



The miracles of science™

MATERIALS MATTER™

Better long-term PV system performance and higher financial returns

AS LIFETIMES IMPROVE, INVESTMENT RETURNS IMPROVE. DUPONT PV MATERIALS STAND THE TEST OF TIME.

The world's demand for energy is escalating, spurred on by population growth and expanding economies. Solar continues to make significant inroads as a key element of the world's overall energy mix. Growth rates are still very high with an annual growth rate at 20% expected over the next five years. Clearly, faster and broader adoption of solar will be required to generate enough power to meet our needs. Grid parity is key.

Grid parity has already been achieved in some parts of the world. By 2016, we expect to reach grid parity in many parts of the world. To maintain this progress, solar installations must continue to deliver a reliable source of energy, as well as a reliable return on investment.

All would agree that the attainment of grid parity requires persistent system cost reduction while improving performance. This cost/performance roadmap will be achieved largely through technological innovation.



SYSTEM LIFETIME IMPACTS INVESTMENT RETURNS

As a system owner or financier, you are always managing risk. In today's market environment, who wouldn't want more certainty about their investment?

There are actions you can take to mitigate your risk and help improve your investment certainty. Clearly, the more reliable the system lifetime is—and the power provided over that lifetime—the more reliable and certain the investment is.

Three factors significantly impact system lifetime—the bill of materials, component design and manufacturing practices. DuPont can guide you with industry-standard

bill of materials, as well as provide your module manufacturer with materials technology that will best match your power output and expected lifetime goals.

Today, DuPont offers the broadest materials portfolio in the PV industry. These materials are not only innovative, they have delivered demonstrable results by almost doubling cell efficiency over 12 years; providing greater reliability and protecting system lifetime with more than 30 years of proven, protective backsheet performance; and reducing overall system cost with technology advancements in efficiency and module protection.

KNOW WHAT IS IN YOUR MODULES—MATERIALS MATTER™

In the past, a system owner didn't need to be an expert in materials technology in PV systems. High quality, proven technologies were assumed. It's still not necessary to be a materials expert, but now you need to be aware of what is in your system and what to ask for.

In today's market, the consolidation in the industry and the efforts to maintain profitability throughout the value chain are driving short-term decisions with long-term implications.

We believe that today's short-term focus is resulting in lower quality and lower performing materials being used in modules, which shifts more risk to PV system owners who may experience far faster power degradation and decreased system lifetime vs. expectation.

Many system owners believe that warranties and "bankability status" will help protect the investment; however, they are no longer effective, on their own, to mitigate risk. Today's industry consolidation means that the module manufacturer that supplied your system may not be around long-term. Get durability and reliability designed into your system by becoming more aware of your system's bill of materials, component design and manufacturing practices.

LEVELIZED COST OF ENERGY (LCOE)—THE BETTER MEASURE OF OVERALL COST OF OWNERSHIP

Today, cost-per-watt (or \$/watt) is often used to express the cost of a PV system. However, \$/watt only describes the purchase price for the initial power capacity for a solar panel; it does not express the overall cost of system ownership.

Many experts advocate the use of LCOE, measured in cost-per-kWh (or \$/kWh), as a much better performance metric. Industry's use of \$/watt creates a short-term focus that overlooks system quality and field failures that can seriously degrade investor returns.

LCOE (\$/kWh) provides a more accurate measure of costs and cash flows that better reflects true system performance and, therefore, true investment returns. LCOE points us toward grid parity as it enables the best cost/performance decisions.

DuPont PV materials are a key driver of system performance and impact LCOE in three ways: increases in system lifetime—with more durable, long-life module protection; increases in efficiency—with fewer modules needed to generate power; and reductions in Balance of System (BoS) cost due to greater efficiency. BoS cost is an increasing percentage of the total input cost as module prices are reduced.

In today's highly competitive market, ongoing PV system cost reductions will continue, but savings must be balanced by risk to get the best long-term investment returns from your system. Changes to a component's design, bill of materials and/or manufacturing practices may lower PV system \$/watt, but it can mean higher LCOE (\$/kWh) if it results in decreased lifetime, faster power degradation and/or increased performance risk.



LONGER MODULE LIFETIME PROVIDES GREATER INVESTMENT RETURNS

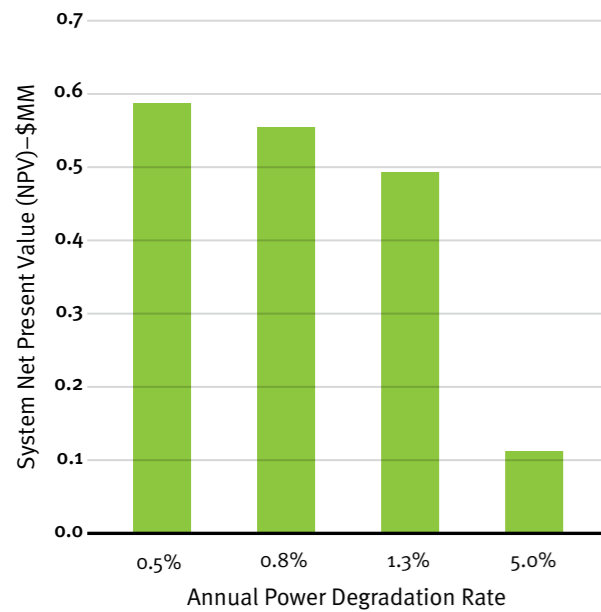
Module lifetime is best described in terms of reliability, durability and safety. Each of these factors is important to delivering the expected internal rate of return (IRR) for solar projects.

Reliability means no early-onset catastrophic failure.
Durability means minimal annual power degradation.
Safety means no injury to people or physical assets, such as buildings.

The bottom line is that the cost of electricity can be reduced significantly when the PV system runs for a longer period of time. In fact, investment returns can increase by more than 30% if the lifetime of the PV system can be increased from 10 to 25 years. Using proven industry standard materials in your backsheet will increase your initial system cost by less than 0.2% vs. unproven materials such as PET. The lifetime gains and resulting financial benefit greatly outweigh the incremental cost of higher quality materials.

DUPONT™ TEDLAR® PVF FILM FOR MODULE BACKSHEETS HELPS ENSURE GREATER LIFETIME POWER OUTPUT AND INVESTMENT RETURNS

Impact of module degradation rate on system PV

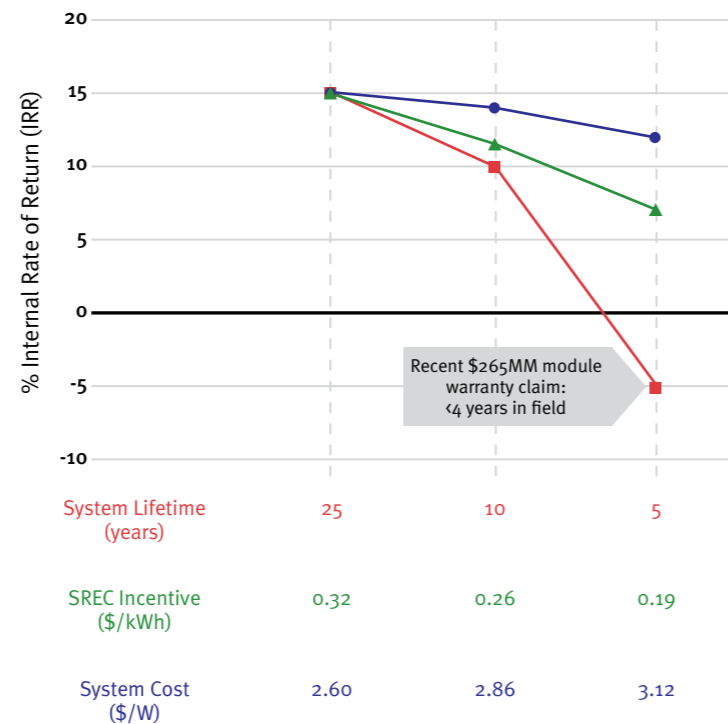


Most financial models for PV systems assume 0.5% annual degradation.

But observed, in-field degradation can range as high as 5.0% per year, resulting in greater than 60% reduction in NPV vs. financial plan.

Assumptions: 1MW system in United States, 100% system availability, 20 year SREC, 30% Investment Tax Credit, 9% discount rate.

System lifetime can impact financial returns much more significantly than system cost or incentives



Assumptions: 1MW system in United States, 0.5% annual degradation, 100% system availability, 20 year SREC, 30% Investment Tax Credit.



BACKSHEETS PLAY CRITICAL ROLE IN PROTECTING PV MODULES AND DELIVERING NEEDED MODULE LIFETIME

Backsheets protect the modules from the environment while providing electrical insulation. A backsheet failure can result in power loss, investment loss and even bodily harm.

Decades ago, the U.S. Department of Energy contracted NASA's Jet Propulsion Laboratory (JPL) to develop a reliable, durable and safe 30-year PV module. Many different types of materials were tested throughout the program, but all of the recommended final designs contained Tedlar® PVF film-based backsheets.

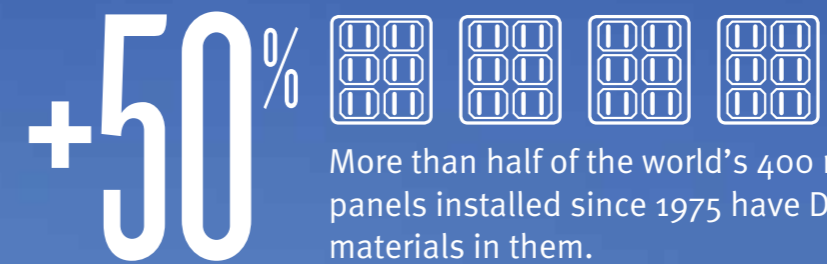
During the development process, failure rates dropped from 45% in early designs to 0.1% in the final set of designs.

Tedlar® based backsheet designs have now been in the field for more than 30 years in all kinds of climates (such as desert, tropical, seashore and mountain) and continue to provide critical, long-life protection to the module, safeguarding the system and enabling long-term PV system returns. Tedlar® offers the optimal balance of properties for weatherability, adhesion and mechanical strength.

Not all backsheets are created equal. In the absence of long-term, field-proven performance, many of today's newer backsheet materials rely on various lab tests to suggest performance in the field.

However, well-established scientific bodies, such as NASA's JPL, and other leading PV research labs, have made it clear that lab tests do not predict lifetime performance. As many scientists have pointed out, long-term outdoor exposure is the ultimate test for all the module components, material quality and manufacturing quality.

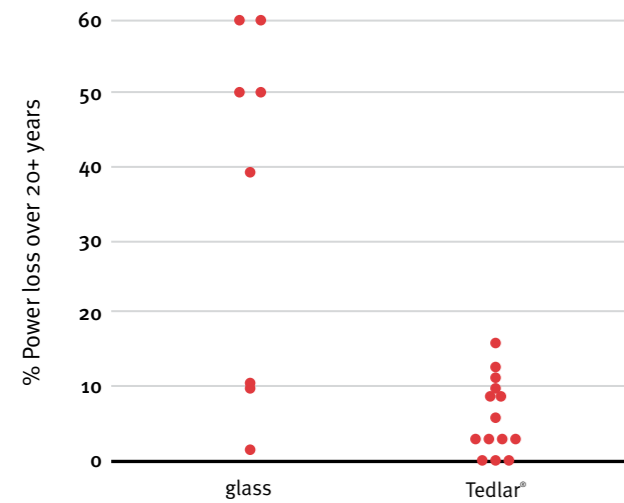
A recent study conducted by the Joint Research Centre (JRC) confirms the JPL finding that modules containing EVA/Tedlar® demonstrate excellent performance for extended periods in the field. To date, Tedlar® based backsheets are the only backsheets with more than 30 years of field-proven lifetime. Other backsheets being used in the field have as little as three to six years of operating history.



ONLY TEDLAR® BASED BACKSHEETS HAVE DEMONSTRATED LOW POWER LOSS IN LONG-TERM PV MODULE APPLICATIONS

Results from the JRC study of modules containing EVA encapsulant

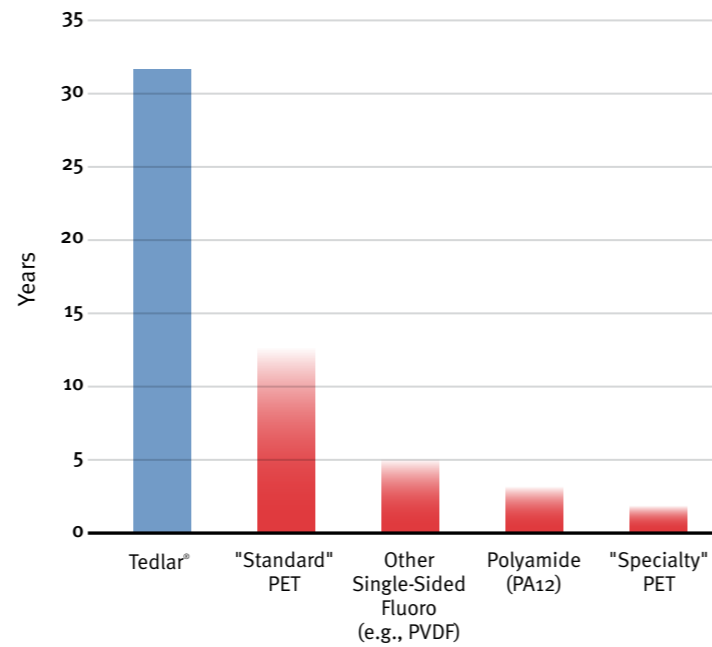
Demonstrated low power loss (0.3%/year) of modules with Tedlar® based backsheets after 20+ years in field



Source: Joint Research Centre 2008 Study*
*Artur Skoczek, Tony Sample, and Ewan D. Dunlop. The Results of Performance Measurements of Field-aged Crystalline Silicon Photovoltaic Modules, Wiley InterScience, 2008.

Years of backsheet use in PV modules

Competitive offerings have not been in the field long enough to judge their durability



CAUSES OF MODULE FAILURES

Although many investors expect low, single-digit failure rates among modules, actual results are much higher. In fact, a recent NREL study¹ indicates that more than 20% of all modules and systems evaluated failed to produce the expected power output over time.

The top four causes of module failure are cell corrosion, interconnect breakage, internal circuitry failure and glass breakage.

During the past 30 years—when most backsheets contained Tedlar®—backsheets were not a significant contributor to system failure, with estimates ranging from just 3% to 10% observed failure rate.

Today, the industry is beginning to see higher failure rates because PET-based backsheets and other lesser-performing and unproven materials introduced during the past five years have now been in the field long enough to show failures.

¹ NREL, Jordan, Kurtz 2011.

INCREASE EFFICIENCY AND REDUCE BALANCE OF SYSTEM (BOS) COST

Every 1% improvement in sunlight conversion efficiency could result in a 5% reduction in the cost of the overall solar power generation system because fewer panels/less panel space would be needed to generate the same amount of electricity.

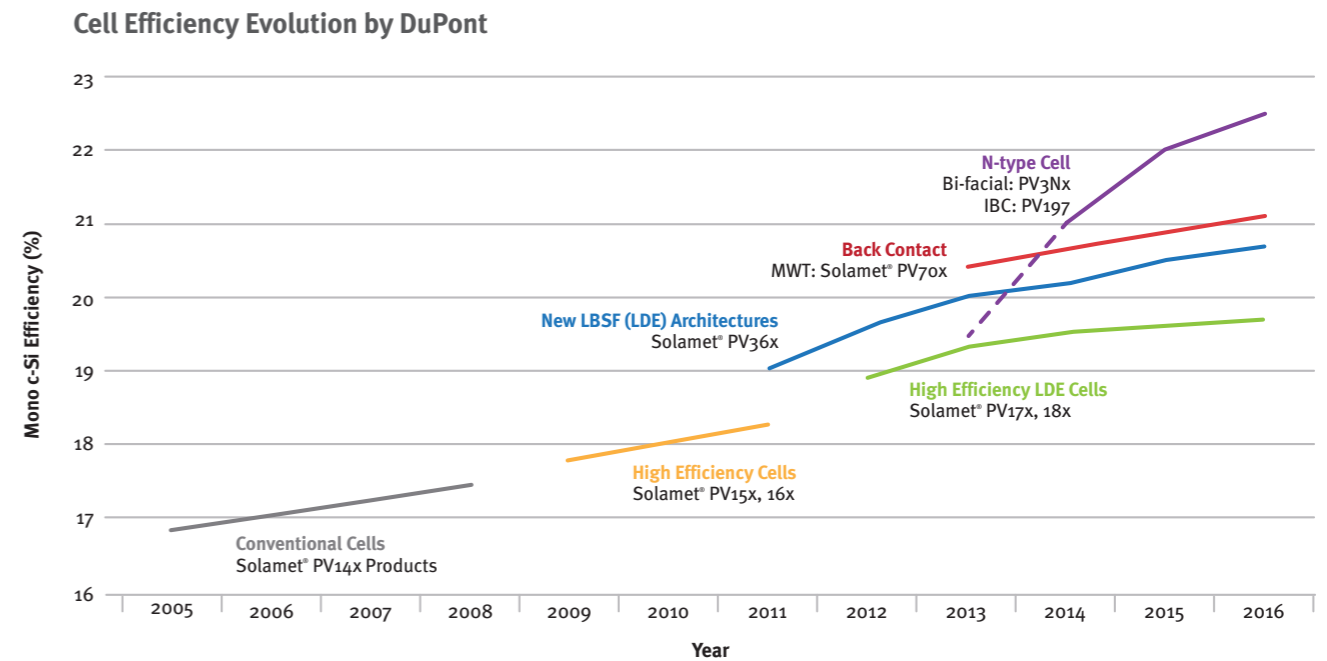
Increased efficiency reduces BoS cost because less land is needed; installation and structure costs are lower; and operating and maintenance costs are reduced.

For a module that costs \$1/watt to manufacture, the savings would be \$.05 (all else being equal).

DuPont™ Solamet® metallization paste boosts the efficiency of solar cells to deliver significantly more power output from solar modules. Solamet® has almost doubled cell efficiency over the past 12 years. This means that you can use half the panels you used 12 years ago to produce the same power output today.

Evolution of mono cell efficiency

The recent success of Solamet® PV18x drives industry performance to the next level



DuPont™ Solamet® is on target to boost cell efficiency to 22% in 2015

FOUR WAYS TO MITIGATE YOUR RISK

1. **Think in terms of cost-per-kWh (\$/kWh) vs. cost-per-watt** because \$/kWh (or LCOE) is a substantially more precise and comprehensive way to describe cost of ownership. Generally, \$/kWh is the standard method used to calculate energy costs using other technologies. Think in terms of lifetime, efficiency and system cost, because these factors contribute to lowering LCOE.

2. **Ensure your system utilizes proven bill-of-materials, system design and manufacturing practices.** It is also important to consider the environment and weather conditions where your system will be installed; the particular application of your system; and how you plan to maintain and monitor your system.

3. **Know what materials are in your module**—because all modules are not created equal. There are big performance differences and you need to be clear about what you need. Specify to performance standard and make sure you get what you have paid for. Request that your module manufacturer certify that the materials used will meet the performance standard you specified.

4. **Work with well-established industry leaders—up and down the value chain—who will prevail long-term** and who will continue to invest and advance the technology that advances and protects the industry.

\$2 BILLION 
DuPont spent more than \$2B in R&D in 2013
in more than 150 R&D Centers worldwide.





SELECT A PROVEN PARTNER TO PROTECT YOUR INVESTMENT

DuPont is a 212-year-old science company with a long history of innovation in the PV industry. For example, we created the first purified silicon for Bell Labs for use in the PV market more than 55 years ago. And, we presented our first technical paper on the use of Tedlar® PVF film in PV applications nearly 50 years ago at a United Nations Conference on New Sources of Energy.

While the PV industry is experiencing great consolidation at both the materials and module manufacturing levels, DuPont stands alone in its long-term presence, commitment and ongoing investment.

DuPont has the broadest materials portfolio in PV. Our capabilities extend from materials to modules, including fundamental PV materials science and cell and module processing, architecture and testing. We are also a PV system owner and PV electricity user, with PV systems at DuPont sites around the world.

DuPont can help you manage your supply chain risk and protect your financial return by providing materials technology and guidance to improve system lifetime and achieve greater efficiency, while reducing overall system costs.

Materials Matter.™ Select DuPont as your partner to protect your PV investment.

**For more information about how DuPont can
help you ensure lifetime power output and investment
returns, visit photovoltaics.dupont.com**



The miracles of science™