2013 IMSA Annual Conference

Solar Powered
Warning Light System Design

July 20, 2013

Presented by Ted Vaeches of Traffic Safety Corp.

Solar Powered Warning Light System Design

- **Our Focus Today**
  - **Integrated Solar Powered Systems Used for Warning Light Systems**
  - **Characteristics**
    - Integrated - Solar Panel, Storage Battery, Charge Controller, and System Controller
    - Independent System - Not tied to an AC Utility Grid
    - Low Power - Connected to LED Devices, Intermittent DC Loads

In-Roadway Warning Warning Lights

LED Edge Lite Signs

LED Beacons

Solar Powered Warning Light System Design

- **Session Objectives – Survey Class on Solar Power System Design**
  - **Survey of Enabling Technologies**
  - **Design Example**
    - Develop an Appreciation of System Requirements
    - Define a Set of Performance Criteria
    - Examine the Effects of Environmental Factors and Component Limitations on System Performance
  - **System Installation Effects on System Performance**
  - **Solar Powered System Benefits**
  - **Solar Power System Deployment Limitations**

Solar Powered Warning Light System Design

- **Presentation Ground Rules**
  - **Ask Questions and Offer Options**
  - **Be Sensitive to Our Time Restrictions**
    - Keep Questions and Responses Concise and Focused
    - More Detailed Discussions – At the End of Presentation, TSC Booth, or Call or Email
  - **Copy of Presentation Available**
    - Provide Business Card, or Send me an Email Request with Your Phone Number

Solar Powered Warning Light System Design

- **Audience Poll**
  - **Experience Designing a Solar Powered Systems?**
  - **Experience Specifying a Solar Powered Systems?**
  - **Experience Installing or Maintaining a Solar Powered System?**
  - **Involved in a Current, or Near Term, Solar Powered System Project?**

Let's Begin

Solar Powered Warning Light System Design

- **Enabling Technologies – Two Groups (Energy Converting and Energy Controlling)**
  - **Energy Converting**

    Solar Panels - Devices that Convert Wide Spectrum Solar Energy into Electrical Energy
    - Cost Decreasing, Efficiency Increasing, and Quality Improving

    Batteries - Devices that Convert Electrical Energy into Chemical Energy for Storage, and then Back Again into Electrical Energy
    - Higher Energy Density, Service Life Increasing, Safer

    Light Emitting Diodes - Devices that Convert Electrical Energy into Narrow Spectrum Light Energy
    - Cost Decreasing, Lumens/Watt Increasing, Useful Life Expectancy Increasing

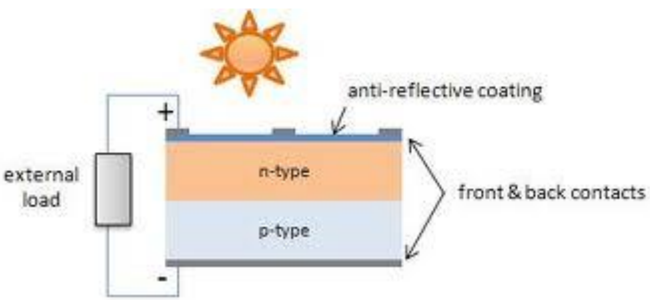
  - **Energy Controlling**

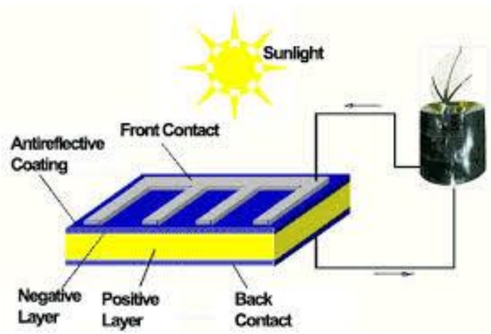
    Charge Controllers - Control the Flow of Electrical Energy Between System Components
    - More Sophisticated in Protecting Batteries and Maximizing Energy Transfer

    System Controllers - Control the Flow of Energy to all External Loads and Interfaces with the System's Activation Devices
    - More Sophisticated in Digitally Controlling Flash Durations and Patterns, and more Flexible in Interfacing with Activation Devices

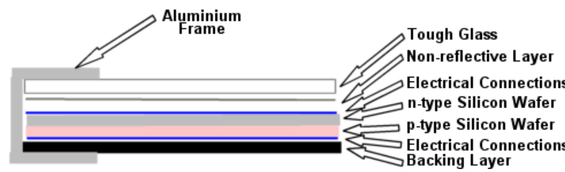
Solar Powered Warning Light System Design

- **Solar Panels**
  PV Cell → PV Module/Panel (Encapsulated Assembly) → PV Modules/Panel → PV Array (Group of Panels)





PV Cell



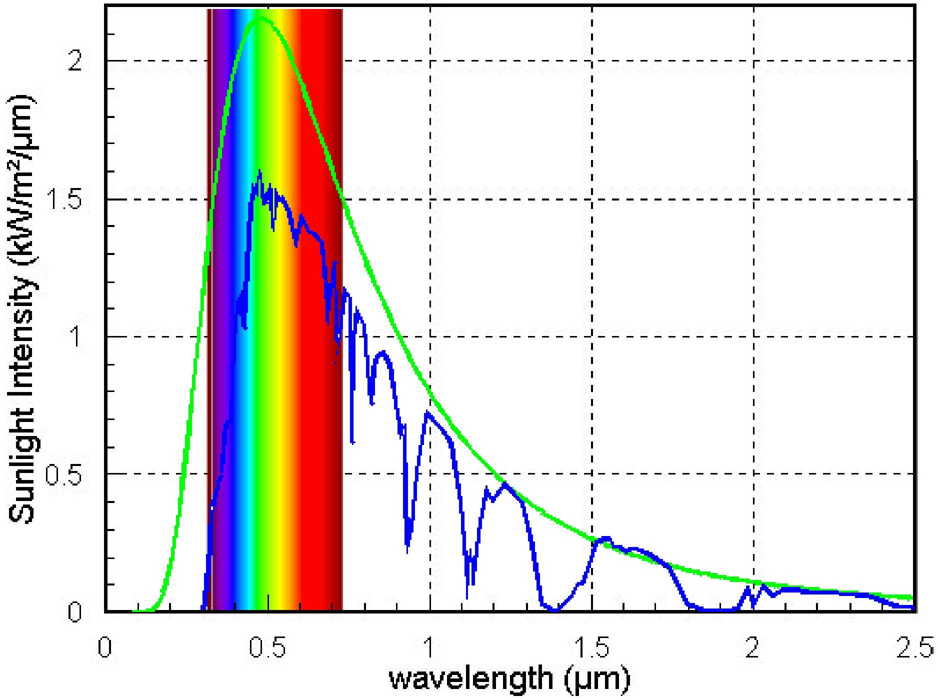
Encapsulated Assembly

PV Cells
Connected in a Solar Module

Panels Making Up An Array

Solar Powered Warning Light System Design

- **Sun's Energy Spectrum at Top of Atmosphere and at the Surface of the Earth**



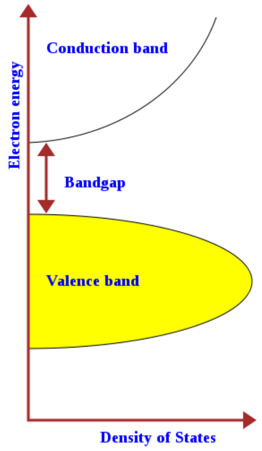
Key Relationships

Wavelength & Frequency
(Inverse)

Frequency & Energy Content
(Direct)

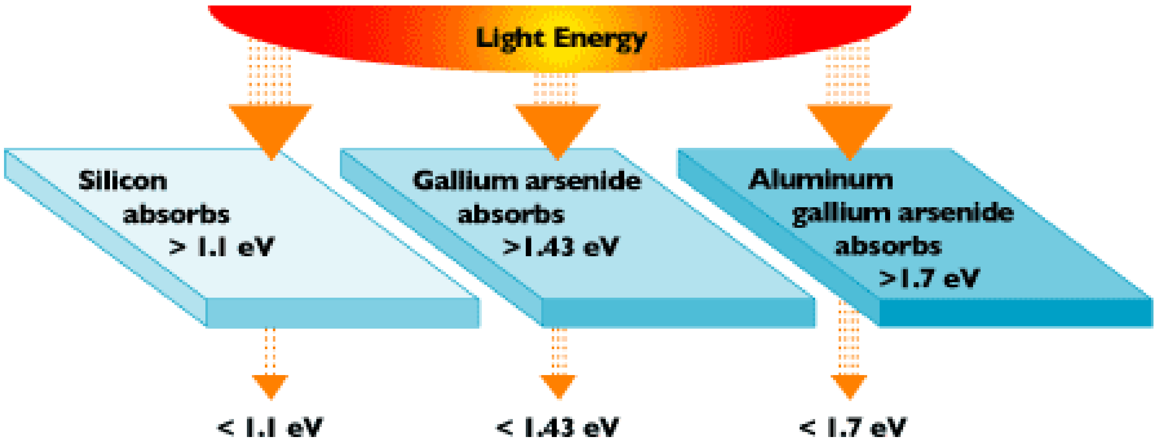
Solar Powered Warning Light System Design

- **Solar Cell Device Physics**
  - For Current to Flow in a Solar Cell **Energy from Sun Light must be Absorbed** by the Valance Electrons which are Bound to the Atoms
  - The **Minimum Energy** Required for Absorption to take Place is Called the **Band Gap Energy**
  - When Energy is Absorbed by the Valance Electrons they Jump to the **Conduction Band** and Current Flows



Solar Powered Warning Light System Design

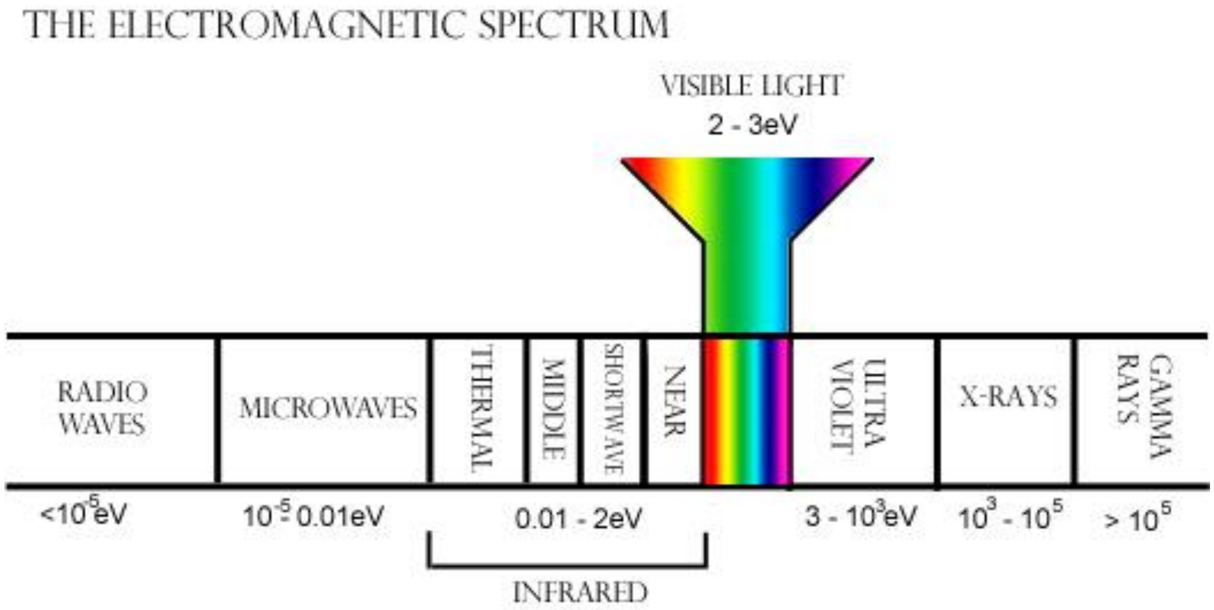
- **Minimum Energy Required for a Photon to be Absorbed by A Valance Electron**



Note: Energy Expressed in Electron Volts

Solar Powered Warning Light System Design

- **Energy of the Electromagnetic Spectrum Expressed in Electron Volts**



Solar Powered Warning Light System Design

- **Batteries**
  - **Batteries have been around for a long time**

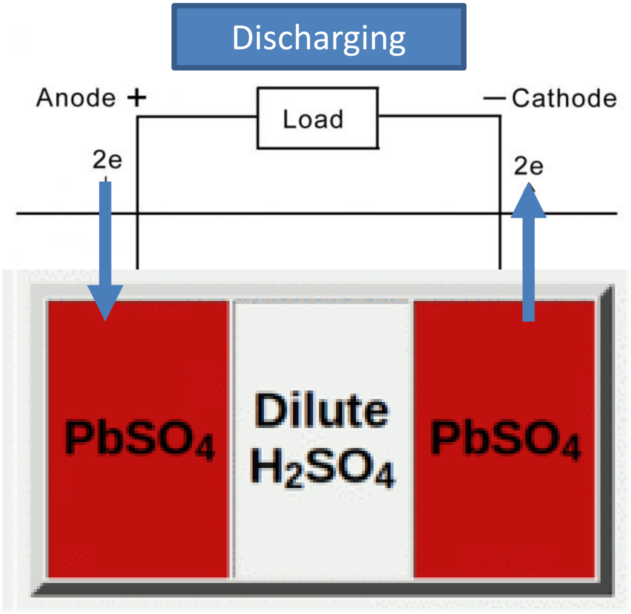
Baghdad Battery/Parthian Battery
250 BC – 224 AD

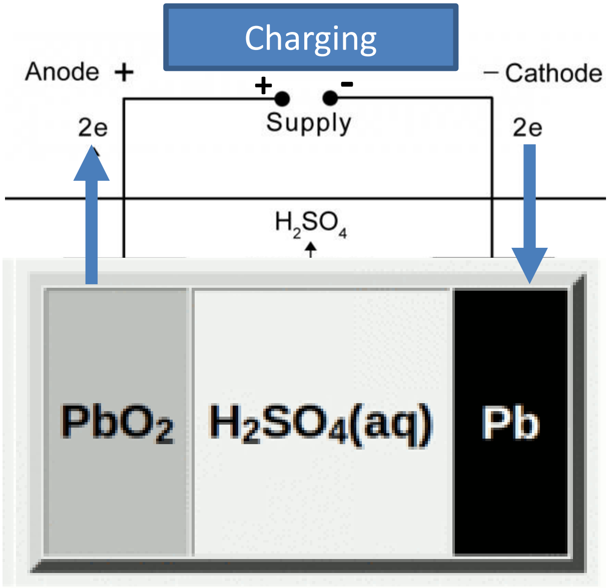
First Battery?

Modern Day VRLA Battery

Solar Powered Warning Light System Design

- **Batteries**
  - **A Battery is a Chemical Device and depends on Chemical Reactions to Store and Release Energy.**



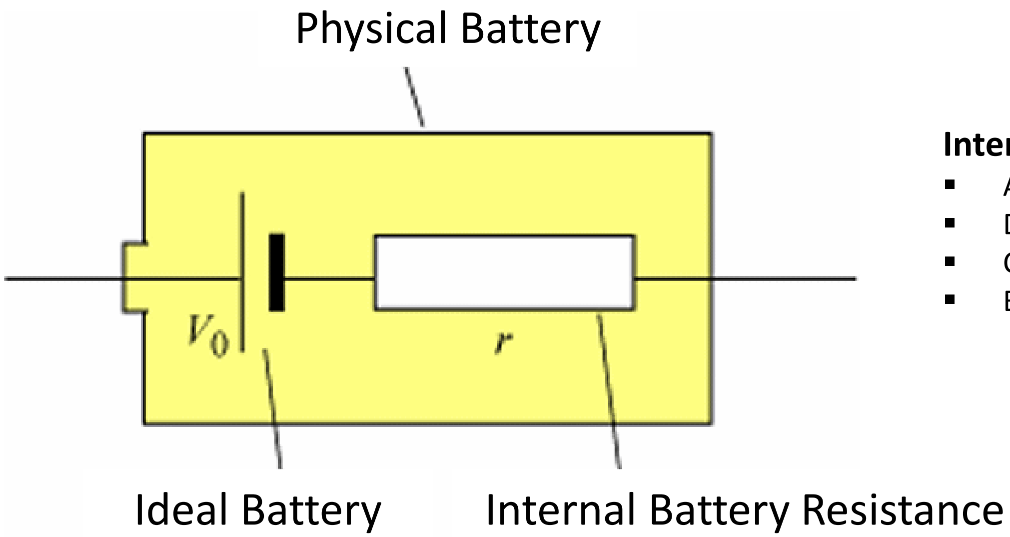


Solar Powered Warning Light System Design

- **Batteries**
  - **Lead Acid Batteries**
    - In a lead acid battery, the **electrodes** are made from **lead**. The **electrolyte** is **sulfuric acid**. Hence the name "Lead-Acid". Rechargeable Battery!
  - **VRLA battery** (**valve-regulated lead–acid battery**)
    - More commonly known as a **sealed battery** is a lead acid rechargeable battery.
    - Because of their construction, VRLA batteries do not require regular addition of water to the cells, and vent less gas than flooded lead-acid batteries.
  - **VRLA Classifications**
    - **Absorbed Glass Mat (AGM) Battery:** An absorbed glass mat battery has the electrolyte absorbed in a fiber-glass mat separator.
    - **Gel battery:** A **gel battery** (also known as a "gel cell") is a VRLA battery with a gelified electrolyte; the sulfuric acid is mixed with silica fume (fine particles of sand), which makes the resulting mass gel-like and immobile.

Solar Powered Warning Light System Design

- **Batteries**
  - **Batteries are not Perfect Voltage Sources, they have Internal Resistance**



Internal Resistance

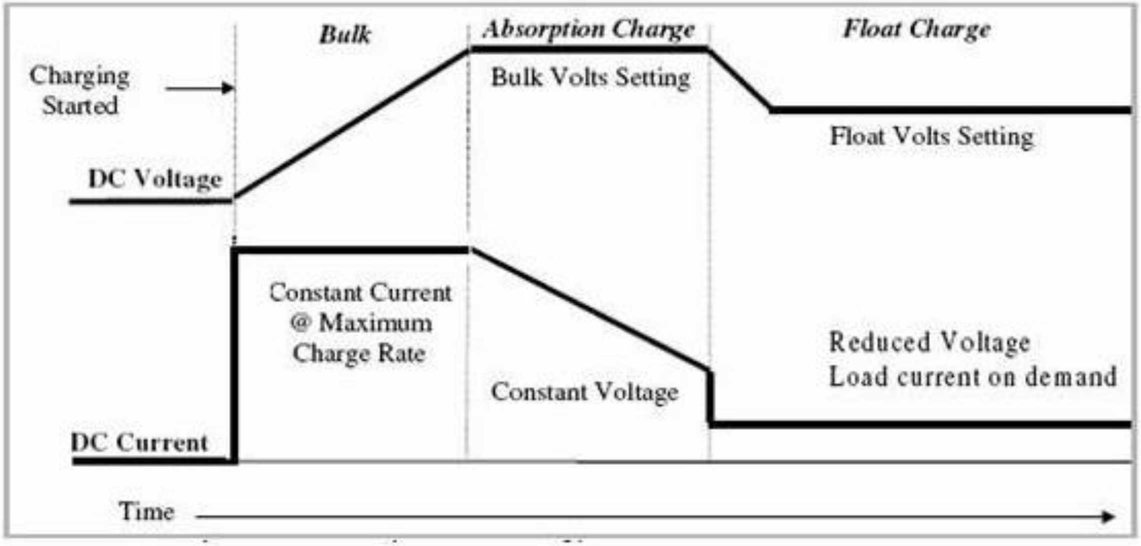
- Ambient Temperature
- Discharge Rate
- Chemical Properties
- Battery Age

Solar Powered Warning Light System Design

- **Charge Controllers**
  - **Major Function – Prevent Over Charging and Undercharging of the Battery**
  - **Other Functions**
    - Prevents Against Excessive Discharging of Battery (Load is Disconnected)
    - Prevents Discharging of Battery through Solar Panel at Night
    - Temperature Sensor to Adjust Battery Voltage Levels to Optimal Levels
    - Status and Error Indicators – Battery State of Charge, Load Fault Conditions
  - **Two Main Types – Pulse Width Modulated (PWM) and Maximum Power Point Tracking (MPPT)**

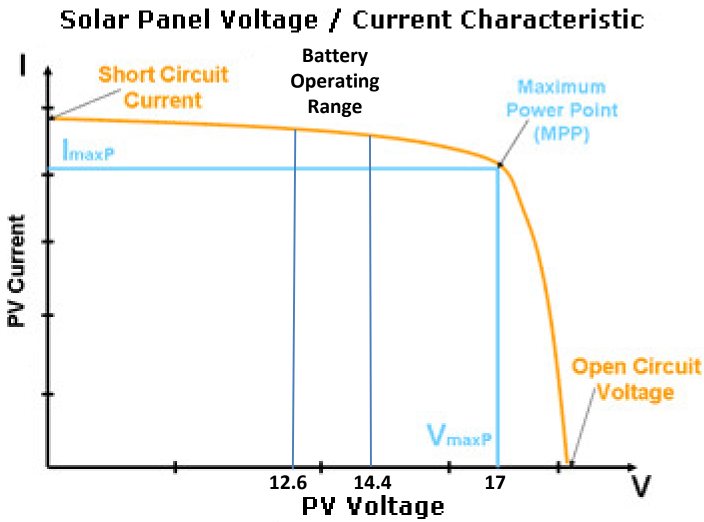
Solar Powered Warning Light System Design

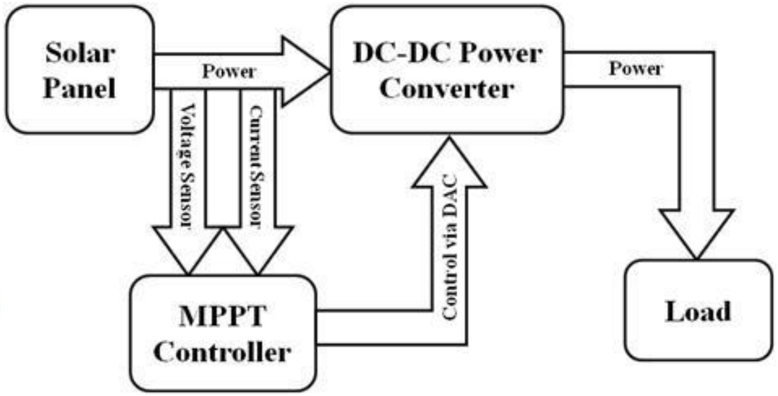
- **Pulse Width Modulated Charge Controller**
  - A **Pulse Width Modulation (PWM)** type of Charge Controller Varies the Width of the Charging Pulses to Maintain the Appropriate Charging voltage on the Batteries Depending on the Charging Phase (Bulk, Absorption, or Float)



Solar Powered Warning Light System Design

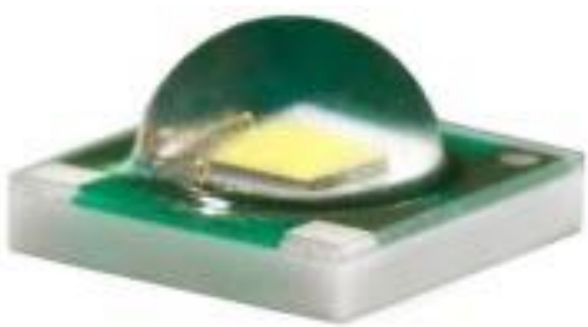
- **Maximum Power Point Tracking Charge Controller**
  - A **MPPT, or Maximum Power Point Tracker** is an Electronic **DC to DC converter** that optimizes the match between the Solar Panel, and the Storage Battery.
  - Most **12 volt Solar panels** are designed to put out around **17 Volts**
  - While Charging, Most Batteries Operate in the Range of **12.6 to 14.4 Volts**





Solar Powered Warning Light System Design

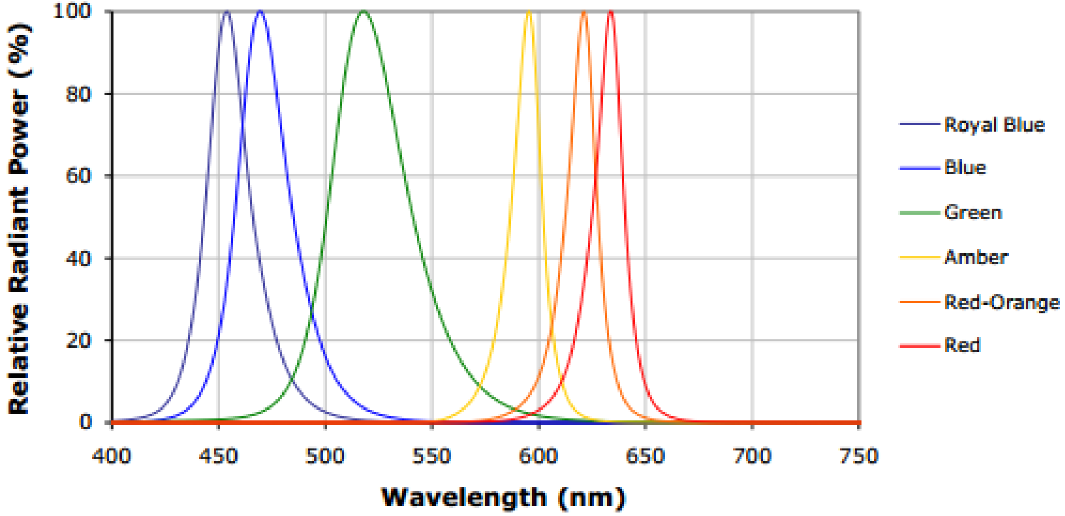
- **Light Emitting Diodes (LEDS)**
  - **Light-emitting diode** (**LED**) is a Solid State (Diode) light source.
  - **Light Emission:** When a light-emitting diode is switched on, electrons release energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.



Example: CREE XP-E

Solar Powered Warning Light System Design

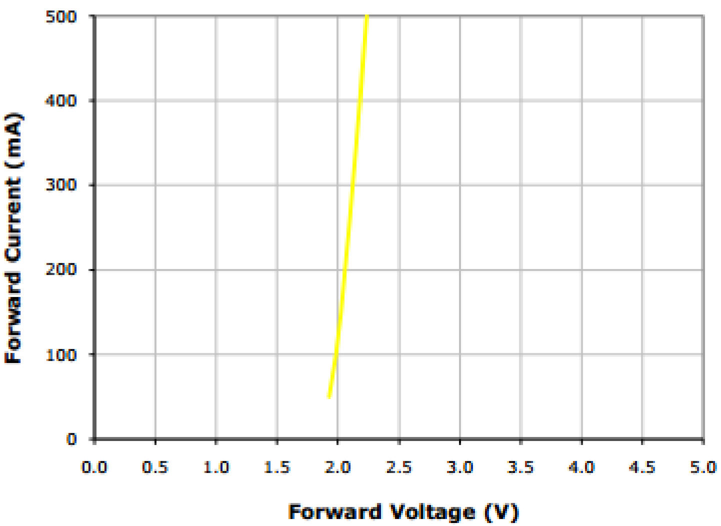
- **Light Emitting Diodes (LEDS)**
  - **High Luminous Efficacy (Lumens/Watt)**
  - **Narrow Spectrum**
  - **Long Useful Life Expectancy**

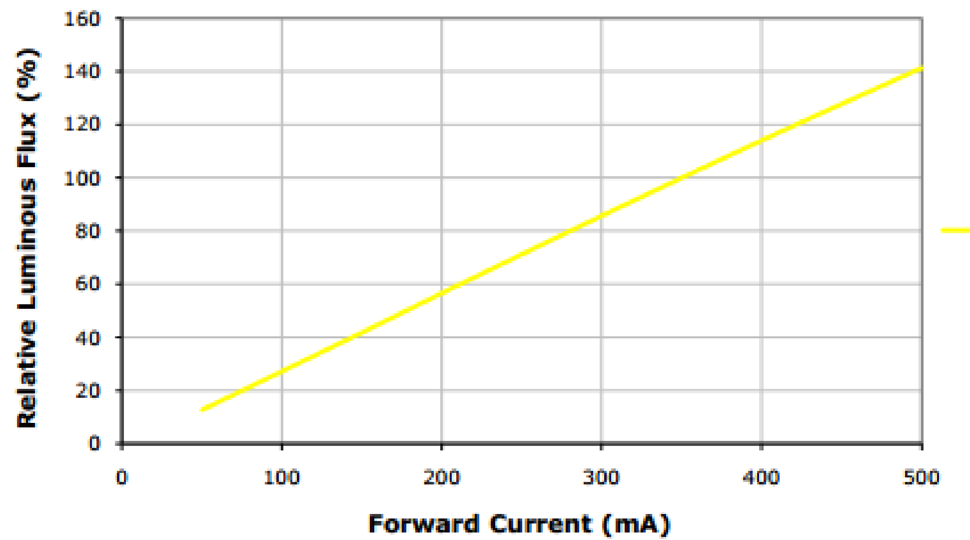


Color

Solar Powered Warning Light System Design

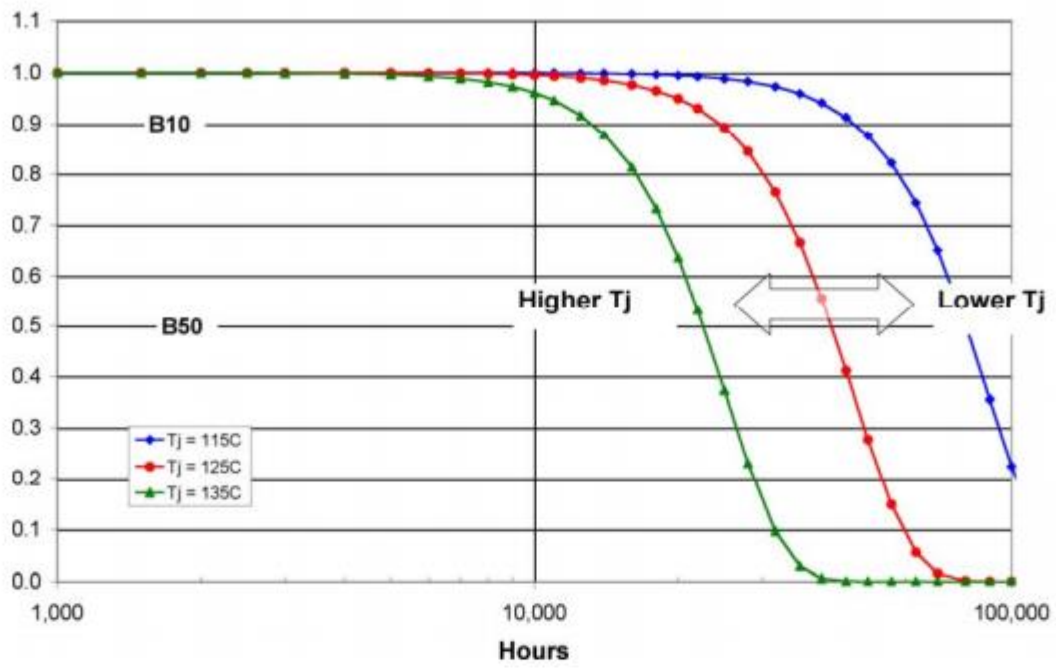
- **Light Emitting Diodes (LEDS)**
  - **Small Increases in Forward Voltage Create Large Changes in Forward Current**
  - **Increasing Forward Current Increases the Light Output of the LED**





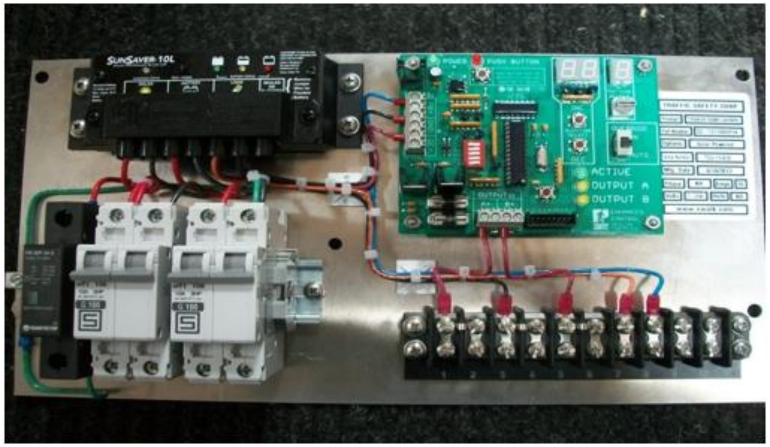
Solar Powered Warning Light System Design

- **Light Emitting Diodes (LEDS)**
  - **To Maintain the Long Life Expectancy of an LED Proper Thermal Heat Sinking is Required**



Solar Powered Warning Light System Design

➢ **System Controller**



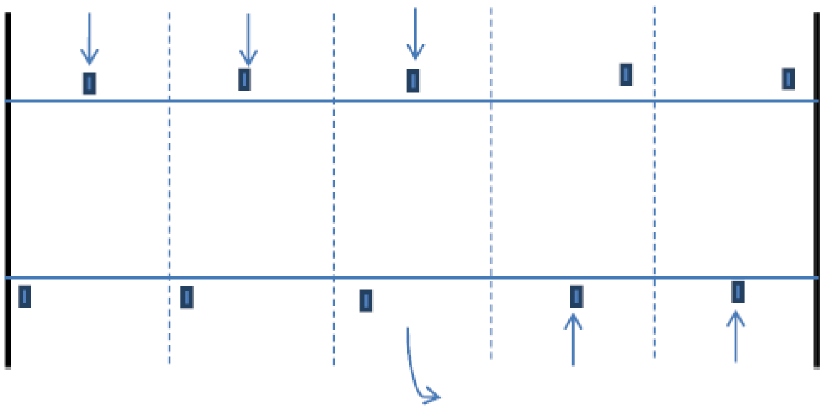
TS1100 System Controller

System Controller Functions

- Generates MUTCD Standard Flash Patterns
- Generates Enhanced Flash Patterns
- Auto-sequencing of Flash Pattern Mode
- Flexible Interfacing to Activation Devices
- Digital Control the Activation Duration
- Dual Outputs with Selectable Flash Patterns
- Continuous Flashing Pattern Mode
- Battery Charge Controller and Battery
- Multiple Disconnects - Solar Panel, Storage Battery, and Load
- Lightning Surge Protection

Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **System Description**
    - **Site Location:** WACO, TX, ZIP Code 76701
    - **Site Description:** Four Lanes of Traffic, Two in Each Direction, Plus a Turn Lane
      Simple Push Button Activation at Each side of the Crosswalk
      Enhanced LED Edge Lit Signs at Each Side of the Crosswalk
    - **MUTCD Requirement for the use of In-Roadway Light Fixtures: 2 Fixtures / Lane for a total of 10**



Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **Equipment Specification**
    - **Light Fixture →** (10) TS600 (Bi-Directional, Flush Profile Fixtures
    - **Enhanced LED Edge Lit Sign →** (2) TS30
    - **System Activation →** (2) AC-X2 Push Button
    - **System Controller →** (1) TS1100SP

TS600
Light Fixture

TS30
LED Edge Lit Sign

X2
Push Button

TS1100SP
System Controller

Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **System Pole Assembly**

Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **Load Calculation (Active and Standby)**
    - **Active Load** → 10 Fixtures (250 ma/Fixture), 2 LED Edge Lit Signs (100 ma/Sign), 2 Push Buttons (10 ma/Push Button), 1 System Controller (50 ma) = 2.8 A (Approximately)
    - **Standby Load** → 10 Fixtures (0), 2 LED Edge Lit Signs (0), 2 Push Buttons (1 ma/Push Button), 1 System Controller (25 ma) = 0.03 A (Approximately)

Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **Usage Estimation:** 340 Crossings/Day @ 30 Sec/Crossing = 175 Min/Day = 3 Hours/Day (Approximately)

Usage	High	Med	Low	
Times	**6-9, 4-7**	**9-4**	**7-6**	
Hours	**6**	**7**	**11**	
Crossings	**30/hour**	**15/hour**	**5/hour**	
Total Crossings	**180**	**105**	**55**	**340 Crossings/Day**

Solar Powered Warning Light System Design

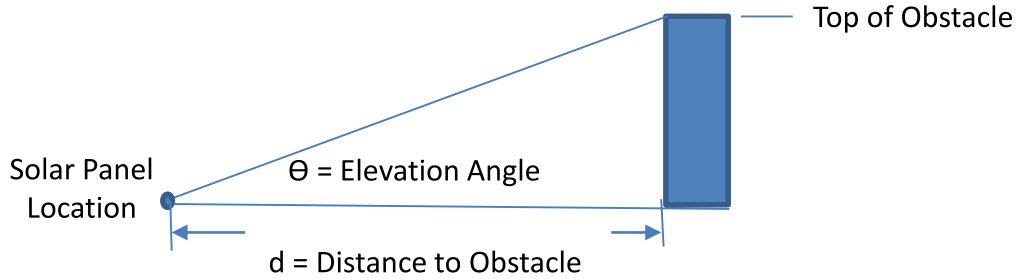
- **Design Example: In-Roadway Warning Light System**
  - **Energy Usage Calculation**
    - **Note:** All Lights Flash with a 50% Duty Cycle
    - Active Hours (3) x 50% Duty Cycle = 1.5 Effective Active Hours

      Effective Active Hours x Active Load = 1.5 x 2.8 = 4.2 Amp-Hours
    - Inactive Hours = (21) + (1.5 from above) = 22.5 Effective Standby Hours

      Effective Inactive Hours x Inactive Load = 22.5 x 0.03 = 0.7 Amp-Hours (Approximately)
    - Total Energy Usage/Day (Average) = 4.2 + 0.7 = 4.9 Amp-Hours/Day

Solar Powered Warning Light System Design

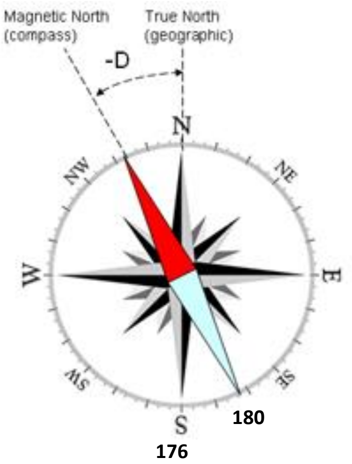
- **Design Example: In-Roadway Warning Light System**
  - **How much Energy is Available at the Site?**
    - Available Sun Energy (Insolation) = Site's Insolation (Available in a Database and Expressed in Terms of Sun Hours), Modified (Reduced) by the Effects of Shading, If Present
    - A Solar Site Survey is Required to Determine if Shading is Present at the Site
  - **How do you Conduct a Solar Site Survey?**
    - Consists of a Series of Measurements of the Elevation Angle from the Panel Location to the Top of Potential Obstructions, and the Distance to the Potential Obstructions.
    - Measurements are made Along the Azimuth, Starting from True South and Extending +, - 90°, at 15° Intervals (1 Sun Hour) from True South.



Note: The Elevation Angle will need to be corrected for the measuring height and height of the panel!

Solar Powered Warning Light System Design

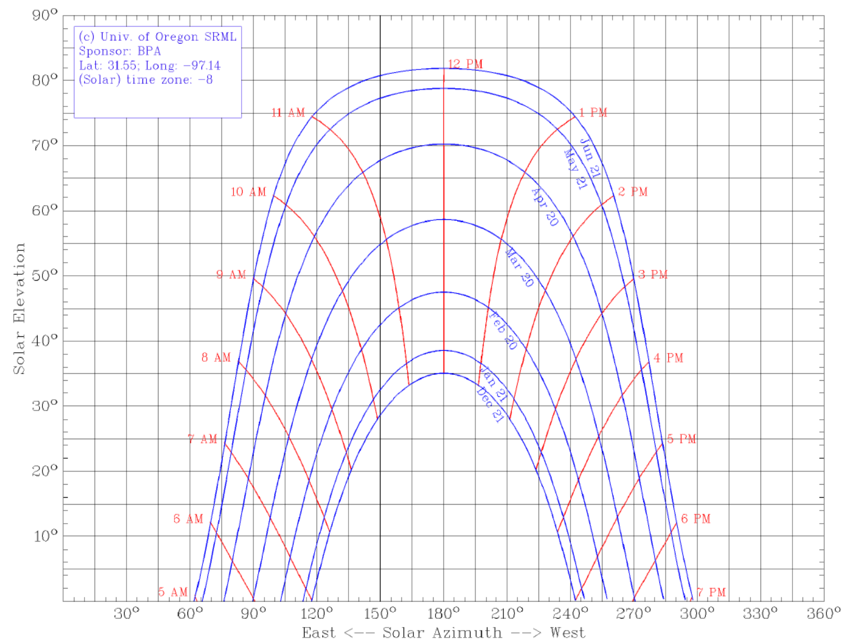
- **Design Example: In-Roadway Warning Light System**
  - **How do you Determine True South?**
    - To Determine **True South** you will need to know the **Magnetic Declination (D)**
    - Magnetic Declination is the Angular Amount that True North deviates from Magnetic North
    - From the Zip Code of the Site (76701) you can look up the Site's Latitude and Longitude and Magnetic Declination. **Latitude** = 31.551955 North, **Longitude** = 97.13833 West, **Magnetic Declination = 4° East (East is Negative)**
    - **True South = 180° + D for WACO** <u>True South = 176° (As Indicated on a Magnetic Compass)</u>



Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **Solar Plots**
    - Next, To Determine if there are Shading Issues, Plot the Results of the Site Survey on a **Solar Plot** for the Site Location to determine the Effects of Obstacles. on Insolation (Sun's Energy) Contributions
    - If the Elevation Angle of a Potential Obstacle is above the Elevation Angle of the Sun, then the Obstacle will Block the Sun – **Shading** – and the Relative Percentage of Available Energy Reduction will need to be Estimated

	Site Measurements		
Geological (True) Directions	Azimuth Angle (Degrees)	Distance to Obstacle (Feet)	Elevation Angle (Degrees)
East	90		
	105		
	120		
	135		
	150		
	165		
True South	180		
	195		
	210		
	225		
	240		
	255		
West	270		

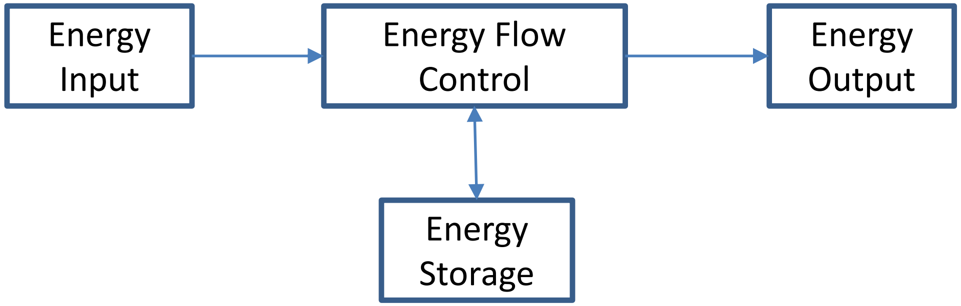


Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **System Performance Criteria**
    - **Days of Autonomy (DOA)** – Measure of a System's Ability to Function (In Days) without Sun Light. A Measure of the Storage Capacity of the System Relative to the Daily Energy Usage. Gives a Measure of the System's Ability to Function Properly Under Periods of High Usage.
      Greater than 5 Days
    - **Array-to-Load Ratio (ALR)** – Measure of System's Ability to Recover (Charge the Storage Battery) After a Period of High Activity, or Lower Than Average Insolation (Sun Energy)
      Greater than 1.1
    - **Battery State of Charge (BSOC)** – Percentage of Charge (Energy Capacity) Available in the Battery. Limiting the Depth of Discharge (Maintaining a Higher State of Charge) Extends the Useful Life of Battery and Reduces Maintenance Costs
      Greater than 80%
    - **Loss-of-Load Probability (LOLP)** - Probability of a Load Disconnect (System Switch-off) due to a Low Battery Charge Condition Caused by Extended Periods of Poor Weather
      Less than 0.1 %

Solar Powered Warning Light System Design

- **Design Example: In-Roadway Warning Light System**
  - **Balancing Energy Input and Output**
  - **Energy Input = Energy Storage + Energy Output to meet Performance Requirements**



Solar Powered Warning Light System Design

- **Effects of Environmental Conditions and Component Limitations on System Performance**

  - **Temperature Effects**
    - Solar Panel - Higher Temperature (Lower Power Output)

  - **Component Aging Effects**
    - Solar Panel – Power Output Decreases with Age
    - Storage Battery – Battery Capacity Decreases with Age
  - **Weather Conditions**
    - Air Moisture (Rain/Fog) Reduces Solar Insolation (Greater Absorption of Light) and Lowers Irradiance Levels

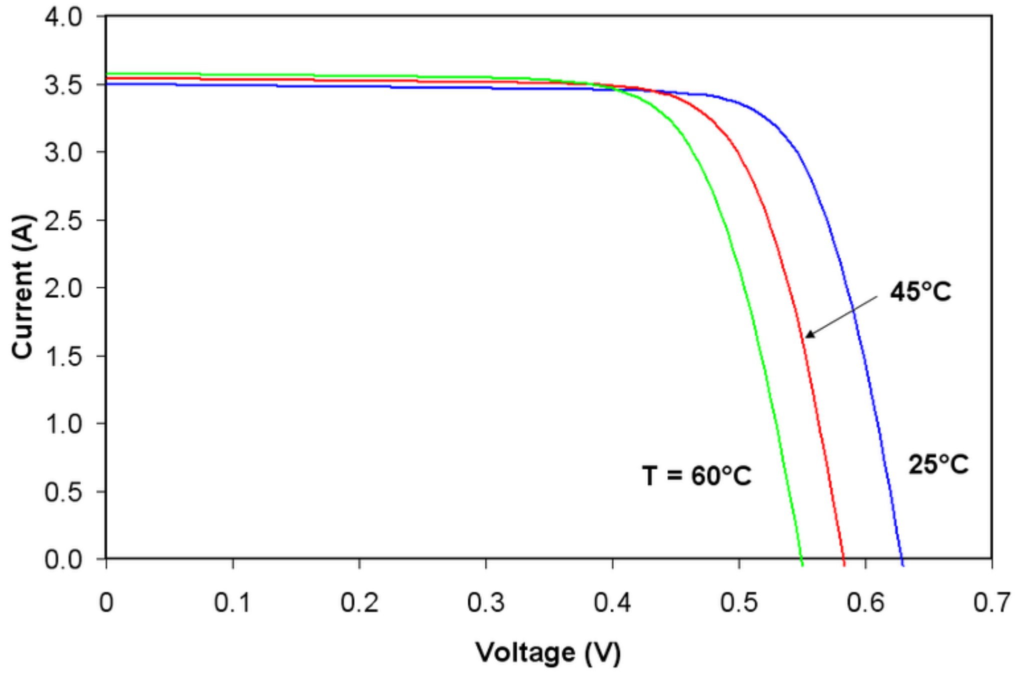
  - **Air Quality Conditions**
    - Dust/Smog Reduces Solar Panel Power Output (Greater Scattering of Light) and Lowers Irradiance Levels

  - **Irradiance Levels and Shading (Soft and Hard)**
    - Effect Solar Panel Power Output - Greater Effect between 9am – 3pm (Solar Time)
      - Reduces the Amount of Solar Insolation Reaching Panels
      - Greater Shading (Lower Power Output)

  - **Battery Characteristics - Discharge Rate and Depth of Discharge**
    - Faster Discharge – Lower Battery Capacity
    - Greater Depth of Discharge – Shorter Service Life
    - Temperature Effects on Battery Capacity and Service Life

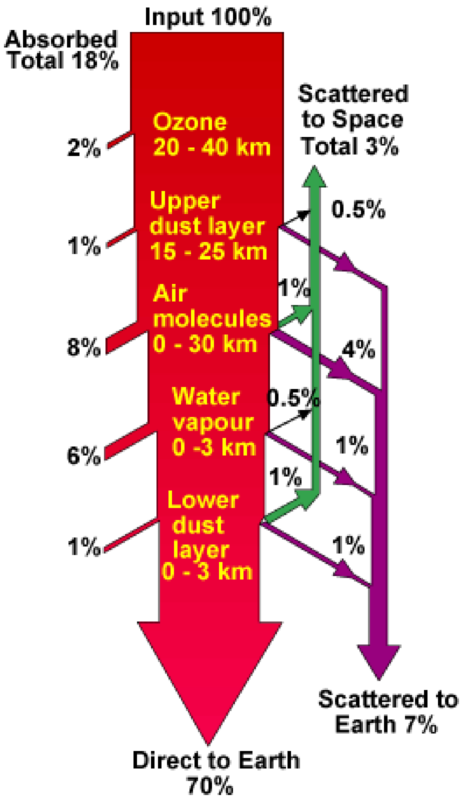
Solar Powered Warning Light System Design

- **Solar Panels - Effects of Temperature on Panel I-V Curve and Power**



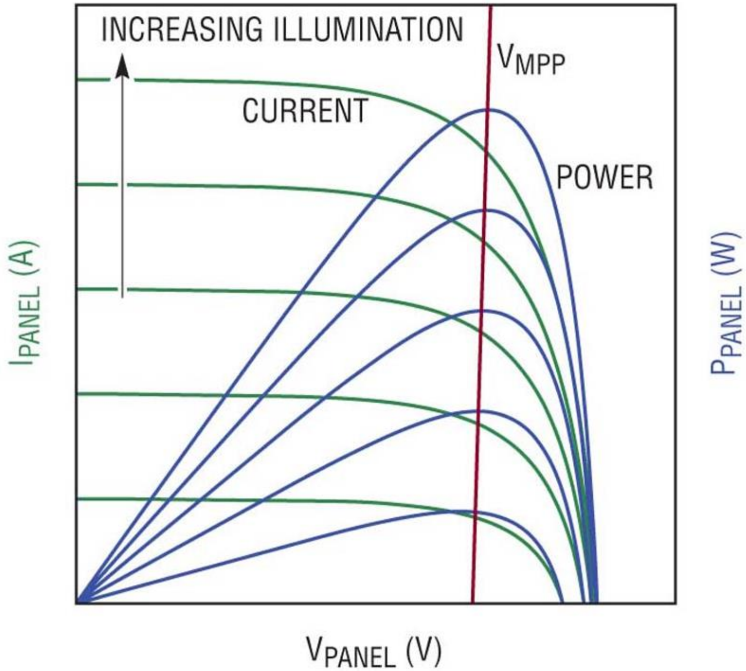
Solar Powered Warning Light System Design

- **Atmospheric Effects on Irradiance Levels**



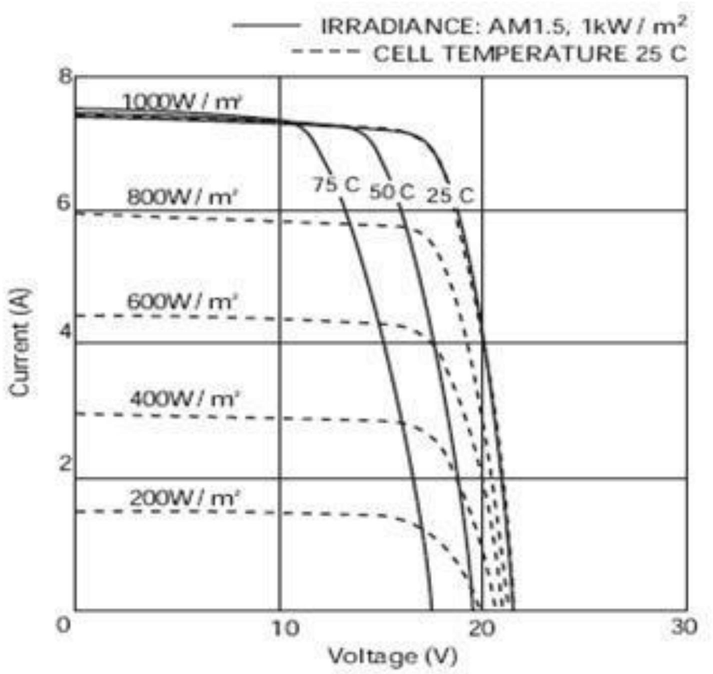
Solar Powered Warning Light System Design

➢ **Solar Panels - Effects of Irradiance (Light Intensity) on Panel I-V Curve**
- Lowered Irradiance Levels Referred to as Soft Shading



Solar Powered Warning Light System Design

➤ **Solar Panels – Standard vs. Photovoltaic Test Conditions**



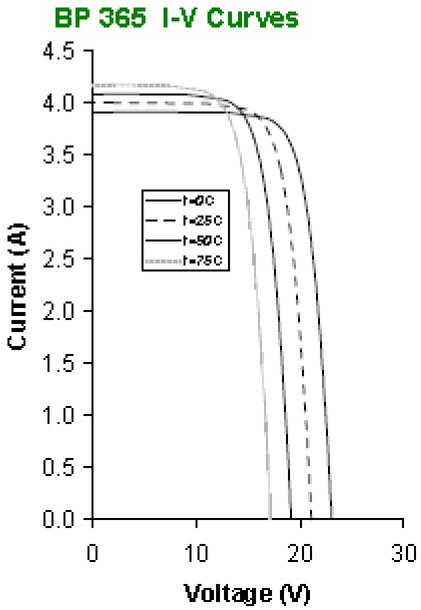
PV Panels Tested Using STC (Standard Test Conditions), Uses 25° C (Cell)

More Realistic to use PTC (PV Test Conditions) for Evaluations, Uses 20° C (Ambient)

Note: PVC = 88% STC

Solar Powered Warning Light System Design

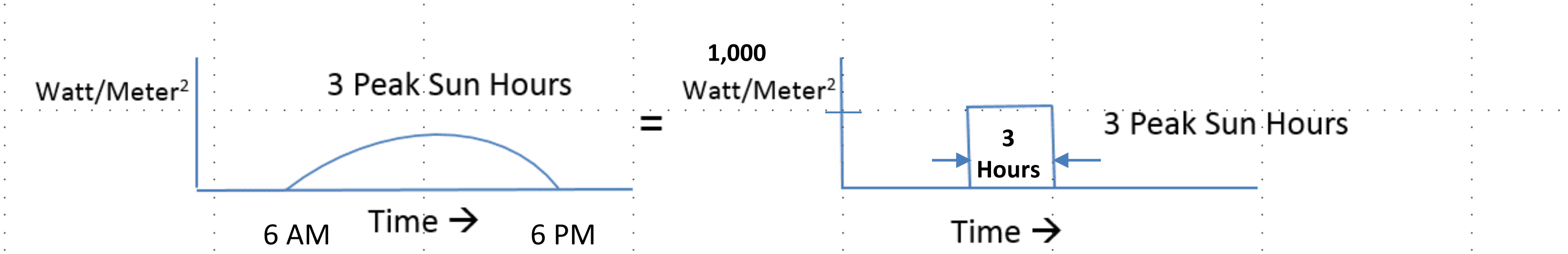
- **Design Example: In-Roadway Warning Light System**
  - **Energy Input**
    - **Energy is generated by the solar panel (Conversion process)**
    - **Solar Panels are rated for a power output under standard conditions**



Electrical Characteristics[2]	BP 365
Maximum power (P_{max})[3]	65W
Voltage at Pmax (V_{mp})	17.6V
Current at Pmax (I_{mp})	3.69A
Warranted minimum P_{max}	60W
Short-circuit current (I_{sc})	3.99A
Open-circuit voltage (V_{oc})	21.7V
Temperature coefficient of I_{sc}	(0.065±0.015)%/ °C
Temperature coefficient of V_{oc}	-(80±10)mV/°C
Temperature coefficient of power	-(0.5±0.05)%/ °C
NOCT (Air 20°C; Sun 0.8kW/m²; wind 1m/s)	47±2°C
Maximum series fuse rating	20A
Maximum system voltage	600V (ETL & IEC61215 rating)

Solar Powered Warning Light System Design

- **Insolation – Average Daily Solar Energy at a Site (Expressed in Sun Hours)**
  - **Peak Sun Hour**

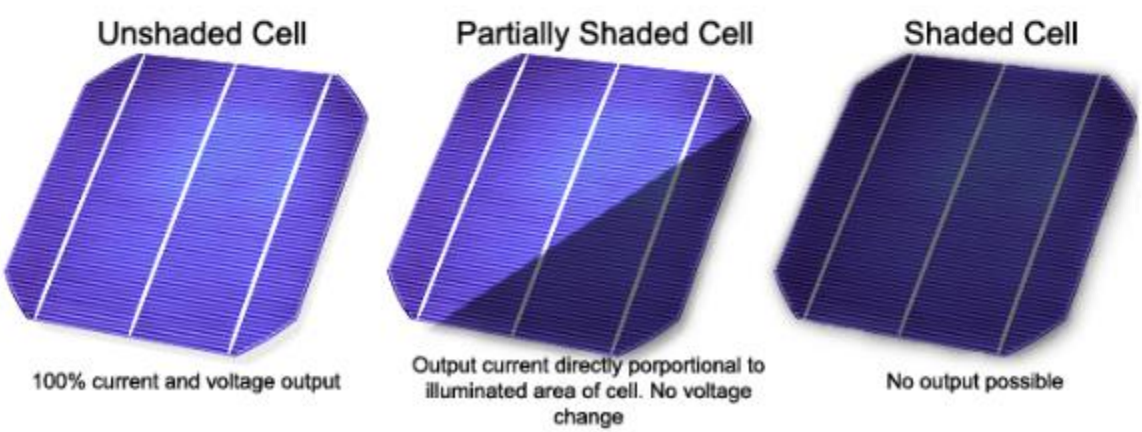


  - **Insolation**
    - Sun's Available Power Varies During the Day
    - Available Energy (Insolation) is Power x Time
    - Standard Power of 1,000 Watts/Meter Squared is Used the Calculation (Solar Panels are Rated at this Level) to Covert the Unit of Energy to Peak Sun Hours (Sun Hours)
    - **Example - BP365: Pm = 65 watts, Vm = 17.6 Volts, Im = 3.69 Amps**

      If Peak Sun Hours = 3, Then Im x Sun Hours = 3.69 x 3 = 11 Amp-Hours (Approximately
    - **Note:** Solar Panel Sizing is Based on the Lowest Monthly Insolation for the Year (Lowest Energy Input) with Shading Effects Taken into ASccount

Solar Powered Warning Light System Design

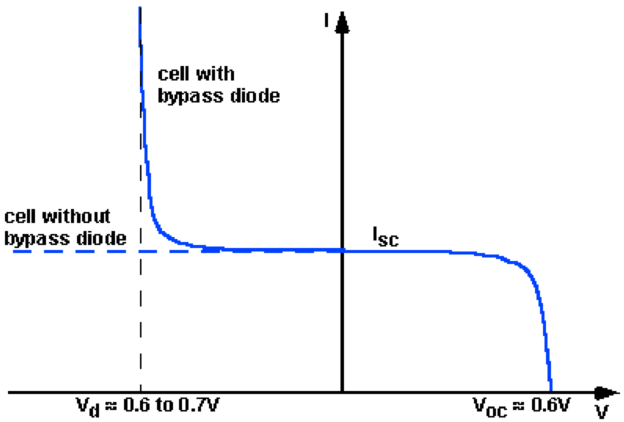
- **Solar Panels – Hard Shading Effects**

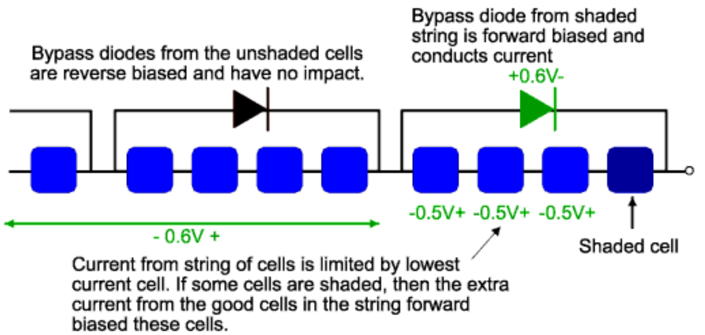


Rated Output	**Current Reduction**	**Current & Voltage Reduction**

Solar Powered Warning Light System Design

➤ **Solar Panel Hard Shading Effects – Bypass Diodes**

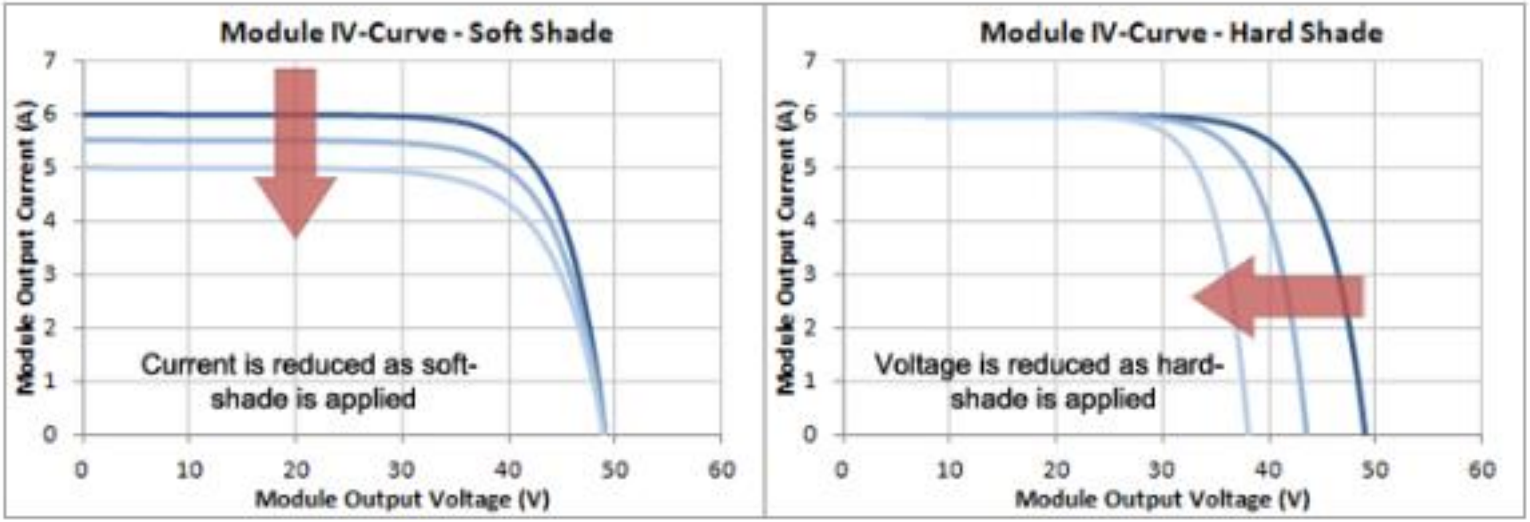




Bypass diodes across groups of solar cells. The voltage across the unshaded solar cells depends on the degree of shading of the poor cell. In the figure above, 0.5V is arbitrarily shown.

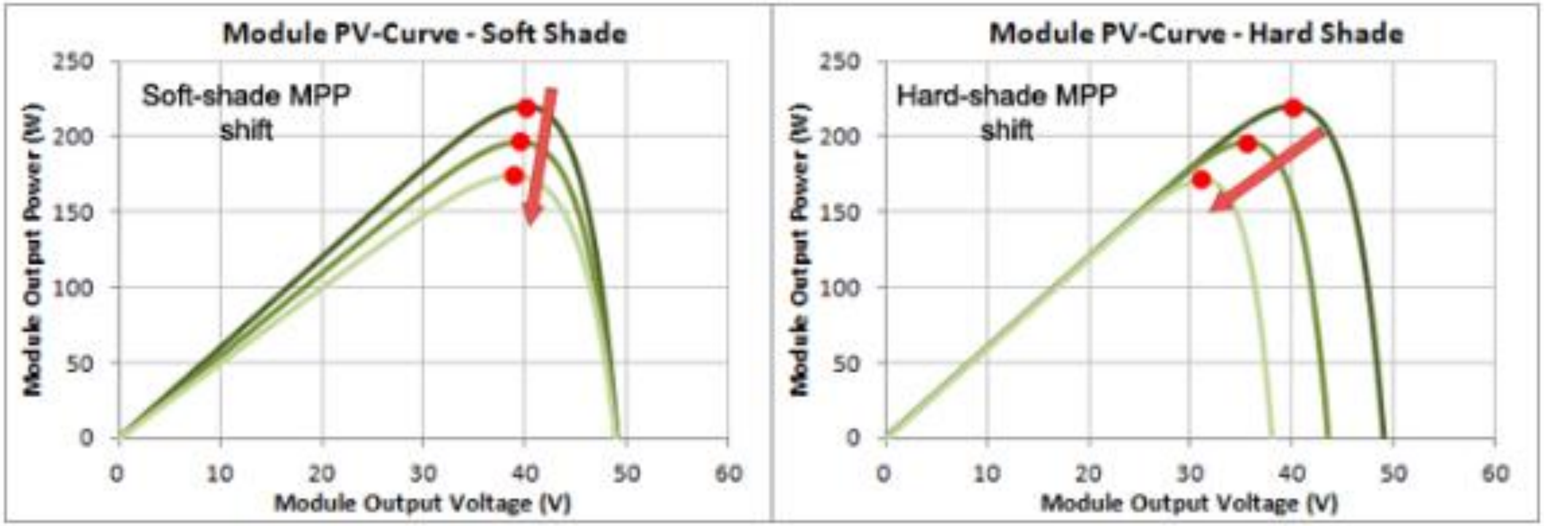
Solar Powered Warning Light System Design

➢ **Solar Panel Shading Effects**



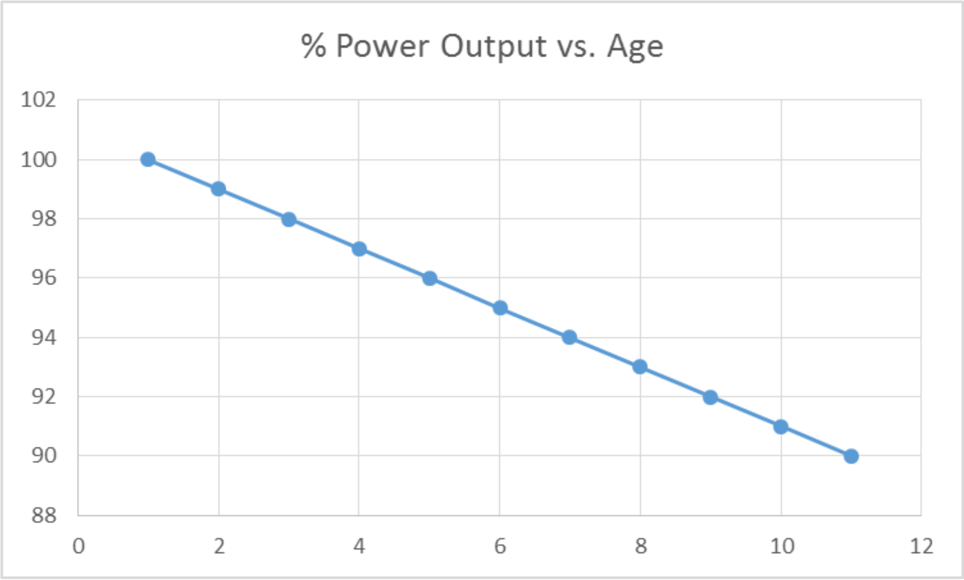
Solar Powered Warning Light System Design

- **Solar Panel Shading Effects**



Solar Powered Warning Light System Design

- **Solar Panel – Effects of Aging on Power Output**



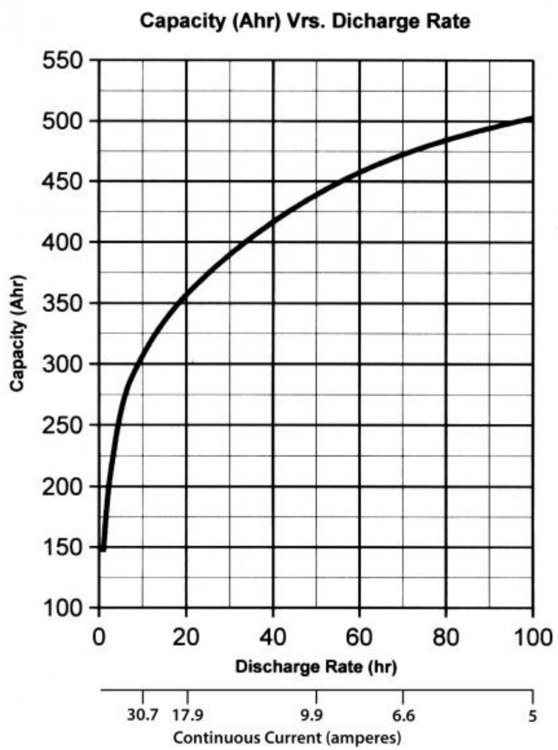
Years

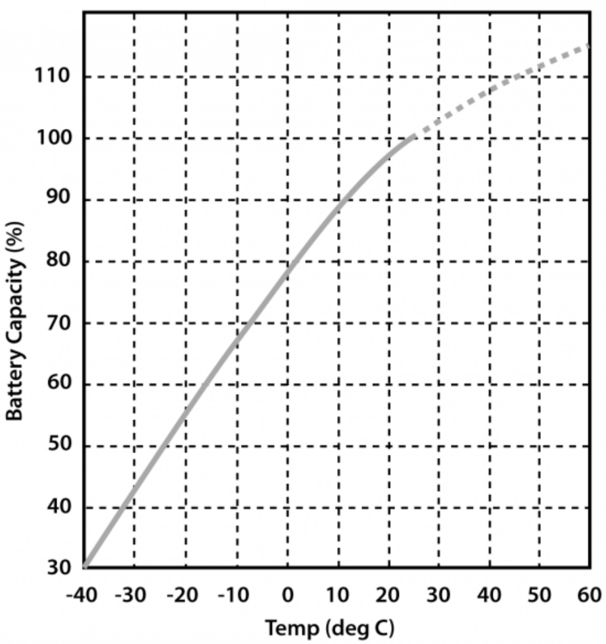
Typical Warranties

10 Year	90% Output Power
25 Year	80% Output Power

Solar Powered Warning Light System Design

- **Battery Characteristics- Effect of Discharge Rate and Temperature on Battery Capacity**

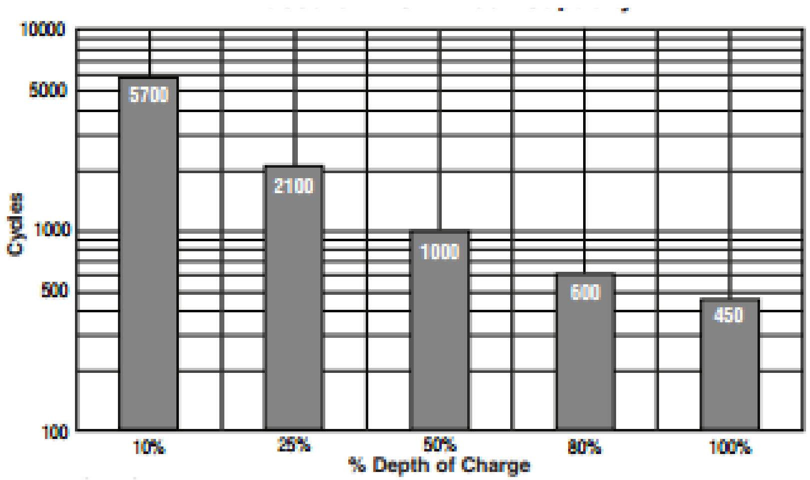




Solar Powered Warning Light System Design

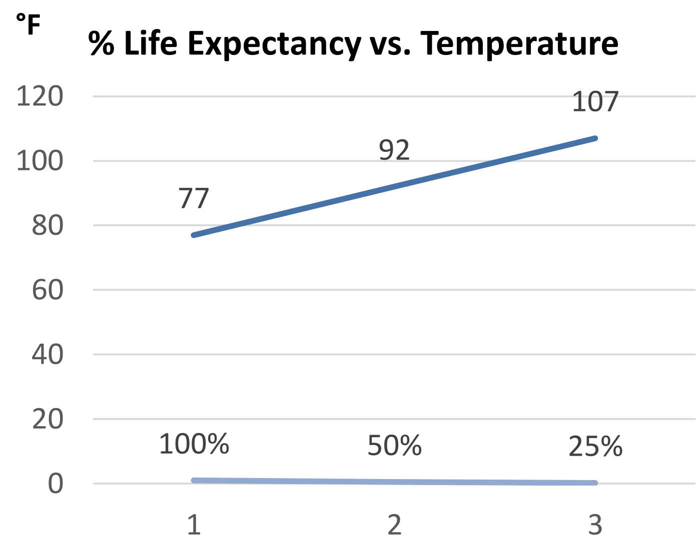
- **Battery Characteristics - Effects of Depth of Discharge and Temperature on Battery Service Life (80% Capacity)**

Life Expectancy vs. Depth of Discharge



Note @10%: 5,700 Cycles = 15.6 Years

% Life Expectancy vs. Temperature



Solar Powered Warning Light System Design

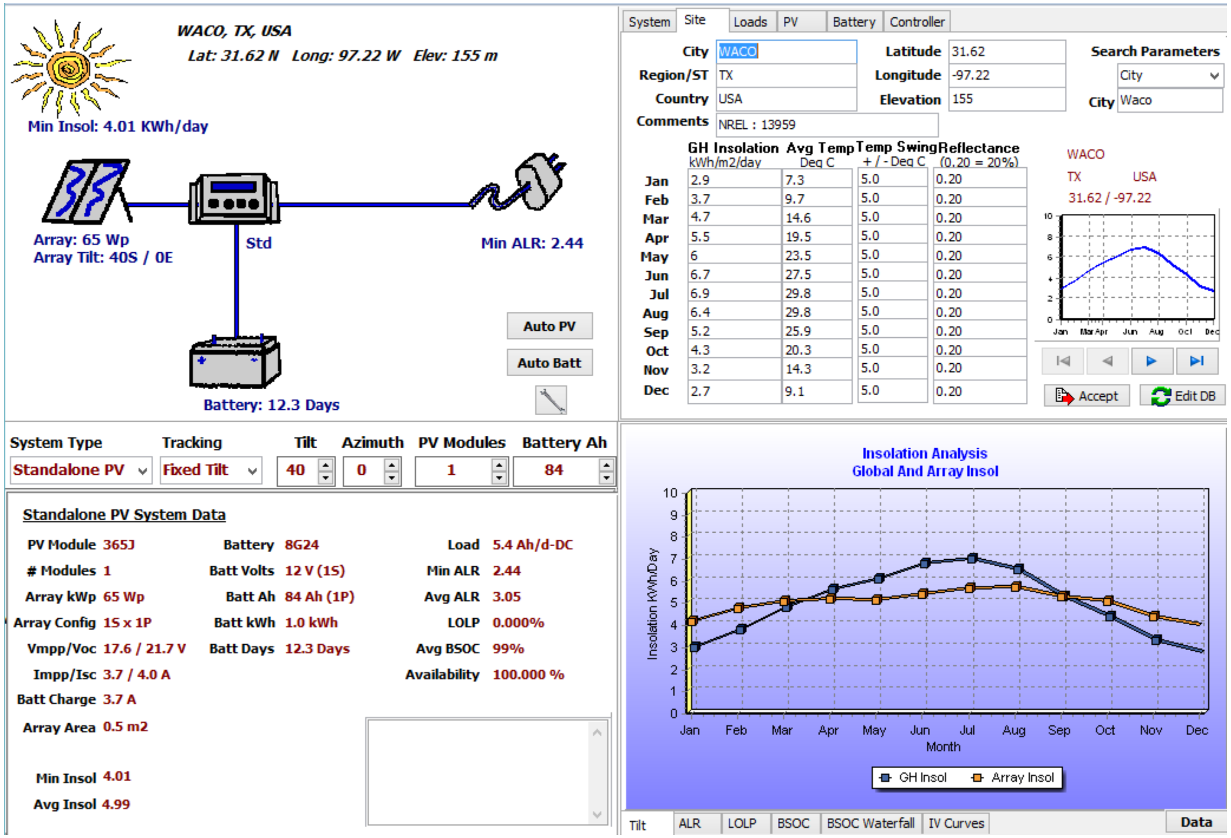
- **Design Example: In-Roadway Warning Light System**
  - **Design Problem**
    - **Given:**
      - Load Current and Energy Usage Requirements (Calculation)
      - Monthly Insolation (Data Base), Adjusted for Shading Effects (Measurement)
      - System Performance Requirements (Specified)
      - Knowledge of the Effects of Environmental and Component Factors
    - **Calculate**:
      - Solar Panel Size (Power and Current Capability)
      - Storage Battery Size (Energy Capacity)

Solar Powered Warning Light System Design

- **Design Process**
  - **If Done Right, Is a Very Involved Process and Requires a Good Deal of Time**
  - **Our Technique**
    - **Assist Customer with Setting System Requirements and Site Survey**
    - **Front End Software** → Used to Calculate the Load Current, Daily Energy Requirements, and Shading Energy Factors
    - **Back End Software** → Used to Take Into Account the Design Performance Requirements, Environmental Factors, and Component Limitations
    - **Result of the Process** → Sizing Report Used to document the Results of the Process that Certifies that a Proper Design Process has been Used and Specifies all Key Design Parameters and Solar Component Requirements
  - **Recommendation** → Always ask for a **"Sizing Report"** when Ordering a Solar Powered System

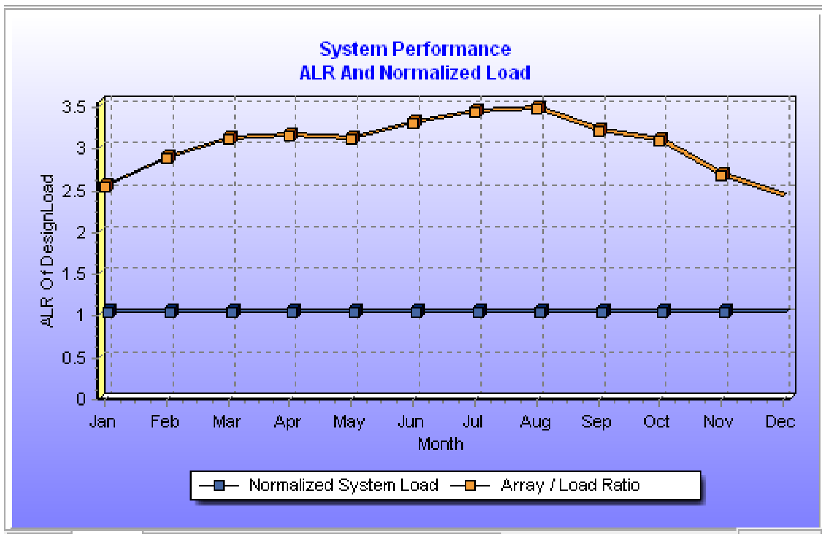
Solar Powered Warning Light System Design

- **Sizing Report Summary**



Solar Powered Warning Light System Design

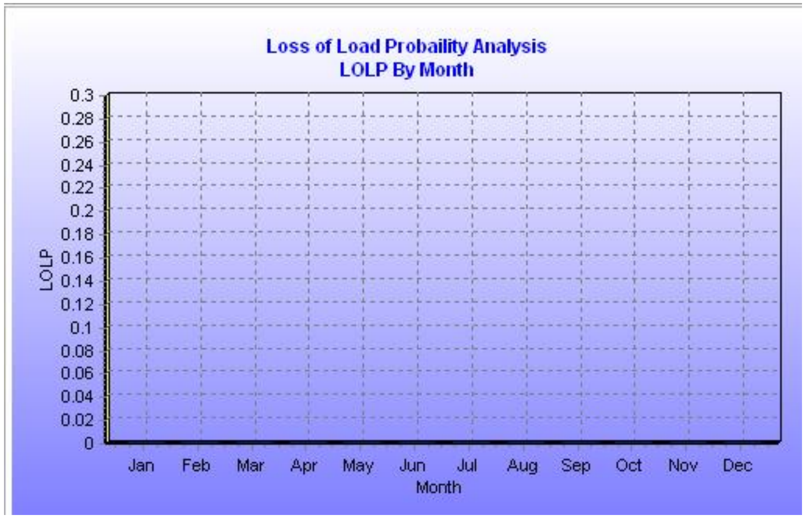
- **Sizing Report – Array to Load Ratio**



	Array	Avg	Array	Load	Night	Sys	Batt	ALR
Mont	kWh/m2	DegC	Ah/Day	Ah/Day	Load %	Loss %	Days	
Jan	4.18	7.3	13.9	5.4	50	10	11.60	2.55
Feb	4.76	9.7	15.8	5.4	50	10	11.73	2.90
Mar	5.11	14.6	17.0	5.4	50	10	11.98	3.11
Apr	5.19	19.5	17.2	5.4	50	10	12.18	3.17
May	5.12	23.5	17.0	5.4	50	10	12.30	3.12
Jun	5.42	27.5	18.0	5.4	50	10	12.34	3.31
Jul	5.66	29.8	18.8	5.4	50	10	12.34	3.45
Aug	5.71	29.8	19.0	5.4	50	10	12.34	3.49
Sep	5.27	25.9	17.5	5.4	50	10	12.34	3.21
Oct	5.10	20.3	16.9	5.4	50	10	12.21	3.11
Nov	4.40	14.3	14.6	5.4	50	10	11.97	2.69
Dec	4.01	9.1	13.3	5.4	50	10	11.70	2.44

Solar Powered Warning Light System Design

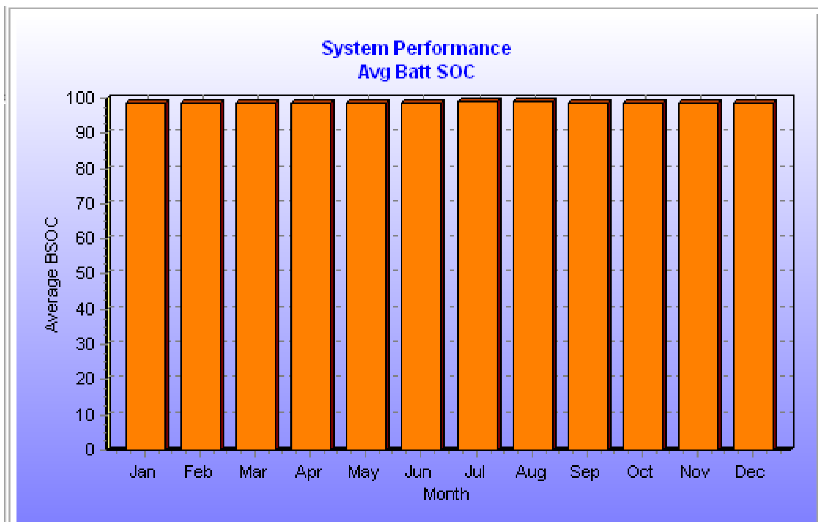
- **Sizing Report – Loss Of Load Probability**



Mont	Array Insol kWh/m2/d	Variability (%)	Correlation (%)	System (%)	Array/Loa Ratio	Avg BSOC (%)	LOLP (%)
Jan	4.18	0.37	0.34	10	2.55	99	0.000
Feb	4.76	0.35	0.34	10	2.90	99	0.000
Mar	5.11	0.30	0.22	10	3.11	99	0.000
Apr	5.19	0.29	0.33	10	3.17	99	0.000
May	5.12	0.28	0.34	10	3.12	99	0.000
Jun	5.42	0.25	0.21	10	3.31	99	0.000
Jul	5.66	0.21	0.22	10	3.45	99	0.000
Aug	5.71	0.22	0.21	10	3.49	99	0.000
Sep	5.27	0.29	0.22	10	3.21	99	0.000
Oct	5.10	0.31	0.22	10	3.11	99	0.000
Nov	4.40	0.36	0.35	10	2.69	99	0.000
Dec	4.01	0.38	0.33	10	2.44	99	0.000

Solar Powered Warning Light System Design

- **Sizing Report – Battery State of Charge**



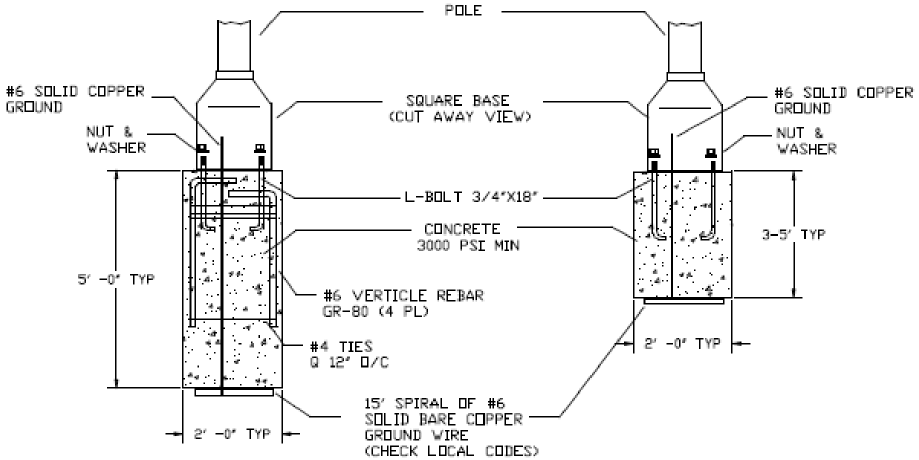
BSOC	Bin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
92-	100	98.9	99.4	99.7	99.9	99.9	99.9	100.0	100.0	99.8	99.7	99.2	98.9
84-	92%	1.0	0.6	0.3	0.1	0.1	0.1	0.0	0.0	0.2	0.3	0.8	1.1
76-	84%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68-	76%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60-	68%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52-	60%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-	52%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36-	44%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-	36%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-	28%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avg		98.5	98.7	98.7	98.8	98.8	98.9	98.9	98.9	98.8	98.8	98.6	98.6

Solar Powered Warning Light System Design

- **System Installation Points**
  - **Pole Foundation Requirements**
    - Wind Loading, Soil Conditions, Local Codes
  - **Panel Orientation**
    - Orient in the True South Direction to Maximize Energy Generation
  - **Panel Tilt**
    - Optimize for Maximum Energy Generation in the Winter Months
  - **Panel and System Grounding**
    - Protection System from Lightning and Maintenance People from Electrical Shocks

Solar Powered Warning Light System Design

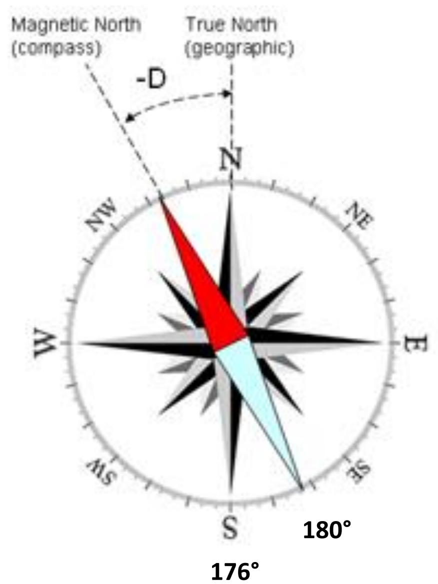
- **System Installation Points**
  - **Pole Foundation Requirements**



Note: Typical plans. Provided for Reference. Consult with a Civil Engineer regarding foundation details for your specific application. Foundations will vary depending on wind conditions, soil type, and items hung on the pole.

Solar Powered Warning Light System Design

- **System Installation Points**
  - **Panel Orientation – Solar Panel Should be Mounted Facing True South for Maximum Performance**



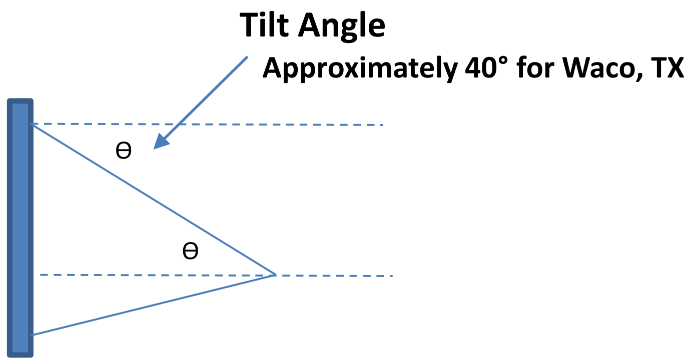
True South = 180° + Declination
(East is Negative)

True South = 176° Magnetic

Solar Powered Warning Light System Design

- **System Installation Points**
  - **Panel Tilt Angle – Solar Panel Should be Tilted**

SITE LATITUDE	NEAR OPTIMAL SOLAR PANEL TILT ANGLE (°)
0 - 9	15
10 - 20	LATITUDE + 5
21 - 45	LATITUDE + 10
46 - 65	LATITUDE + 15
65 - 90	80



Waco, TX → Latitude = 31.5°
Tilt Angle = 31.5 + 10 = 40°

Solar Powered Warning Light System Design

- **System Installation Points**
  - **Panel Grounding**

Solar Powered Warning Light System Design

- **Benefits of Solar Powered Systems**
  - **Allows Installation at Remote Sites**
  - **No Restoration Concerns or Expenses**
  - **Fast Deployment**
  - **Low Operating Costs**
  - **Equipment Costs are now Comparable to AC Powered Systems**

Solar Powered Warning Light System Design

- **Solar Power System Deployment Limitations**
  - **Areas of Low Insolation**
  - **High Wind Areas**
  - **Architectural Compatibility Concerns**
  - **Future Environmental Concerns**
  - **Large Obstructions (Buildings)**

Solar Powered Warning Light System Design

Traffic Safety Corporation
Website: www.xwalk.com

Ted Vaeches
Marketing Manager

Office Phone: 888-446-9255

Cell Phone: 916-267-1008

Email: Ted.Vaeches@xwalk.com