Solar PV in PA: Intro to the Design of New Construction & Retrofit Residential Systems

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PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

NARI CEU Approved

PHRC

Pennsylvania Housing Research Center

- The Pennsylvania Housing Research Center serves the home building industry and the residents of Pennsylvania by improving the quality and affordability of housing.
- We conduct applied research, foster the development and commercialization of innovative technologies, and transfer appropriate technologies to the housing community.
- The PHRC is housed within the Department of Civil & Environmental Engineering at Penn State. For more information about the PHRC (publications, webinars, conferences), check out our website, phrc.psu.edu.

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PHRC Housing Conference | March 13 & 14

- Early Bird Registration is open!
  - http://bit.ly/2018PHRCHousingConference
- Conference & accommodations at The Penn Stater
- Session topics include:
  - Codes
  - Construction
  - Design
  - Land Development

3

Continuing Education

- At end of the program, you can register for a certificate to receive the following credits for this session:
  - 1.0 PA Dept L&I Contact Hour
  - 1.0 PDH
  - 1.0 AIA LU|HSW (PHRCWEB119)
  - 1.0 ICC Contact Hour (0.1 CEU) (16586)
  - 1.0 NARI hour/CEU

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AIA Info

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Description

- Pennsylvania's Alternative Residential Energy Provisions include solar photovoltaic systems as an optional entrance requirement. Building off PHRC's Energy Auditing 101 webinar in January 2018, this webinar will provide an overview of how to design new construction and retrofit solar photovoltaic systems for Pennsylvania homes. The webinar will include how to assess anticipated or actual home energy usage to evaluate sizing needs, how to conduct a solar site assessment for roof- or ground-mount applications, how to use tools like PVWatts for anticipated system output for grid-tied and off-grid systems, and how to place roof-mounted solar photovoltaic panels to comply with 2015 IRC 605.11 requirements.

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Learning Objectives

1. Review components of grid-tied, grid-tied with battery backup, and off-grid solar photovoltaic systems to reduce environmental impacts from site and source energy consumption.
2. Evaluate anticipated or actual source and site residential energy consumption for solar PV system sizing needs.
3. Learn how to analyze a site for solar PV system suitability, including for shading, economic feasibility, structural safety, and resulting anticipated energy output.
4. Review 2015 IRC code requirements that affect roof system placement for fire safety.

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Outline

- **Brief introduction**
- **Component details**
- **System details**
- **Community solar overview**

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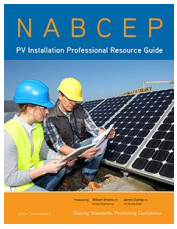
Solar Professionals



NABCEP
Raising Standards. Promoting Confidence.

1. **PV Design Specialist**
2. **PV Installer Specialist**
3. **PV Installation Certified Professional**

- PV System Inspector Certification
- PV Commissioning & Maintenance Specialist
- PV Technical Sales

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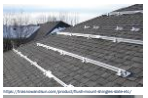
Two Scales

Onsite Production
(Distributed Generation)

Community Solar
(Distributed Generation *or* Grid-/Utility-Scale)

Intro to Solar PV Systems

1. **Photovoltaics**
2. **Power Conditioning Equipment**
3. **Balance of System Components**



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Solar PV System Design Principles

1. Face the sun
2. Avoid shading
3. Design for the year

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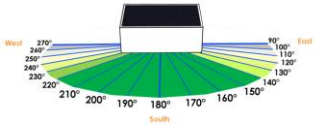
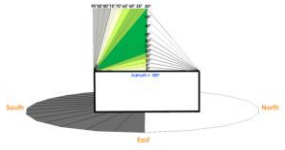
Principle #1: Face the Sun (Fixed array)

1. Orientation



Azimuth Angle

2. Pitch

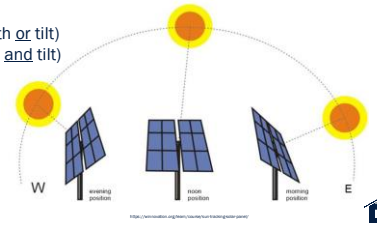


Tilt Angle

14

Principle #1: Face the Sun (Tracking array)

- Ground mounted
- Single axis (azimuth or tilt)
- Dual axis (azimuth and tilt)



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Principle #2: Avoid shading

Site Shading

1. Surrounding buildings
2. Trees
3. Poles
4. Utility lines (existing)

Home Shading

1. Dormers
2. Chimneys
3. Vent stacks
4. Landscaping
5. Utility lines (installed)

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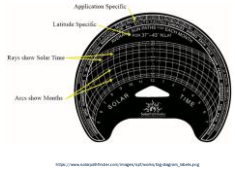
Assess Shading with Solar Pathfinder



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Google Sunroof

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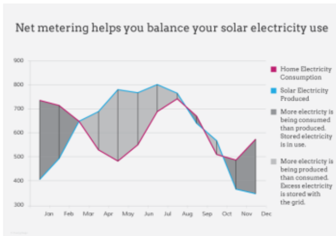
Principle #3: Design for the Year

- **Grid-Tied: Net metering policy**
  - Investor-owned utilities in PA required to offer this service
  - Grid as "energy storage"
  - Get credit for excess summer production in winter
  - Bi-directional meter
- **Design for annual production to match annual usage**
  - Only get cost of supply, not cost of distribution, for annual Net Excess Generation (NEG)



https://www.energysage.com/solar/101/net-metering-for-home-solar-panels/

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Outline

- Brief introduction
- **Component details**
- System details
- Community solar overview

https://www.civicsolar.com/projects/2016kw-jinkosolar-ground-mount

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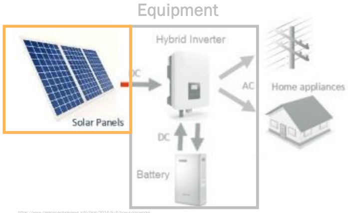
Solar PV Systems

1. **Photovoltaics**
2. Power Conditioning Equipment
3. Balance of System Components



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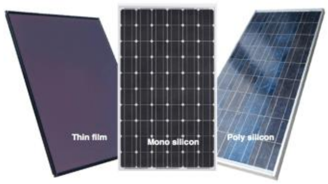
Solar Photovoltaics

1. **Crystalline Silicon**
   - Monocrystalline
   - Polycrystalline
2. **Thin Films**
   - CIGS (Copper Indium Gallium Selenide)
   - CdTe (Cadmium Telluride)
   - Amorphous silicon
   - Organic photovoltaic cells



https://www.cleanenergyreviews.info/blog/pv-panel-technology

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Photovoltaics: Crystalline Silicon

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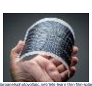
https://solar-to-the-people.com/monocrystalline-vs-polycrystalline-solar-panels/

Photovoltaics: Thin Films



http://solarpanelsphotovoltaic.net/lets-learn-thin-film-solar-panels/

http://dynamicsolartech.com/wp-content/uploads/2011/06/TransparentBIPV.jpg

https://www.hanergyamerica.com/flex-panels-gallery

https://www.pv-tech.org/products/solaria-provides-powervision-series-of-customized-architectural-glass-modul

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Thin Films: Solar Shingles

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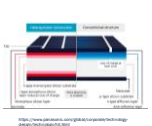
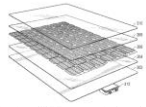
Thin Films: Solar Shingles

Hybrid: Tesla Solar Roof





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Hybrid: Tesla Solar Roof

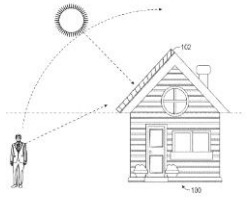
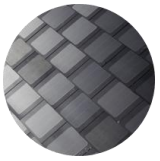


FIG. 1

Street View

Sun View



https://electrek.co/2018/09/07/tesla-patent-secret-solar-roof-tiles-camouflage/

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Hybrid: Tesla Solar Roof

https://electrek.co/guides/tesla-solar-roof/

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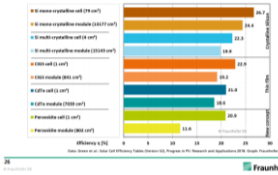
Solar Modules: Efficiencies

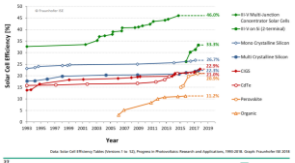
Efficiency Comparison of Technologies:
Best Lab Cells vs. Best Lab Modules



Data: Green et al.: Solar Cell Efficiency Tables (Version 53), Progress in PV: Research and Applications 2018, Graph: Fraunhofer ISE 2018

Fraunhofer ISE

Development of Laboratory Solar Cell Efficiencies



Data: Solar Cell Efficiency Tables (Versions 1 to 52), Progress in Photovoltaics: Research and Applications, 1993-2018, Graph: Fraunhofer ISE 2018

Fraunhofer ISE

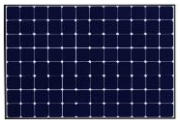
https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/Photovoltaics-Report.pdf

Solar Modules: Measurements

JinkoSolar Eagle 60P **260 W** polycrystalline panel

65.00" × 39.05" = 17.6 ft2

260 W / 17.6 ft2 = **14.8 W/ft2**



Sunpower X21 **345 W** monocrystalline panel

61.4" × 41.2" = 17.6 ft2

345 W / 17.6 ft2 = **19.6 W/ft2**

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Solar Modules: Measurements

SunTegra **100W** shingle

52.06" × 19.75" = 7.14 ft2

100 W / 7.14 ft2 = **14.0 W/ft2**

SunTegra **67W** tile

52.00" × 13.75" = 4.97 ft2

67 W / 4.97 ft2 = **13.5 W/ft2**

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Solar Module Details

1. **UL listed and labeled components**
   - Typically required for grid interconnection

2. **Warranties**
   - Production Warranty
     - Min: Guarantee >80% production after 25 years
     - Best: Guarantee >92% production after 25 years
   - Equipment Warranty
     - Average: 10-12 years without failing
     - Best: 25 years without failing

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Choose Tier 1 or Tier 2 Modules

- Ranking by Bloomberg New Energy Finance on company "bankability"
  - Typically (but not always) reflects a combination of QA/QC, manufacturing output, and company longevity
- Choose Tier 1 or Tier 2 modules for fewer potential issues down the lines (e.g. warranty fulfillment)
  - Both monocrystalline and polycrystalline modules on the list
- NABCEP design professionals will be in the know on quality ranking of modules

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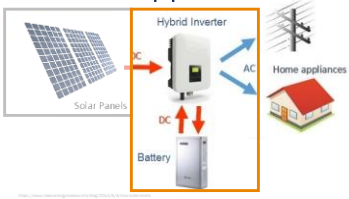
Solar PV Systems

1. Photovoltaics
2. **Power Conditioning Equipment**
3. Balance of System Components



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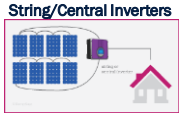
Power Conditioning Equipment: Inverters

NO SHADING ISSUES

String/Central Inverters



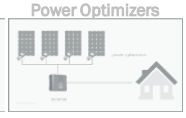
- One central inverter for all panels of same orientation and slope

SOME SHADING ISSUES

Microinverters

- Individual inverters for each panel (located under each panel)
- No central inverter needed

Power Optimizers



- Individual power optimizers for each panel (located under each panel)
- Still need central inverter

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All images from https://www.energysage.com/solar/101/string-inverters-microinverters-power-optimizers/

String Inverters

- Different inverter specifications needed if grid-tied, grid tied w/ batteries, or off-grid
- Standard vs. hybrid inverters
- Sizing & specifications by NABCEP professional

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String Inverters: Locations

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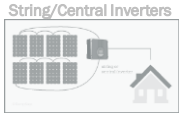
Power Conditioning Equipment: Inverters

NO SHADING ISSUES

String/Central Inverters



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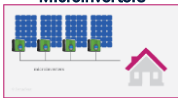
SOME SHADING ISSUES

Microinverters



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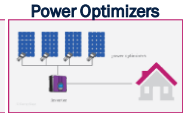
Power Optimizers



- Individual power optimizers for each panel (located under each panel)
- Still need central inverter

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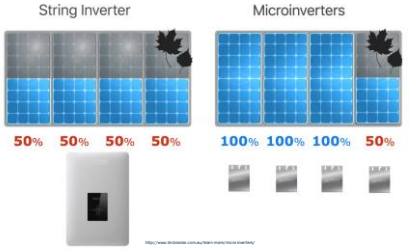
Inverters: Shading Issues



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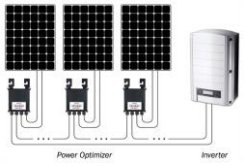
Microinverters & Power Optimizers

- Pros: Shading challenges, decreased installation time for integrated panel-microinverter assemblies
- Con: Access for serviceability



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Power Conditioning Equipment: Batteries

- Off-grid: Required
- Grid-tied: Optional
  - Uninterruptible power supply (UPS)
  - Time of Use Rates (TOU)
- Most common solar PV system battery types:
  - Lead acid
  - Lithium ion

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Uninterruptible Power Supply: Grid Outage

- Customers may ask for solar PV system when really are looking for an uninterruptible power supply (UPS)
- If grid-tied with NO batteries, cannot use solar PV system when grid is down
  - Safety for workers fixing the grid
  - Exception: SMA Sunny Boy with Secure Power Supply
    - Allows up to 2000W to be plugged in while system still producing solar energy (i.e. won't work at night)
- If grid-tied WITH batteries, will revert to battery storage

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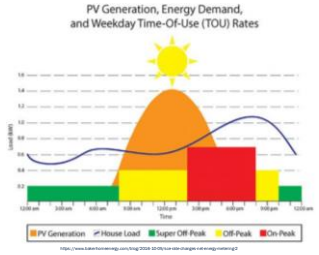
Time of Use Rates



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Batteries: Lead Acid

Batteries: Lithium Ion

46 https://www.lithiumbatterypower.com/products/12v-50ah-lithium-battery

https://www.energy-storage.news/news/simpliphi-to-enter-crucial-storage-market

Lithium Ion: Tesla Powerwall

47 https://www.revolvenergy.com/blogs/tesla-powerwall-2-cuts-costs/

https://www.inverse.com/article/39089-tesla-powerwall-puerto-rico-solar-elon-musk

Batteries: Space Considerations

- **Number and size of batteries depends on customer needs**
  - Grid Tied: Typically sized for 1-2 days power outage
  - Varying loads per customer
- **Find out what battery types your NABCEP certified designer typically uses**
  - Depending on type and if installing indoors, may need a dedicated space with continuous active ventilation
  - May also install in garages or outside
- **Plan for adequate battery storage space**

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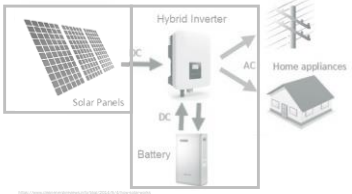
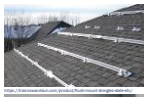
Solar PV Systems

1. Photovoltaics
2. Power Conditioning Equipment
3. **Balance of System Components**





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Racking: Roof Mount

- **Rails** (Unirac Solar Mount)

- **Railless** (Unirac Sunframe)

- **Railless** (Unirac Sunframe Microrail)

- Aesthetics
- Ease of installation
- Quality
- Installer preferences

All images from https://unirac.com/

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Roof Mount: Standing Seam Metal Roofs

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Roof Mount: Tesla Solar Roof

https://www.teslasolarroof.com/tesla-solar-roof-california-emergency-responder-training-video/

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Ground Mount

- **Fixed: Standard Ground Mount or Pole Mount**
- **Trackers: Pole Mount**

https://spruceranching.com/ground-solar-mounting.html

https://solargeneration.net/portfolio/scott-residence/

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Inverter Details

1. **UL listed and labeled components**
   - Typically required for grid interconnection
2. **Warranties**
   - Equipment Warranty
     - Average: 5-10 years without failing
     - Best:
       - String: 12 years
       - Microinverters: 12-15 years
       - Power optimizers: 25 years

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Outline

- Brief introduction
- Component details
- **System details**
- Community solar overview

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Zero Energy Ready Home Standard

Exhibit 1: DOE Zero Energy Ready Home Mandatory Requirements for All Labeled Homes

	Area of Improvement	Mandatory Requirements
Energy Efficiency	1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Program Version 3 or 3.1 [10, 11]
	2. Envelope[12]	☐ Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. [13] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 or 2015 IECC levels[14, 15]
	3. Duct System	☐ Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance[16]
	4. Water Efficiency	☐ Hot water delivery systems (distributed and central) shall meet efficient design requirements[17]
	5. Lighting & Appliances[18]	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ☐ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets ☐ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
Occupant Health	6. Indoor Air Quality	☐ Certified under EPA Indoor airPLUS [11]
Future Proofing	7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [19]

www.energy.gov/eere/buildings/zero-energy-ready-home

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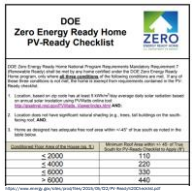
Zero Energy Ready Home: PV-Ready Checklist

Area of Improvement	Mandatory Requirements
7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [19]



DOE
Zero Energy Ready Home
PV-Ready Checklist

Conditioned Floor Area of the House (sq. ft.)	Minimum Roof Area within +/- 45° of True South for PV-Ready Home (sq. ft.)
≤ 2000	110
≤ 4000	220
≤ 6000	330
> 6000	440

1. **Min. sun requirements in the home's zip code**
   5 kWh/m²/day average solar radiation
2. **Little to no shading** on the home's site
   - *Trees, tall buildings, power lines*
   - *Dormers, vent stacks*
3. **Free roof space +/- 45 degrees of true south**

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Zero Energy Ready Home: PV-Ready Checklist

Area of Improvement	Mandatory Requirements
7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [19]

Image courtesy of IBHS

1. Install conduit from the roof to the inverter
2. Install conduit from the inverter to the electrical panel
3. Install a 4'x4' plywood panel area to mount the inverter and balance of system components, *and*
4. Install a 70 amp dual pole breaker in the electrical box

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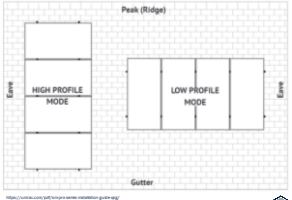
Example: Roof Sizing

- **Mount modules horizontally or vertically**
  - Confirm racking equipment compatibility
- **Width/length of modules**
- **1"-1.25" spacing between modules to fit clamps**



https://unirac.com/pdf/iron-pro-series-installation-guide.jpg/

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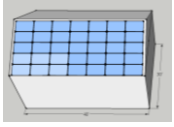
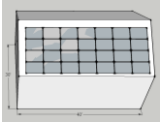
Example: Roof Sizing

Example: 40'x30' house, 7/12 pitch roof facing south, no overhangs



- JinkoSolar Eagle 60P **260 W** polycrystalline panel
- 65.00" × 39.05" = 17.6 ft2
- No/tiny roof design tweaks: **35 panels** (**9.1 kW** system)



- Sunpower X21 **345 W** monocrystalline panel
- 61.4" × 41.2" = 17.6 ft2
- No roof design tweaks: **28 panels** (**9.7 kW** system)
- Minor roof design tweaks: **35 panels** (**12.1 kW** system)

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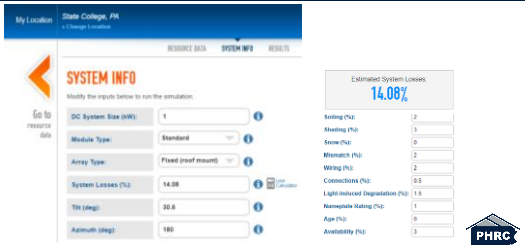
Example: System Inputs - PVWatts.NREL.gov



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PVWatts Outputs (State College, PA)

Standard efficiency panels, Roof Mount, 7/12 pitch roof facing south

Premium efficiency panels, Roof Mount, 7/12 pitch roof facing south

Standard efficiency panels, Open Rack, 30.6 degree fixed tilt facing south

Premium efficiency panels, Open Rack, 30.6 degree fixed tilt facing south

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PVWatts Outputs (State College, PA)

Standard efficiency panels, 1-axis tracker, 30.6 degree tilt (facing south)

Premium efficiency panels, 1-axis tracker, 30.6 degree tilt (facing south)

Standard efficiency panels, 2-axis tracker (facing south)

Premium efficiency panels, 2-axis tracker (facing south)

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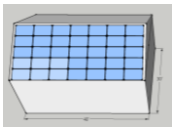
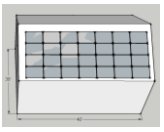
Example: System Outputs

Example: 40'x30' house, 7/12 pitch roof facing south, no overhangs



- JinkoSolar Eagle 60P **260 W** polycrystalline panel
- 65.00" × 39.05" = 17.6 ft2
- No/tiny roof design tweaks: 35 panels (9.1 kW system)
- 9.1 kW @ 1,227 kWh / kW-yr = **11,166 kWh/yr**



- Sunpower X21 **345 W** monocrystalline panel
- 61.4" × 41.2" = 17.6 ft2
- No roof design tweaks: 28 panels (9.7 kW system)
- Minor roof design tweaks: 35 panels (12.1 kW system)
- 9.7 kW @ 1,255 kWh / kW-yr = **12,173 kWh/yr**
- 12.1 kW @ 1,255 kWh / kW-yr = **15,185 kWh/yr**

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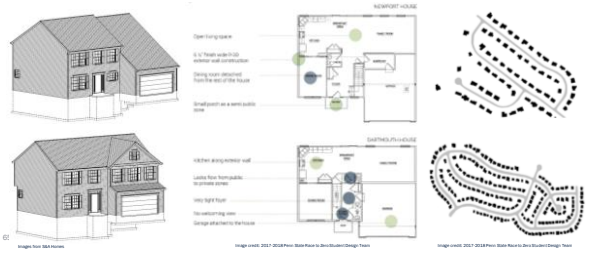
Case Study: 2017-2018 Race to Zero Student Design Competition



Images from S&A Homes

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

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Race to Zero Case Study: Solar PV for N/S roofs

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

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Race to Zero Case Study: Similar Floor Plans

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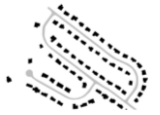
All images - credit: 2017-2018 Penn State Race to Zero Student Design Team

Race to Zero: Spacing/Shading Concerns



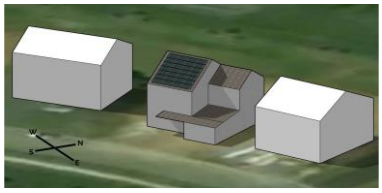


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Image credit: 2017-2018 Penn State Race to Zero Student Design Team

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

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Race to Zero: Efficiency First + Expandability

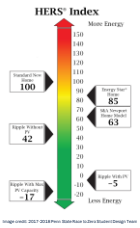

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Image credit: 2017-2018 Penn State Race to Zero Student Design Team

Roof Section	Panels	Panel Angle (degrees)	Energy Generated (kWh)	Ripple Energy Consumption	HERS w/o PV	HERS w/ PV
Main Roof	32	27	10,950	10,949	42	-5
Front Garage	9	7	3,110			-17

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

SunPower E-Series: E20-327

www.solarbrs.com.au/327w-sunpower-e20-327-solar-module-1968x1026x40mm

Image credit: 2017-2018 Penn State Race to Zero Student Design Team

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Retrofits: Hall Of Shame

Building orientation issues | Roof size issues | Architectural issues | Vent stack issues

All images from https://greensunnj.com/solar-hall-of-shame/

Retrofits: Aesthetics

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https://greensunnj.com/solar-hall-of-shame/

https://www.homebuilding.co.uk/solar-panels-thermal-or-pv/

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Retrofits: Tesla Solar Roof

https://electrek.co/guides/tesla-solar-roof/

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Sketch Retrofit Potential: Google Sunroof

https://www.google.com/get/sunroof#p=0

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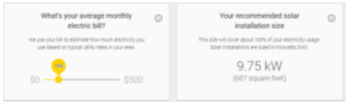
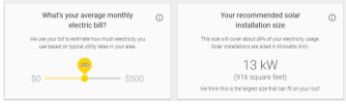
Sketch Retrofit Sizing: Google Sunroof

Example

Gas Heat (current)
- $100 electric bill
- 9.75 kW system
- 687 ft2 (out of 916 ft2 available)
- 100% electricity offset



Electric Heat (conversion)
- $250 electric bill
- 13 kW system
- 916 ft2 (out of 916 ft2 available)
- 49% electricity offset



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Off-Grid Solar: Batteries + Generator

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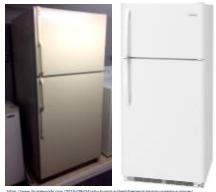
Retrofit & Off-Grid: Energy Efficiency First!

Old Refrigerator
1,599 kWh / year (measured)

Premium Panels (Monocrystalline)
- 1,255 kWh / kW-yr
- Need 1.28 kW system
- 345 W/ panel
- **3.7 panels**
- 65.1 ft2

Standard Panels (Polycrystalline)
- 1,222 kWh / kWh-yr
- Need 1.3 kW system
- 260 W/panel
- **5.0 panels**
- 88.0 ft2



ENERGY STAR Refrigerator
363 kWh / year (rated)

Premium Panels (Monocrystalline)
- 1,254 kWh / kW-yr
- Need 0.29 kW system
- 345 W/ panel
- **0.84 panels**
- 14.8 ft2

Standard Panels (Polycrystalline)
- 1,222 kWh / kWh-yr
- Need 0.30 kW system
- 260 W/panel
- **1.2 panels**
- 21.1 ft2

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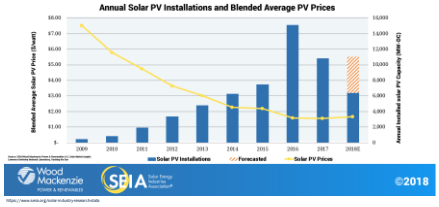
Solar PV System Costs

- **Get latest prices from NABCEP professionals**
- **Prices have fallen 43% in the past 5 years (seia.org)**



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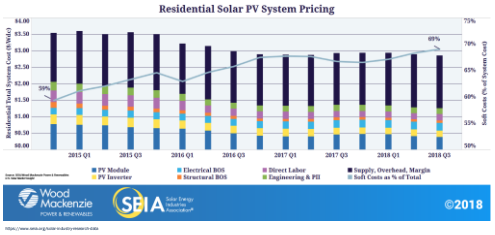
Solar PV System Costs



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Outline

- Brief introduction
- Component details
- System details
- **Community solar overview**

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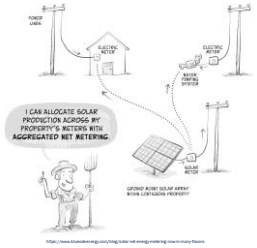
Net Meter Aggregation (current)



- **Allows aggregation of multiple usage meters with the solar production meter**
- **Current rules in PA:**
  - Must be same property owner
  - Meters must be within 2 miles of each other
  - Solar production meter must have some sort of load (can't be purely production)
- **Policy currently designed for farms & businesses with multiple close-by buildings**
  - Example: install the solar PV system on an electrified barn to virtually use in the house + for the water pump

programs.dsireusa.org/system/program/detail/65

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PA Solar Future Plan (Nov. 2018)

- Target: **10% solar PV electricity generation in PA by 2030**
- Combination of distributed generation & utility/grid-scale installations
- Some of the strategies include:
  - Increased Alternative Energy Portfolio Standards
  - Increase access to capital for solar PV financing
  - Streamlined land use policies
  - Expand virtual net metering
  - Remove barriers to Community Solar
  - Enable Property Assessed Clean Energy (PACE) financing programs

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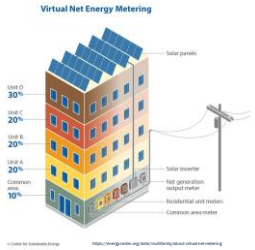
Virtual Net Metering



- **Billing calculations vs. hardwired equipment requirements**
- **Current net meter aggregation rules:**
  - Must be same property owner
  - Meters must be within 2 miles of each other
- **Potential rule changes:**
  - Does not have to be the same owner/end user
  - Increase distance stipulations between meters

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Community Solar

- Greater solar PV system placement potential, especially for shading conditions
- Subscribers purchase defined share/credits for solar PV energy production for their electric bills

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Conclusions

- Think ahead when incorporating solar PV systems into home designs
- Variety of solar modules & solar PV systems components
- Work with a NABCEP professionals to design & install best systems for your needs
- Consider energy efficiency first
- Future policy changes may expand solar PV system options for homes in PA

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Resources

- Pennsylvania's Solar Future Plan: https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Pennsylvania's-Solar-Future-Plan.aspx
- Residential Consumer Guide to Solar Power (July 2017): http://files.dep.state.pa.us/energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Pollution%20prevention%20and%20Energy%20assistance/SolarFuture/FS-Solar_FAQ.pdf
- Solar Electricity FAQs (for homeowners): http://files.dep.state.pa.us/energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Pollution%20prevention%20and%20Energy%20assistance/SolarFuture/FS-Solar_FAQ.pdf
- Considering a Solar Photovoltaic System? (for homeowners): http://files.dep.state.pa.us/energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Pollution%20prevention%20and%20Energy%20assistance/SolarFuture/FS-Solar_PV_System.pdf
- Residential Consumer Guide to Community Solar (SEIA): https://www.seia.org/sites/default/files/Residential%20Consumer%20Guide%20to%20Community%20Solar%20-%20FINAL.pdf
- PA Net Metering Policy: http://programs.dsireusa.org/system/program/detail/65

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Questions?

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Solar PV in PA: Intro to the Design of New Construction & Retrofit Residential Systems

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