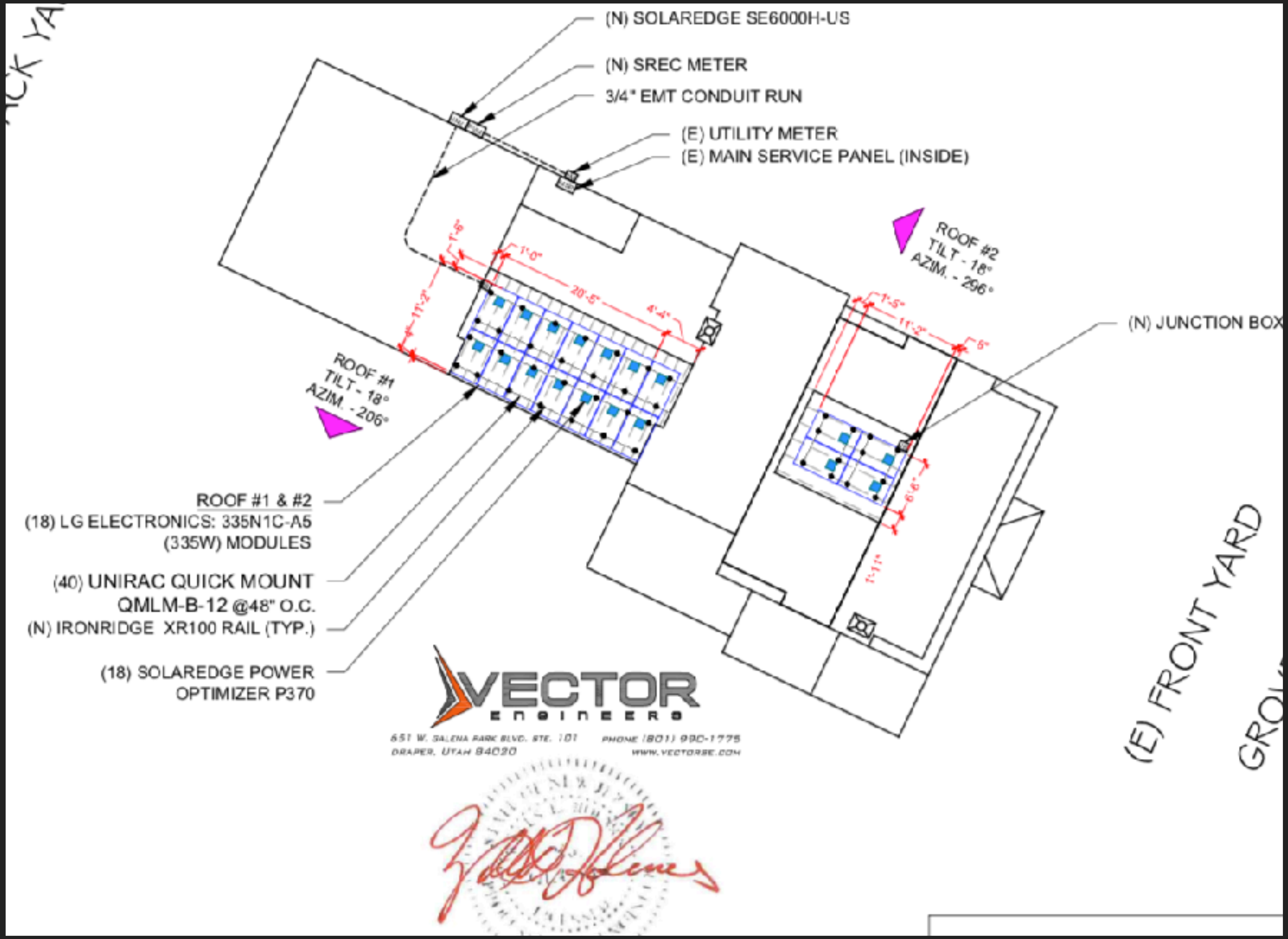
SOLAR STRATEGIES

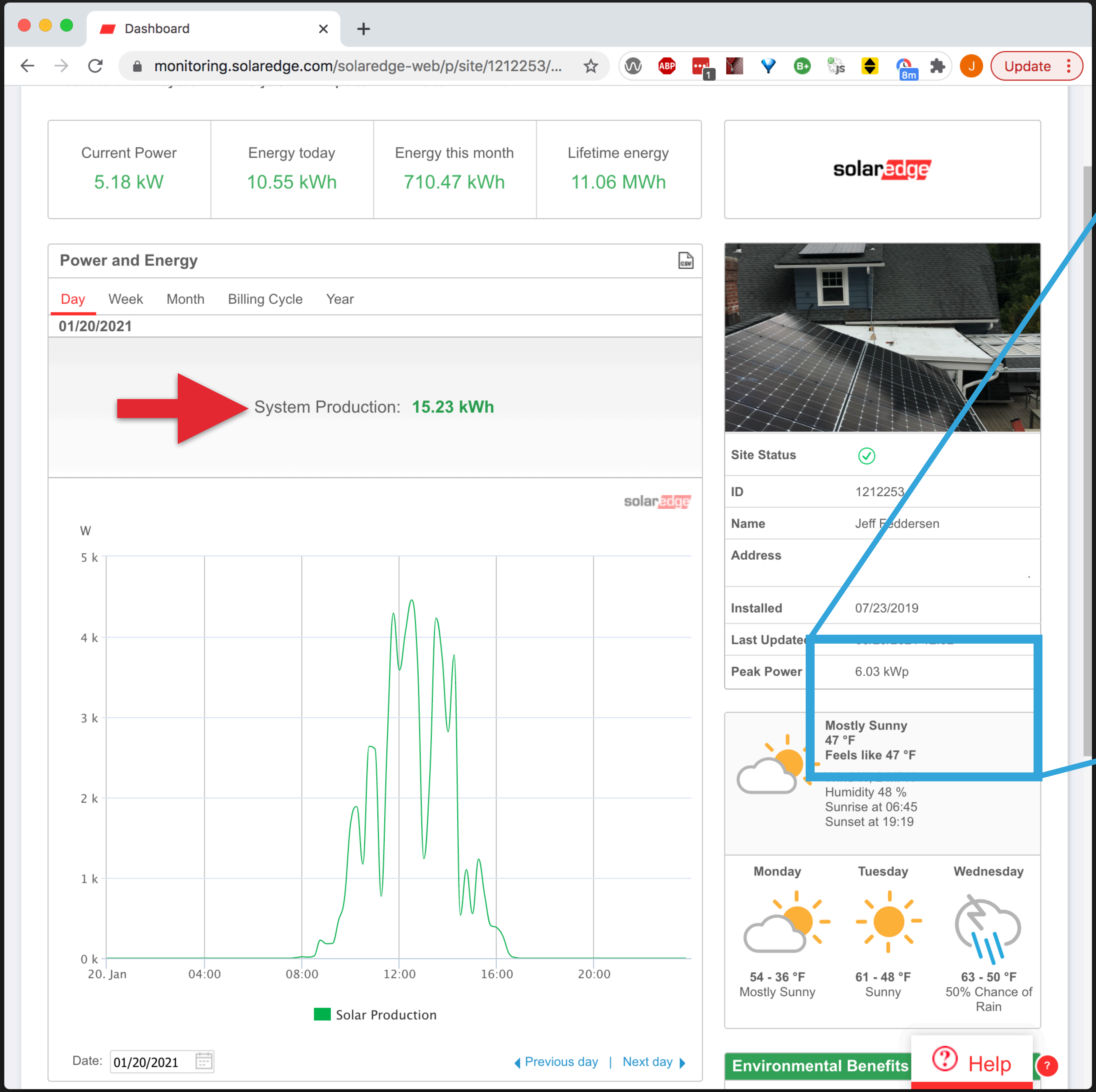
PLANNING SOLAR PROJECTS

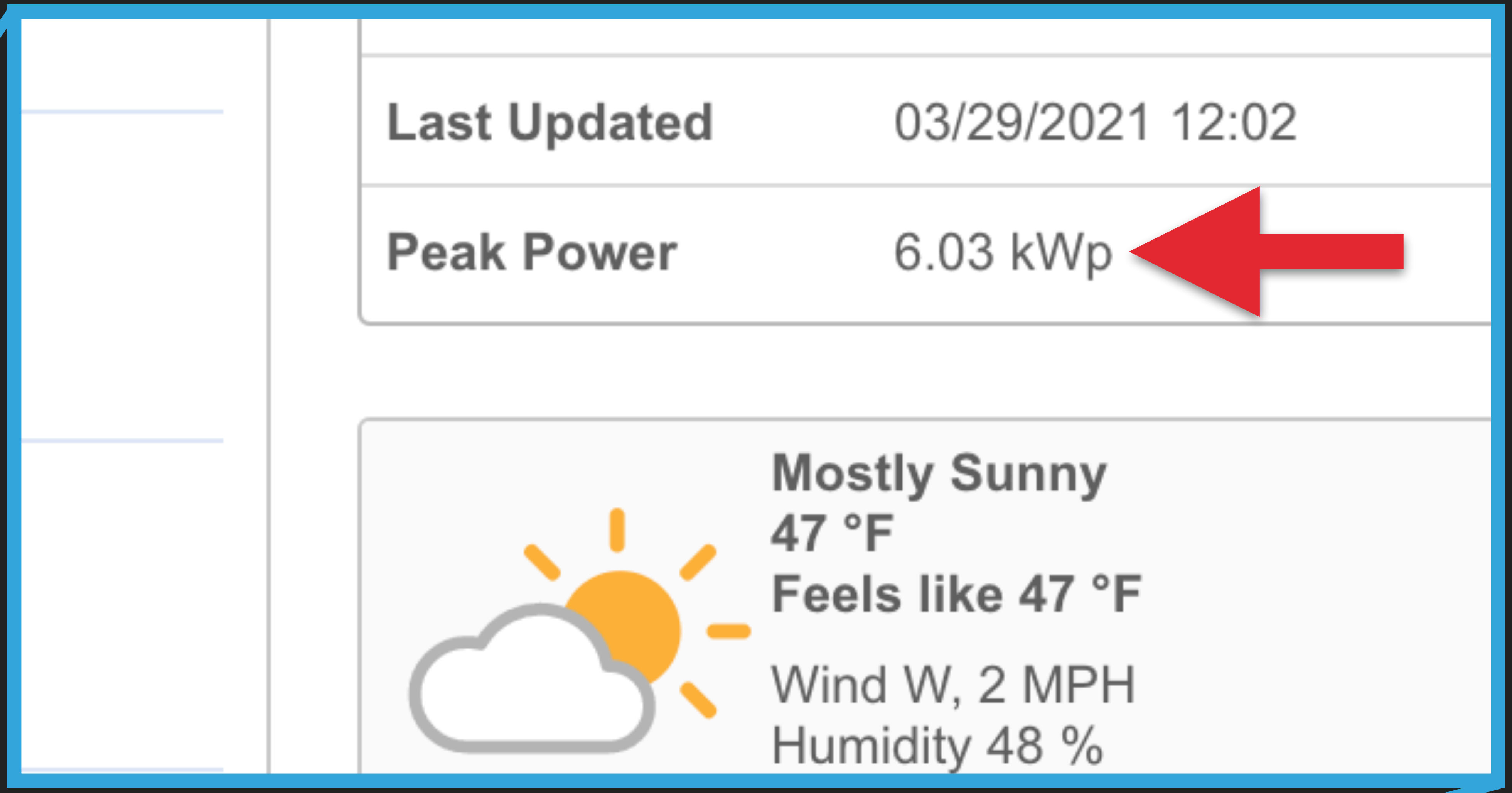
0. **Real-world introduction, sun hours**
1. **Get Light**
    1.1. Assessing Irradiance
    1.2. Shade Hurts!
    1.3. Testing
2. **Reduce Use**
    2.1. Energy Budget
    2.2. Deep sleep
    2.3. Go slow
3. **Put it Together**
    3.1. Sizing solar and storage for an imaginary application

A REAL-WORLD EXAMPLE (JEFF'S HOUSE!)



18 335W PANELS = 6030W PEAK





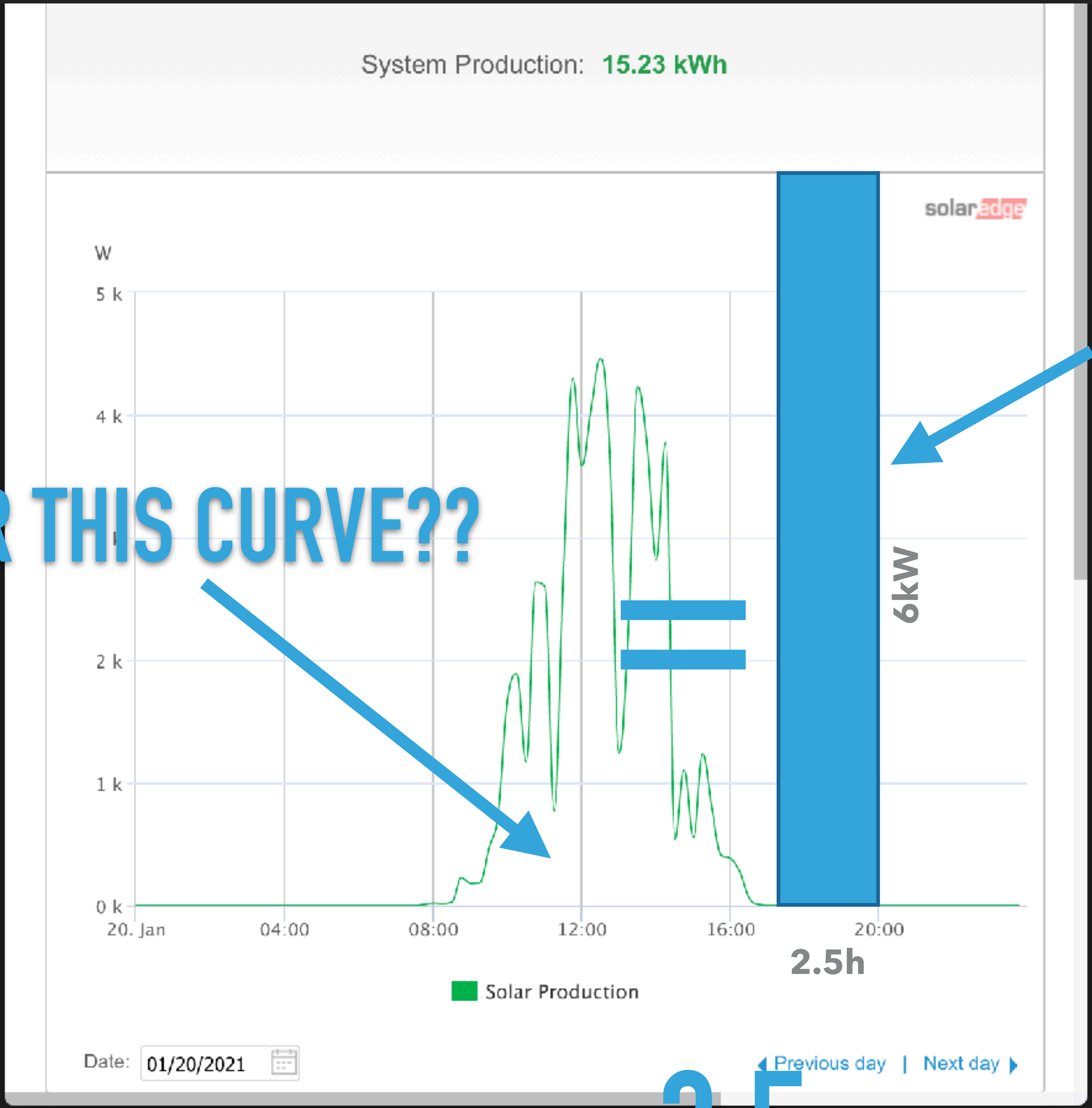
15.23 / 6 = 2.5

Think of this as meaning: *"The total energy I got today is as if I got the full output of my system (6kW) for 2.5 hours"*

In other words…

AREA UNDER THIS CURVE??

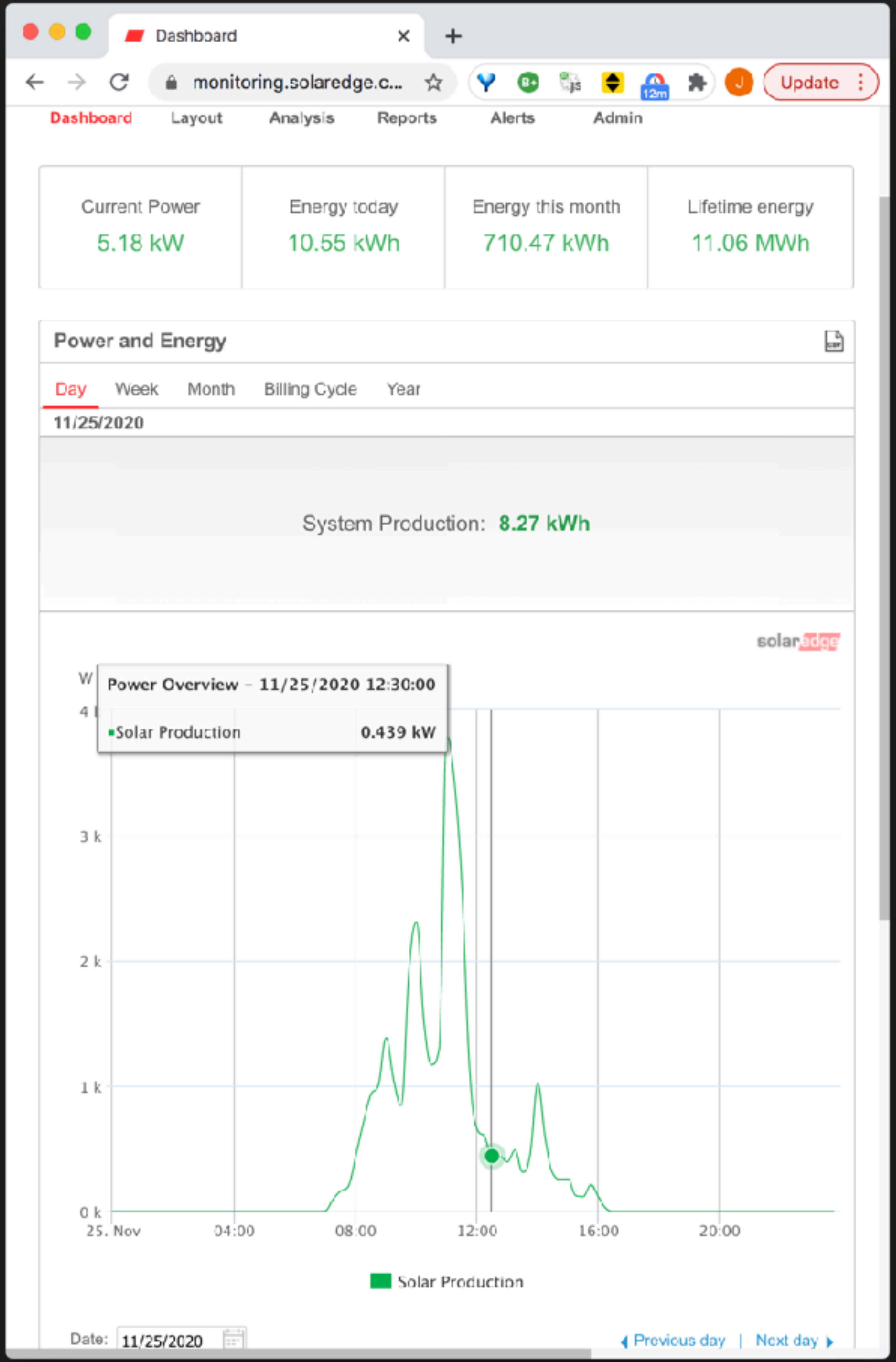
(psst: calculus integral)



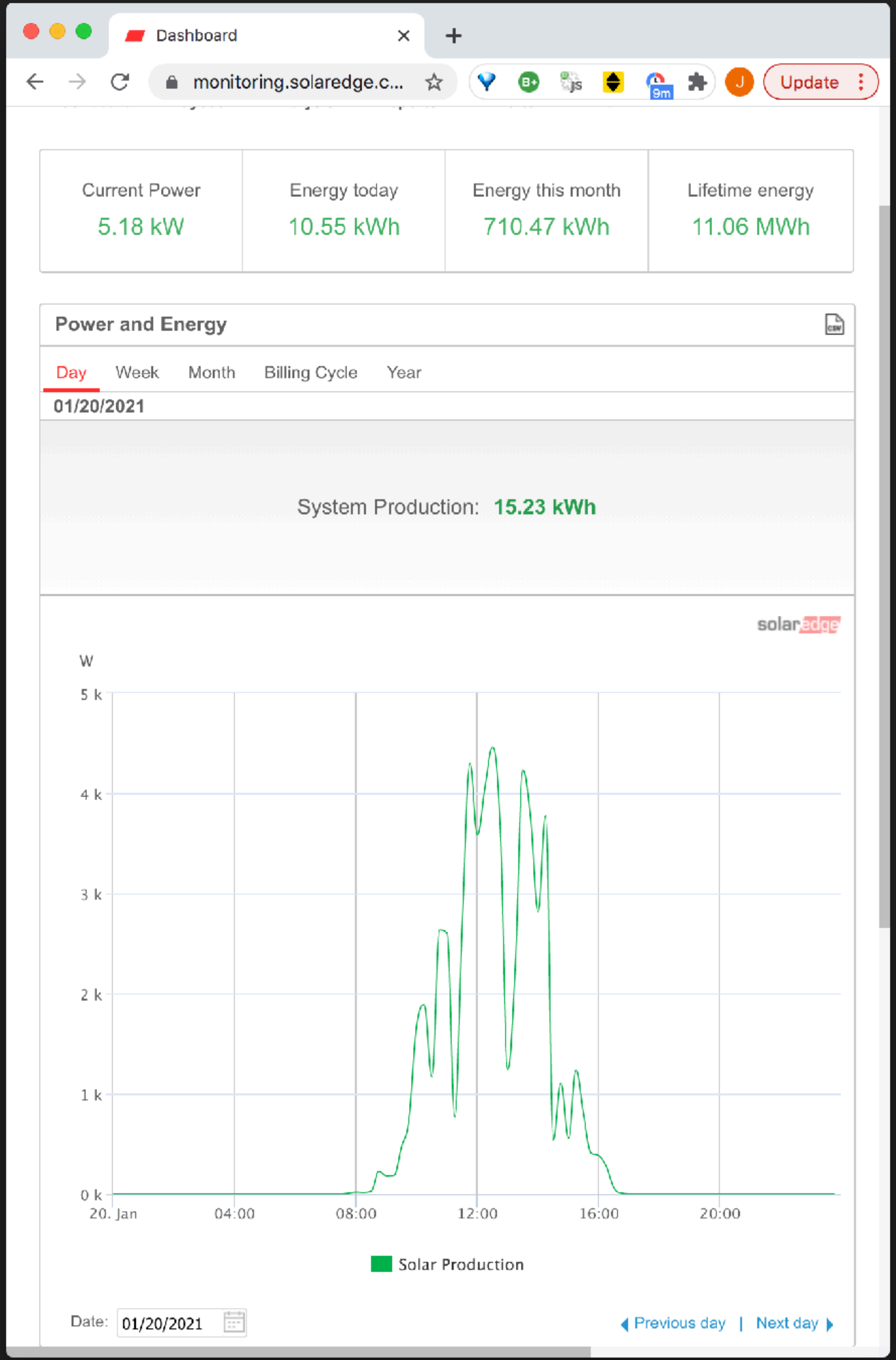
AREA OF THIS RECTANGLE

(arithmetic!)

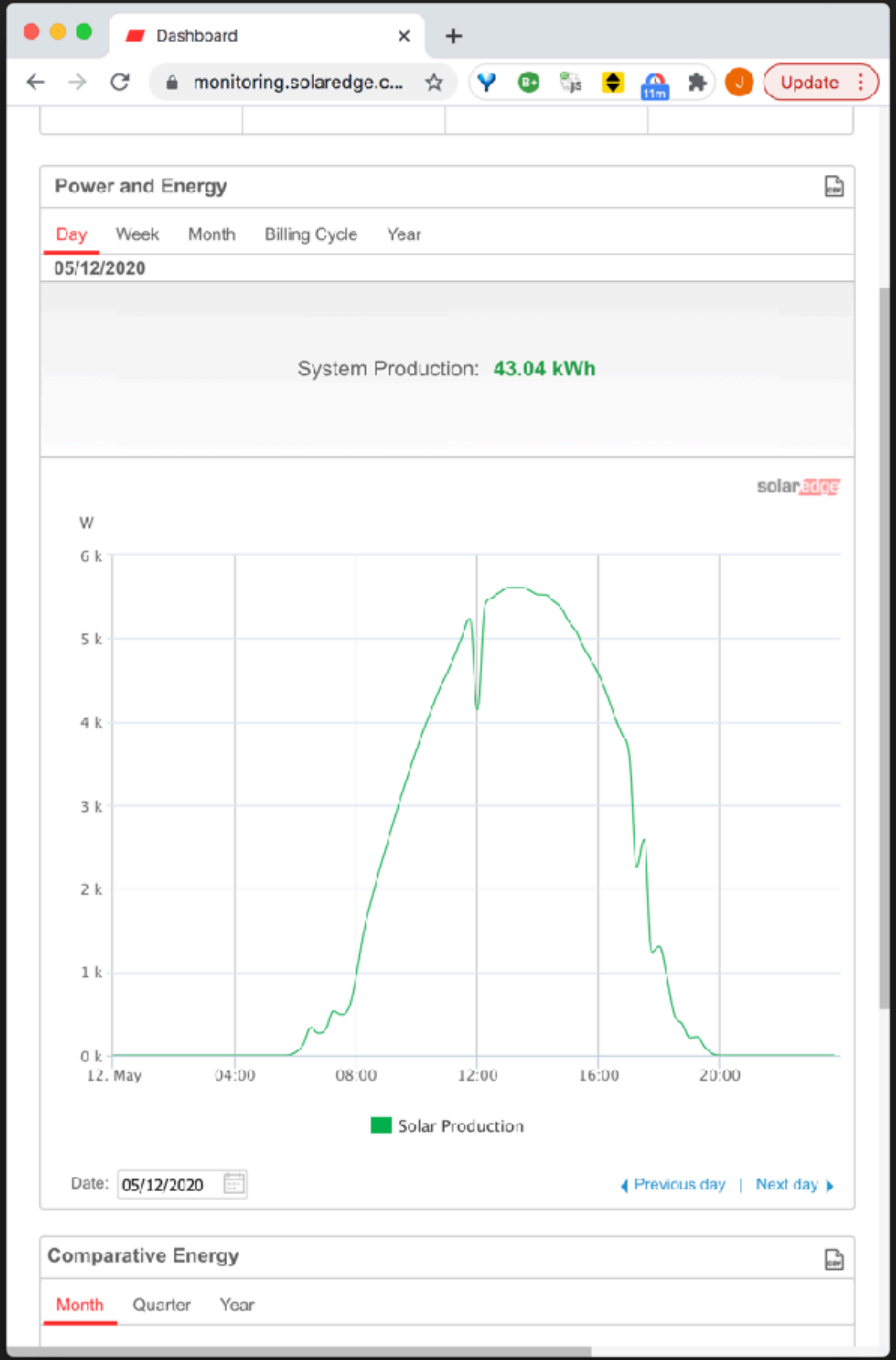
15.23 / 6 = 2.5



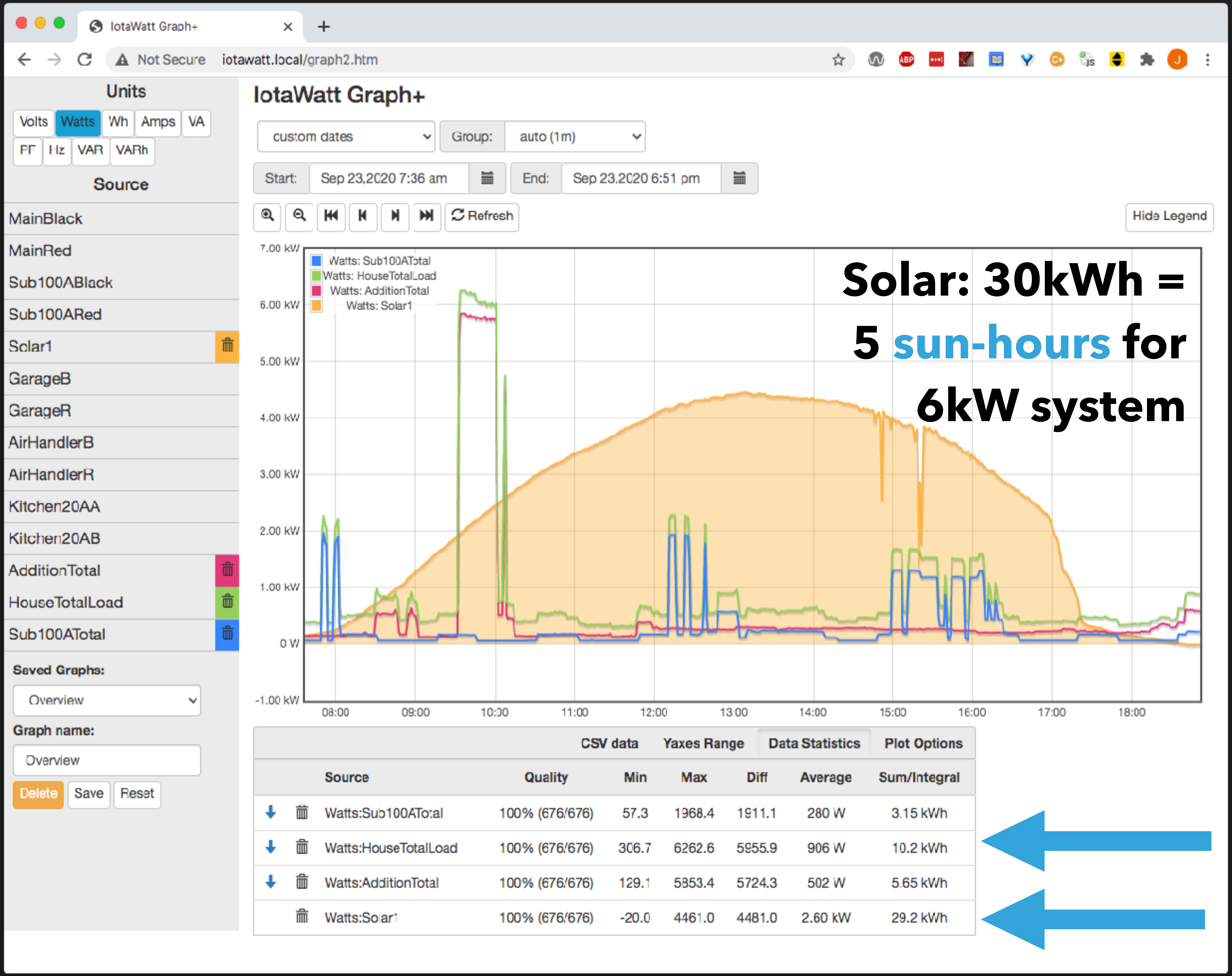
8.27 / 6 = 1.4



15.23 / 6 = 2.5



8.27 / 6 = 7.2



10kWh Application

30kWh Solar

GET LIGHT

THE SUN'S APPARENT POSITION CHANGES DAILY AND SEASONALLY. WEATHER HAPPENS. DEAL WITH IT.

image:physicsforums.com

image: solarsystem.nasa.gov

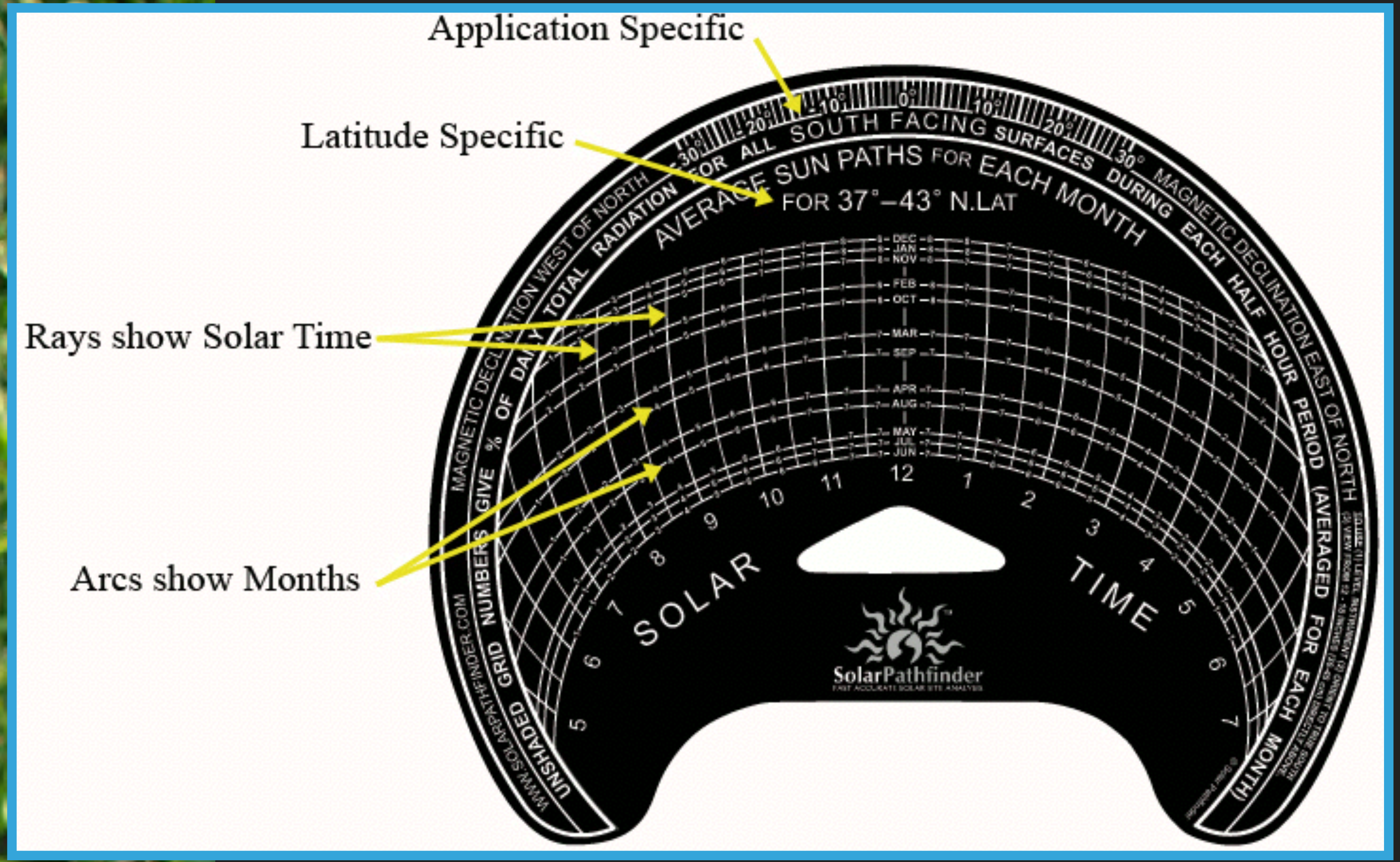


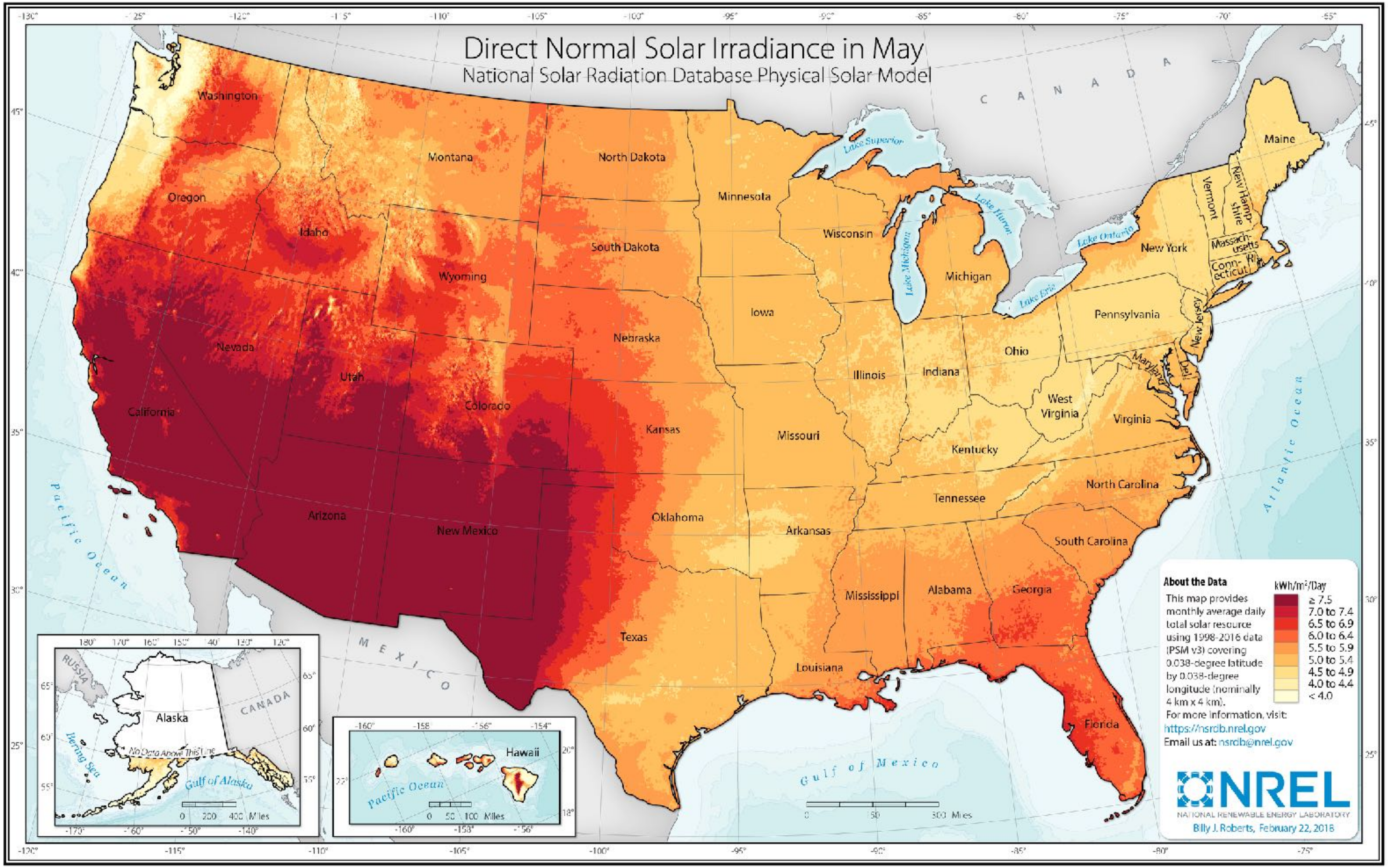
image: https://www.solarpathfinder.com/

AVOID SHADING!

THIS PANEL'S POWER REDUCED **39%**

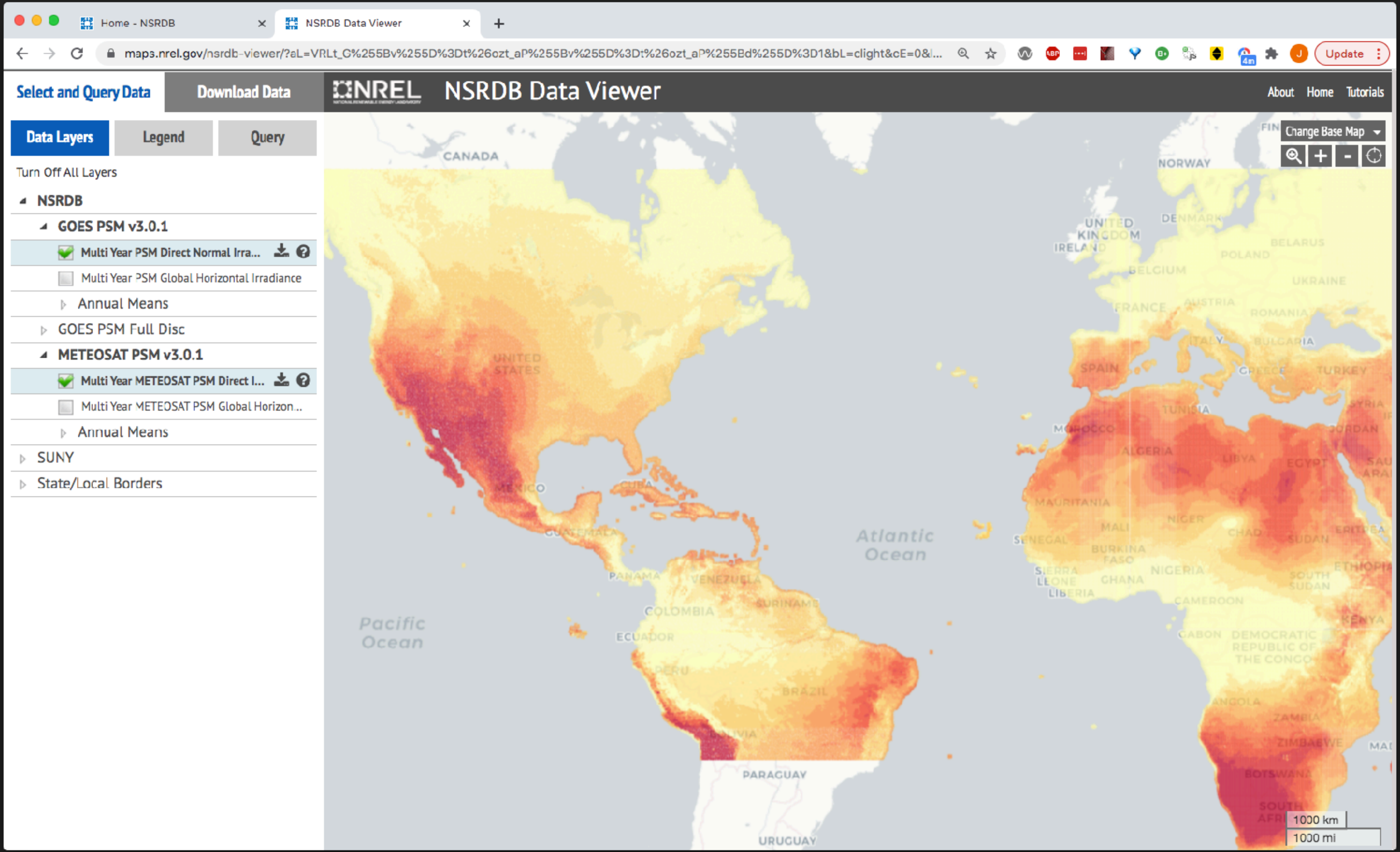
Solar panels typically consist of several cells in series. Like **kinking a hose**, shading one cell reduces the effectiveness of the entire series string.

https://www.builditsolar.com/Experimental/PVShading/PVShading.htm



Note unit is same as AM1.5 Irradiance

NREL NATIONAL SOLAR RADIATION DATABASE



https://nsrdb.nrel.gov/

NREL PVWATTS

Watts® Calculator — NREL

Location | 370 Jay Street Brooklyn NY | » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to resource data

SYSTEM INFO

RESTORE DEFAULTS

Modify the inputs below to run the simulation.

DC System Size (kW):	1
Module Type:	Standard
Array Type:	Fixed (open rack)
System Losses (%):	14.08
Tilt (deg):	20
Azimuth (deg):	180

Loss Calculator

Draw Your System

Click below to customize your system on a map. (optional)

Go to PVWatts® results

+ Advanced Parameters

RETAIL ELECTRICITY RATE

To automatically download an average annual retail electricity rate for your location, choose a rate type (residential or commercial). You can change the rate to use a different value by typing a different number.

Rate Type:	Residential
Rate ($/kWh):	0.232

PVWatts® Calculator — NREL

My Location | 370 Jay Street | » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

1,391 kWh/Year*

System output may range from 1,358 to 1,445 kWh per year near this location. Click HERE for more information.

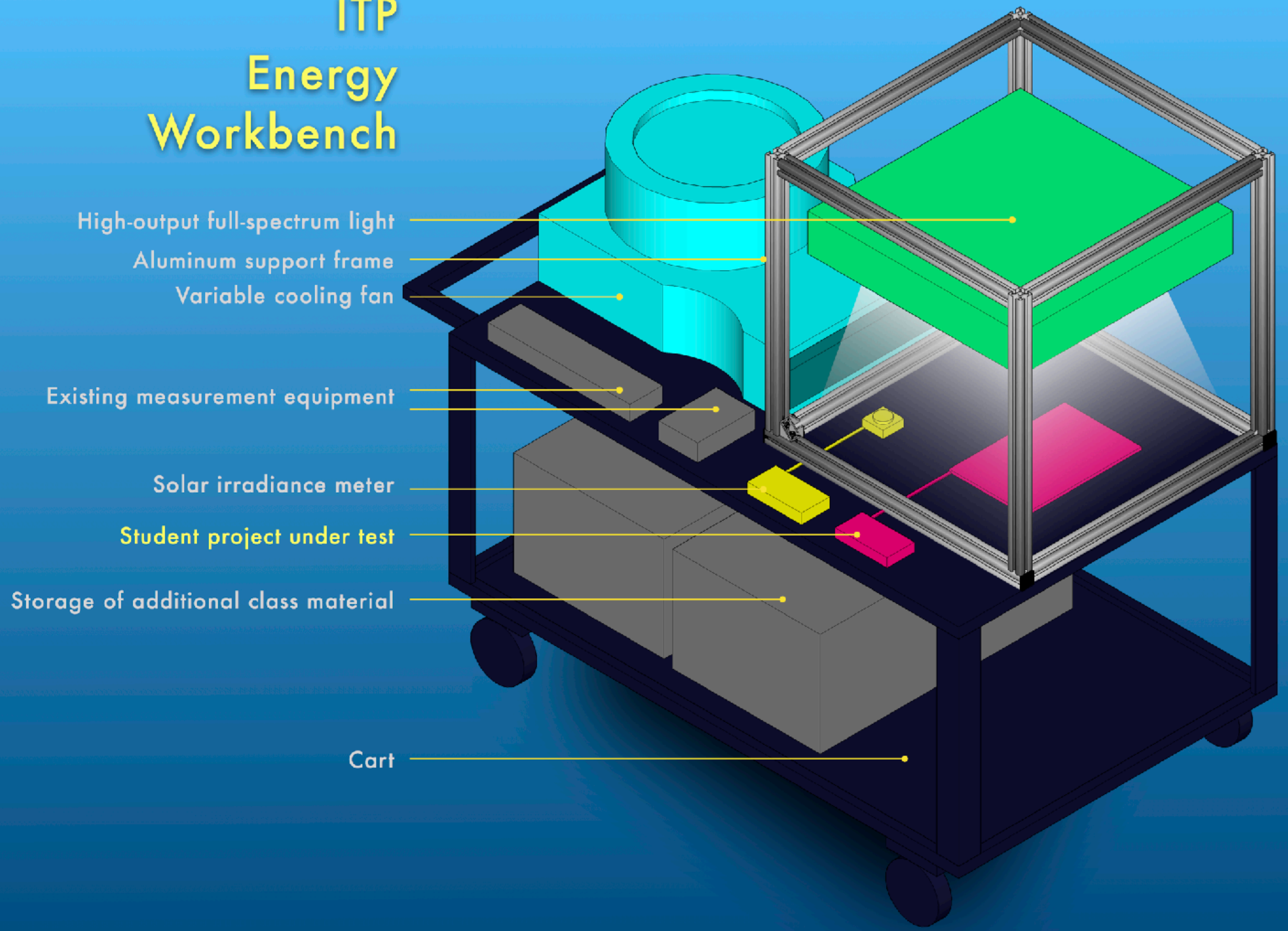
Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.72	90	7
February	4.47	94	7
March	4.99	115	9
April	6.00	129	10
May	6.20	136	11
June	6.44	133	10
July	6.68	141	11
August	6.50	132	10
September	6.05	126	10
October	5.16	114	9
November	4.13	93	7
December	3.61	86	7
Annual	5.33	1,389	$ 108

User Comments

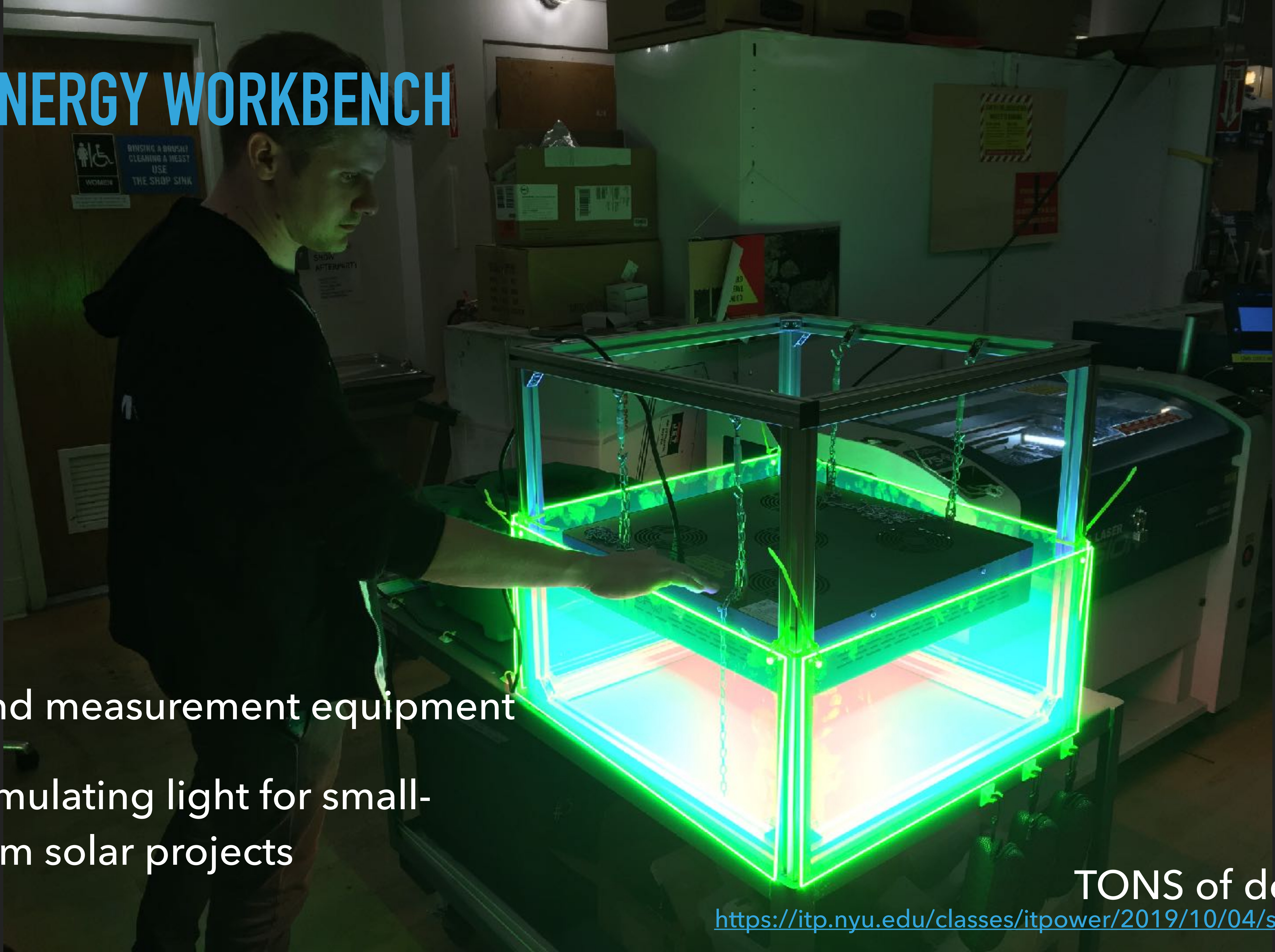
Type here to add optional comments to printout.

https://pvwatts.nrel.gov/

ITP Energy Workbench



ITP ENERGY WORKBENCH

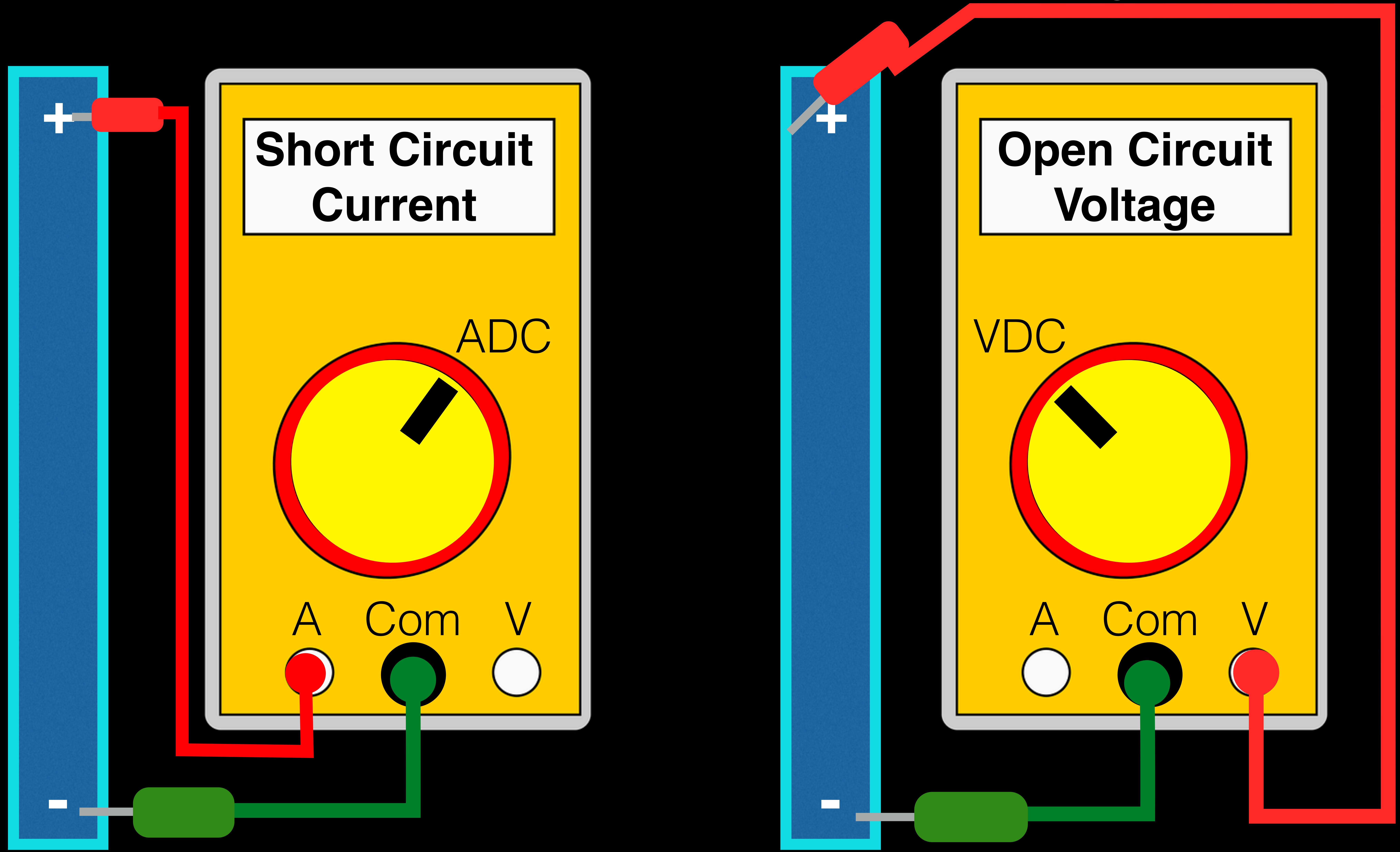


Test and measurement equipment

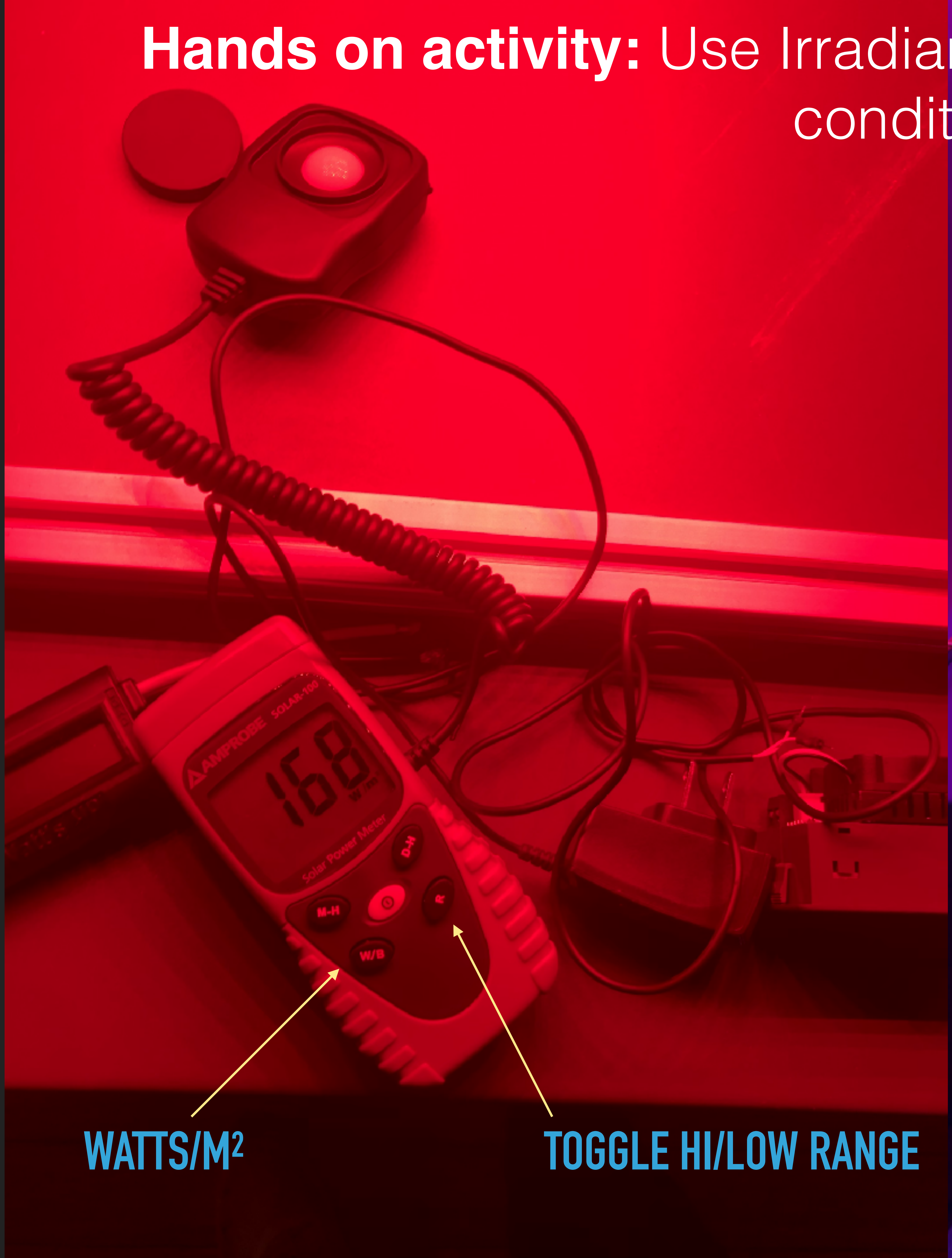
Sun-simulating light for small-medium solar projects

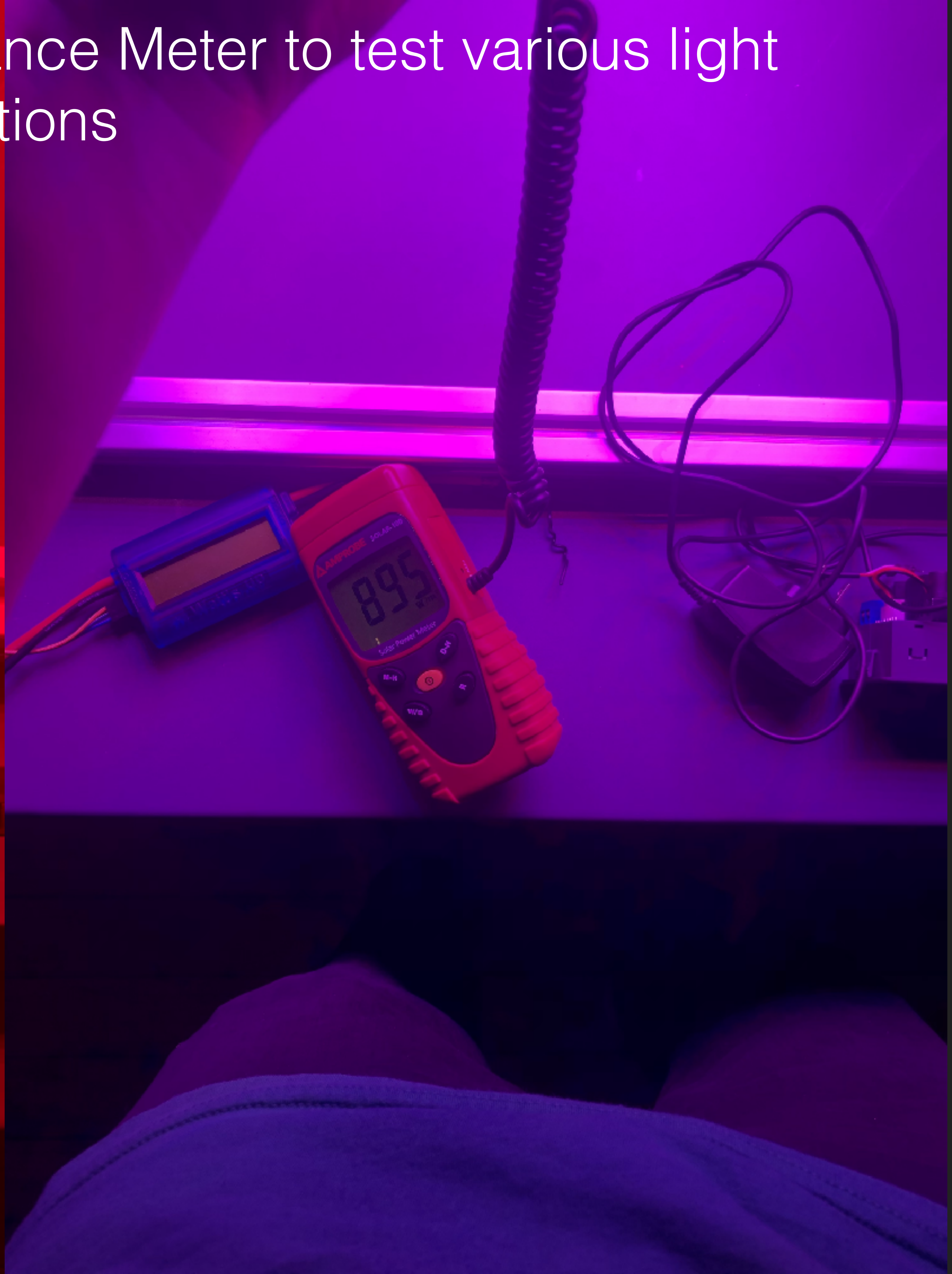
TONS of detail here:
https://itp.nyu.edu/classes/itpower/2019/10/04/solar-cart-guide/

Hands on activity: Take some PV and a multimeter and record SCC and OCV under various conditions, including outside.



Hands on activity: Use Irradiance Meter to test various light conditions





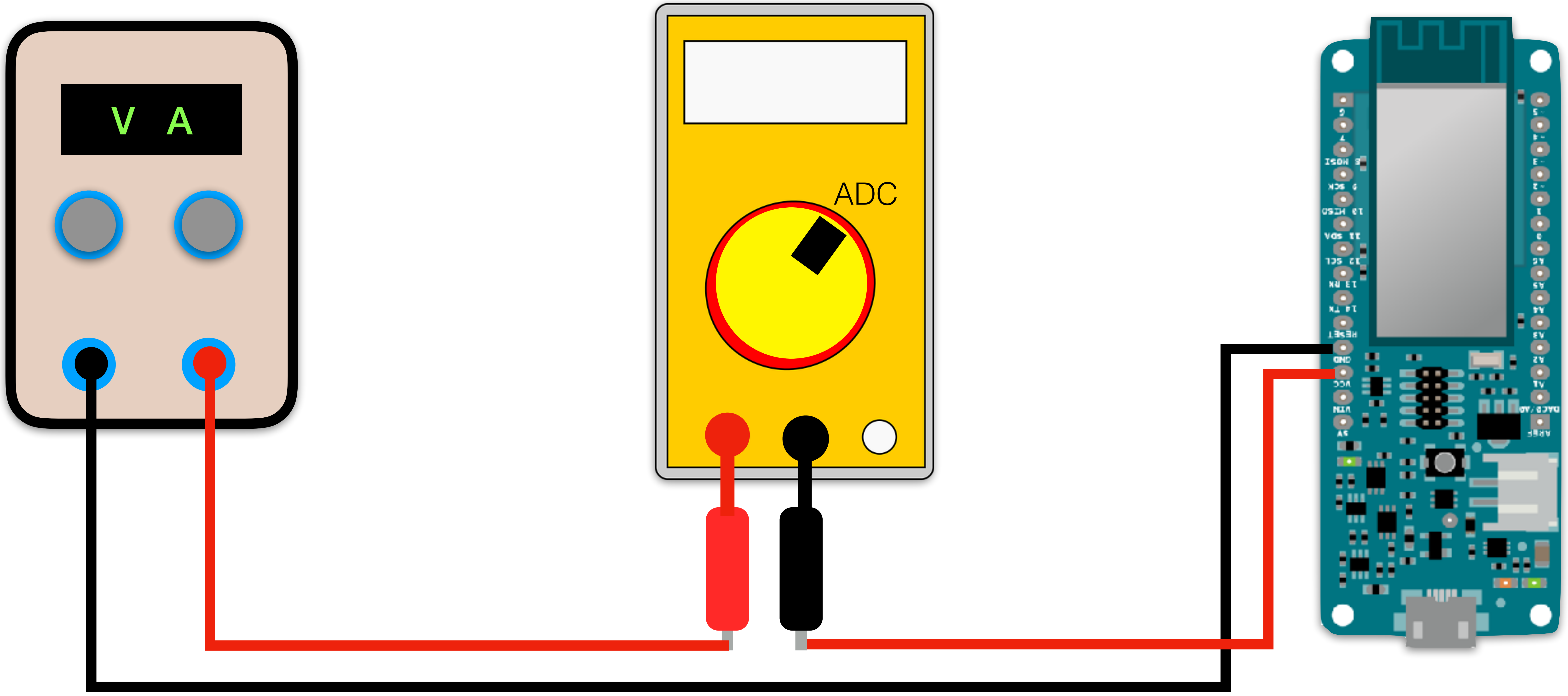
REDUCE USE

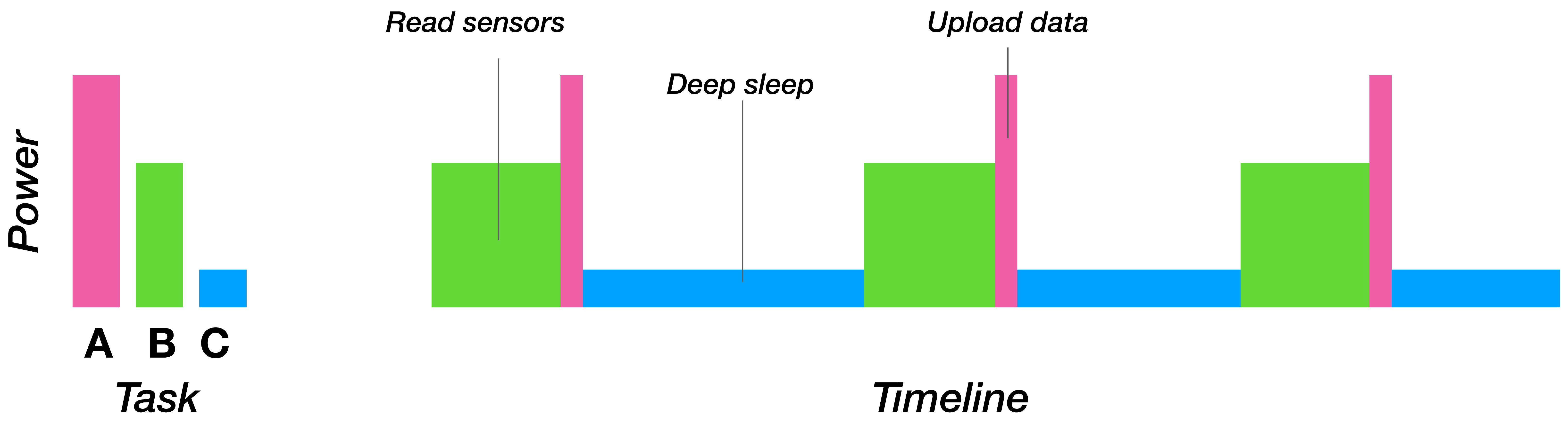
UNDERSTAND YOUR PROJECT'S ENERGY USE. USE AS LITTLE AS POSSIBLE TO DO YOUR JOB.

Energy-aware design

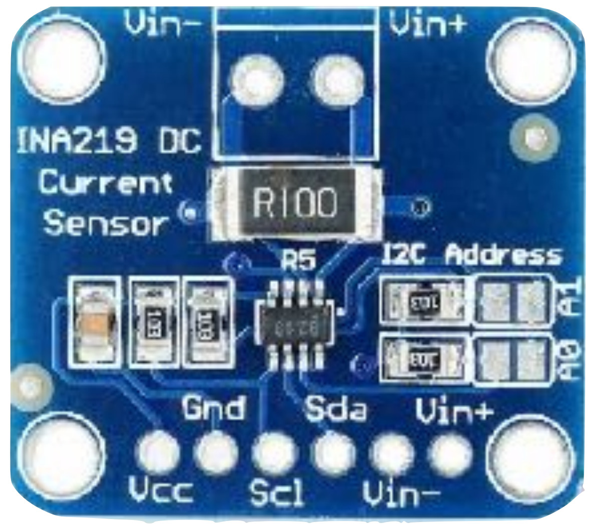
- Pick a platform and **understand approximate energy requirements**. Use this to…
- … **measure the power** used doing various tasks you need for your project (for example, reading a sensor, connecting to wifi and uploading data).
- Create an **energy budget** based on time spent doing tasks and the power needed for those tasks.

**** These can apply to projects of any size…***


V A
ADC


Read sensors
Upload data
Deep sleep
Power
A B C
Task
Timeline

Other measurement options



Low-power design

- Consider a platform's **power options** and **clock speed**.
- Research **deep sleep** options for your platform.
- Minimize hardware. **Power down required peripherals** when not in use.
- **Reduce frequency** of energy-intensive operations.
- Monitor **available energy** and adjust actions accordingly.


Library Manager
Type All
Topic All
sleep
Adafruit SleepyDog Library by Adafruit Version 1.1.1 INSTALLED
Arduino library to use the watchdog timer for system reset and low power sleep. Arduino library to use the watchdog timer for system reset and low power sleep.
More info
ALog by Andrew Wickert , Chad Sandell , Northern Widget LLC , University of Minnesota
Low-power general-purpose data logger library, written for the Arduino-based ALog but expandable to other devices. This toolkit handles power management, the clock, and the SD card for a lightweight field data field data logger, and contains pre-made functions for a range of sensors.
More info
Install
Charge n Boost by Gijs van Berne
A library for the Charge 'n Boost lithium charger and usb booster This library provides functions to read and control the Charge 'n Boost board.
More info
DeepSleepScheduler by Pete Version 2.1.2 INSTALLED
Lightweight, cooperative task scheduler with configurable sleep and task supervision. Provides an easy to use API to schedule tasks, supervise them with the hardware watchdog on AVR and puts the CPU to sleep while no task is running. Tasks can be schedule from interrupts and it supports multiple CPU architectures with the same API.
More info
RTCVars by Lars Friedrichs
This library eases the storage of variables in reset-safe RTC memory. Variables stored there survive all kinds of resets as long as there is no hard reset. It provides boilerplate code to securely store relevant state data in RTC memory so it may survive (unexpected) reboots or deep sleeps. Supports ESP only at this time, will change in the future.
More info
Sleep_n0m1 by Noah Shibley, Michael Grant
A library that sets the Arduino into sleep mode for a specified length of time, or until an interrupt An Arduino library to place the arduino into sleep mode for a specific length of time, or a specific number of sleep cycles.
More info
TaskScheduler by Anatoli Arkhipenko
A light-weight cooperative multitasking library for arduino and esp8266 microcontrollers. Supports: periodic task execution (with dynamic execution period in milliseconds or microseconds – frequency of execution), number of iterations (limited or infinite number of iterations), execution of tasks in predefined sequence, dynamic change of task execution parameters (frequency, number of iterations, callback methods), power saving via entering IDLE sleep mode when tasks are not scheduled to run, event-driven task invocation via Status Request object, task IDs and Control Points for error handling and watchdog timer, Local Task Storage pointer (allowing use of same callback code for multiple tasks), layered task prioritization, std::functions (esp8266, esp32 only), overall task timeout, static and dynamic callback method binding.
Close

PUT IT TOGETHER

ARE YOU A PESSIMIST OR OPTIMIST?

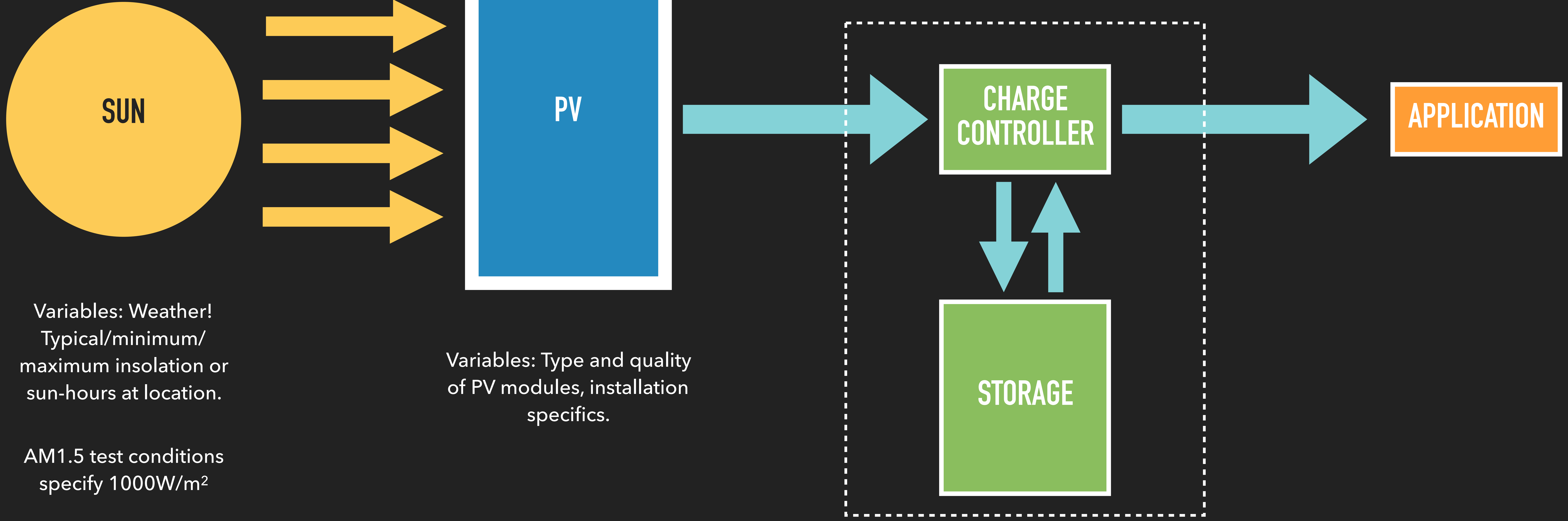
TYPICAL OFF-GRID SOLAR

0-1000W/m^2

η : 10-25%

η : 75-90%

Variables: CC design, battery chemistry and environment



Variables: Weather! Typical/minimum/ maximum insolation or sun-hours at location.

AM1.5 test conditions specify 1000W/m^2

Variables: Type and quality of PV modules, installation specifics.

Sources:
Insolation based on AM1.5 standard
PV efficiency based on various PV datasheets e.g.LG355N1C-V5 (20.7%)
Round trip storage efficiency numbers vary greatly; summary of several sources from DOE available:
https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance

TYPICAL OFF-GRID SOLAR

RECIPE

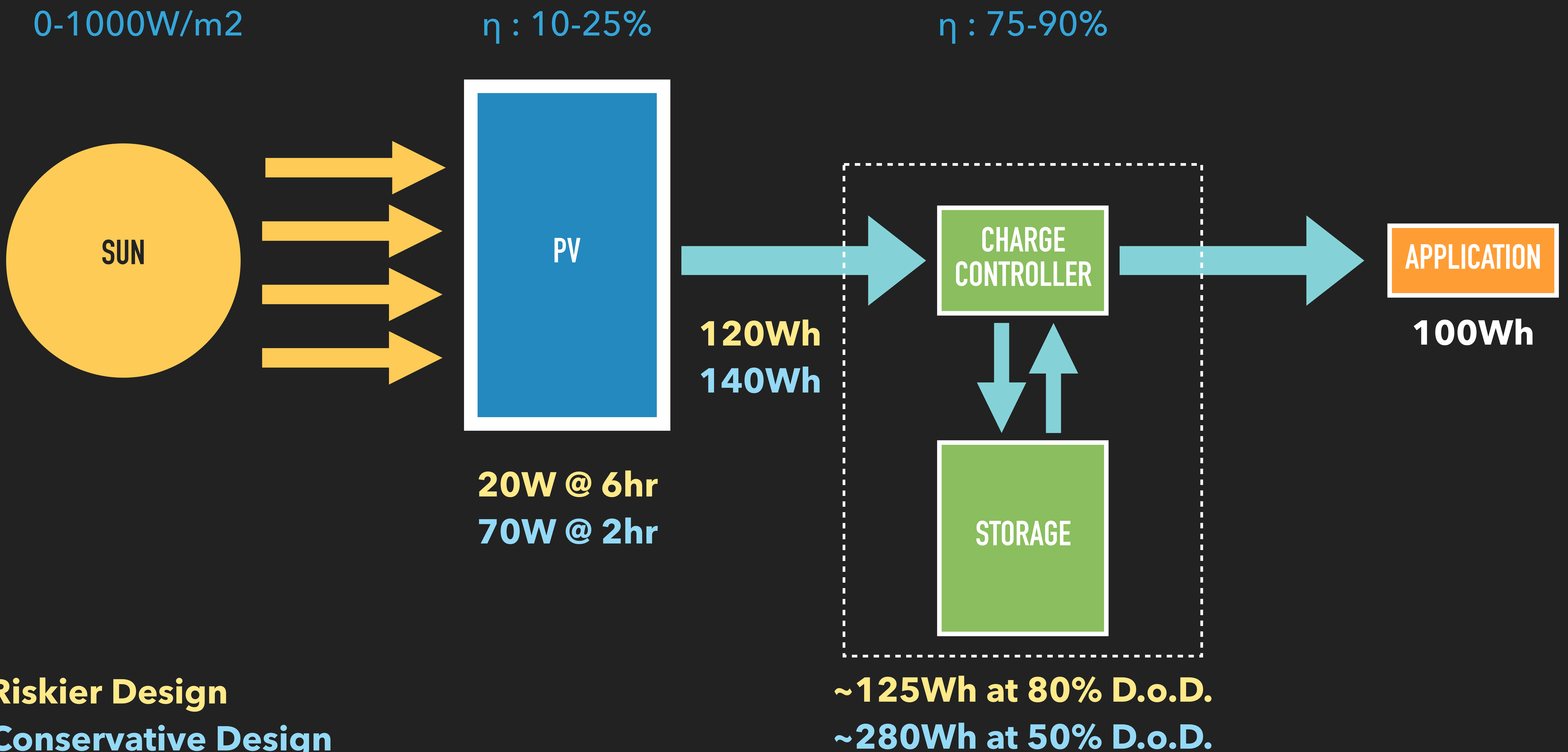
1. Understand the **application you are trying to power.** Rough first pass: average power (W) * hours used per day = daily Wh. Look for ways to **reduce required power**.

2. Determine required **energy from storage** using round-trip storage efficiency. Size total storage based on required energy, charge and discharge currents, acceptable depth of discharge, etc.

3. Determine **PV power requirements** based on input energy required, daily insolation at site, and design requirements for charge time, bad weather tolerance, etc.

TYPICAL OFF-GRID SOLAR

Assumption: we use what we get per day



Riskier Design

Conservative Design