Solar Photovoltaics in the 21st Century

An In depth look at Solar Electric PV.... So Far

Thanks To
North Texas Renewable Energy Group
North Texas Chapter of the Texas Solar Energy Society
A 501c3 Non-Profit, FTID#74-1962704
And REI
4515 LBJ Fwy. Dallas, TX 75244

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Presented by: Jim Duncan,
Founder & Principal
North Texas Renewable Energy Inc.
Solar Photovoltaics:

- A brief history of solar PV
- The global PV industry
- Types of PV material
- PV design issues
- Installation issues
- System monitoring
- Emerging technology
- Got insurance?
- Texas, the US and Global PV market
- Energy payback vs. financial payback
- The global solar PV market, Solyndra et al vs. China
- Texas Renewable Energy Industries Assoc. TREIA.ORG
- ONCOR incentive program
- Federal Investment Tax Credit and Grants program
- Return on Investment vs. Payback
Something new under the sun indeed.

Post war technology led to many discoveries but none as big as the transistor.
In 1958 Vanguard was the US answer to Sputnik. Communication was lost in 1964 but the craft is still in orbit.

The Hubble orbiting telescope had 2 solar arrays totaling almost 60 M². Power density: 47 W/M²
We’ve come a long way in a short time

1982 Vs. 2010

35 Watts
Vs.
230 Watts

◊

94 W/M²
Vs.
153 W/M²

◊

$6.50/W
Vs.
$1.00/W
Mono-crystalline silicon ingots

Cell Production

99.9999% pure silicon is used for PV cells.

Poly-crystalline silicon ingots

Efficiency of silicon: Photons to electrons is about 20% for production PV cells.

In China, polysilicon production fell significantly in Q3 2012 to 7,631 Metric Tons, down from 12,998 MT in 2Q, 58%
Finished cells are 150 mm diameter 150-200 μm thick

- ~28% of the Earth's crust is silicon.
- 2\textsuperscript{nd} hardest mineral in nature

200 Microns X 120 Cells = .60 Inches
Silicon is ~33% of cost of a mono-crystalline Si PV module

Worldwide demand has driven **PV grade silicon** prices up then down >90%

2006 - $390.00/kilo
2012 - $22.00/kilo

Automation has reduced manufacturing cost by 80%
Thin Film

- CIGS Copper indium gallium selenide ◊ 10-14 %
- CIS Copper indium selenide ◊ 9-12 %
- aSi Amorphous silicon ◊ 5-9 %
- CdTe Cadmium telluride ◊ 10-12 %

- +Lower production cost
- +Less sensitive to heat
- +Better low and diffuse light performance
- -Lower Power Density

This film mounted between glass substrate and no rigid aluminum frame.

Triple junction shingles are in high demand.
Design & installation considerations

- Electrical code compliance, NEC code standards specific for photovoltaic installations
- NEC Section 690 for PV, 692 - fuel cells, 694 - small wind, 705 – Interconnected....sources, 720 – Low Voltage <50V
- Structural code permits & inspections are required by more jurisdictions. Array must meet wind load & lift requirements
- Other permits and licensing requirements, Fire safety first for first responders
- Homeowner associations
- Quality installation practices assure that the roof won’t leak
- The system must perform as expected over its lifetime
Typically a One Line Drawing and a Plan Drawing will need to be submitted for review to permitting departments. If Plan Checkers are unfamiliar with residential PV systems, more detail makes for an easier permitting package.
Lots of ways to do the job wrong…

Dissimilar metals will eventually corrode even with aluminum's layer of oxidization.

All electrical, and ground, equipment must be rated for “conditions of use”
Labels denote locations that are important or may cause injury from electric shock.
Structural Considerations, wind loads

Table 1. Allowable withdrawal loads for lag screws in seasoned wood, pounds per inch of penetration of threaded part*.

<table>
<thead>
<tr>
<th>Lumber Type</th>
<th>Southern Yellow Pine</th>
<th>Douglas Fir</th>
<th>White Spruce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity: G</td>
<td>0.58</td>
<td>0.51</td>
<td>0.45</td>
</tr>
<tr>
<td>Screw Diameter: D (in)</td>
<td>Allowable withdrawal load: P (lb/in)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>281</td>
<td>232</td>
<td>192</td>
</tr>
<tr>
<td>5/16</td>
<td>332</td>
<td>274</td>
<td>227</td>
</tr>
<tr>
<td>3/8</td>
<td>381</td>
<td>314</td>
<td>260</td>
</tr>
</tbody>
</table>

*Adapted from Marks’ Standard Handbook for Mechanical Engineers, latest edition, McGraw-Hill. Withdrawal loads are calculated using the formula \( P = 1800G^{3/2}D^{3/4} \), where \( P \) = withdrawal resistance in lb/in, \( D \) = screw shank/nominal diameter in inches, and \( G \) = specific gravity.

Installers must get lag bolts into solid wood to guarantee adequate strength in high winds.
Flashing, the NRCA says so!

(National Roofing Contractors Association)

Messy but guaranteed water-tight

What were they thinking?
Integrating flashed mounting structure, different type roofing requires different approach.

Clay barrel tiles

Flat stone or clay tile type flashing replaces the entire tile

Standing seam roof with non-penetrating clamps
Roofing companies may void warranties if unauthorized penetrations are put through “their” metal roofing.

Always check with the roof installer before you start.
Says OSHA

A full body harness is absolutely necessary for safe work on steep or tall roofs.

SAFETY FIRST!

Scaffolding is far easier to climb than a ladder. It also allows room for storing tools & equipment at the roof level.
Technology BOS (Balance of System) advancements driven by PV installer demands as well as NEC requirements.

Roof mounted combiner/fuse holder used as an unlisted DC disconnect.

Roof mounted combiner/fuse holder with integrated DC disconnect. Meets 2011 NEC requirements.
Roof mounted DC combiner that doubles as a disconnect, v.1

Disconnects for DC current near the PV array

Inverter integrated AC and DC disconnect, coming to rooftops everywhere.
DC to DC power optimizers reduce shading losses and improve overall system efficiency

Shade mitigation technology prevents shaded modules from reducing power from the entire string of modules

Centralized inverters are still needed, output is still DC but power levels are optimized at the module
Micro-inverters eliminate the need for a roof mounted disconnect. They also eliminate shade induced losses.
AC micro-inverters eliminate centralized inverters and feed directly into the homes AC service panel.

Micro-inverters attach directly to the PV module eliminating all DC wiring and simplifying installation.
What’s going on up there? Is my PV array performing as designed?

Weather monitoring provides vital weather data necessary to calculate system output.

Integrated software or 3rd party data management programs make it possible
Online and wireless subscription PV monitoring as close as a video screen

Wireless Desktop Monitors

Wireless smart phone apps are available if you just can’t live without data
Commissioning the finished system; installer protected and customer satisfied.

Measure and document the system AC Wattage output to confirm proper operation.

Infrared thermometer and pyranometer or reference cell to determine actual temp compensated DC power.

At the same time create a benchmark for future performance checks.

Check for ground faults in DC & AC wiring for varying resistance that may indicate damage to insulation.

Avoid complaints by the customer and service calls due to poor system performance.
How big were those hailstones that were in the yard?

Got insurance?

Lightning surges from strikes can cause damage from a distance.
An entire industry has developed around flat roof buildings using a ballasted mounting system. Approximately 40% of US solar PV is commercial.
CMU (concrete masonry unit) ballast blocks allow a non-penetrating mounting structure designed and engineered for flat roofs.
Blue Wing Solar Project
COMPLETED IN 2011

• 14.4 Megawatt AC thin film fixed array
• Largest in Texas – 10th largest in US
• CPS Energy San Antonio municipal electric utility
• 215,400 panels
• 30 year PPA [power purchase agreement]
• CPS owns 7% of the ERCOT generating capacity
Fort Hood, Texas

- 684 kW photovoltaic system
- $3 million Fort Hood project - No cost to the Army or the taxpayers
- Paid for by the private contractor that owns & maintains the base housing
- Generates about 20 percent of the energy needs of the military families at Liberty Village.
- Generate an estimated 1,000,000 kWh of energy annually
Nellis Air Force Base Arizona

- 14 MEGAWATTS
- COMPLETED DEC 2007
- 172,800-200W THIN FILM PV MODULES
- 54-250 KW INVERTERS
- 25% OF BASES POWER
- 2.2¢ PER KW HR
- $1 MILLION PER YEAR SAVINGS
- DOD OWNED

***************
EXISTING DOD INSTALLATIONS

- Los Angeles Air Force Base in California
- Fort Hood Army Base in Texas
- Peterson & Schriever Air Force bases in Colorado Springs, Colo
- Hickam Joint Base Pearl Harbor in Honolulu
- Davis-Monthan Air Force Base in Tucson, Ariz.

The U.S. Department of Defense plans to open up 16 million acres of its land for renewable energy development.
What’s ahead for the US solar market?
Texas was #10 in 2011.
TOTAL GLOBAL INSTALLED PV IN MEGAWATTS 2011

- GERMANY: 17193
- SPAIN: 3784
- JAPAN: 3622
- ITALY: 3494
- CZECH REP: 1953
- CHINA est: 1800
- US: 1234
- FRANCE: 1025
- BELGIUM: 803
- SOUTH KOREA: 635
- REST OF EU: 333
- CANADA: 200
- GREECE: 206
- SLOVAKIA: 145
- AUSTRIA: 103
- UK: 66

TOTAL GLOBAL INSTALLED PV IN MEGAWATTS 2011
Historic trend in energy payback time of crystalline silicon PV modules
Depending on the type of PV system and the location of the installation, the **Energy Payback Time** ([*Embodied Energy*]) is between 0.5 and 1.4 years.

Life Cycle Analysis takes the following actors into consideration:
- Material sourcing
- Manufacturing
- Installation
- Operation
- Decommission and recycling.

**PV manufacturing:** 506 gCO²/kWh electricity
**PV produces electricity with only 16 to 32 gCO²/kWh.**

(Grans CO² equivalent per kilowatt hour produced)

What’s the Payback?

What’s your retail cost per kilowatt hour? 10¢?

10¢ \times 20 \text{ kW hr./day} = $2.00 \times 365 \text{ days} = $730.00

$15,000.00 \div $730.00 = 20 \text{ years}

House?
Car?
Bass boat
Swimming pool?
Lake home?
Land?
Stocks?
This paper demonstrates that, over the life of solar assets, lease or PPA financing structures can deliver a nominal 10% internal rate of return (IRR) to the federal government on the federal investment tax credit (ITC) for residential and commercial solar projects.
Loan Guarantees
Solyndra vs. China

Billions of U.S. Dollars

SOLYNDRA  TRINA  SUNTECH  JA SOLAR  YINGLI  LDK
In September 2011 Hyundai Heavy Industries Co., a South Korean shipbuilder, scrapped plans to build two solar photovoltaic power plants in Arizona. Hyundai decided to drop the $700M projects because of the economic slowdown. The projects signed in August of 2011 was for a total of 175 megawatts of capacity.

Solyndra LLC, Evergreen Solar and Spectra Watt filed for bankruptcy in September 2011. These US based solar PV manufacturers could not compete with Chinese PV manufacturers.

Between 2007 and 2011 the wholesale price for silicon PV dropped by 90% thanks to China and their aggressive national policies.

Large-scale U.S. venture capital project funding in Q3 2011 came to $2.4 billion. This was much higher than the $1.6 billion in large-scale funding in Q2.

Research for the Solar Energy Industries Association (SEIA), found that in 2010, the U.S. exported a total of $5.6 billion in manufactured solar goods while importing a total of $3.8 billion, for a 35% net export gain of $1.9 billion. $2.6 billion was in poly-silicon for PV and $1.4 billion for PV manufacturing equipment.
TREIA.org is supporting a number of legislative bills during Texas’ 82nd legislative session to help promote and expand the presence of Renewable Energy in Texas. TREIA is already tracking over 30 bills related specifically to renewable energy in Texas.

One of the most important will be to increase the Renewable Portfolio Standard, a mandate that requires Retail Electric Providers to purchase an increasing amount of wholesale power from renewable energy sources over the next 10 years.

Also a mandate for statewide incentives for solar PV installations paid for by a 20¢ per month fee added to all residential electric bills.

Finally a mandate that all retail electric power providers offer to buy all electric power from qualified renewable energy generators, this includes all investor owned, coop, and municipal utilities. The cost per kilowatt hour would be based on the fair market value of power at the time it’s generated.
• 20¢ x ~5,000,000 = $1,000,000/month
• US Census: >9 million housing units in Texas will provide <$1,000,000 in solar incentives.

Oncor, Texas’ largest Transmission & Distribution provider.

• Oncor “Take a Load Off Texas” solar incentive program.
• $22,000,000 in rebate payments between 2009 & 2012
• Paid $2.00 per DC Watt for residential, $1.50 per Watt Commercial

Residential PV system:
3000 W = 3 kilowatts
$6.25 per Watt = $18,750
$2.00/W = $6,000 cash rebate
$12,750 = Installed price or $4.25 per Watt
30% Investment Tax Credit (ITC) for solar photovoltaic (PV) projects, expanded under the George W. Bush administration as a part of the Energy Policy Act of 2005.

The result of the ITC was immediate and dramatic.
2009 to 2010: **100% growth**.
2010 to 2011: **60% growth**.

**1603 Treasury Grant Program**

This federal ITC was modified as a grant-in-lieu of tax credit program under the Obama Administration.
Then there’s the electric utilities....

To DISCONNECT or NOT TO DISCONNECT
That is the Question

Current design safety features for inverter disconnection IEEE 1547 have been created >10 years ago when the penetration of Grid Tied Solar PV was insignificant.

INVERTER MANUFACTURERS, IEEE, UTILITIES, UL are working to create a flexible design & process ... for interconnecting Distributed Generation [DG] to the existing Utility Infrastructure.

Advanced Inverters + Smart Meters = PEAK DEMAND
12th Annual
Renewable Energy Roundup
& Green Living Fair

The Biggest
All Sustainable
Event in
The South!

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Speaker Opportunities
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in cooperation with: The Sierra Club - Lone Star Chapter
OUR TIME IS COMING

[Just wait until the next legislative session...]  

Thank you for your attendance
and your attention.

Questions?
Achieving the rare and final stage of oil grief:

#6 Smug Satisfaction.

Mitsubishi 185-watt solar panels

SMA 5000-watt inverter

Speedy but bug-like plug-in hybrid (coming!)

Cost of fill-up: $0
• Chinese production of crystalline silicon (c-Si) solar cells will reach 15.1GW in 2011. China is projected to install 522MW of PV which will likely break through the 1.5GW barrier in 2011 (1GW PV = 4,000,000 250W PV modules)

• In 2010, #1 Germany installed over 7 GW of PV

• In the US, 878 MW of photovoltaic capacity was installed in 2010

• Installations in the U.S. residential PV market during the second quarter of 2011 fell 5.9% to 59.9MW, down from 63.6MW in the first quarter.

• DOE funding for loan guarantees for all sustainable projects: $40bn since Bush administration - $16bn during the Obama administration.

• Large-scale U.S. venture capital project funding in Q3 2011 came to $2.4 billion. This was much higher than the $1.6 billion in large-scale funding in Q2

• Manufactured with 506 gCO2eq/kWh electricity (European mix), PV system will produce electricity with only 16 to 32 gCO2eq/kWh.
Care about our Texas air, water, and economy?  

*Join us for our*

**Campaign Action Meeting**

to re-power Texas with clean energy

**Thursday, January 17th, 2013**

7-8:30 PM

Union (coffee shop)

5622 Dyer St., Dallas

(behind Twisted Root & down Dyer from Ozona's)

[https://www.facebook.com/events/462703480444534/?context=create](https://www.facebook.com/events/462703480444534/?context=create)
IV Curve Tracer show the characteristics of a PV cell, module or array.

Fill Factor Compares MAXIMUM POWER to THEORETICAL POWER

Temperature Coefficient VOC & ISC

Internal Electrical Resistance can cause power losses only detectable using an IV Curve tracer.