Chapter 3

Site Surveys and Preplanning

Customer Development • Site Assessment • Locating PV Arrays • Shading Analysis • Project Planning and Preparation

Overview

- Objectives of a site survey.
- Identifying locations for installing PV arrays and other equipment.
- Assessing the type and condition of roofing systems or other structural support.
- Using solar shading calculators to evaluate shading on potential PV array locations.
- Evaluating electrical services and suitability for PV system interconnection.
- Documenting the site layout and conditions.
- Planning installation and project logistics.
- Conducting a hazard assessment and safety training.

Preliminary Assessment

- An initial assessment for a PV installation involves gathering information to determine the feasibility and project requirements.
- **Customer development:**
  - Discuss needs and expectations
  - Complete sales, contracting and financing
- **Site conditions:**
  - Solar resource and environmental factors
  - Verify electric energy consumption and costs
  - Use satellite imagery and mapping tools
- **Installation preplanning:**
  - Array location and structural support
  - Hazard assessment
  - Design and plan review
  - Electrical, fire, safety and building codes
  - Equipment and manpower needs

Site Surveys

- **The objectives of a site survey include:**
  - Determine a suitable, unshaded area for installing the PV array.
  - Assess the type and condition of roof or other mounting surface for the array, and determine the appropriate structural attachments.
  - Evaluate existing electrical services and identify utility interconnection options.
  - Determine appropriate locations for inverters, switchgear and other equipment.
  - Document layout and dimensions of site, and gather any other information required for permitting and system installation planning.
  - Identify safety hazards, logistical and materials handling issues associated with conducting the system installation.

Site Survey Checklist

- **A site survey checklist is used to document site conditions relative to a PV installation, including:**
  - Locations for installing PV arrays and other equipment
  - Condition of roofing and structural support
  - Shading issues
  - Environmental factors
  - Size of electrical services
  - Codes and local requirements

Site Survey Equipment

- **Safety Equipment**
  - Appropriate PPE including hardhats, safety glasses, safety shoes, gloves and fall protection systems.
- **Tools**
  - Basic hand tools, ladders, flashlights, mirrors and magnifying glasses for inspections.
- **Measuring Devices**
  - Tape measures, compasses, levels, protractors and solar shading calculators.
- **Electrical Meters:**
  - Voltmeters, ammeters, watt and watt-hour meters, and power analyzers.
- **Documentation and Record Keeping:**
  - Graph paper, calculator, audio recorders, cameras and electronic notebooks.
- **System Documentation:**
  - System design information or project plans as available.

Site Survey Equipment

System Documentation

- Organizing system documentation is a critical part of site surveys and preplanning, and is required for building permits, utility interconnection and some incentive programs.
- Key components of a system documentation package should include:
  - System design and equipment specifications
  - Site layout drawings and equipment locations
  - Owner/operator manuals for the system and major components
  - Electrical and mechanical drawings
  - Installation, operating and maintenance procedures
  - Site survey and shading analysis (required by some rebate programs)

Seaward Solar SolarCert Elements Software

- Compile and store complete PV system documentation package per IEC 62446.
- Create test reports, import documents and produce installation diagrams.
- Export test reports and inspection certificates in PDF format.
- See: www.seawardsolar.com

Hazard Assessment

- A hazard assessment is conducted during a site survey to identify all safety hazards employees may be exposed to during construction.
- Primary hazards during a PV installation are electrical and fall hazards.
- The employer shall eliminate the hazards where possible and train employees in the recognition and avoidance of unsafe conditions, including the proper use of PPE.

Safety Training

- Safety training is provided to workers prior to beginning construction, and should cover the following areas:
  - Recognition and avoidance of job site hazards
  - Controls and work practices used to reduce or eliminate the hazards
  - Use and care of personal protective equipment
  - Proper use and storage of tools and equipment
  - Locations of medical and first-aid supplies
  - Locations and use of fire extinguishers and other safety equipment
  - Emergency procedures
  - Designated safety monitors and their responsibilities

Local Requirements

- PV system installations must comply with all applicable building codes.
- Interactive PV systems require interconnection approval from the local utility company.
- Incentive programs may also place additional requirements on eligible PV systems.

Environmental Conditions

- **The site environmental conditions have important consequences on the design and installation of PV systems.**
  - Minimum and maximum site temperatures dictate operating limits for equipment, PV array voltage and string sizing.
  - The solar radiation resource determines the system energy production.
  - Maximum winds speeds affect the design of array mounting systems.
  - Other local environmental conditions may also need to be considered, such as in seismic or heavy snowfall regions.

Electrical Services

- **The electrical service and distribution equipment in a facility dictate the methods used and the size of the PV system that can be interconnected to the grid.**
- **Considerations for electrical services include:**
  - Size of distribution transformer
  - Location of service entrance
  - Service rating and maximum fault currents
  - Size, ratings, location and condition of distribution panels
  - Condition of grounding electrode and grounding systems.

Equipment Locations

- **Establish appropriate locations for system equipment based on design and code requirements, including:**
  - Locations for installing PV arrays, inverters, batteries and other major components.
  - Shortest routing for conduit and wiring systems.
  - Consider accessibility for installation, maintenance and safety.
- **The NEC requires sufficient access and working space about electrical equipment (see Art. 110).**

Locating PV Arrays

- A key objective of site surveys is to verify or determine a suitable location for installing PV arrays.
- Factors to consider include:
  - Available surface area and orientation
  - Accessibility and working spaces
  - Fire safety codes and wind loads
  - Shading obstructions
  - Structural attachments and support
  - Proximity to other equipment
  - Aesthetics

Array Surface Area

- PV module characteristics and array layout dictate the overall surface area required for a given generation capacity.
- Fire safety codes, wind loads and accessibility must be considered when evaluating suitable array locations and layouts.

National Park Service/Jim Dunlop

Jim Dunlop

Array Area Calculations

- Power densities for PV arrays can vary between 6 and 15 watts per square foot (W/sf), depending on module efficiency and array layout.
- For a 175-watt PV module with an area of 14.4 sf, the module power density is:
  - 175 W / 14.4 sf = 12.2 W/sf
- For a 4 kW PV array, the total module surface area is:
  - 4000 W / 12.2 W/sf = 328 sf
  - Approximately the area of 10 sheets of 4x8 plywood
- Due to required space for access, additional area is usually required for the overall PV array installation and other equipment.

Array Area Requirements

Commercial Rooftop: 500 kW PV Array

Ground-Mounted Arrays

- **Site surveys for ground-mounted PV arrays should consider:**
  - Zoning and land use issues
  - Terrain, elevations and grading requirements
  - Soil type and array ground-cover
  - Water table, flood zones and drainage
  - Array foundation requirements
  - Security requirements, fencing and service vehicle access

Roofing Evaluation

- **Roofing systems are a major consideration in the design and installation of roof-mounted PV arrays. Key items to evaluate during a site survey include:**
  - Building type and roof design
  - Roof dimensions and orientation
  - Roof surface, condition and structural support
  - Roof access and fall protection methods required

Roof Designs

- Roofing designs are classified by the shape of the roof surface and how they transmit loads to structural support members.
- The type of roof design affects the usable area for installing PV arrays, due to fire safety codes, wind load distributions, and surface orientation.


Hip Roof


Flat Roof


Gable Roof


Cross Hip Roof


Monoslope Roof


Cross Gable Roof

Roof Dimensions

- Roof dimensions that affect the design, installation and performance of PV arrays include:
  - Roof pitch (slope)
  - Roof direction
  - Roof length, width and area

Roof pitch and slope:

2/12 = 9.5°	6/12 = 26.6°
3/12 = 14°	8/12 = 33.6°
4/12 = 18.4°	12/12 = 45°

Roofing Material

- The type of roof surface affects the choice of PV mounting system attachments and weathersealing methods.
  - Inspect roof condition during a site survey - older roofs may require replacement prior to PV installations.

Roofing Material	Life (yrs)	Features
Asphalt Shingle	15-20	Low cost
Concrete Tile	30-50	Require additional structural support, not used in freeze/thaw climates
Standing Seam Metal	50+	Use zinc and aluminum coatings, require sealants on low slope roofs
Membrane & Built-Up	30+	Common for commercial flat roofs
Wood Shakes	<30	Typically cedar, lightweight, combustible
Slates	100+	Very high cost

Roof Structure

- **Most roof structures are capable of supporting rigidly attached PV arrays. Roofing structure details to investigate during site surveys include:**
  - The type, materials and dimensions of structural members (beams, trusses or rafters)
  - Location and spacing between structural members
  - Thickness of roof surface and decking or membrane to structural members
  - Access to attic spaces to install blocking or additional structural support
- **Signs of structural issues include:**
  - Broken trusses or dips in the roof surface
  - Dry rot due to water leakage
  - Cracks in walls, columns or foundations

Fire Safety Codes

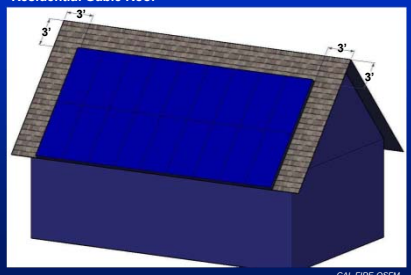
- **Fire safety codes impact the location of PV arrays on building rooftops, and address firefighter safety concerns.**
- **Minimum setbacks are required for roof-mounted PV arrays and equipment to permit firefighters safe access, pathways and areas for smoke ventilation.**
- **See:**
  - *Solar Photovoltaic Installation Guideline*, California Dept. of Forestry and Fire Protection, Office of the State Fire Marshal: http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf
  - Solar America Board for Codes and Standards: www.solarabcs.org

Fire Safety Codes: Residential Buildings

- **Access:**
  - Hip roofs shall have one (1), 3-foot wide clear access path from the eave to the ridge on each roof slope where modules are located.
  - Single ridge roofs shall have two (2), 3-foot wide access paths from the eave to the ridge on each roof slope where modules are located.
  - Modules installed on both sides of hips or valleys shall be located no closer than 1½ feet to the hip or valley. Modules can be directly adjacent to a hip or valley if modules are located on only one side.
- **Ventilation:**
  - PV modules shall be located no higher than 3 feet below the ridge.

Fire Safety Codes: Residential Gable Roof

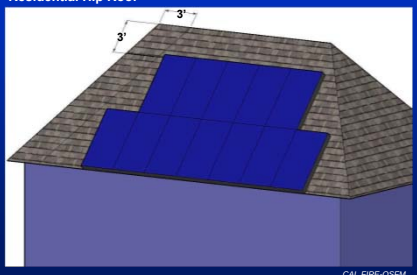
Residential Gable Roof



CAL FIRE-OSFM

Fire Safety Codes: Residential Hip Roof

Residential Hip Roof



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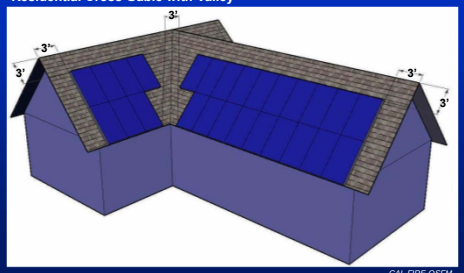
Fire Safety Codes: Residential Cross Gable w/ Valley

Residential Cross Gable with Valley



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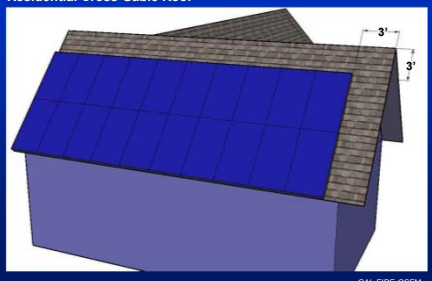
Fire Safety Codes: Residential Cross Gable Roof

Residential Cross Gable Roof



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Fire Safety Codes: Commercial Buildings

- **Access**
  - A 6-foot wide clear perimeter shall be provided around the entire array, or a 4-foot clear perimeter is allowed where the shortest roof dimension is 250 feet or less.
  - Perimeter access is also usually provided for worker safety, shading and wind load concerns.

Fire Safety Codes: Commercial Buildings

- **Pathways**
  - Straight line clear pathways a minimum 4 feet wide and located over structural members shall be provided along the center line of both roof axes, and to skylights, ventilation hatches and standpipes.
  - A minimum of 4 feet clear space is also required around roof access hatches with at least one pathway not less than 4 feet clear pathway to parapet or roof edge.

Fire Safety Codes: Commercial Buildings

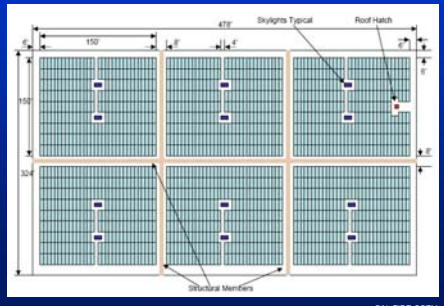
- **Ventilation**
  - Arrays shall be no greater than 150 by 150 feet along either axis.
  - Ventilation options between array sections shall be either:
    - A pathway eight feet or greater in width
    - Four feet or greater in width pathway and bordering on existing roof skylights or ventilation hatches
    - Four feet or greater in width pathway and bordering 4' x 8' "venting cutouts" every 20 feet on alternating sides of the pathway

Fire Safety Codes: Commercial Buildings

- **Location of DC Conductors**
  - To reduce trip hazards and maximize ventilation opportunities:
    - Raceways and wiring systems should be located as close as possible to the ridge, hip or valley.
    - Conduit runs between sub arrays and to DC combiner boxes should be as short as possible and minimized in pathways between the array.
  - DC wiring should be run in metallic conduit or raceways when located within a building to provide additional protection for venting operations.

Fire Safety Codes: Large Commercial Example

Large Commercial (Axis > 250') 8' Walkways



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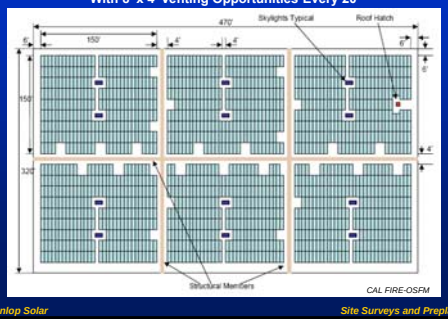
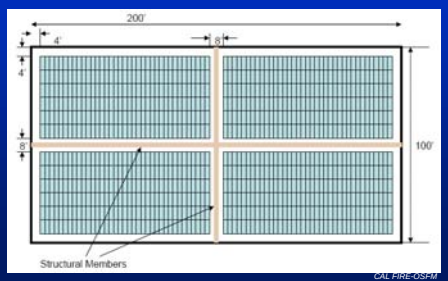
Fire Safety Codes: Large Commercial Example

Large Commercial (Axis > 250') 4' Walkways
With 8' x 4' Venting Opportunities Every 20'



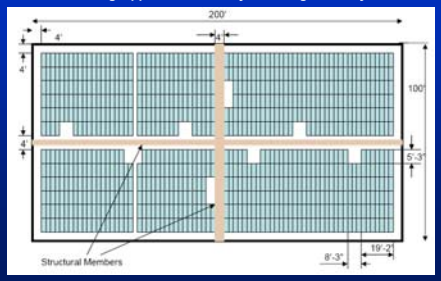
Fire Safety Codes: Small Commercial Example

Small Commercial (Axis < 250') 8' Walkways



Fire Safety Codes: Small Commercial Example

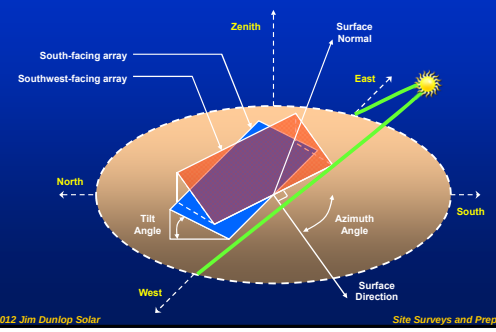
Small Commercial (Axis < 250') – 4' Walkways
Venting Opportunities Every 20' Along Walkway



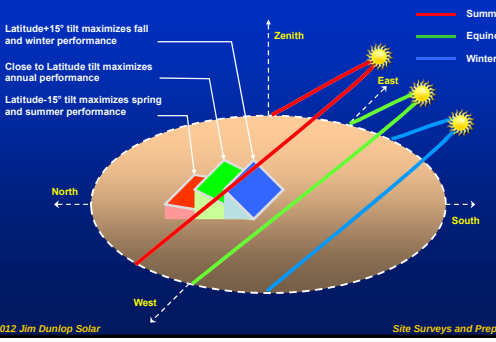
Array Orientation

- **Maximum annual solar energy is received on a fixed surface that faces due south, and is tilted from the horizontal at an angle slightly less than the local latitude.**
  - Autumn and winter performance is enhanced by tilting arrays at 15° greater than latitude.
  - Spring and summer performance is enhanced by tilting arrays 15° lower than latitude.
- **Fixed surfaces with azimuth orientations of ±45° degrees from due south and with tilt angles ±15° of local latitude will generally receive 90 to 95% or more of the annual solar energy as for optimally tilted south-facing surfaces.**

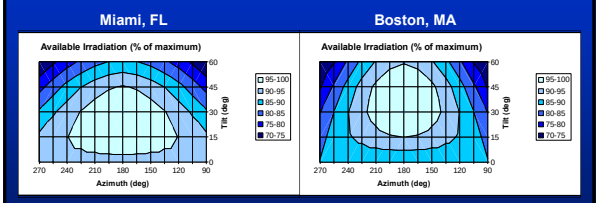
Array Orientation



Array Tilt Angle



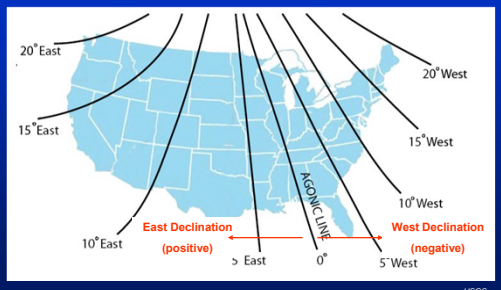
Array Tilt and Azimuth Angles



Magnetic Declination

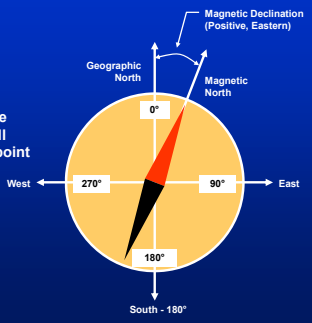
- Magnetic declination is the angle between true geographic north and the magnetic north poles.
- Magnetic declination varies with location and over time:
  - The western U.S. has positive, or easterly declination.
  - The eastern U.S. has negative, or westerly declination.
  - Magnetic declination is zero along a line running from Pensacola, FL to Duluth, MN, called an agonic line.

U.S. Magnetic Declination



Magnetic Compass

- Magnetic compass readings must be corrected for local magnetic declination.
- The western U.S. has positive (eastern) declination, and will cause a compass needle to point east of the geographic north pole.



Shading Obstructions

- Shading of PV arrays blocks usable solar energy and reduces array output.
- Potential shading obstructions include:
  - Trees and vegetation
  - Buildings and structures
  - Power lines, poles and towers
  - Roof-mounted obstructions including chimneys, vents, antennas and dormers
  - Other parts of the array

Sharp Solar

Shading Obstructions

- Obstructions to the north can shade PV arrays during summer months early in the morning and late afternoon when the sun is in the northern part of the sky.

FSEC

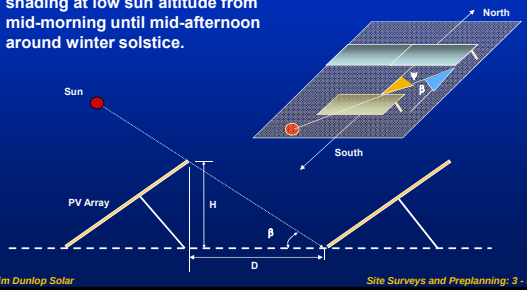
Row Shading

- A minimum separation distance is required to prevent multiple rack-mounted rows of PV arrays from shading one another.
- Greater separation distances are required for taller arrays, higher latitudes, and to avoid shading for longer periods of the day.

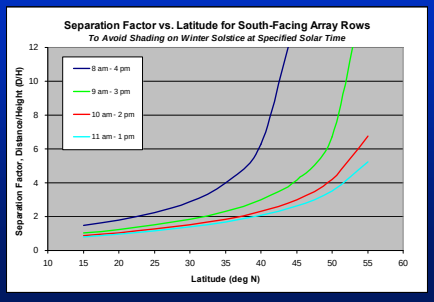
FSEC/Jim Dunlop

Row Shading

- Spacing between rows (D) must be wide enough to prevent shading at low sun altitude from mid-morning until mid-afternoon around winter solstice.



Separation Distance



Solar Shading Analysis

- Shading of PV modules and arrays reduces power and energy output.
- PV arrays should be installed on surfaces that are unshaded between 9 a.m. and 3 p.m. solar time throughout the year.
- Several tools are available to determine the extent of shading in the solar window:
  - Solar PathFinder: www.solarpathfinder.com
  - Solmetric SunEye: www.solmetric.com
  - Acme Solar Site Evaluation Tool (ASSET): www.we-llc.com

Solar Shading Calculators

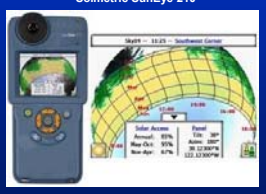
- Solar shading calculations are devices used to determine the extent of shading in the solar window.

Solar Pathfinder

Solmetric SunEye

Solar Shading Calculators

Solmetric SunEye 210



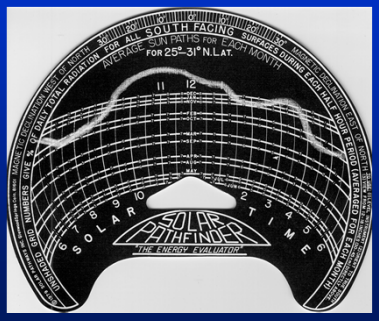
Wiley Electronics ASSET

Solar Pathfinder

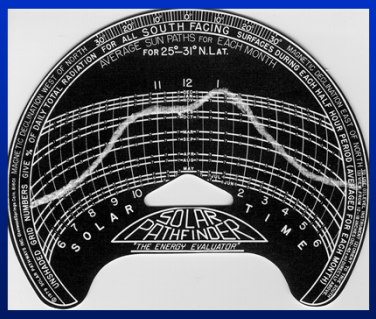
Leveling Base, Sunpath Chart and Glass Dome

Adjusting for Magnetic Declination

Solar Pathfinder Diagram: Minimal Shading



Solar Pathfinder Diagram: Extensive Shading



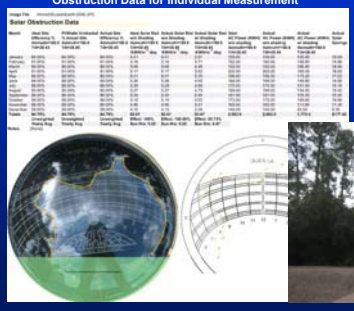
Solar Pathfinder Assistant Software

Shading Measurement Locations

Site Reeport

Solar Pathfinder Assistant Software

Obstruction Data for Individual Measurement



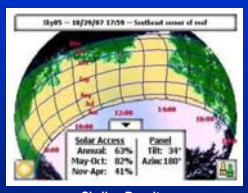
South View of Site

Solmetric SunEye 210

- Digital shading analysis tool
- Includes digital camera with fish eye lens, electronic compass, inclinometer and optional GPS.
- Produces immediate results in the field, USB interface to PC software.

Solmetric

Solmetric SunEye

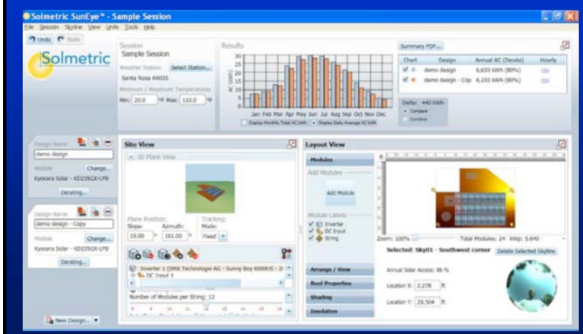


Skyline Results

Solar Access Averages

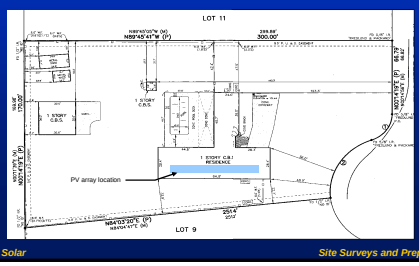
Solmetric

Solmetric PV Designer Software



Site Layout

- A site layout diagrams the property or facility for a planned PV system installation and identifies locations for the PV array and other equipment.



Energy Audit

- Energy consumption for electrical loads are key factors in sizing stand-alone PV systems, and for grid-connected PV systems with battery storage for critical load backup.

Electrical Load	Power (W)	Avg. Daily Time of Use (hr)	Avg. Daily Energy (watt-hours)
Lighting	200	6	1200
Refrigerator	300	9.6 (40% duty cycle)	2880
Microwave	1200	0.5	600
Pumps	1000	1	1000
TV and entertainment equipment	400	4	1600
Fans	300	6	1800
Washer	400	0.86 (3 hours 2 times per week)	344
Miscellaneous plug loads	200	12	2400
Total all loads	**4000 W (4 kW)**		**11,824 Wh (11.8 kWh)**

Energy Use

- Electric utility bills may be used to evaluate long-term energy consumption.
- Watt and watt-hour meters may be used to measure the power demand and energy consumption for specific circuits and appliances.


Your electric statement

Account number:

DO NOT PAY

Satellite Imagery for Site Surveys

- Google Earth/Maps: www.google.com
- Roof Ray: www.roofray.com
- Local property appraiser's websites



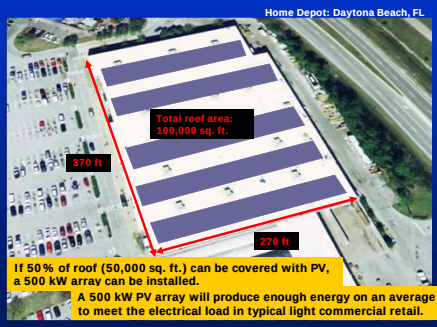
Google Earth

ROOFRAY

Satellite Imagery

- Satellite imagery can be used for PV system site surveys to find suitable areas for installing PV arrays, and to determine coordinates, distances and areas of buildings and properties.

Big Box Retail 500 kW PV System



If 50% of roof (50,000 sq. ft.) can be covered with PV, a 500 kW array can be installed.

A 500 kW PV array will produce enough energy on an average basis to meet the electrical load in typical light commercial retail.

Estimating Tools

- PVWATTS:
  - http://rredc.nrel.gov/solar/codes_algs/PVWATTS/
- In My Back Yard (IMBY):
  - www.nrel.gov/eis/imby/
- Simple calculation:
  - DC Rating x DF = Peak AC Power Output (kW)
    - Derating factor (DF) factor includes inverter efficiency losses and other derating factors, usually 0.75 to 0.85
  - Peak AC Power Output (W) x Peak Sun Hours = Energy Production (kWh/day)

Estimating PV System Energy Production

INTERACTIVE PV SYSTEM PERFORMANCE WORKSHEET

Estimating and Verifying System AC Energy Production

PV Array DC Power Rating at STC - 1000 W/m², 25 °C (kW)	**10**
Derating Factors	
Nameplate Ratings	0.95
Inverter and Transformer	0.95
Module Mismatch	0.98
DC Wiring	0.98
AC Wiring	0.99
Soiling	1.00
Shading	0.85
Sun Tracking	1.00
Age	1.00
Combined Derating Factors	0.73
Estimated System AC Power Output at STC - 1000 W/m², 25 °C (kW)	7.3
Temperature Adjustments	
Array Power-Temperature Coefficient (%/°C)	-0.5
Average Array Operating Temperature (°C)	45
Estimated System AC Power Output at 1000 W/m² and Average Operating Temperature (kW)	6.6
Solar Radiation Received	
Solar Irradiation in Plane of Array (kWh/m²/day)	5
Estimated System AC Energy Output at Average Operating Temperature (kWh/day)	**29.5**

PVWATTS Output

PVWatts — AC Energy & Cost Savings

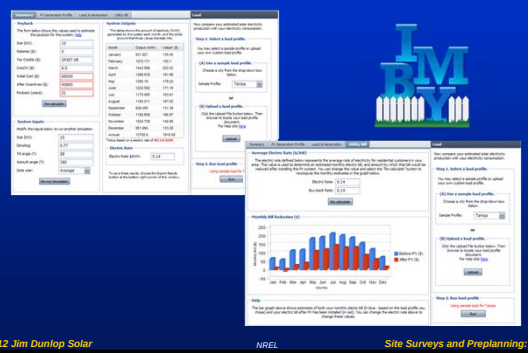
Station Identification	
City:	Daytona Beach
State:	FL
Latitude:	29.18° N
Longitude:	81.05° W
Elevation:	12 m
PV System Specifications	
DC Rating:	500.0 kW
DC to AC Derate Factor:	0.750
AC Rating:	375.0 kW
Array Type:	Fixed Tilt
Array Tilt:	29.2°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	9.0 ¢/kWh

Results

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	4.34	47442	4269.78
2	4.96	49473	4452.57
3	5.81	63084	5677.56
4	6.14	62707	5643.63
5	5.98	62491	5624.19
6	5.67	56218	5059.62
7	5.74	59329	5339.61
8	5.65	58791	5291.19
9	5.51	55536	4998.24
10	4.84	51063	4595.67
11	4.67	48783	4390.47
12	4.23	46323	4169.07
Year	5.30	661241	59511.69

NREL

In My Backyard (IMBY)



NREL

Software

- **Public Domain (NREL/DOE)**
  - PVWATTS: www.nrel.gov/rredc/pvwatts/
  - In My Back Yard (IMBY): www.nrel.gov/eis/imby/
  - HOMER: www.analysis.nrel.gov/homer/
  - Solar Advisor Model (SAM): www.nrel.gov/analysis/sam/
- **Commercial**
  - Clean Power Estimator: www.cleanpower.com
  - PVSYST: www.pvsyst.com
  - OnGrid: www.ongrid.net
  - PVSol: www.solardesign.co.uk/
  - PV F-Chart: www.fchart.com
  - Maui Solar Software: www.mauisolarsoftware.com/
- **Manufacturers**
  - Inverter string sizing and various system sizing and design tools

Installation Planning

- **Planning the installation process utilizes information gathered during a site survey, and includes:**
  - Completing and adapting the system design.
  - Submitting applications for permits, utility interconnection and incentives.
  - Defining the project schedule, manpower and equipment needs.
  - Identifying and resolving construction activity conflicts such as power outages or alterations to the site.
  - Coordinating other logistics with the customer such as site access, worker facilities, waste collection and storage areas.

Summary

- **Site surveys involve an assessment of all issues relative to planning a PV installation.**
- **Locations for PV arrays and other equipment are selected based on space, performance and code requirements.**
- **A shading analysis evaluates the impacts of shading at potential PV array locations and helps estimate the reduced solar energy received.**
- **The type and condition of a roofing system and structural support define the mounting system required.**
- **Electrical services establish the allowable methods and maximum size of PV systems that can be interconnected at a site.**
- **A site layout details the dimensions of site and locations for PV equipment.**


Questions and Discussion
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