SOLAR ELECTRIC INVESTMENT ANALYSIS SERIES

Assessing System Cost

Agricultural Energy Efficiency Initiative of
Virginia Cooperative Extension / Virginia Tech
December, 2017

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Program Learning Objectives

- Understand historical price trends of PV solar
- Recognize the impact of PV system cost including:
  - Hard Cost
  - Soft Cost
  - Other and Ongoing Cost
- Influence of Module Power and Efficiency
- Identify lessons learned and additional resources

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DISCLAMER:

This presentation and/or the information provided is not meant and should not serve as financial or legal advice and should only be used as an educational resource. Be sure and **consult with your financial advisor, tax accountant, utility provider, and/or attorney** before signing an agreement.

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Historical Price Trends of Photovoltaic Solar

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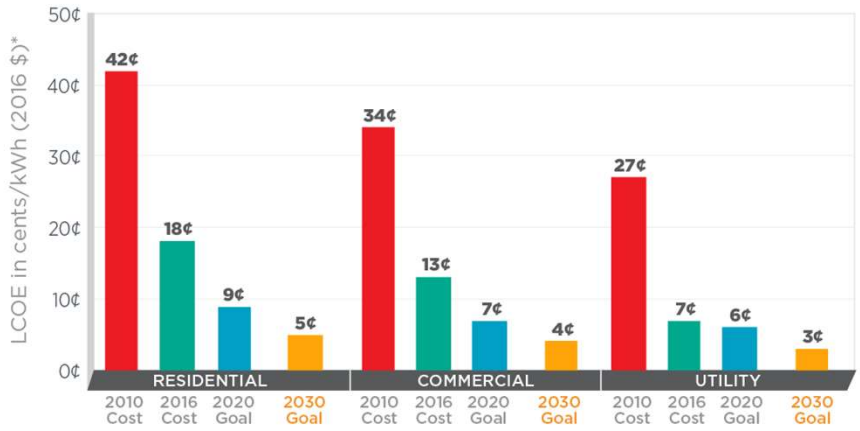
SunShot Progress and Goals



*Levelized cost of electricity (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. Utility-scale PV uses one-axis tracking.

energy.gov/sunshot

SunShot U.S. Department of Energy

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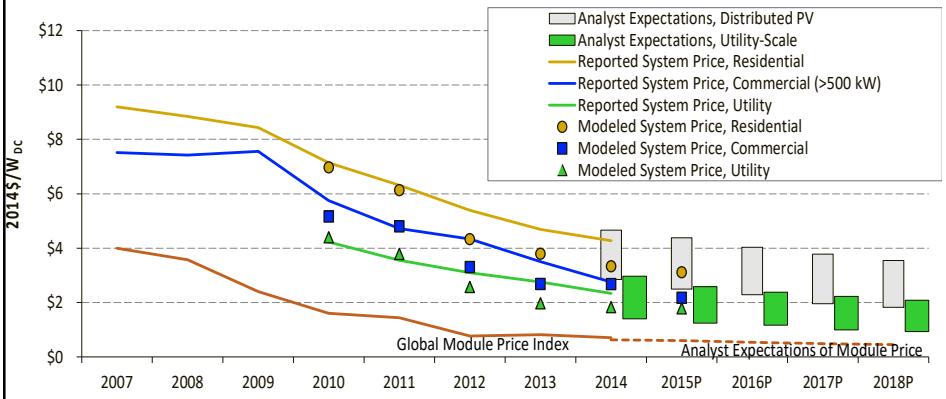
Reported and Analyst-Projected Average U.S. PV System Prices over Time



Data Source: U.S. Department of Energy, SunShot. *Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections. 2015 Edition* . NREL/PR-6A20-64898

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2010: 51 kW DC Rooftop System

- Incentives – 30% ITC, Bonus Depreciation, SREC Agreement, Ohio Advanced Energy Fund Grant
- Total System Cost - $305,270
- Installed Cost per Watt DC - **$5.98**
- Payback Period – **3 years**

2016: 100 kW DC Rooftop System

- Incentives – 30% ITC, Bonus Depreciation, SREC Agreement
- Total System Cost - $186,518
- Installed Cost per Watt DC - **$1.85**
- Payback Period – 7.5 years (**9.9 years** modified)

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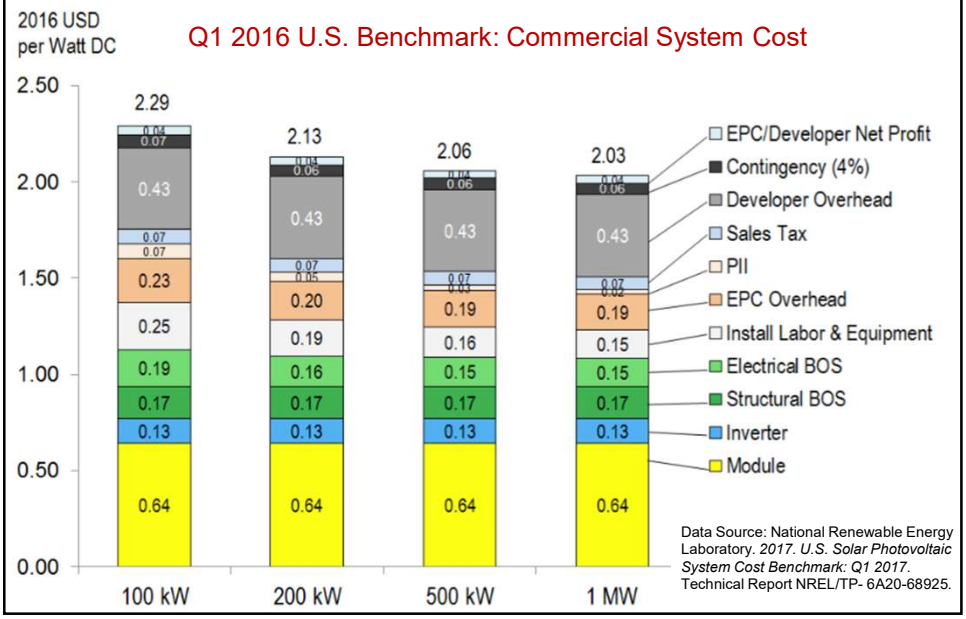
Q1 2016 U.S. Benchmark: Commercial System Cost



Data Source: National Renewable Energy Laboratory. *2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017.* Technical Report NREL/TP- 6A20-68925.

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Solar System Cost Structure: Hard Cost

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Photovoltaic Solar System Hard Cost

- Modules
- Inverters
- Balance of System (BOS)
  - Electrical
  - Structural

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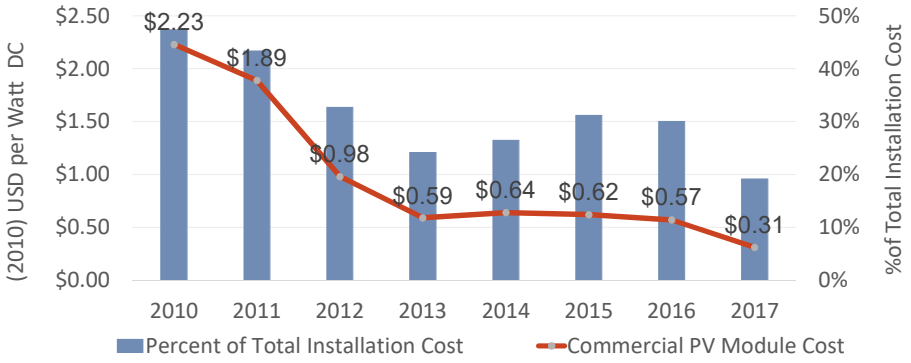
Hard Cost – Module

NREL Commercial PV Benchmark Summary (Inflation Adjusted), 2010–2017



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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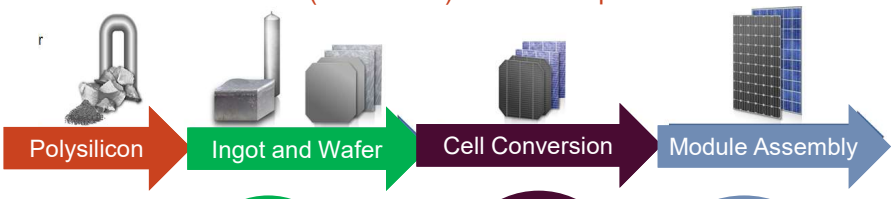
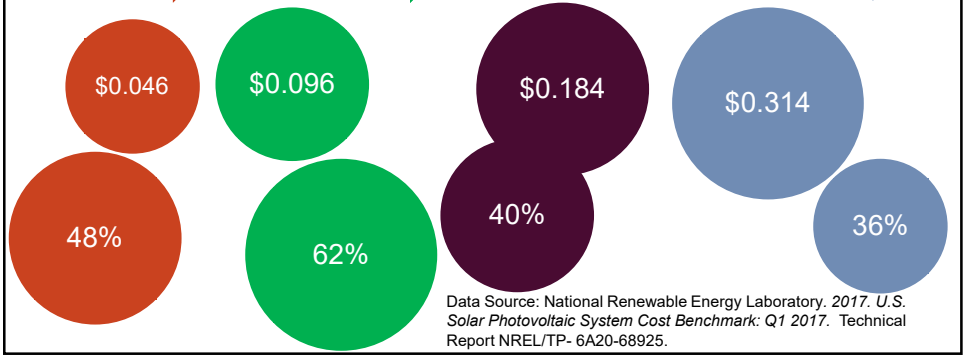
Module Level Bottom-Up Manufacturing Cost Model Results

Total Percent Reduction (2014-2017) at Each Step and Final 2017 Cost





Data Source: National Renewable Energy Laboratory. *2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017.* Technical Report NREL/TP- 6A20-68925.

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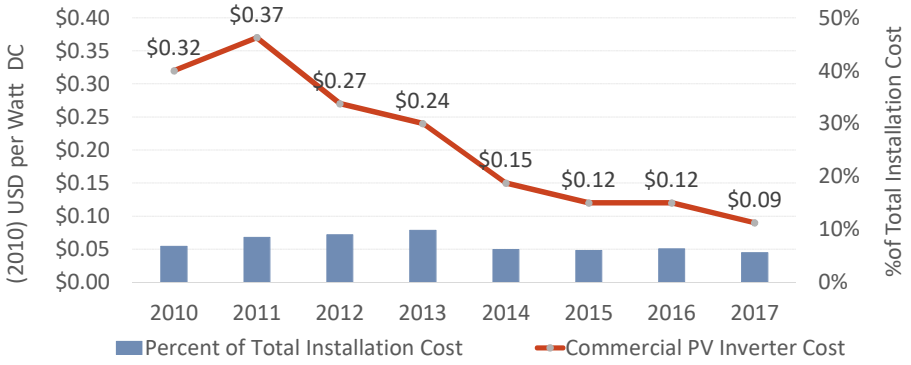
Hard Cost – Inverter

NREL Commercial PV Benchmark Summary (Inflation Adjusted), 2010–2017



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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Inverter Price Conversion (2016 USD)

Inverter Type	Primary Sector	USD/Wac	DC-to-AC Ratio	USD/Wdc
Single Phase String Inverter	Residential	0.176	1.15	0.15
Three Phase String Inverter	Commercial	0.15	1.15	0.13
Micro-inverter	Residential	0.45	1.15	0.39
DC Power Optimizer String Inverter	Residential	0.20	1.15	0.17
Central Inverter	Utility Scale	0.12	1.40	0.09

Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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NEC 2014: Article 690.12 Rapid PV Shutdown

- Scope: Only applies to PV system circuits "on or in buildings." Thus, ground-mounted system is not required to have rapid shutdown capability.
- Requirement: "Conductors more than 5 feet inside a building or more than 10 feet from an array will be limited to a maximum of 30 V and 240 VA within 10 seconds of shutdown."
- Goal: During power shutdown (i.e. fire on the building or utility power loss), for first responders (such as fire fighters), DC conductors in each string of PV arrays are most dangerous: Because DC side can still be energized even if inverter is shut down. The goal is to decrease the risk first responders face by having PV system conductors at a certain distance away from the PV arrays so that conductors are de-energized to a safe level.

Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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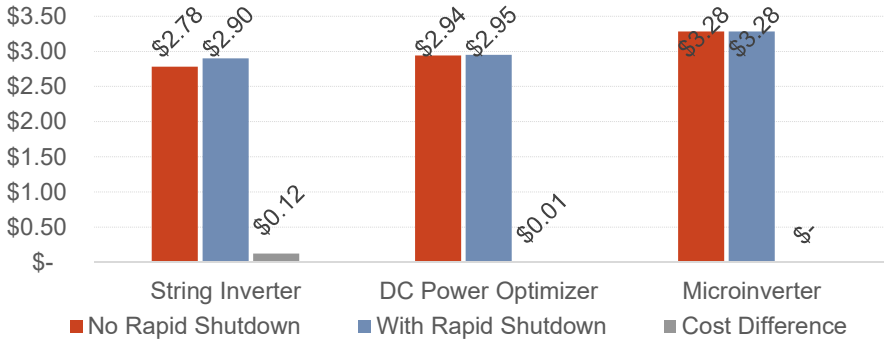
Impact of Rapid Shutdown and Different Inverter Solutions (Q1 2016 Commercial Prices $/dcw)



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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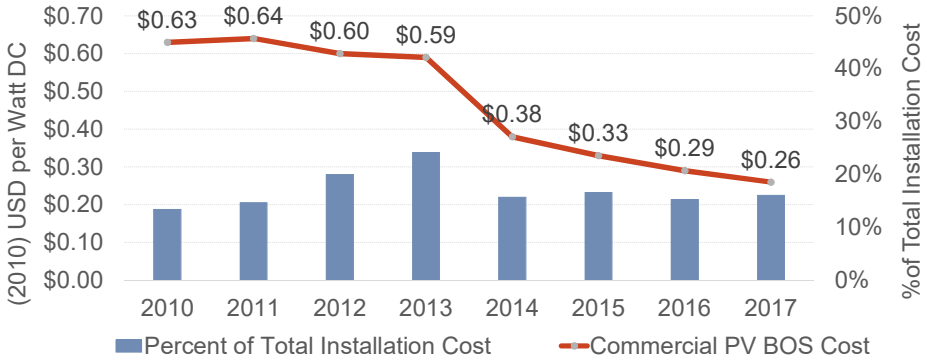
Hard Costs – BOS Structural and Electrical

NREL Commercial PV Benchmark Summary (Inflation Adjusted), 2010–2017



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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Solar System Cost Structure:

Soft Cost

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Photovoltaic Solar System Soft Cost

- Installation and Labor
- Permitting, Inspection, and Interconnection (PII)
- Land Acquisition
- Sales Tax
- Engineering, Procurement, and Construction (EPC)
- Developer Overhead and Net Profit

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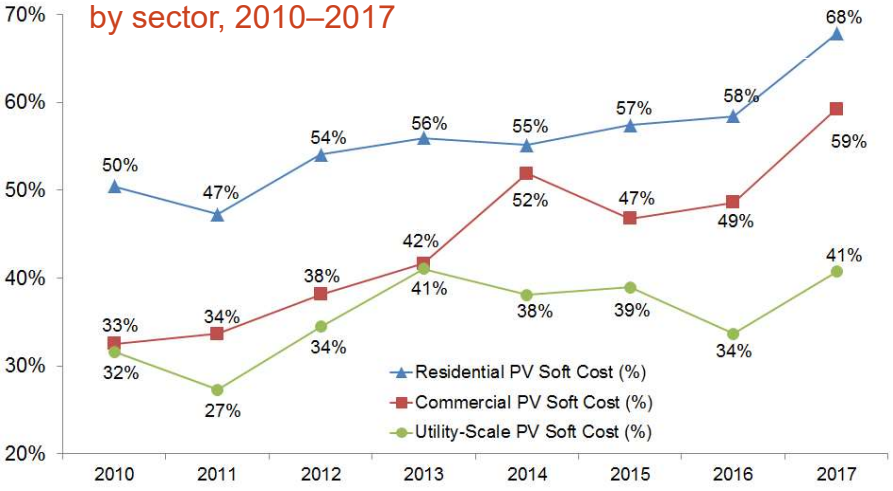
Modeled trend of soft cost as a proportion of total cost by sector, 2010–2017



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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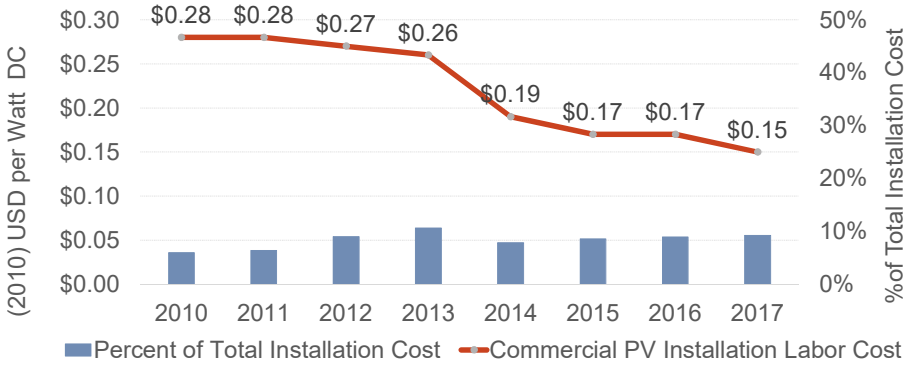
Soft Cost - Installation Labor

NREL Commercial PV Benchmark Summary (Inflation Adjusted), 2010–2017



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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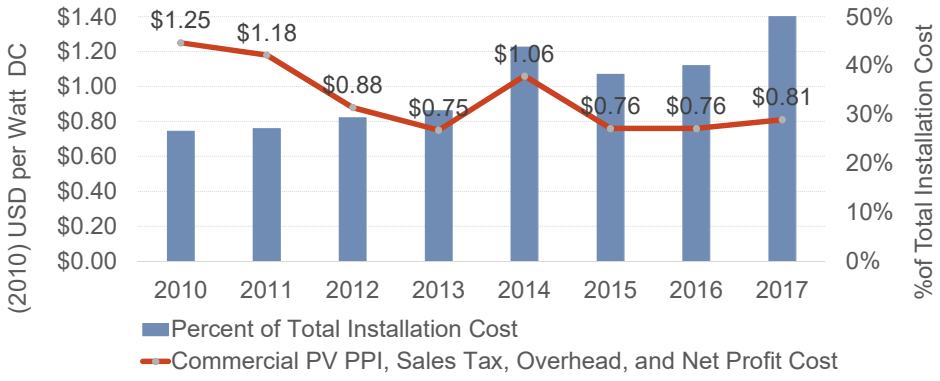
Soft Cost - PII, Sales Tax, Overhead, and Net Profit

NREL Commercial PV Benchmark Summary (Inflation Adjusted), 2010–2017



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"Other" and Ongoing Solar System Cost

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Other System Cost Considerations

- Debt to Equity Ration and Cost of Capital
- Sales Tax
- Property Tax
- Insurance
- Operations and Maintenance

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Sales and Property Tax Incentives

- 25 states have an incentive program for sales tax exemption (not including VA).
- 36 states (plus DC & PR) have a property tax exemption/incentive program.
- In VA there is 100% property tax exemption for the assessed value of equipment and facilities used in:
  - Projects equaling 20MW or less w/ initial interconnection request is filed or before December 31, 2018.
  - Projects equaling 20MW or less that serve a public institution of higher education or private college.
  - Projects equaling 5MW or less for w/ interconnection request filed on or after January 1, 2019

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Insurance

- Residential PV installations do not draw attention from insurance companies because they can usually be included under a homeowner's policy (DOE 2003) as long as they are rooftop-mounted.
- To remain feasible in terms of risk, non-residential PV installations require a variety of insurance products,4 including general liability, property, and environmental risk insurance. By purchasing these types of coverage, developers create a financial backstop for the project.
- While the manufacturer's warranty will provide some limited defect coverage, the system owner usually purchases property insurance to protect against risks not covered by the warranty or to extend the coverage period.

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Insurance

- Determine if it is covered with existing policy
- Review coverage limits and determine if they need adjusted
- Understand the required deductible before coverage starts
- Is there a difference between roof top vs. ground mount?

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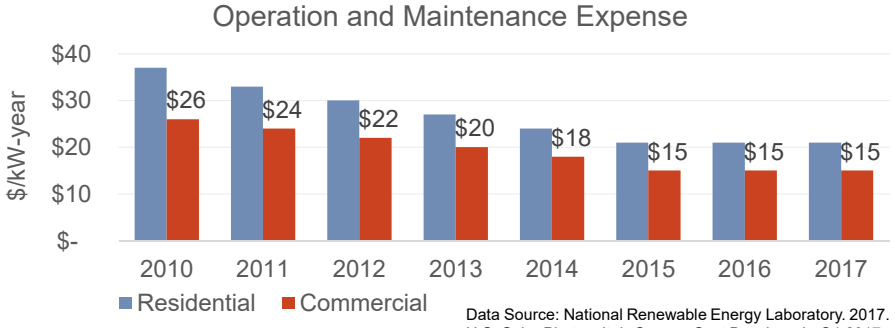
Ongoing Annual Expenses - Operation and Maintenance

operation and maintenance - represent ongoing annual expenses required to maintain, service and/or replace critical components of a PV solar system.



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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Influence of Module Power and Efficiency

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Factors Affecting Solar Cell Efficiency

- Wavelength - Sunlight that reaches the earth's surface has various wavelengths (ultraviolet, visible, infrared). Photons can be reflected, pass right through, or absorbed and turned into heat. Some photons have the right amount of energy to separate electrons from their atomic bonds to produce electric current.
- Recombination - When an electron encounters a hole, they may recombine and therefore cancel out their contributions to the electrical current.
- Temperature - Solar cells generally work best at low temperatures.
- Reflection - A cell's efficiency can be increased by minimizing the amount of light reflected.

Data Source: U.S. Department of Energy, (2013). *Solar Performance and Efficiency*. Available at: https://energy.gov/eere/energybasics/articles/solar-performance-and-efficiency

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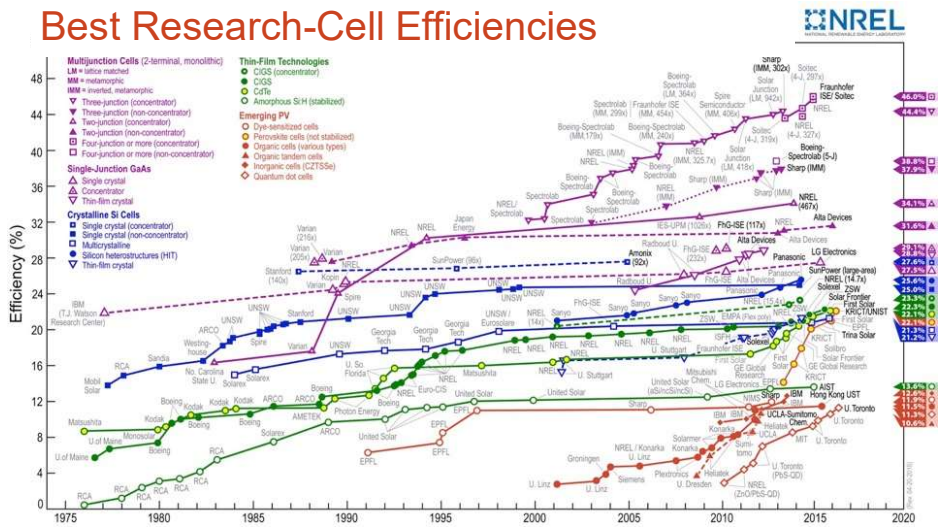
Best Research-Cell Efficiencies



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PV Solar Cell Efficiencies

- Cell efficiency results are provided within different families of semiconductors:
  - Crystalline silicon cells
  - Single-junction gallium arsenide cells
  - Thin-film technologies
  - Multi-junction cells
  - Emerging photovoltaics

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PV Solar Cell Efficiencies

- The maximum theoretical efficiency that a single-bandgap solar cell can achieve with non-concentrated sunlight is about 33.5%, primarily because of the broad distribution of solar emitted photons.
- High-efficiency multijunction devices use multiple bandgaps, or junctions, that are tuned to absorb a specific region of the solar spectrum to create solar cells having record efficiencies over 45%.

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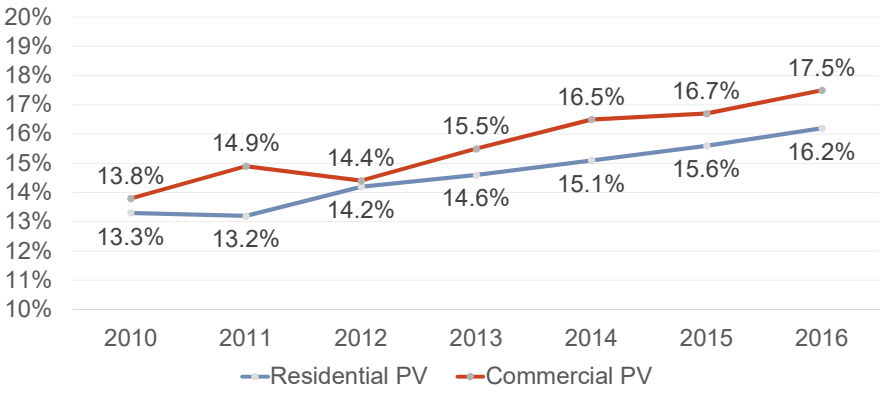
Module Efficiency Trends from the California NEM Database (Go Solar CA 2017), 2010–2016



Data Source: National Renewable Energy Laboratory. 2017. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Technical Report NREL/TP- 6A20-68925.

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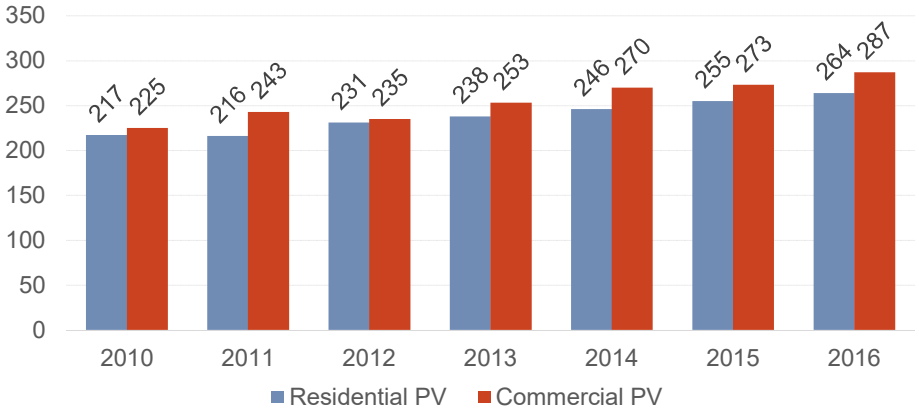
Module Power Trends from the California NEM Database (Go Solar CA 2017), 2010–2016



Data Source: U.S. Department of Energy, SunShot. *Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections. 2015 Edition* . NREL/PR-6A20-64898

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Impact of Module Size and Efficiency on Overall System Cost

Improvements in module size and efficiency has reduced the number of modules required to construct a system. This trend helps to…

- Reduce hardware costs (electrical and structural BOS)
- Reduce soft costs from direct labor and related installation overhead.

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Lessons Learned and Additional Resources

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Not All Photovoltaic Solar Systems Are Created Equal!

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System Cost – Evaluate Multiple Proposals

- Direct Capital Costs – Costs directly associated with the PV solar system and can be clearly assigned to a specific piece of equipment related to the project.
- Indirect Capital Cost - Costs represent the soft cost associated with the project. Common examples of indirect capital costs for a PV solar system include the installation costs (labor), grid interconnection, engineering, permitting, environmental studies, and sales tax.
- Ongoing Annual Expenses – Insurance, **operation and maintenance cost** represent ongoing annual expenses required to maintain, service and/or replace critical components of a PV solar system.

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System Cost – Evaluate Multiple Proposals

100 kW Rooftop System	Proposal #1	Proposal #2	Proposal #3
Energy Savings over 25 Years	$682,000	$596,000	$264,760* After Tax
Payback Period in Years	2.9 Years	7.6 Years	9.9 Years
Assumed Value of Energy	.11 / kWh	.10 / kWh	.086 / kWh
Energy Escalation Rate	10% (10 Yr.)	5% (annual)	3.7% (annual)
System Cost (Gross/Net)	$425,000 / $41,900	$310,000 / $125,000	$186,500 / $60,000
Cost Gap	$383,100	$185,000	$126,500

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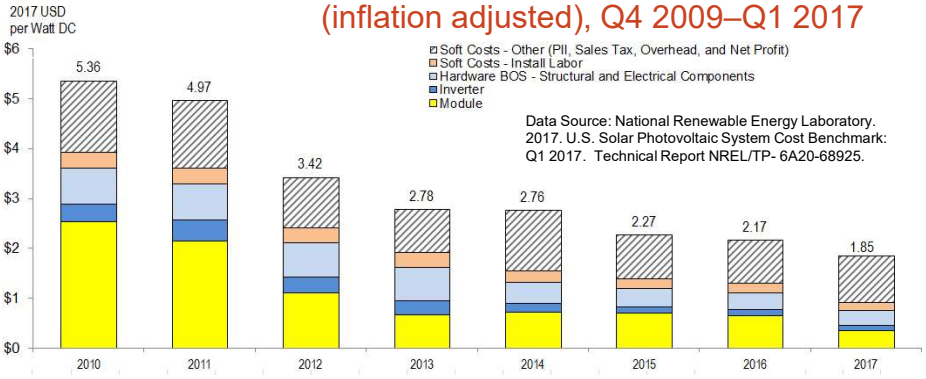
NREL Commercial PV System Cost Benchmark Summary (inflation adjusted), Q4 2009–Q1 2017



100 kW Rooftop System	Proposal #1	Proposal #2	Proposal #3
Installed Cost Per DC/Watt	$4.25	3.10	$1.86

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In Aggregate, Small Details Make a **BIG** Difference

- System production
- Energy savings assumptions
- Operations and maintenance costs
- Insurance
- Financing cost
- Additional grants and incentives
- Taxable vs. nontaxable income
- Sales tax
- Property tax

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Lessons Learned

- Base your evaluation on the total system cost (the number you have to put on the check!)
- Identify the differences between systems
- Compare system and MFG. component warranties
- Ask for other farms they worked with and make a visit
- System costs keep falling, when should you decide to install a system?

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Conduct your own Analysis

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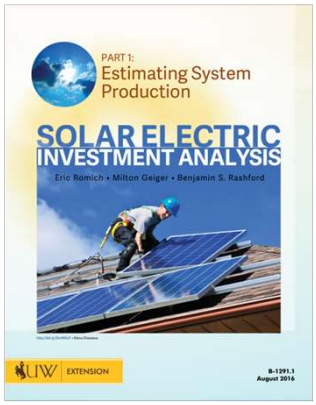
Additional Resources



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Thank You!

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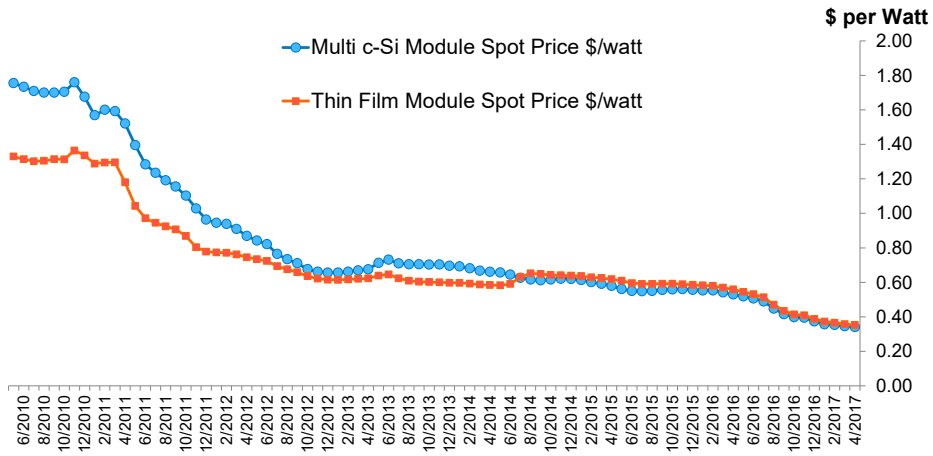
Module Price (Monthly, May 2010–April 2017)



Data Source: National Renewable Energy Laboratory (NREL). *2016. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017.* Technical Report NREL/TP-6A20-66532.