Solar Power Generation

Doug Elgin – Alabama Solar Association

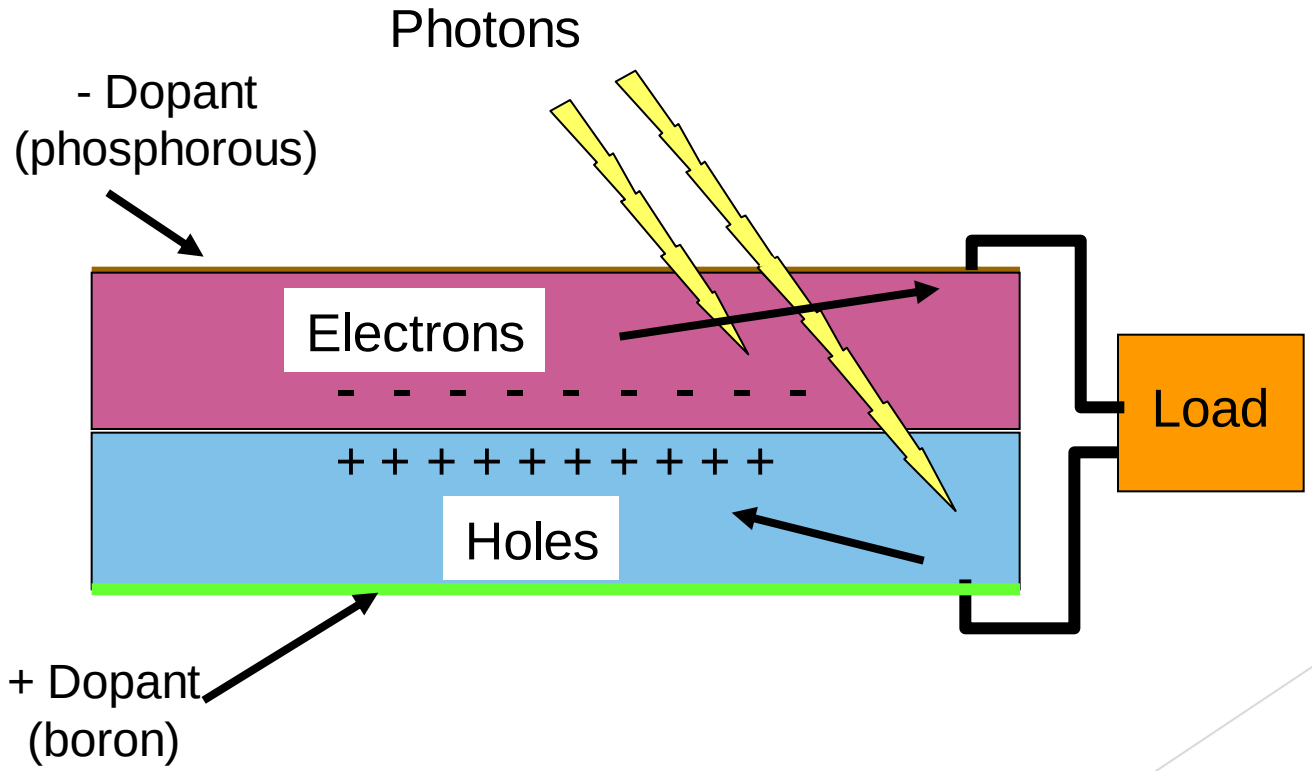
2017

Alabama Solar Association

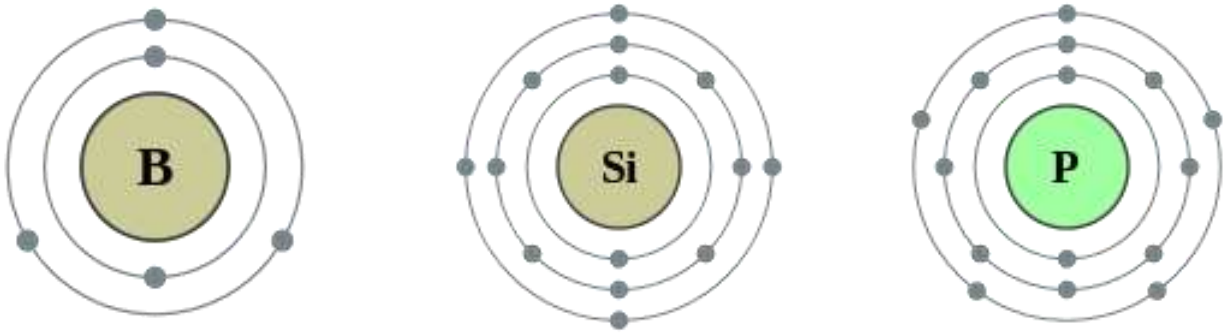
- We are a volunteer organization
- We promote all things solar, energy conservation, and living green
- We sponsor speaking and demonstration events for the public
- We'd love to have you join us, dues are minimal - $24/yr for individuals
- Barring that, give us your e-mail address and we will keep in touch
- Visit us at **www.AL-Solar.org**

How does PV Work?

- Light photons knock electrons out of the valence band into the conduction band. The excess electrons are attracted through the load to the “holes” in the plus-doped side of the cell.



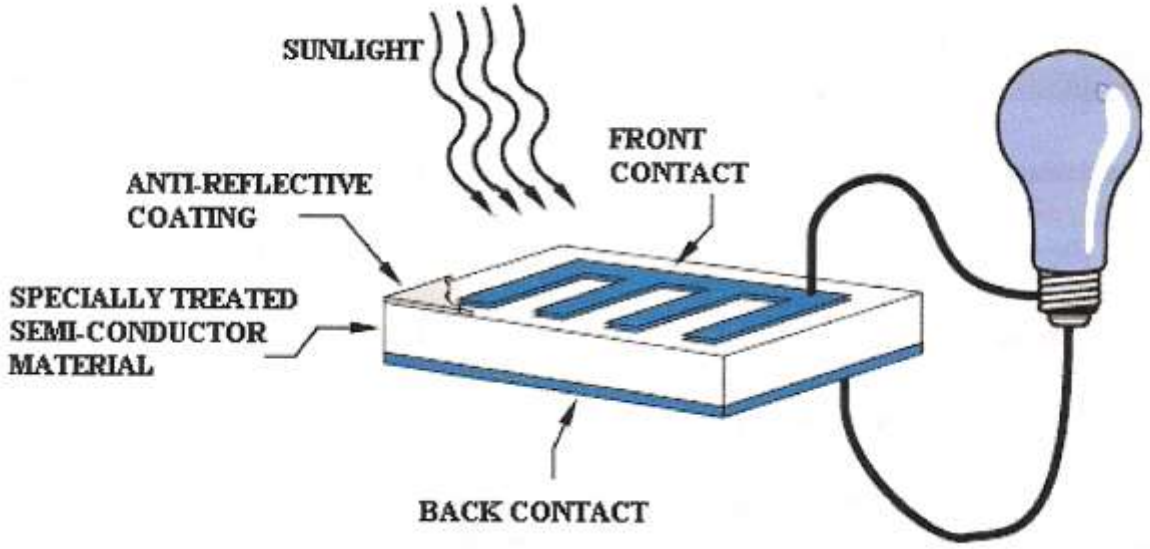
Electron Configurations



- The outer shell of Si is happiest with 8 electrons (would make the element inert). It is reasonably satisfied sharing 4 electrons with another element
- With Phosphorous (P), there is one extra electron (it has 5 in the outer shell). With Boron (B), it is one short.
- With P dopant, a photon comes in and is absorbed, moving the electron to a more excited state in the next higher shell (moves it from a valence band to a conduction band)
- That electron tends to wander around, and with the other “loose” electrons creates a negative charge that pushes around the circuit.

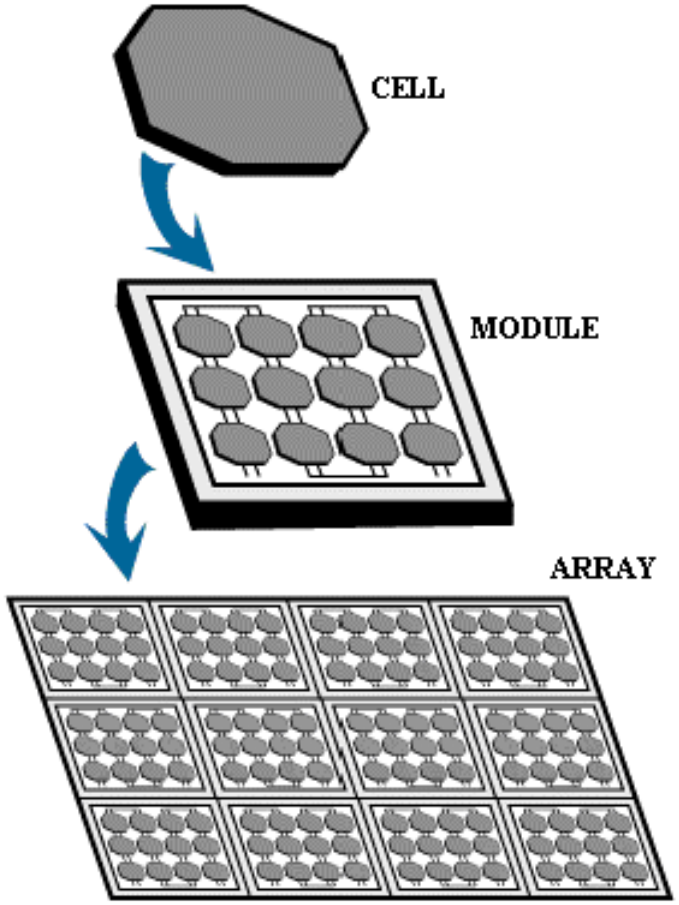
PV cell at work

- The charge of the excess electrons causes electrons to flow around the circuit. Note the need for a front and back collection contact and an anti-reflective coating (and a protective transparent covering).



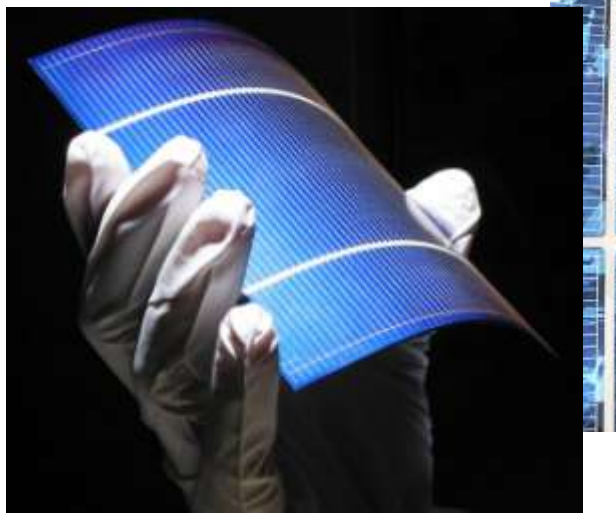
Putting it together

- Individual cell produces ~3-4 watts at about 0.7 volts
- Need many cells in parallel and series to get desired voltage and power



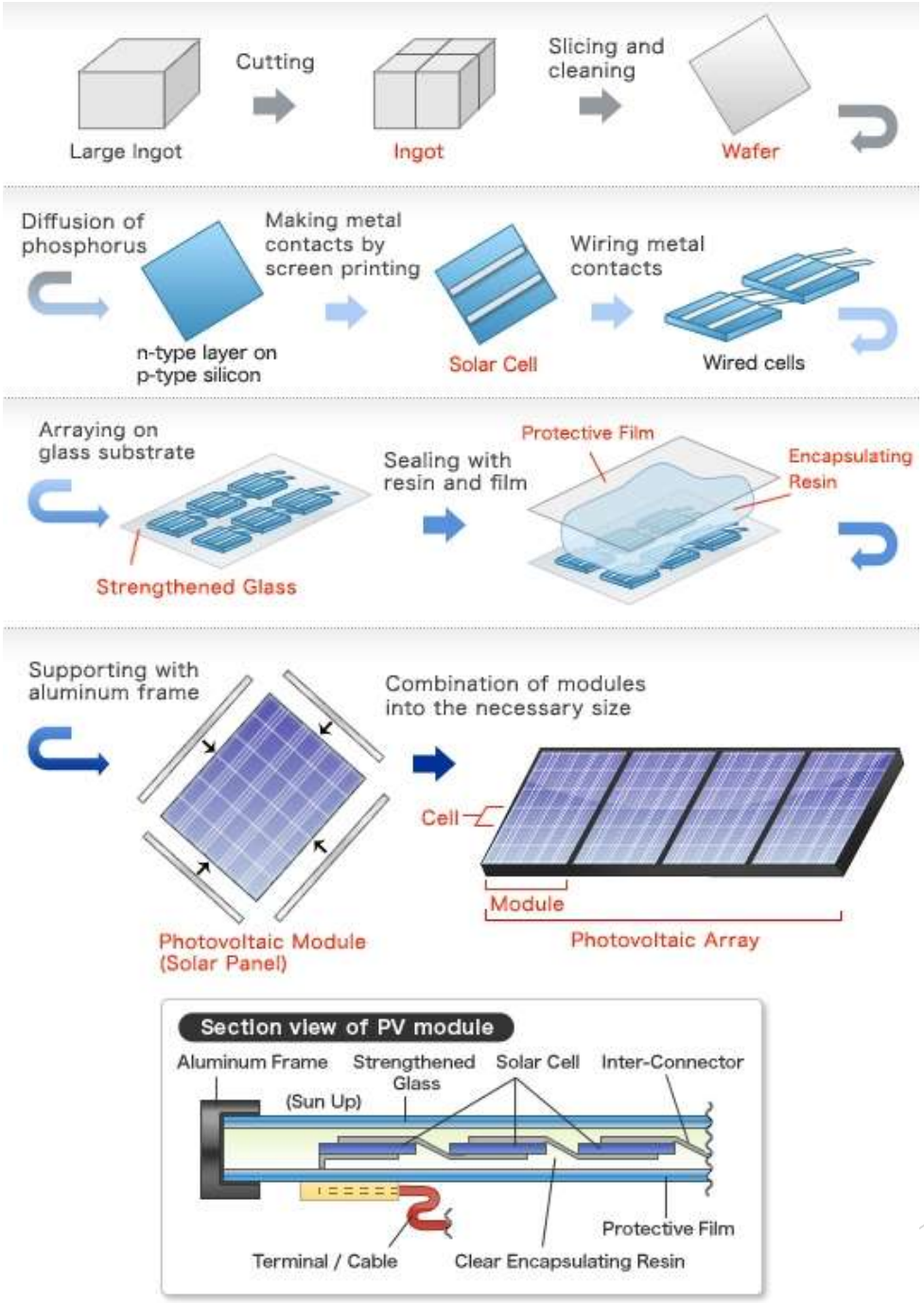
Types of PV

- Monocrystalline Silicon
- Polycrystalline Silicon
- Other
  - Amorphous
  - CdTe
  - Thin film
  - Perovskite

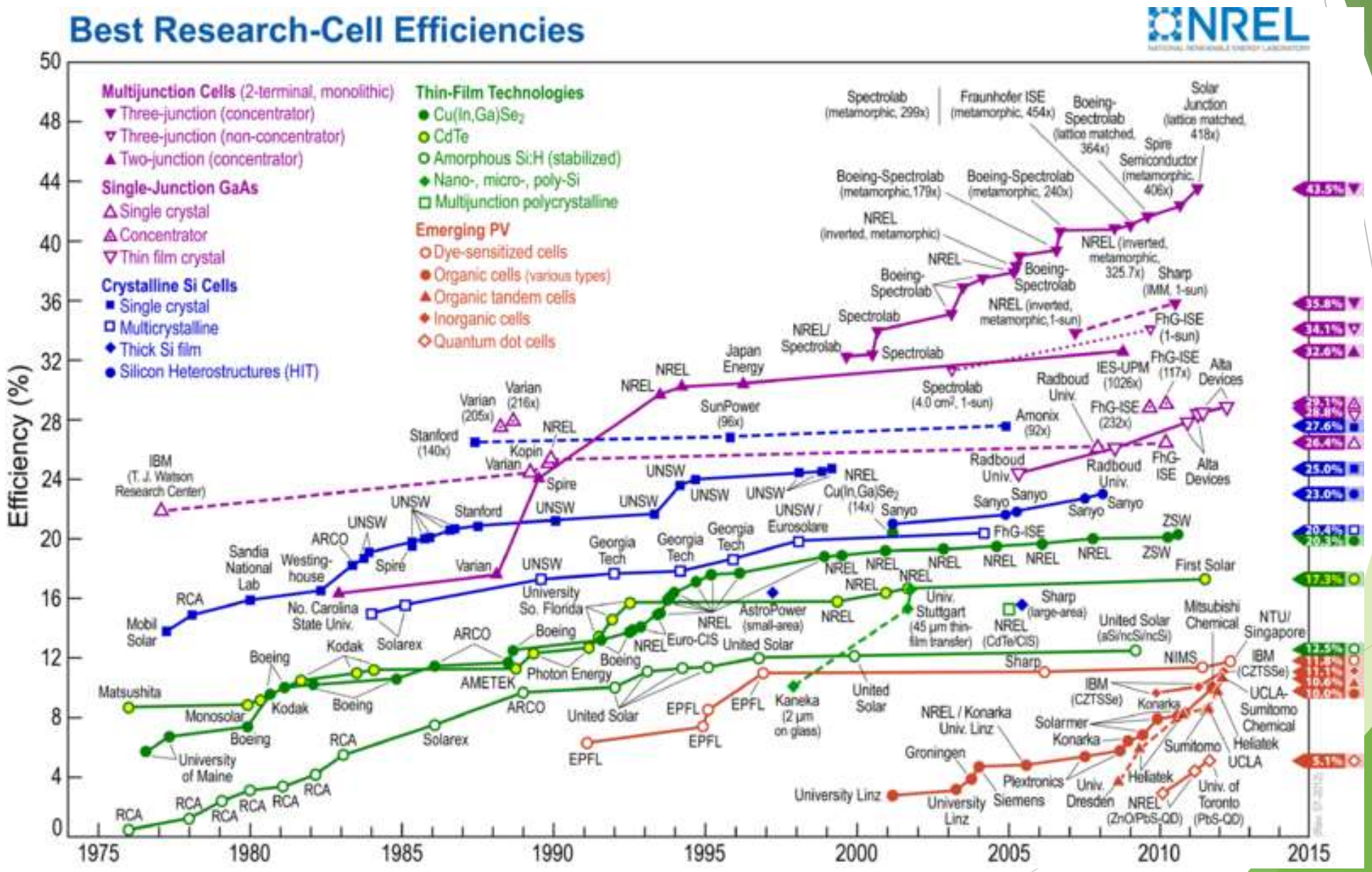


How They Are Made

- This is a monocrystalline silicon example



Solar Cell Technology Is Improving



What's The Pro and Con

Pro

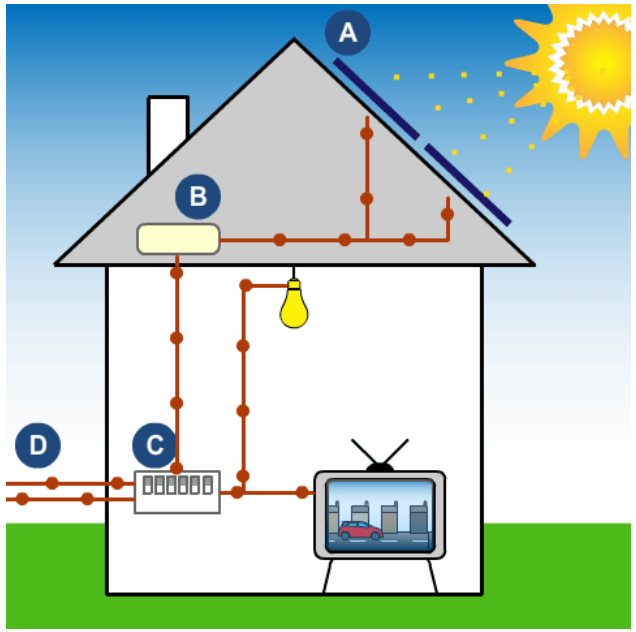
- Saves money
- Does not pollute
- Can provide power if utility fails
- Helps the utility – peak use is during the day
- Insurance against inflationary cost increases
- Increases the value of your home (by about $5/watt of PV capacity)
- Cool to talk about at cocktail parties

Con

- Initial Cost
- Payback is slow (adding some risk)

Types of installations

- Grid-tied
  - A. Solar Array
    B. Inverter
    C. Director
    D. To/from the grid



- Off-Grid
  - Needs batteries to store energy. (Batteries have a shorter life – about 6-15 years.)

Installation Choices

- Roof
- Ground
- Other
  - Trackers
  - Solar shingles

This is ASA's Firefly

- Off-Grid design
- 3 panels (modules)
- Can generate up to 690 watts
- 1 battery in trailer
- Charge Controller with maximum power point management
- 1000 watt inverter

Local Home Example

- Ground installation
- Reflectors increase output
- In back yard
- 20 panels
- 3,500 watt capacity (reflectors add about 20% to that)

A Commercial System in Huntsville

The REG Plant (Memorial & Airport)

- 135 kW capacity
- Demonstration center
- Trackers, ground mount, carport example

Various Mounting Choices

Mount style	kWh/m^2/day	Rel. Perf. (%)
Fixed horizontal	4.37	92
Fixed, 24 - 31°, facing So.	4.74	100
Azimuth track, 30 °	5.65	119
1 axis track, 30 °	5.95	126
2 axis track	6.13	129
Fixed, 30 ° with reflectors	5.70	120

This is for Huntsville, Alabama

Life Cycle

- Most arrays designed for 25 years
- Electronics last many years (typically all solid state)
- Batteries (for off-grid systems) typically last 6 - 15 years (depends somewhat on discharge depth)

Typical Panels

- 65” X 40”
- 190 to 300+ watts capacity
- 12 to 100+ volts output
- ~$1 per watt

Output vs. Capacity

- An array is rated at its peak power output
  - But ½ of the day - it's night
  - Inverter losses
  - Cloudy periods
  - Off-axis light
- Output for fixed array will average about 15% of peak capacity in Huntsville
- 1 kW system yields about 1410 kWh/yr or about $12/mo. at 2017 Huntsville Utilities rate

Example – Install a 5.04 kW PV System

- 16 Solar Astroenergy poly-Si 315W panels, 5000W inverter, mounting rails, power optimizers - $8008 from Wholesale Solar
- Tax, ship, installation, permitting (ground - 30°) – about $9,992
- Panels measure 334 ft^2
- Generates about 7,109 kWh x 1.2 (for reflectors) = 8,531 kWh per year to the grid (average household consumes about 12,000 kWh per year)
- Payback varies with utility buyback price and incentives

Example-5.04 kWh system from Wholesale Solar - $8,008.00

16 solar panels

16 power optimizers

Inverter

Racking

Cabling

Additional Costs

- Tax, Shipping
- Installer. Provides:
  - Engineering
  - Permitting
  - Utility coordination
  - Installation
  - Hookup
  - Miscellaneous additional hardware
- Total turnkey cost adds up to about $18,000

Another Example

- A generic estimate by a local installer for a 5kW PV system as a turn-key
- $17,500 (before incentives)

Incentives

- Federal – 30% tax credit
- Huntsville Utilities – buys PV generated power at retail (in 2017)
  - This is the “Green Power Providers” program
  - $1,000 installation incentive
- Nexus – 30%, $3,000 max – requires energy audit. (This program has been sporadically available)
- TVA limits you to no more than the power you use (usually OK up to 10 kW capacity).
- Huntsville also says not in front yard.

Payback

- Payout
  - $8,008.00 paid out for package
  - $9,992 paid out for tax, shipping, engineering, permitting, installation
  - - $5,400 from Fed
  - - $1,000 from Huntsville Utilities
  - Net cost is $11,600
- Income
  - 8,531 kWh per year sold at $0.10 per kWh = $853
- Breakeven = 12 years (less with Nexus help)
- Another factor – TVA electricity costs have been escalating historically at 4.4%/yr. They project 3% forward.

Net Present Value (NPV)

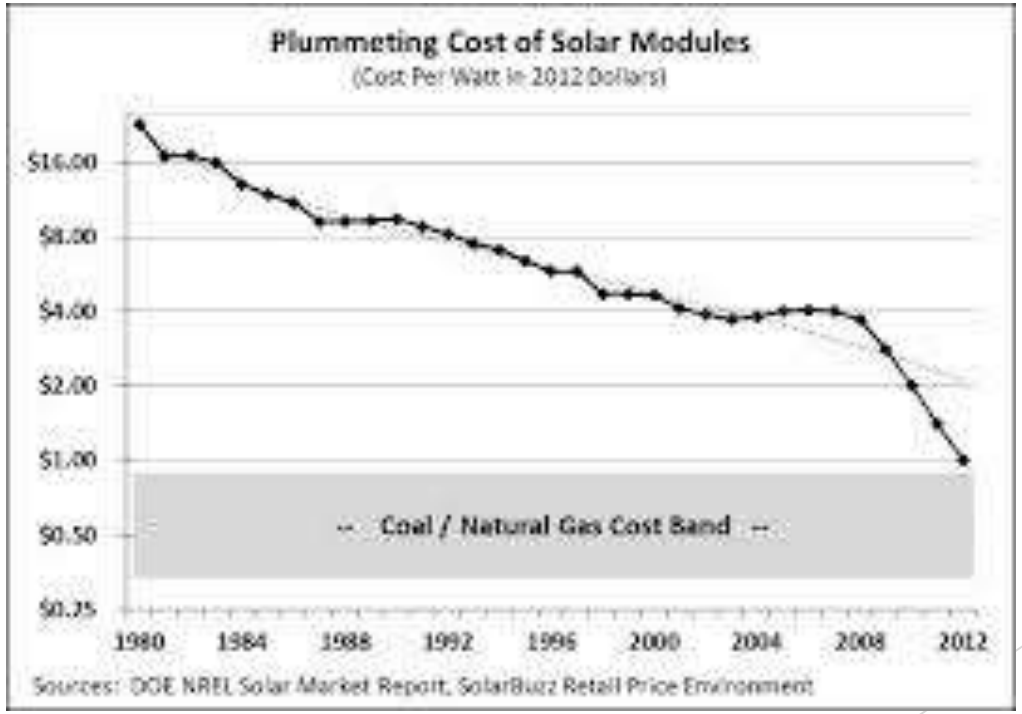
- NPV is value today of a series of discounted financial flows
- Assume you are thinking of installing a grid-tied PV solar system in Huntsville, Alabama
  - $11,600 outlay after incentives for 5.04 kWh PV system
  - Assume selling power at $0.10/kWh with 3.2% inflation rate
  - Allow for solar panel degradation over 30 years
  - Assume discount rate of 3%
- The NPV is about $11,800 – that is, you're about $11,800 ahead by doing this project

Grid Parity

- Grid parity is when the cost of generating power from solar panels is at or below the cost from the utility company.
- 5.04 kW solar system cost – about $18,000
- Generates 8,531 kWh/yr for 25 yrs which the utility sells for $0.10 / kWh = $21,330
- Achieves grid parity

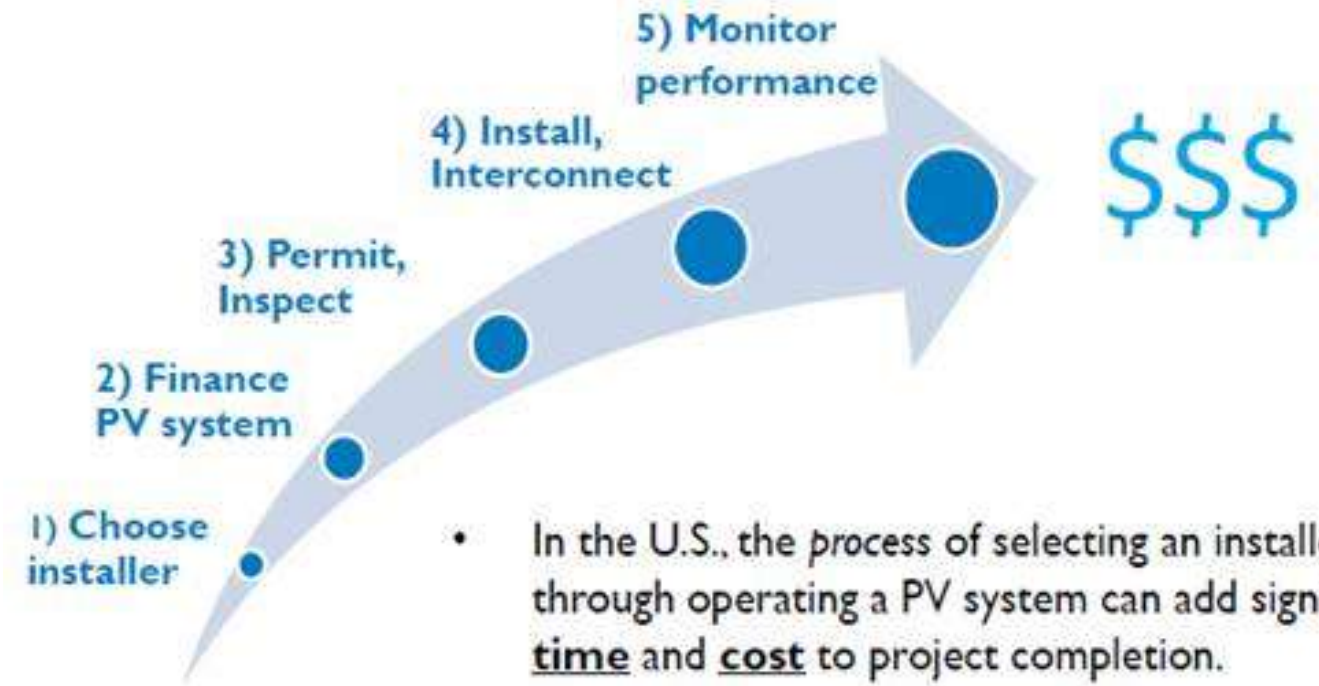
PV Costs Are Still Coming Down

- Historical PV costs
  - Trend has been much like Moore's Law
  - This trend is about -7%/yr
  - Right now prices are running ~$1.00/watt
  - This curve may be bottoming out



Soft Costs

There is more to a system than hardware



- In the U.S., the *process* of selecting an installer through operating a PV system can add significant **time** and **cost** to project completion.
- Inefficient supply chains, O&M, and delays can also increase cost.
  - Need for streamlined processes.

(from Ardani, NREL, May 2012)

Reducing Costs Further

- The next cost reductions will need to come from “soft costs”
- 2 to 4 times the cost of the solar panels goes into the mounting bracketry, inverters, permitting, customer acquisition, and labor
- Germany has cut the soft costs down by a factor of 2 over US numbers
- DOE is investing R&D effort to reduce these costs

Local Providers

- Southern Solar Systems
- Affordable Energy Solutions
- Outpost Solar
- Solar Energy, Alabama
- Huntsville Solar Works
- Many others. See more at our website, AL-Solar.org

If You Would Like To Do Your Own Analysis

- www.RETScreen.net
  - Much detail available
  - Complicated program
- Browse for PVWatts
  - Good first order estimator
- Many other choices

Summarizing

- PV is getting to be more and more affordable
- The payback period for a home system is still longish (but getting better)
- PV solar systems are at, or close to, grid parity
- The value to the environment is great