



# Enhanced Absorption in Ge Nanostructures for Increased Photovoltaic Efficiency

Research Experience for Teachers

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## Calculating Ideal Values for GeC

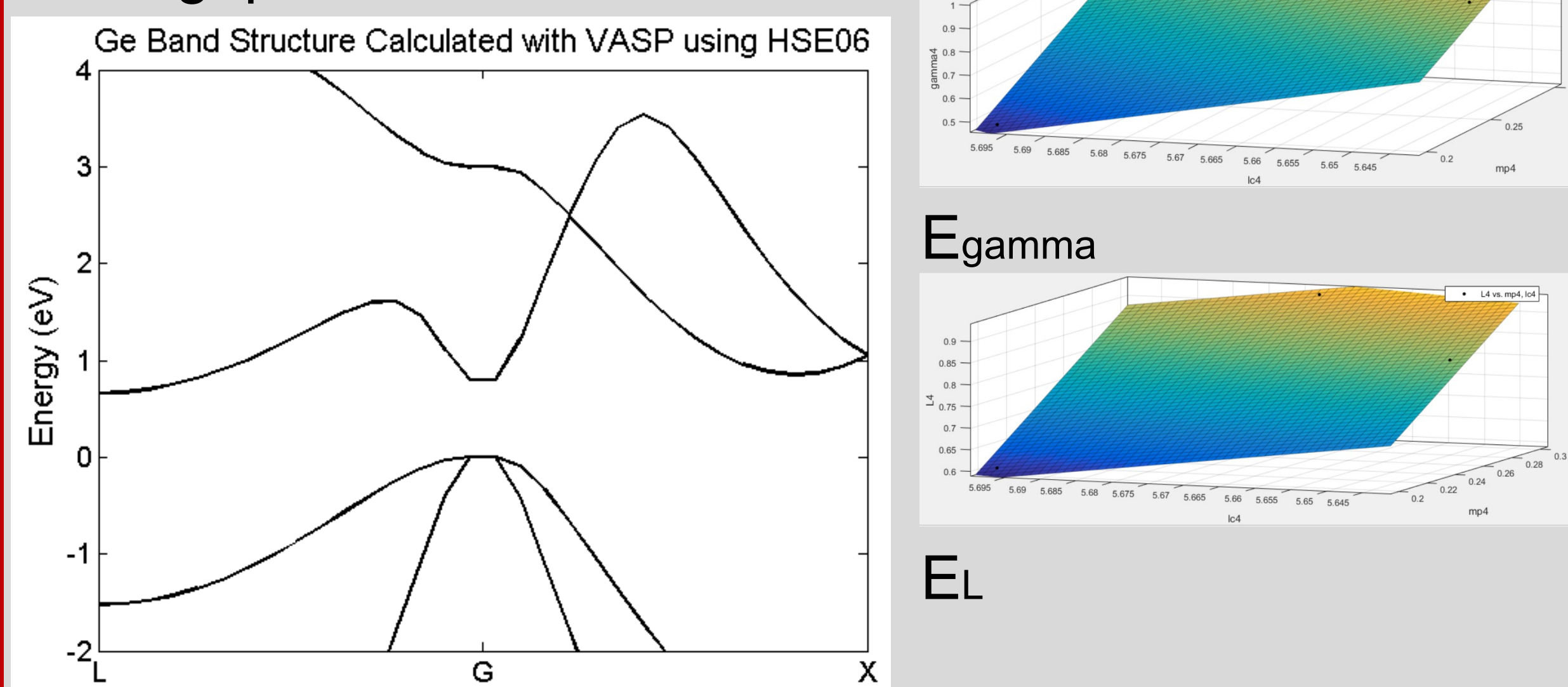
Using MATLAB to calculate the necessary parameters to make Ge simulations match experimental results.

Lattice constant = 5.61285Å

Mixing parameter = 0.1600

$E_g\Gamma = 0.80\text{eV}$        $E_gL = 0.66\text{eV}$

Bandgap = 0.66eV



## Connection to the Classroom

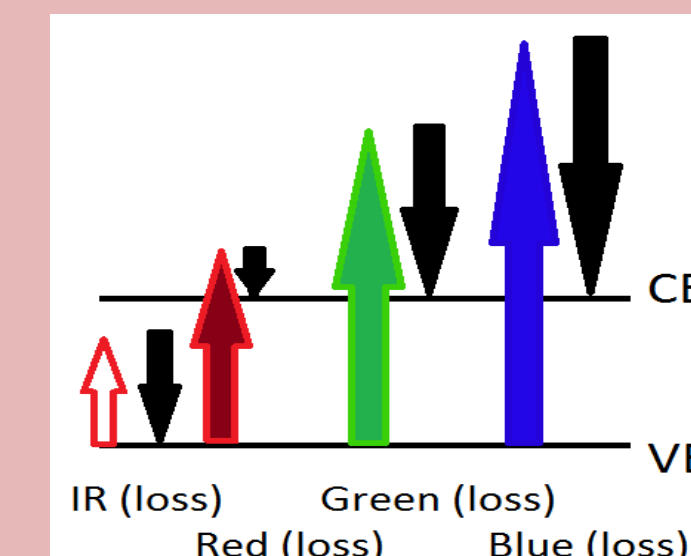
### Photovoltaic cells:

### Analogs for Plant Leaves.

Photovoltaic cells can be a useful analog for the leaves on plants, and utilized for teaching photosynthesis.

Plants capture energy from the sun utilizing special molecules called chlorophyll  $\alpha$  &  $\beta$ . These molecules are able to absorb certain wavelengths of light and transfer the energy from those light waves to a pair of electrons. These electrons get boosted to higher energy states, and are then transferred to electron carriers. A similar process takes place in photovoltaic cells.

In photovoltaic cells, energy from certain wavelengths of light is used to boost electrons to higher energy levels. Depending on the material used to produce the cells, different wavelengths are used at varying efficiencies. The light waves are like the three little bears, some have too much energy, some have too little, and some are just right. Those with too much can still be used, but all the extra energy is lost as heat, and reduces efficiency.



## Curriculum Development

A lot of time and development went into designing and building a meter for the students to use that could easily and accurately measure voltage and current from a solar cell. Unfortunately the currents produced by the solar cell, under the testing conditions desired for the experiment, were too low for the meter. Therefore the curriculum will use store bought multimeter, and students will measure voltage and current separately.



## Curriculum Highlights

## Practicing the Scientific Method

Students are to carry out the 7 steps of the scientific method using solar cells as analogs for the leaves of plants.

**Problem:** Which wavelengths of light are most efficient for our photovoltaic (PV) cells?

**Research:** Readings and internet searches on light, photovoltaic cells, and solar energy.

**Hypothesis:** If we measure the energy produced by our cells utilizing different wavelengths of light, then we will be able to assess which wavelengths are most efficient for our PV cells.



**Experiment:** Design, Conduct, and Record Data.

**Analyze:** Create graphs of voltage vs. wavelength, current vs. wavelength, and power vs. wavelength.

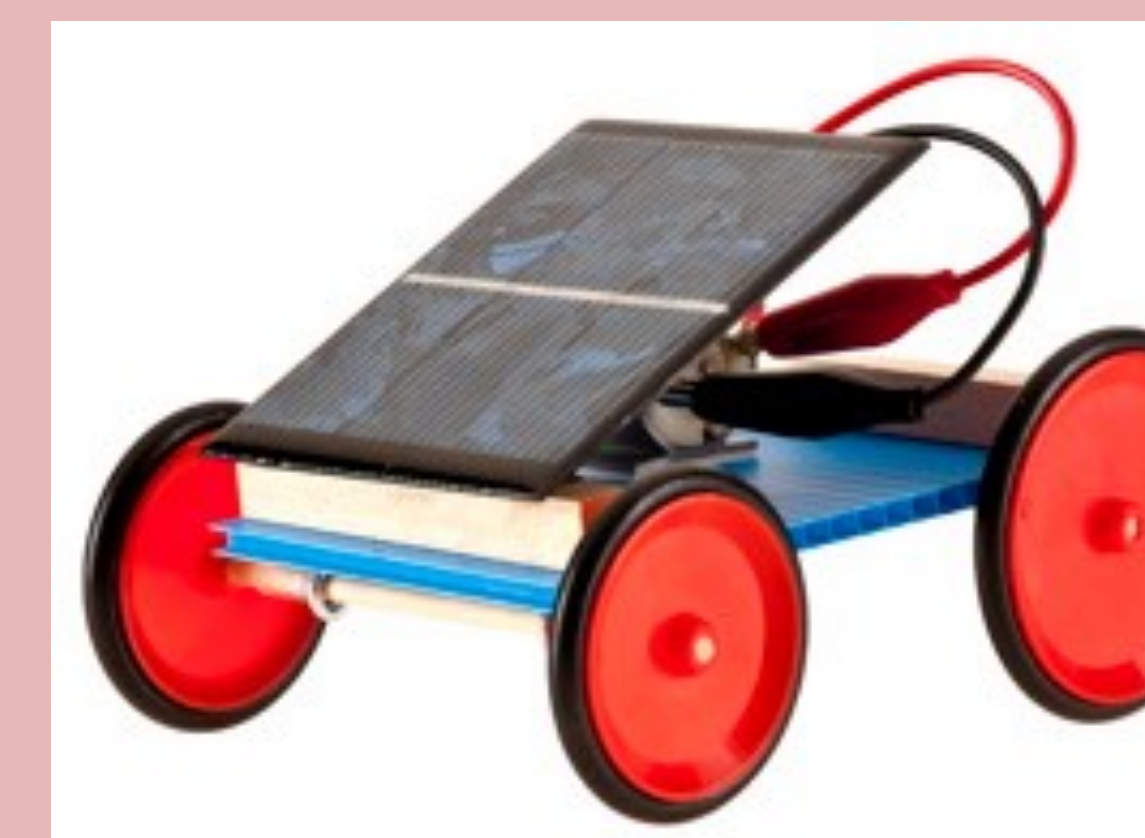
**Summary:** Describe results and graphs.

**Conclusion:** Which wavelength created the most watts, and which is the most efficient for that solar cell.

**Race day:** Students will use their conclusion to race solar powered cars utilizing the wavelength of light they believe to be most efficient or powerful.

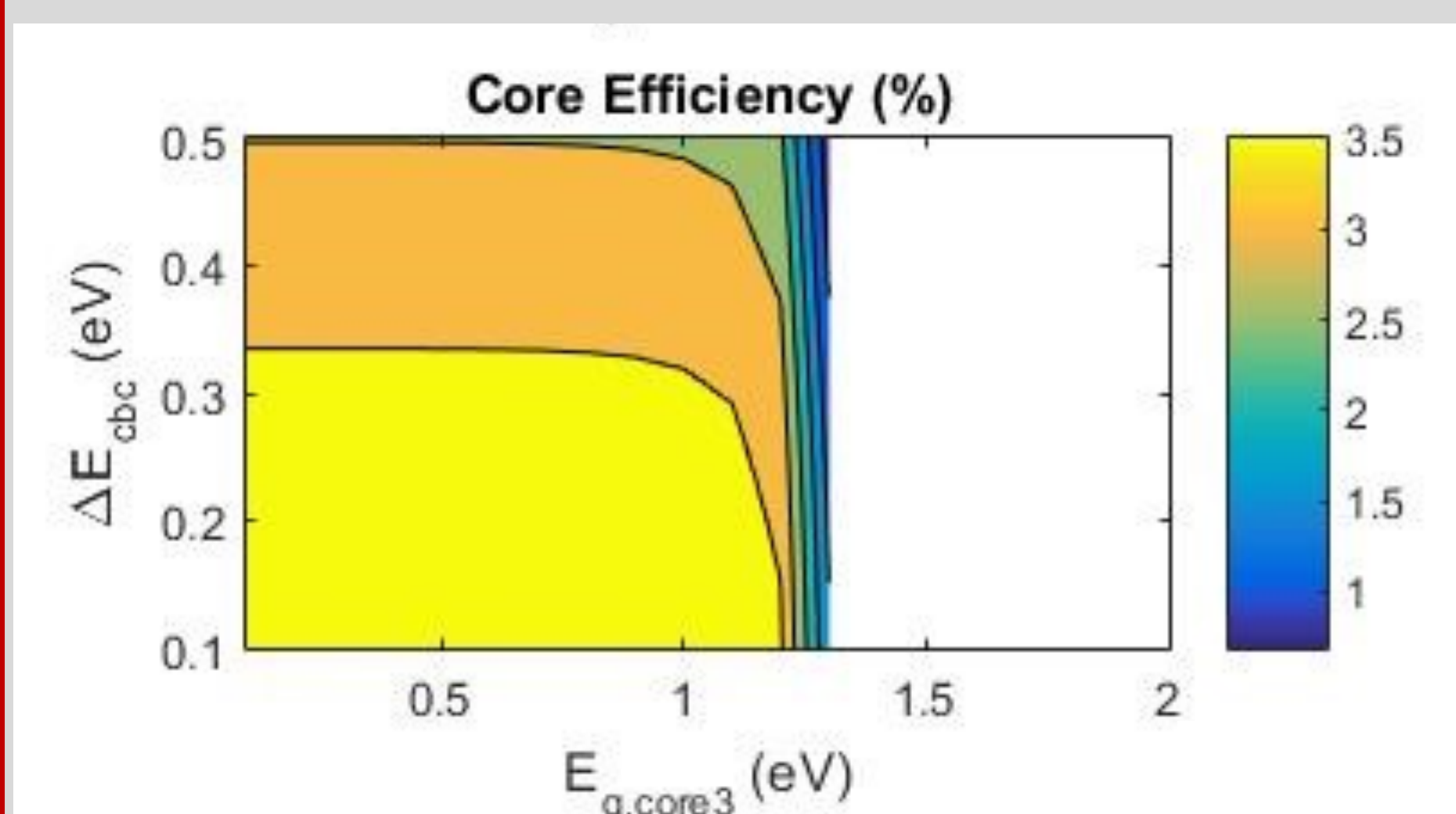


**Discussion:** We will end with a discussion about what they learned, and what additional questions could still be asked, tested.

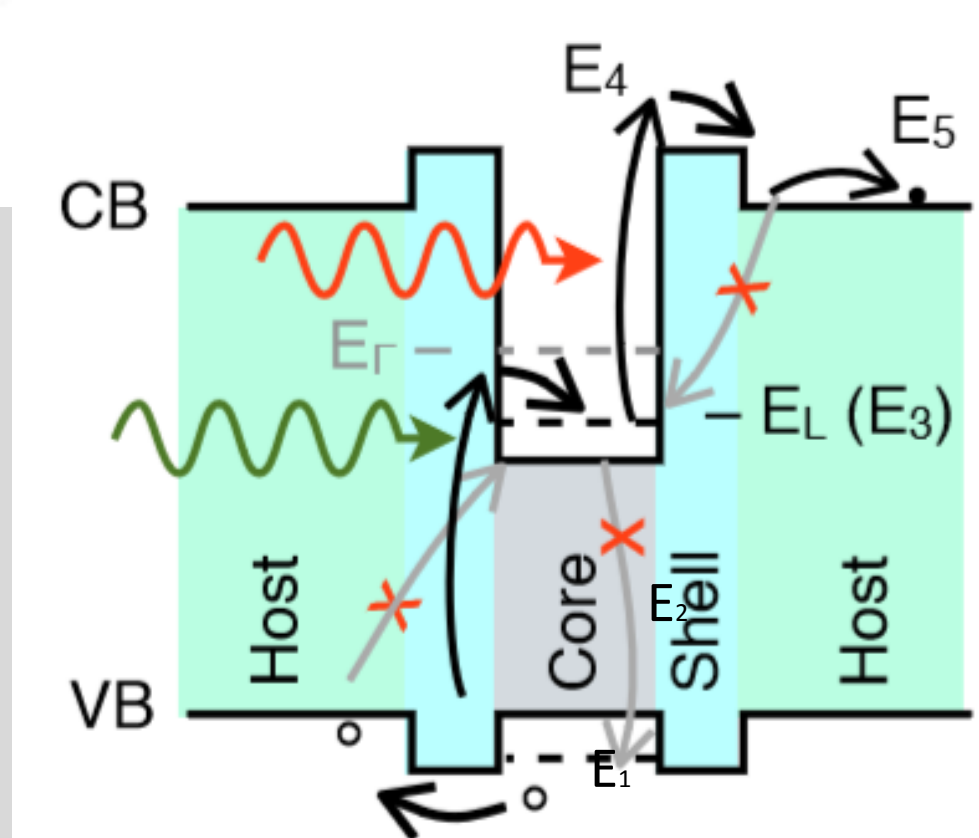


## Theoretical Optimizing Efficiency of CSUNs

Manipulating absorption rate out of the quantum dot (R25) and absorption rate within the quantum dot (R13) values to see how that affects efficiency values.



Altering R25 made no significant changes in efficiency, but altering R13 boosted efficiency from 10<sup>-5</sup>% to 3.5%.



## LED Output and PV Cell Efficiency

Wavelength measured using spectrophotometer.

Color Button	Wavelength (nm) Light	Voltage of Solar Cell (V)	Current of Solar Cell (mA)	Power (mW) (Calculated) SC	Efficiency (%) Calculated
1 Red (R)	630	3.57	0.55	1.96	12.7
6 Green (G)	518	3.60	0.62	2.23	10.5
11 Blue (B)	460	3.83	0.64	2.45	9.9

Voltage and Current measured directly, using multimeter.

Power calculated as  $W = E \times I \times 0.7$

W – Power in milliWatts

I – Current in milliAmps

E – Voltage in Volts

0.7 – Fill factor

Efficiencies calculated using the following equations.

Red:  $V_{in}/(10 \times 1.97) \times 0.7 =$

Blue:  $V_{in}/(10 \times 2.70) \times 0.7 =$

10 – number of cells in series on solar panel

1.9 –  $E_{eV} = 1240\text{nm}/630\text{nm}$

3.1 –  $E_{eV} = 1240\text{nm}/460\text{nm}$

Green:  $V_{in}/(10 \times 2.39) \times 0.7 =$

0.7 – Fill Factor

2.4 –  $E_{eV} = 1240\text{nm}/518\text{nm}$

## Acknowledgements

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