Thin Film
TECHNOLOGY ADVANTAGE

RECORD-SETTING PERFORMANCE

Get superior efficiency, higher energy yield, and long-term reliability from an affordable, field-proven module. Thin Film CdTe photovoltaic (PV) technology continues to set performance records in both research and real-world environments.

The 17.0% thin film module efficiency beats best-in-class multicrystalline. It also holds the current world record for CdTe PV module efficiency, achieving 18.2% for an advanced, full-size module. And the innovative design and quality construction pass the industry's most rigorous protocols.

THIN FILM MODULES vs STANDARD SILICON MODULES

Land Use Advantage

As a result of higher efficiency, Cat® modules offer higher power density with comparable land use when compared to typical c-Si modules, resulting in more installed capacity per square meter (m^2).

Specific Energy Yield Advantage

Thin film high efficiency modules have a proven specific energy yield advantage to deliver more usable energy per nameplate watt than conventional c-Si modules. Specific annual energy yield captures operating data over a year of module performance during varying real-world conditions where temperature, sunlight intensity, and solar spectrum all change throughout the days and seasons.

$$\text{SPECIFIC ENERGY YIELD} = \frac{\text{TOTAL ENERGY (MWh) PRODUCED}}{\text{INSTALLED NAMEPLATE CAPACITY (MWp)}}$$

THIN FILM MODULE

LAND USE

A

POWER DENSITY

IS WATTS (W) OF INSTALLED CAPACITY PER SQUARE METER (m^2)
at Nominal Operating Cell Temperature (NOCT) of 45°C
(800W/m^2, 20°C air temperature, AM 1.5, 1 m/s wind speed)

11,236 Thin film
117.5 (W) modules
1 module = 0.72 m^2

IN ORDER TO GET **1 MW DC** YOU'D NEED

4.348 Silicon (c-Si)
310 (W) modules
1 module = 1.94 m^2

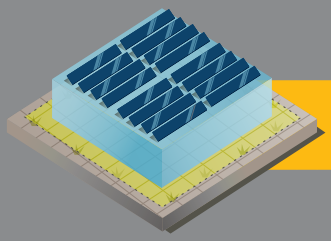
8,090 m^2 Thin film **modules**

8,435 m^2 Silicon **modules**

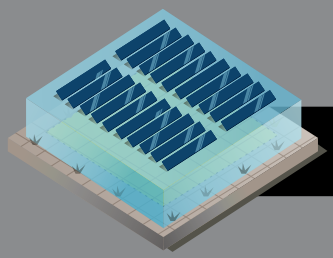
B

GET THE SAME INSTALLED CAPACITY WITH LESS LAND USED

USING 50% GROUND COVERAGE RATIO



Thin film
16,180 m^2
of land used



Silicon (c-Si)
16,870 m^2
of land used

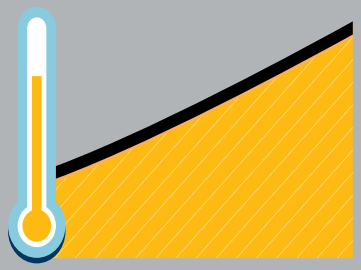
AS A RESULT, YOUR POWER DENSITY (MWh/m^2) WILL BE

4.3% BETTER POWER DENSITY

SPECIFIC ANNUAL ENERGY YIELD

A

SUPERIOR TEMPERATURE COEFFICIENT



UP TO 3% MORE SPECIFIC ANNUAL ENERGY YIELD (SY) THAN c-Si

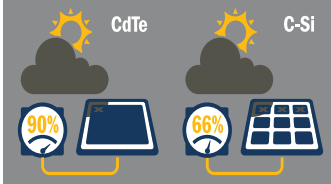
B

BETTER SPECTRAL RESPONSE

UP TO 6% MORE SPECIFIC ANNUAL ENERGY YIELD (SY) THAN c-Si IN HUMID CONDITIONS

C

BETTER SHADING RESPONSE



1% MORE SY THAN c-Si

A+B+C= 10% BETTER SPECIFIC ANNUAL ENERGY YIELD

Up To 14.3% Energy Density Advantage

Given the same land area with an equivalent module ground coverage ratio, thin film CdTe modules produce more annual energy from the same land area as c-Si.

THE THIN FILM ADVANTAGE

Higher Energy Production in Hot Conditions

The nameplate power for all PV modules, regardless of manufacturer or technology, is established at standard test conditions (STC). Standard test conditions do not define an ambient operating temperature, but do define the PV module temperature as 25°C. Module temperatures are typically 25°C to 30°C above the ambient temperature. As the module temperature exceeds the STC of 25°C, the power output for all PV modules decrease. In warm and hot climates, the module operating temperature will exceed 25°C for as much as 90% of the generating hours, resulting in a decrease in power. The temperature coefficient of a module can be used to calculate the power decrease as the module temperature increases. The Cat thin film panels have a lower temperature coefficient than cSi modules and will produce more energy as the module temperatures increase.

Thin film CdTe module temperature coefficient is 0.28%/°C, compared to ~0.45%/°C for c-Si modules. For example, on a 40°C day, a thin film module would reach 65°C operating temperate. In such conditions the thin film modules produce up to 5% more power than c-Si modules on average. Over a year in hot climate conditions, this high temperature advantage adds up to 3% more annual energy than c-Si modules.

Spectral Response Advantage in Humid Conditions

Sunlight is comprised of multiple wavelengths and various intensities of light. The intensity of wavelengths that reach the earth's surface is influenced by atmospheric conditions. The largest impact on intensity is due to water vapor in the atmosphere, commonly correlated to high humidity.

PV technologies respond differently to different light wavelengths. On humid days, water in the atmosphere reduces specific wavelengths of available light. Because Cat CdTe modules are less sensitive to reductions in wavelengths most affected by this type of high atmospheric water content, the thin film modules produce up to 6% more annual energy in humid conditions.

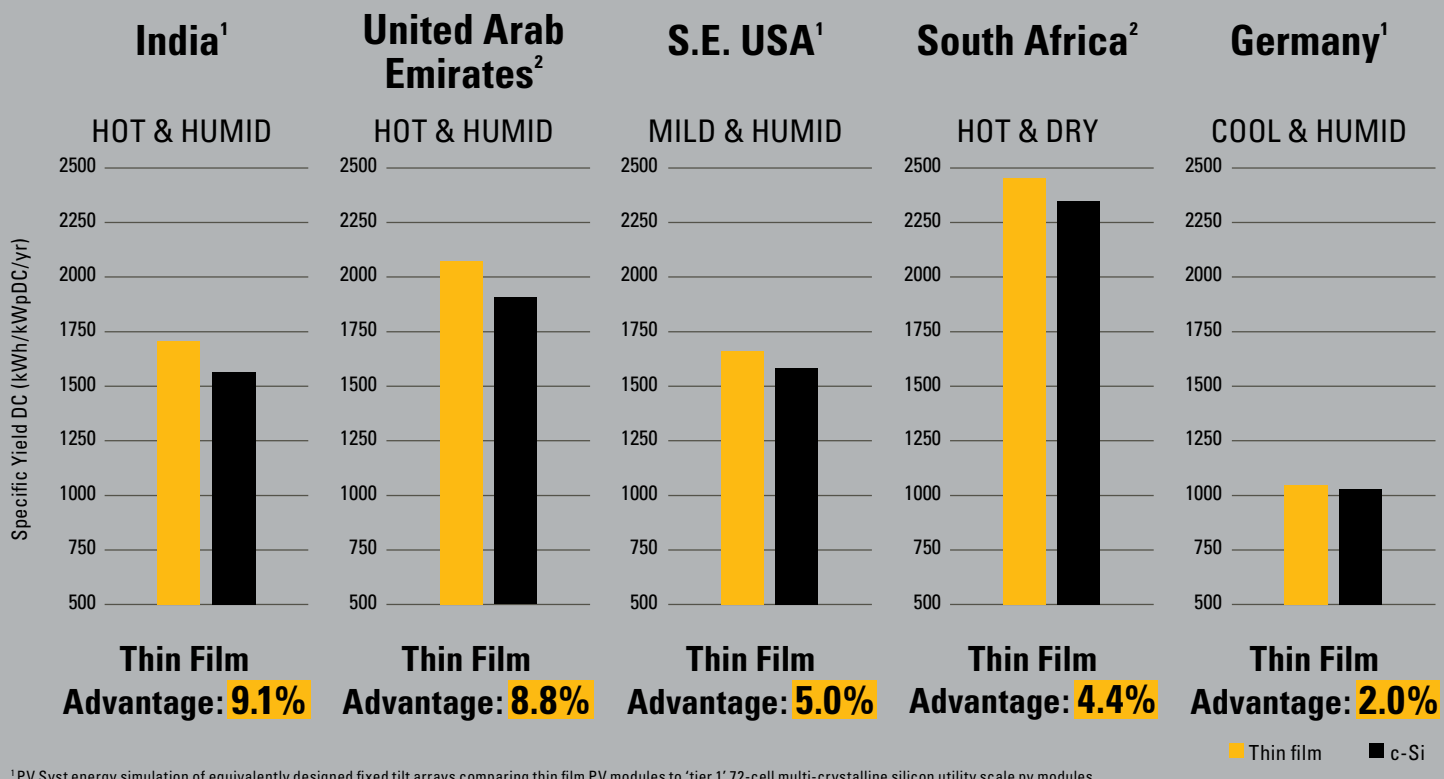
Minimal Power Loss with Better Shading Response

When shading occurs, thin film's unique cell design ensures only the shaded portion is impacted, while the rest of the module continues to produce power. Typical c-Si modules turn off disproportionately large portions of module to protect them from damage. In an environment with 10% shading, a thin film module will still produce 90% power, compared to a 30% loss of power with a standard c-Si module.

Greater Energy Yield Drives Lower Levelized Cost of Electricity (LCOE)

While module efficiency identifies the power produced by a module in standard test conditions, the specific annual energy yield metric shows the energy produced in a year of real world conditions. When evaluating return on investment (ROI) for a solar power plant, energy yield has a big impact on the overall LCOE. Thin film high efficiency modules are proven to deliver more usable energy per nameplate watt than conventional silicon-based modules. For an equivalently designed and installed power plant priced at the same $/watt, a thin film plant will produce more energy, resulting in a lower LCOE ($/MWh).

Specific annual energy yield in different regions of the world:



[1] PV Syst energy simulation of equivalently designed fixed tilt arrays comparing thin film PV modules to 'tier 1' 72-cell multi-crystalline silicon utility scale pv modules
[2] PV Syst energy simulation of equivalently designed single-axis tracker arrays comparing thin film PV modules to 'tier 1' 72-cell multi-crystalline silicon utility scale pv modules

INCREASING PLANT VALUE

Predictable lifetime energy is critical to confidently project the expected value of sellable energy from a PV plant designed for long-term operation. The quality and reliability of thin film technology is proven both in short- and long-term field performance that meets or exceeds expected returns.

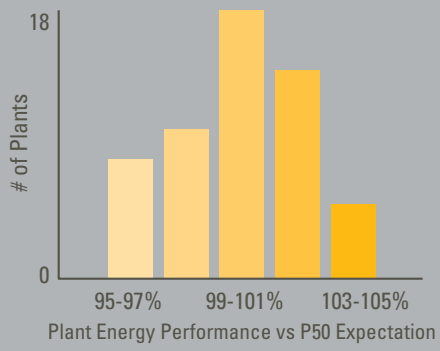
With the solar industry's rapid innovation cycles, PV technology relies on independent laboratory-accelerated testing protocols to determine the suitability and performance of modules in the field. Independent lab test results backed by a 25-year linear output warranty ensure your Cat module will provide reliable lifetime performance.

Cat CdTe modules have been field-deployed and independently monitored by NREL with a documented long-term median power degradation rate of -0.45% per year. This low degradation rate positively impacts the long-term reliability and LCOE over the life of the entire power plant.

1,000MW

OF MONITORED SITES PERFORMING **AT OR ABOVE EXPECTED OUTPUT** FOR OVER

10 YEARS



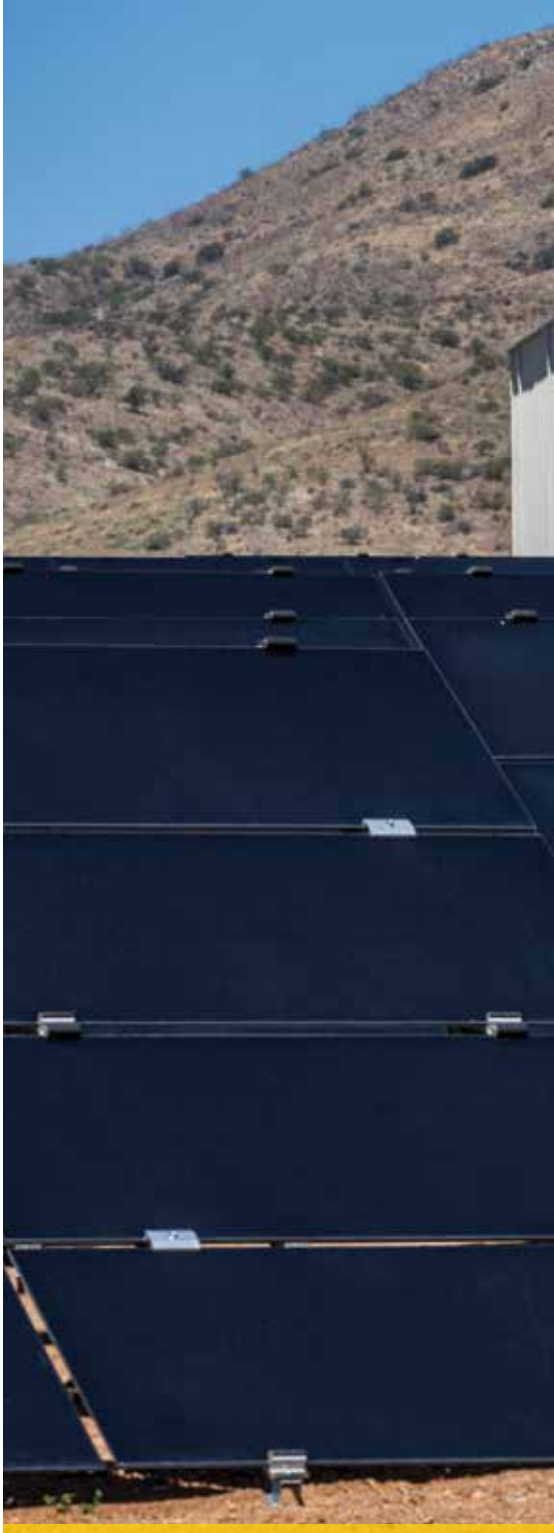
96% of Plants within ±5% of PEP

Test	Description	Results
IEC 61646/IEC 61730 Certification	Basic industry market entry certifications	**PASS** *1500V certification level*
Thresher Test	Multiplies basic IEC 61730/61646 test cycles and durations 2X to 4X	**PASS** *<5% Power output drop*
Long-Term Sequential Test	6-month accelerated protocol to evaluate long-term harsh climate durability	**PASS** *1st thin film module and one of only 5 modules in the world to pass.*
Atlas 25+ Certification	12-month weathering-intensive certification through projected 25+ year harsh climate field lifetimes	**PASS** *One of only 4 modules in the world to pass.*
IEC 62804 PID-Resistant Certification	Demonstrates high resistance to potential induced degradation at extreme ±1500V voltages at most extreme 192hr 85C/85% RH test levels, enabling confident floating and grounded applications	**PASS** *1500V*
IEC 60068 Certification Desert Sand Resistance	Demonstrates minimal power loss and package integrity resistant to wind-blown particulates	**PASS**

LOW-COST FINANCING

There is unparalleled use of thin film modules in financed projects around the world. Many financial institutions appreciate the integrity of thin film projects and market-leading technologies in high yield solar projects for their superior ROI. The world's leading PV investors and financial institutions see a pattern of more value and less risk than competing alternatives.

Thin film topped the list of the 20 PV module brands most used in debt-financed projects in Bloomberg New Energy Finance's report, "PV module bankability 2014: where's the trust?"



More Energy – Lower LCOE

From large industrial installations to small rural communities, your thin film installation produces more energy, more consistently, over the long term. By design, thin film technology delivers a higher energy density than the competition. Through predictable performance and a lower rate of depreciation, thin film technology lowers LCOE. And with the global Cat dealer network, support is always available. We're built to give you the advantage.

BUILT FOR IT.™

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