ENGINEERS WITHOUT BORDERS USA

SOLAR ELECTRICITY

BASICS & HANDS-ON

2015 REGIONAL CONFERENCES

PRESENTED BY THE EWB-USA
ENERGY STANDING CONTENT COMMITTEE

INTRODUCTION

What is the EWB-USA Energy Standing Content Committee?

- ESCC is a group of subject-matter experts, with decades of experience in energy technologies
- Dedicated to serving EWB-USA energy projects through creation of guidelines, educational materials, and direct consultation

A few members of the ESCC

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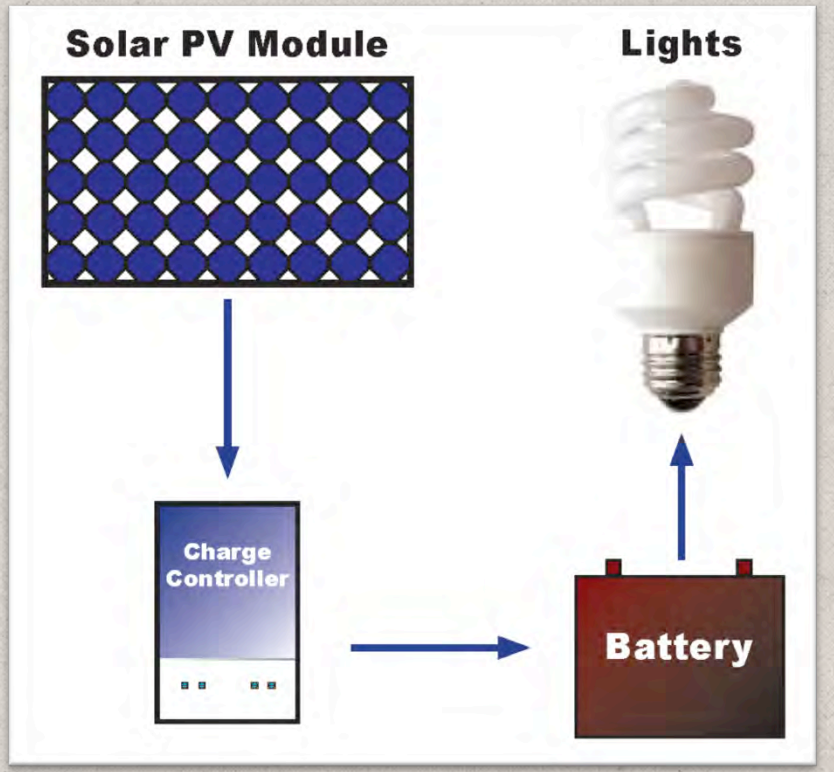
INTRODUCTION
Why This Presentation?

- Common applications
- Components
- Resources
- Hands-on
- What it's not:
  - Comprehensive
  - Design focused (but other resources are available)

Solar pumping system, Cameroon (Georgia Tech Student Chapter)

APPLICATIONS
Solar Lighting

- Major components
  - Solar module
  - Charge controller
  - Battery
  - Lights
- Benefits: Lights! Can improve education and economics
- Common failures
  - Batteries (more later)
  - Overuse of resources, causing batteries to fail
  - Lack of maintenance



Typical parts for a solar lighting system

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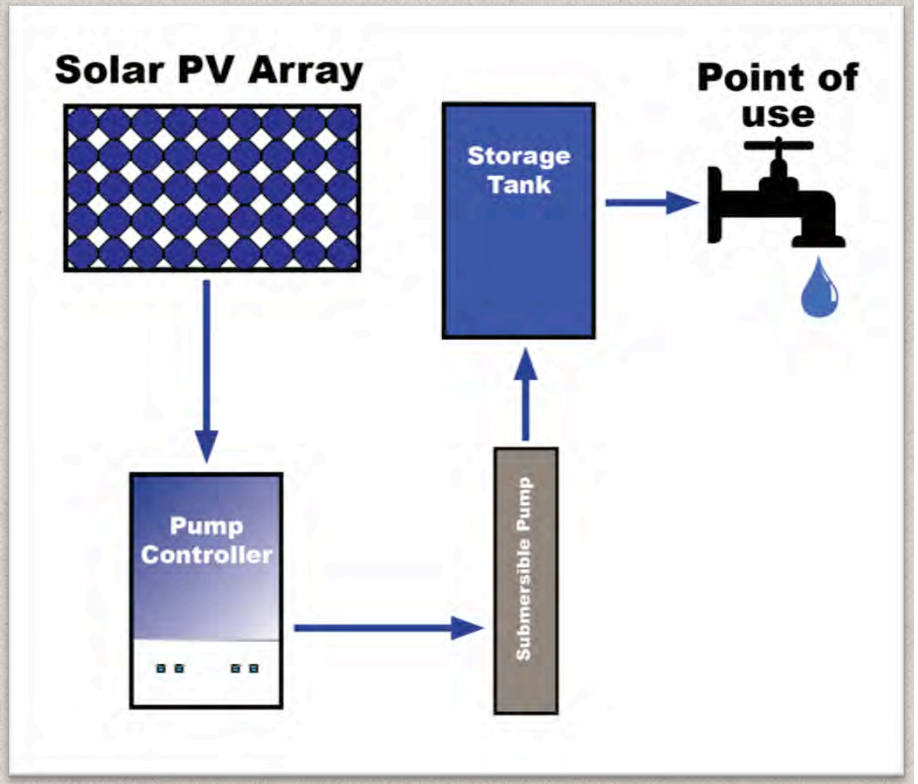
APPLICATIONS
Solar Water Pumping

- Major components
  - Solar module
  - Controls
  - Solar pump
  - Batteries (in some cases)
- Benefits: Water! Health benefits, agriculture, etc. Common failures or challenges
  - Pump failures
  - Limited water supply; needs increase over time



Typical parts for a solar water pumping system

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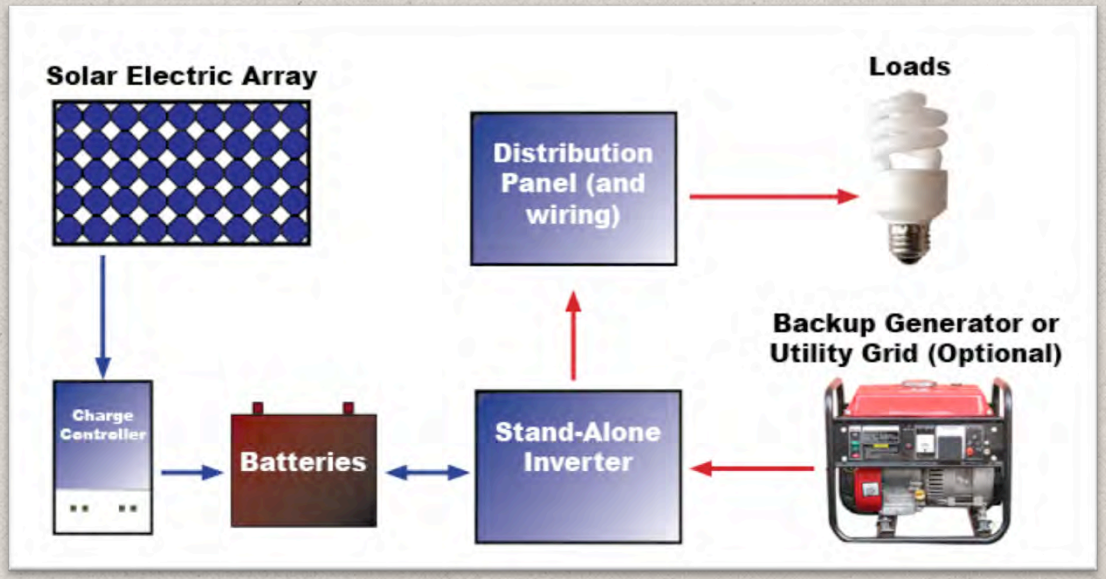
APPLICATIONS

Household or Facility Electricity Supply

- Major components
  - Solar module
  - Charge controller
  - Batteries
  - Inverter
  - Distribution wiring
- Benefits: Lights, appliances, etc.
- Common failures or challenges
  - Battery failure
  - Increased and unforeseen loads strain system
  - Lack of maintenance



Typical parts for household or facility electricity supply

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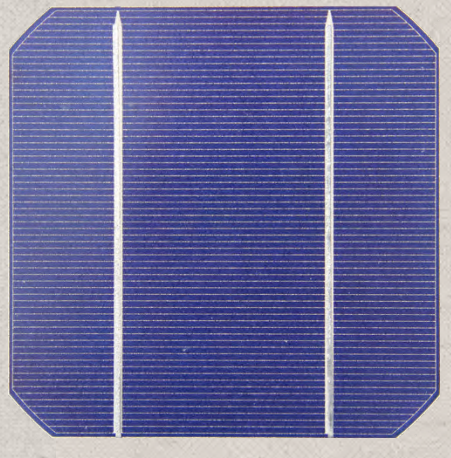
SYSTEM COMPONENTS
SOLAR ELECTRIC MODULES

Some Solar Terminology

- **Cell: individual component that converts sunlight into DC electricity**
- **Module: A group of cells wired together in series (for desired voltage) and parallel (for desired current)**
  - **May be monocrystalline, polycrystalline, or thin film.**
- **Array: A group of modules or panels mechanically connected or grouped**

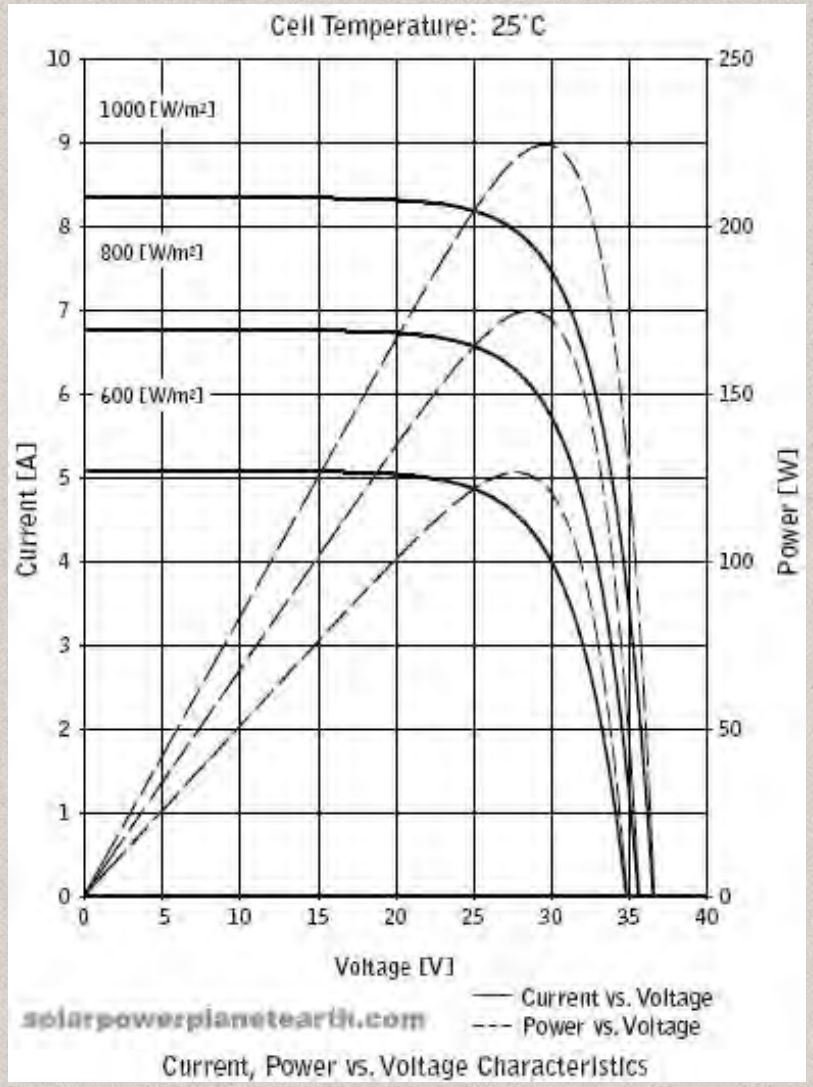
A solar array



A single cell from a PV module

SYSTEM COMPONENTS
Module performance

- Look at the specification label on an individual module or on manufacturer data sheets
- I/V Curves show power production for specific insolation & temperature
- Many factors such as sunlight intensity, shading, load resistance and cell temperature affect module performance



A single cell from a PV module

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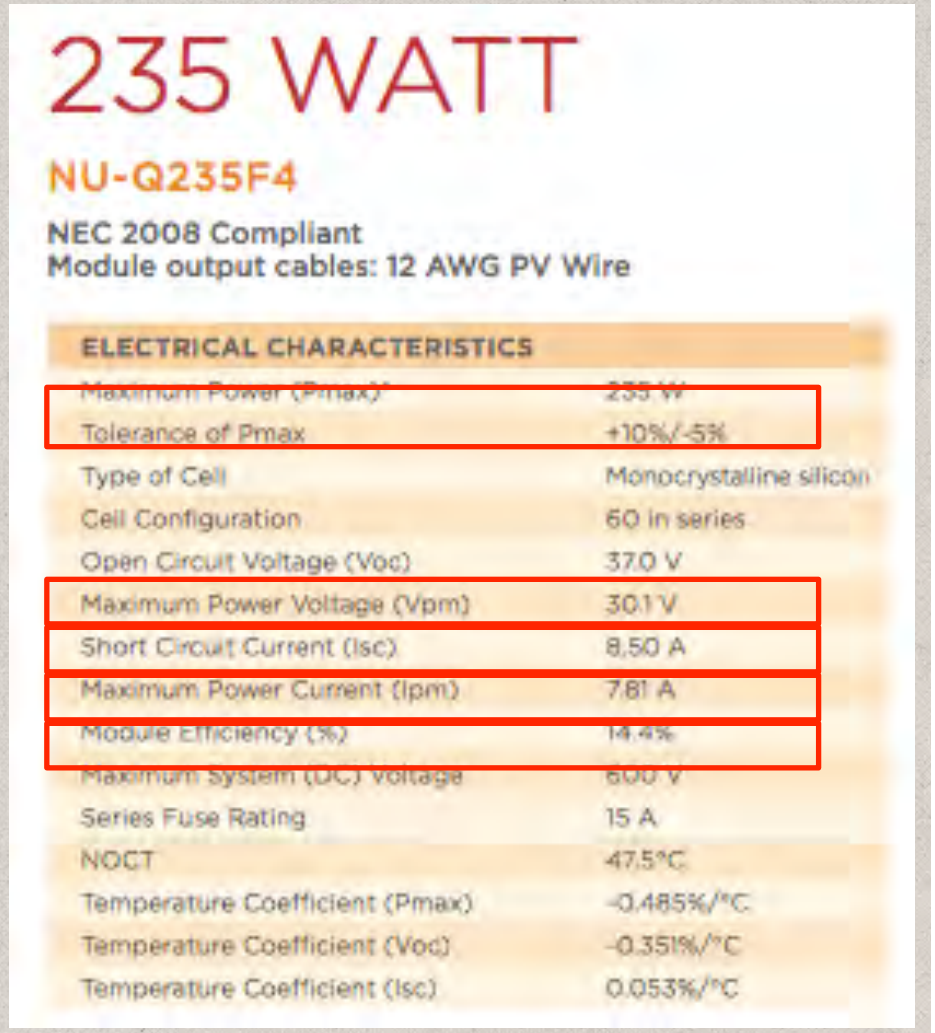
SYSTEM COMPONENTS

Module specification labels

- Max Power (Pmax) = Max Power Current (Imp) x Max Power Voltage (Vpm)
- Open Circuit Voltage (Voc) = max voltage with no current flow
- Short Circuit Current (Isc) = max output current under no load
- @Voc, Isc: P = 0 watts



235 WATT

NU-Q235F4

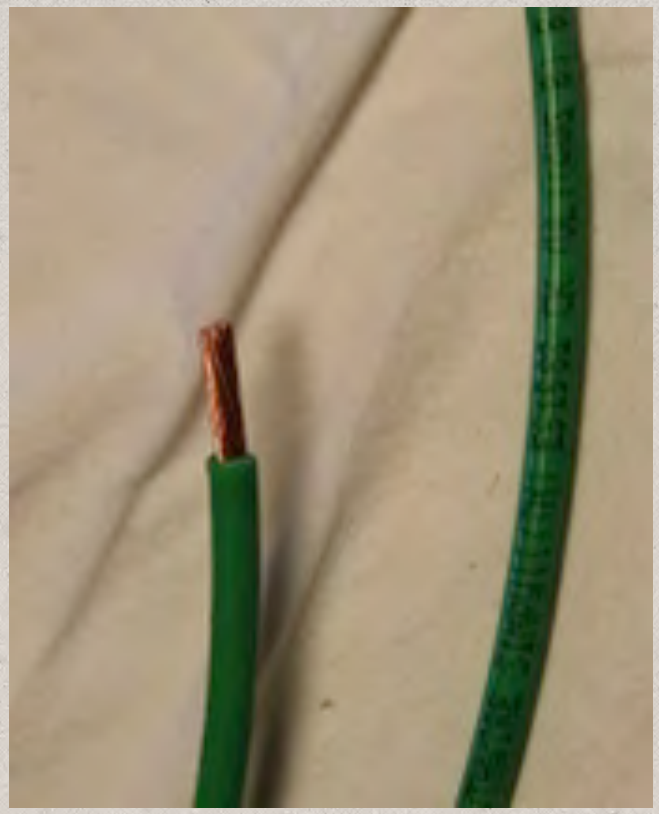
NEC 2008 Compliant
Module output cables: 12 AWG PV Wire

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	235 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Monocrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	37.0 V
Maximum Power Voltage (Vpm)	30.1 V
Short Circuit Current (Isc)	8.50 A
Maximum Power Current (Ipm)	7.81 A
Module Efficiency (%)	14.4%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.351%/°C
Temperature Coefficient (Isc)	0.053%/°C

A single cell from a PV module

SYSTEM COMPONENTS
Wiring

- For safety, wire size is determined by currents in the PV system
- For performance, wires are sized for appropriate voltage drop.
- Specific types of wires are required for various conditions.
- Electrical codes may specific color schemes, if and when wiring should be run in conduit, and details on how to properly size wiring
- Equipment and system grounding are usually required by electrical codes



Stranded copper wire

SYSTEM COMPONENTS

Overcurrent Protection

- Circuit breakers and fuses
- Required to protect circuits from electrical current which exceeds wire ampacity
- Electrical codes often require ungrounded conductors be protected by overcurrent protection
- Make sure overcurrent protection is rated for AC or DC as appropriate, and for proper voltage.

A DC-rated fuse

A DC circuit breaker

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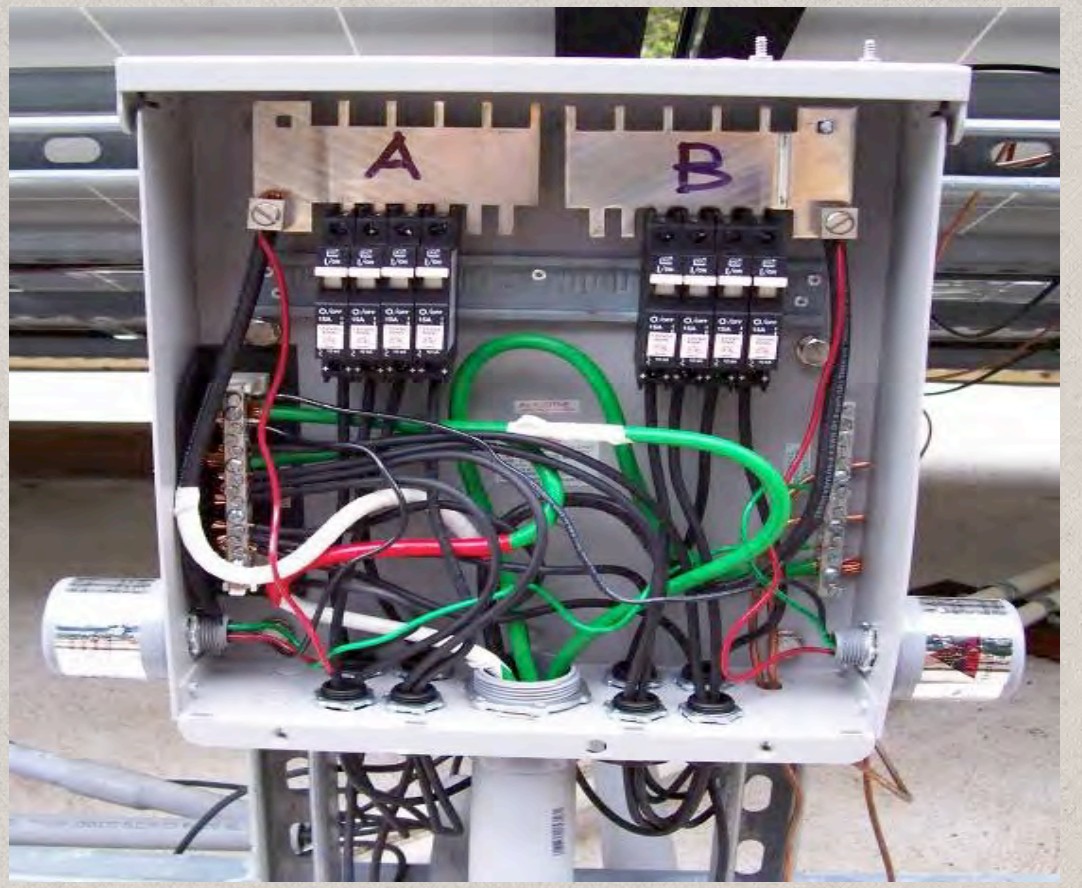
SYSTEM COMPONENTS

Combiner Boxes



A rooftop DC array combiner

SYSTEM COMPONENTS

Charge Controllers

- Monitors battery voltage
- Prevent batteries from becoming overcharged by regulating current
- Types: shunt, single-stage, diversion, pulse width modulation (PWM), MPPT
- PWM: most used
- Multi-stage charging algorithms: Bulk, absorption, and float
- Discharge protection (LVD)
- Many use maximum power point tracking (MPPT) to gain maximum energy
- Some controllers come in pre-wired enclosures also containing inverters and disconnects

A 6A charge controller with load terminals

SYSTEM COMPONENTS
Batteries

- Chemical storage of direct current electricity
- Storage for cloudy days, night, emergency backup
- Weakest link in the PV system: inefficient, susceptible to overcharging or overdischarge
- Can be divided into “deep-cycle” and “shallow-cycle construction
- Lead acid recommended for EWB-USA projects
  - Liquid vented
  - Valve Regulated Lead Acid (VLRA)

A small sealed lead acid battery

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SYSTEM COMPONENTS
Inverters

- Converts voltage from DC to AC
- Solar panels produce a DC voltage but many loads you power will require AC
- Desired features:
  - Efficient – often used with loads less than rated capacity
  - Frequency regulation
  - Ease of servicing in the field
  - Reliable, modular
- Each type of inverter (grid-tied, grid-tied with battery, stand-alone) has additional special features

A 300-watt true sine wave inverter

SYSTEM COMPONENTS
Disconnects

- Required to disconnect each piece of equipment in the PV system from power sources
- Must be easily accessible
- Can be circuit breakers or switched fuses (fuses are not considered disconnects)

A disconnect switch

BEST PRACTICES & ADDITIONAL INFO

ESCC RESOURCES

Recommendations for Solar PV Projects

- **Detailed recommendations for design, installation, start-up and testing, and documentation.**
- **On EWB-USA member website, *under Project Resources>EWB-USA Guidelines.***
- **Appendices include definition of terms, a list of related standards, and a checklist**

Design Checklist for Solar PV Projects

Steca charge controller, SureSine inverter, and 63A DC circuit breaker

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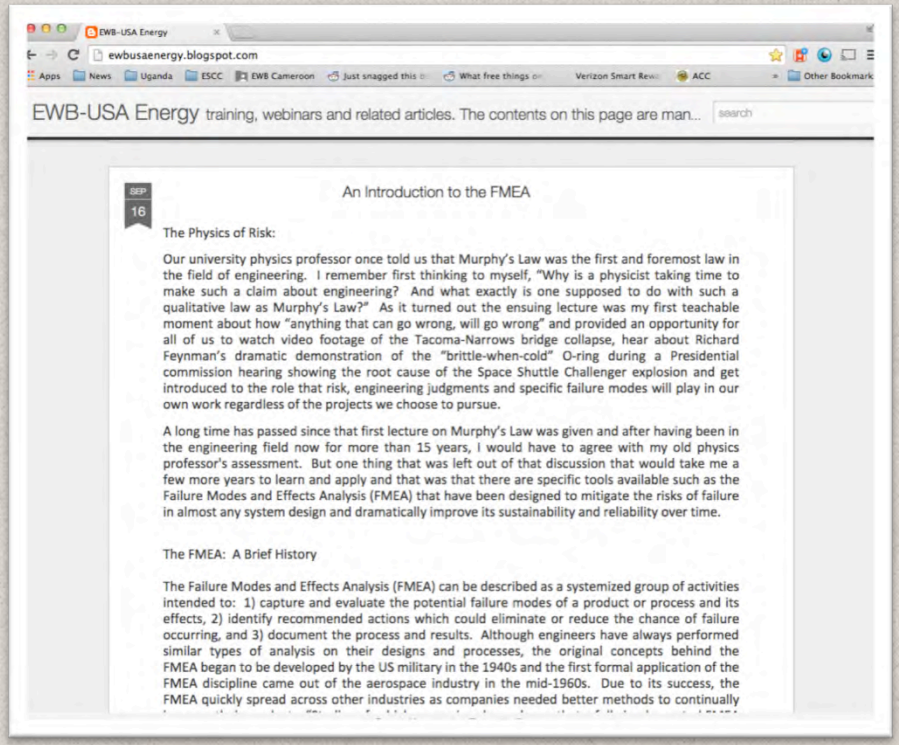
BEST PRACTICES & ADDITIONAL INFO

ESCC RESOURCES

EWB-USA Energy Blog

- Available at ewbusaenergy.blogspot.com
- A variety of original content and links to existing content
- Recent articles/links include:
  - An Introduction to the Failure Modes and Effects Analysis
  - Battery Operation & Maintenance (O&M) Tutorial
  - Solar PV Array Maintenance Checklist
  - More!



A recent post on the ESCC blog

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BEST PRACTICES & ADDITIONAL INFO

OTHER RESOURCES

- Technical best practices PowerPoint (available on request)
- Community-Driven Empowerment—An EWB-USA Approach to Solar PV in Developing Communities
  - Hardcopies available here, or electronic by request

Connecting microhydroelectric system penstock sections, Guatemala (Marquette University Student Chapter)

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ESCC Contact and Services Provided

Battery bank with wiring tray and charge controllers

Contact Us:

- Email: ewbenergy@gmail.com
- Blog: ewbusaenergy.blogspot.com

We Can Help With:

- Coaching services
- Informal consultation and pre-TAC review
- Post TAC hold or denial consultation
- Informal mentorship
- Travel as professional mentors
- Resources

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