sustainable Energy, LLC.

NREL/FS-7A40-67180 • May 2018

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