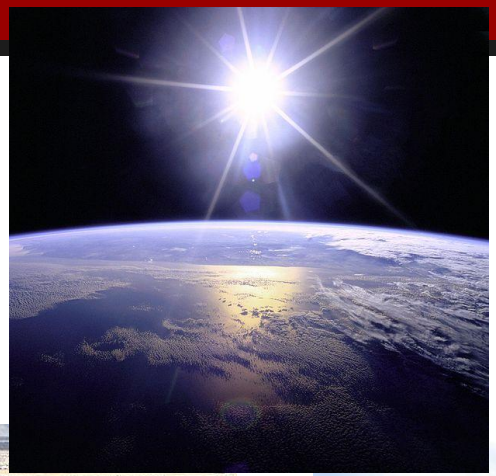
Photovoltaics

Jacob J. Krich

Photo voltaics

(sun)light electricity

Jacob J. Krich

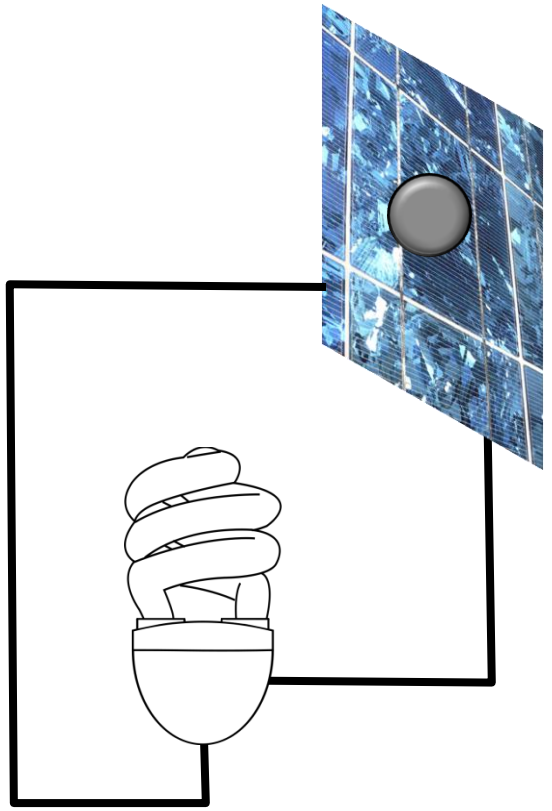


http://commons.wikimedia.org/wiki/File:Giant_photovoltaic_array.jpg – Nellis AFB, NV. 15MW

http://en.wikipedia.org/wiki/File:Full_Sunburst_over_Earth.JPG

http://commons.wikimedia.org/wiki/File:Kilver_Juni_2009_028.jpg Kilver Castle

Photovoltaics turn photons into electricity



Photovoltaic effect

http://commons.wikimedia.org/wiki/File:Polycristalline-silicon-wafer_20060626_568.jpg
http://www.openclipart.org/detail/21570 (CFL)

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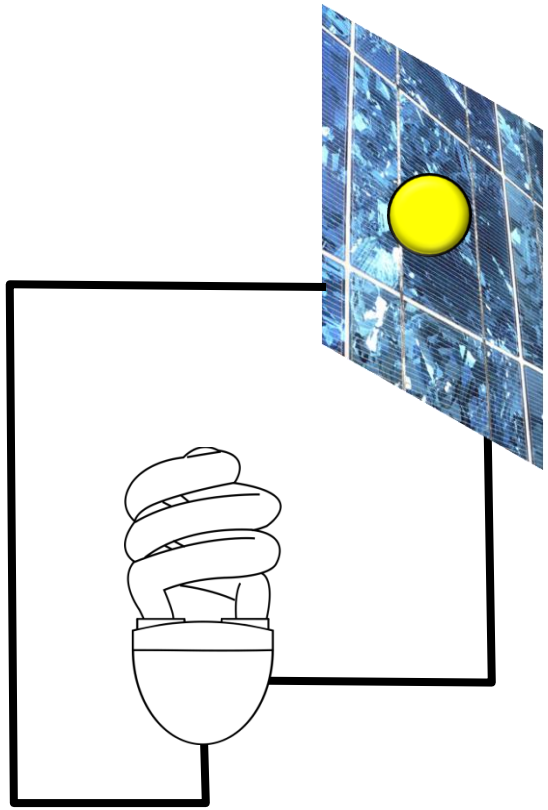

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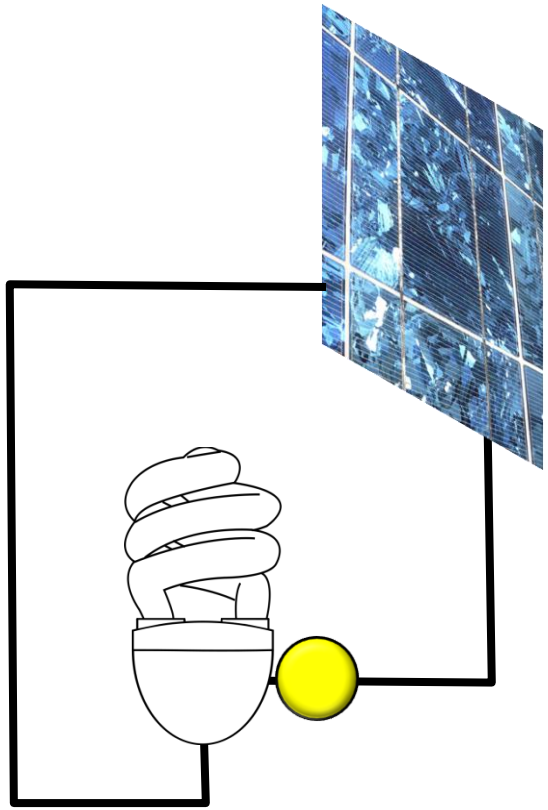

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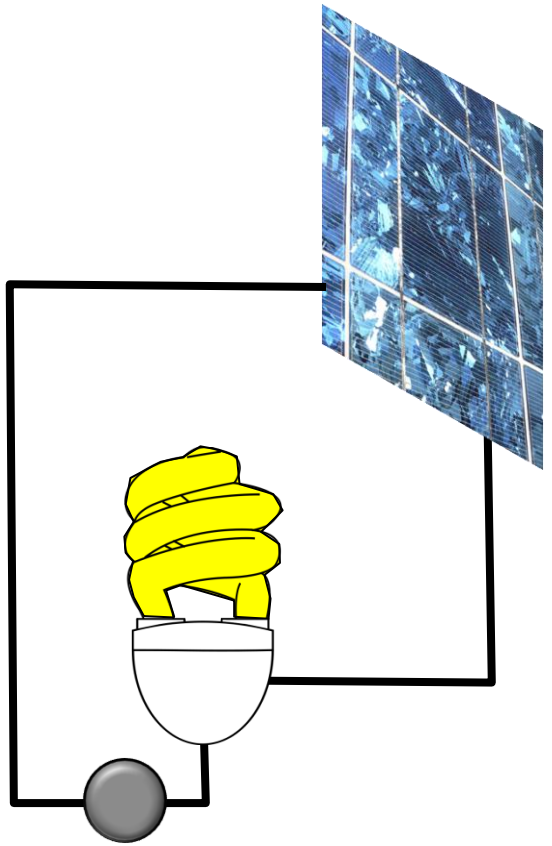

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Let's go deeper

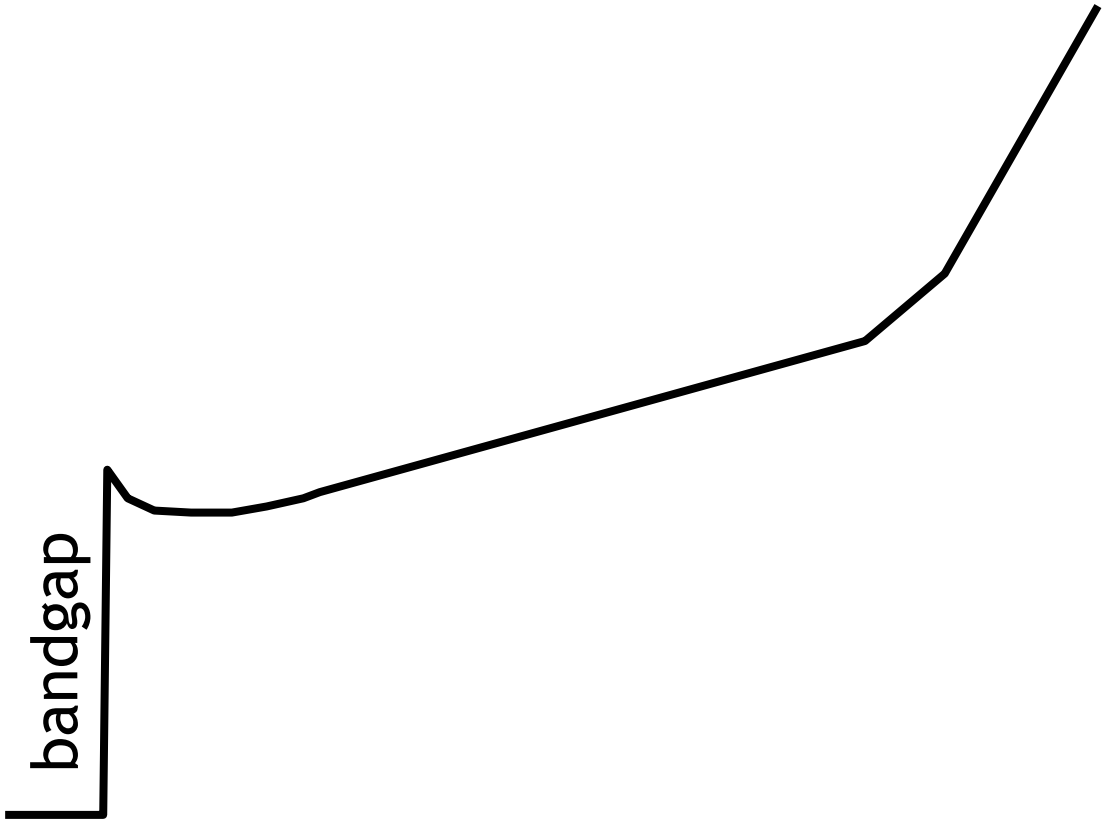
- How well **can** photovoltaics work?

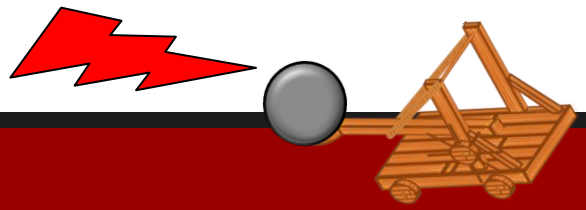
- Two simple rules will help us understand the limits to photovoltaic efficiency.

The PV rules

A photovoltaic material has a **bandgap**.

Rule 1: Only absorb photons with energy greater than the **bandgap**.





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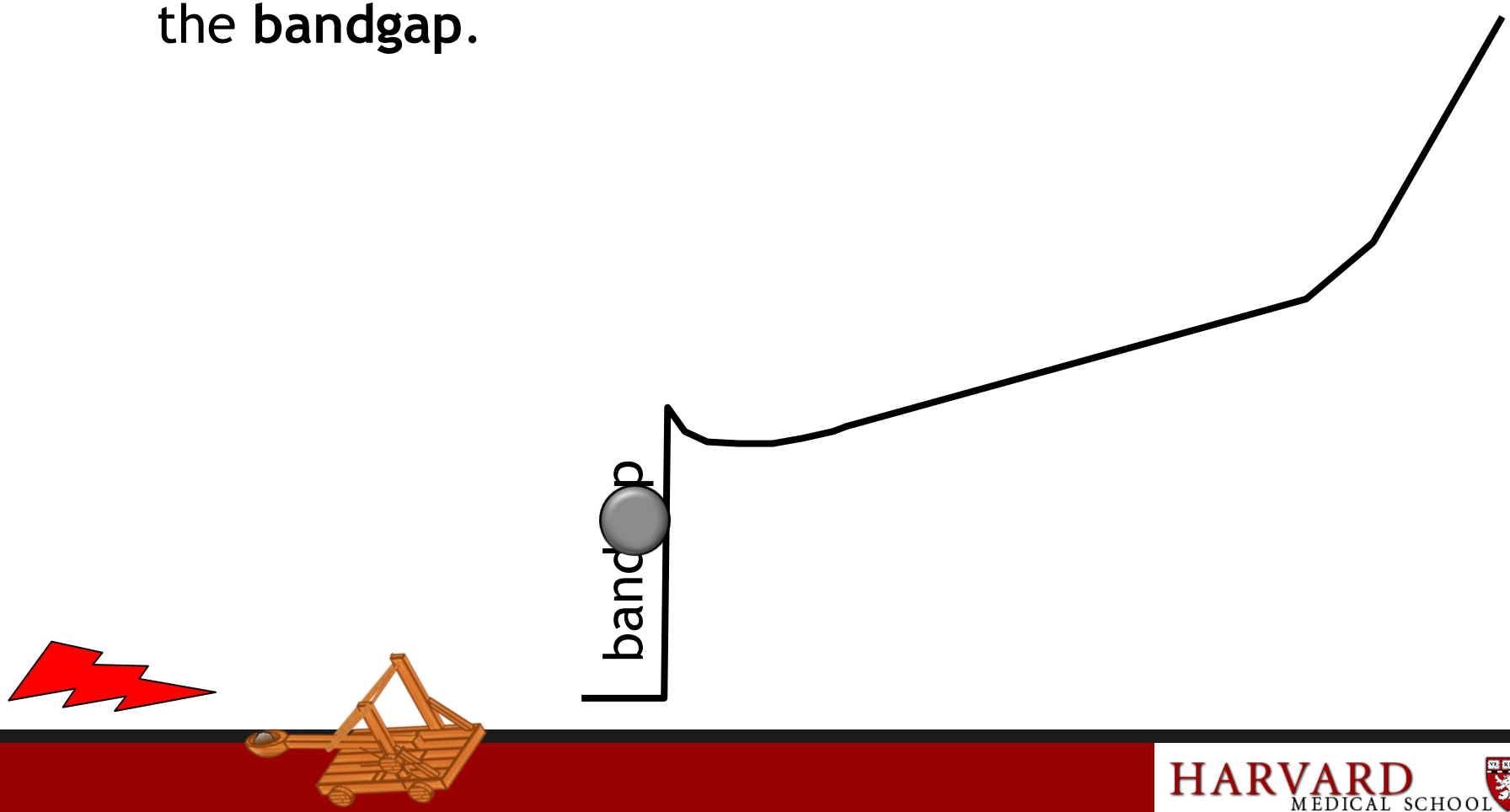

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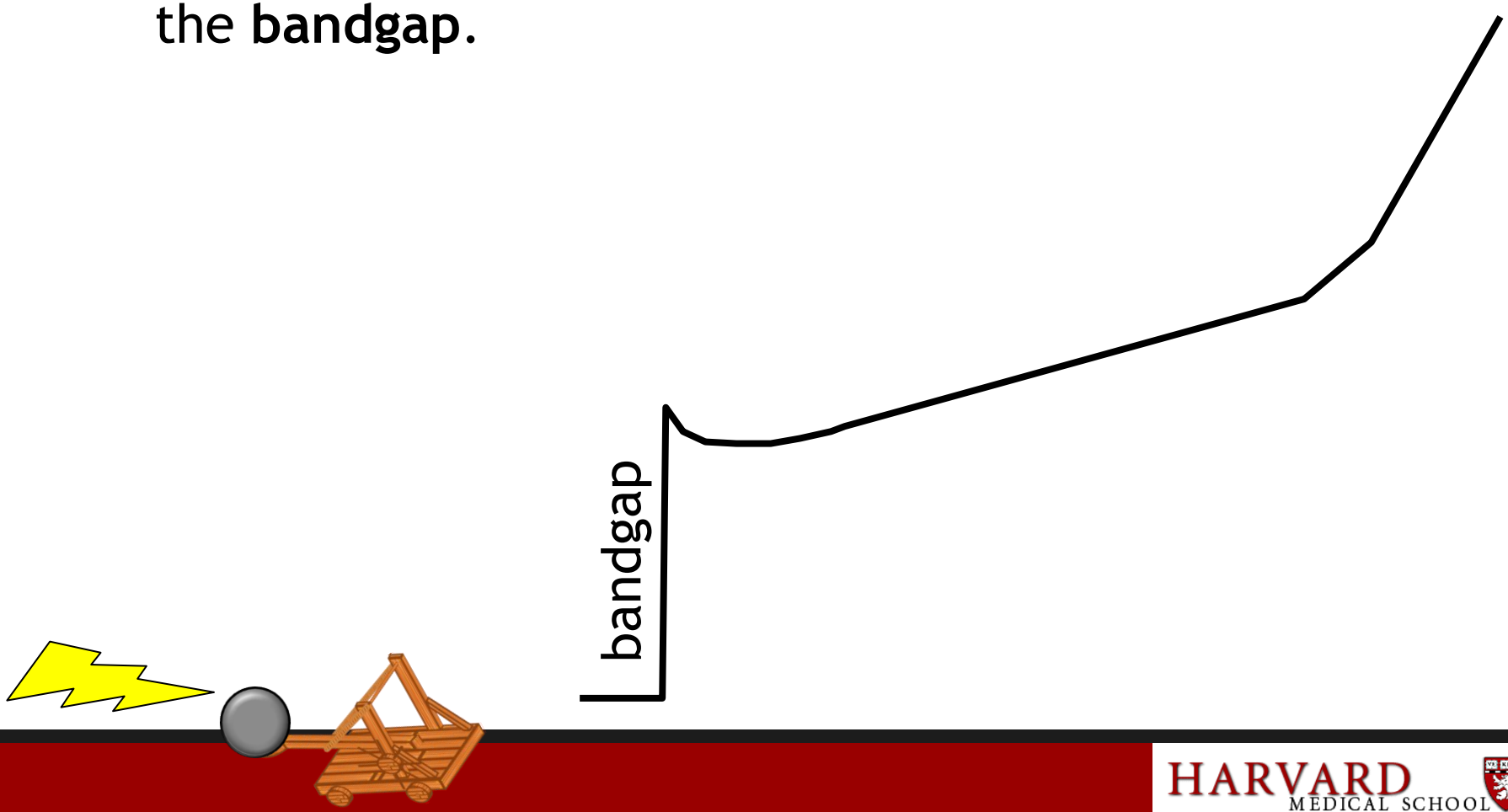

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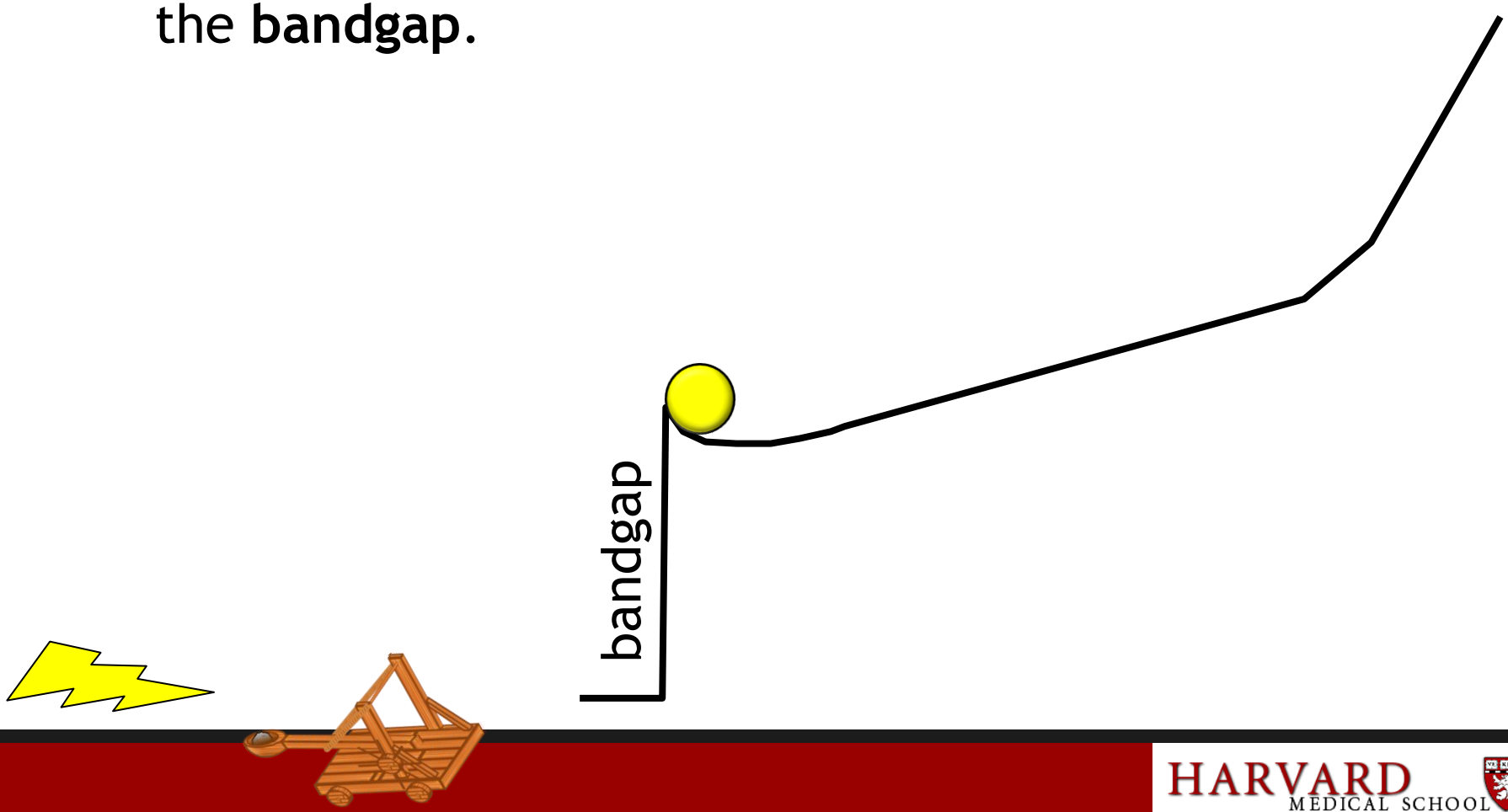

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A photovoltaic material has a **bandgap**.

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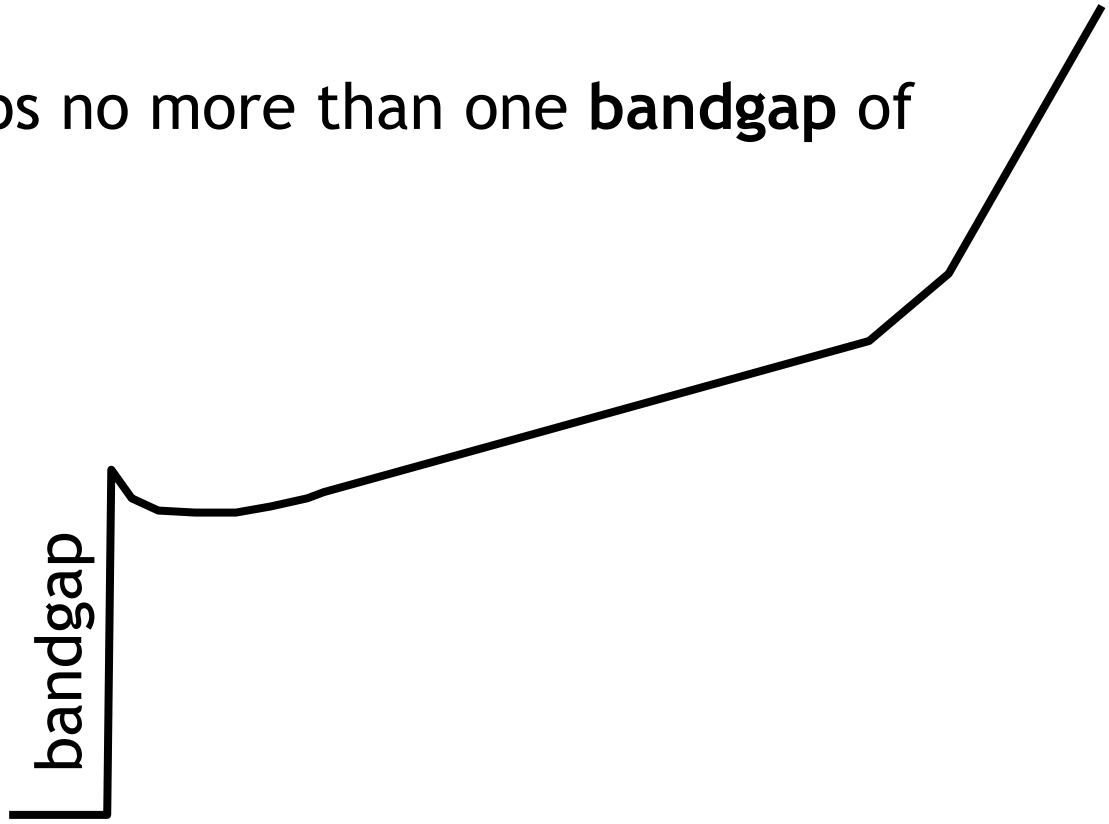
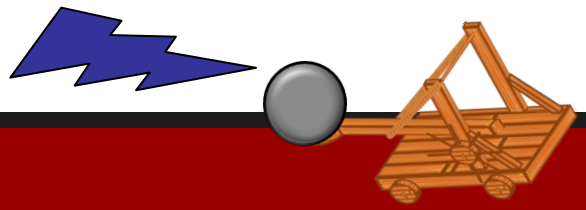
Rule 2: Electron keeps no more than one **bandgap** of energy.





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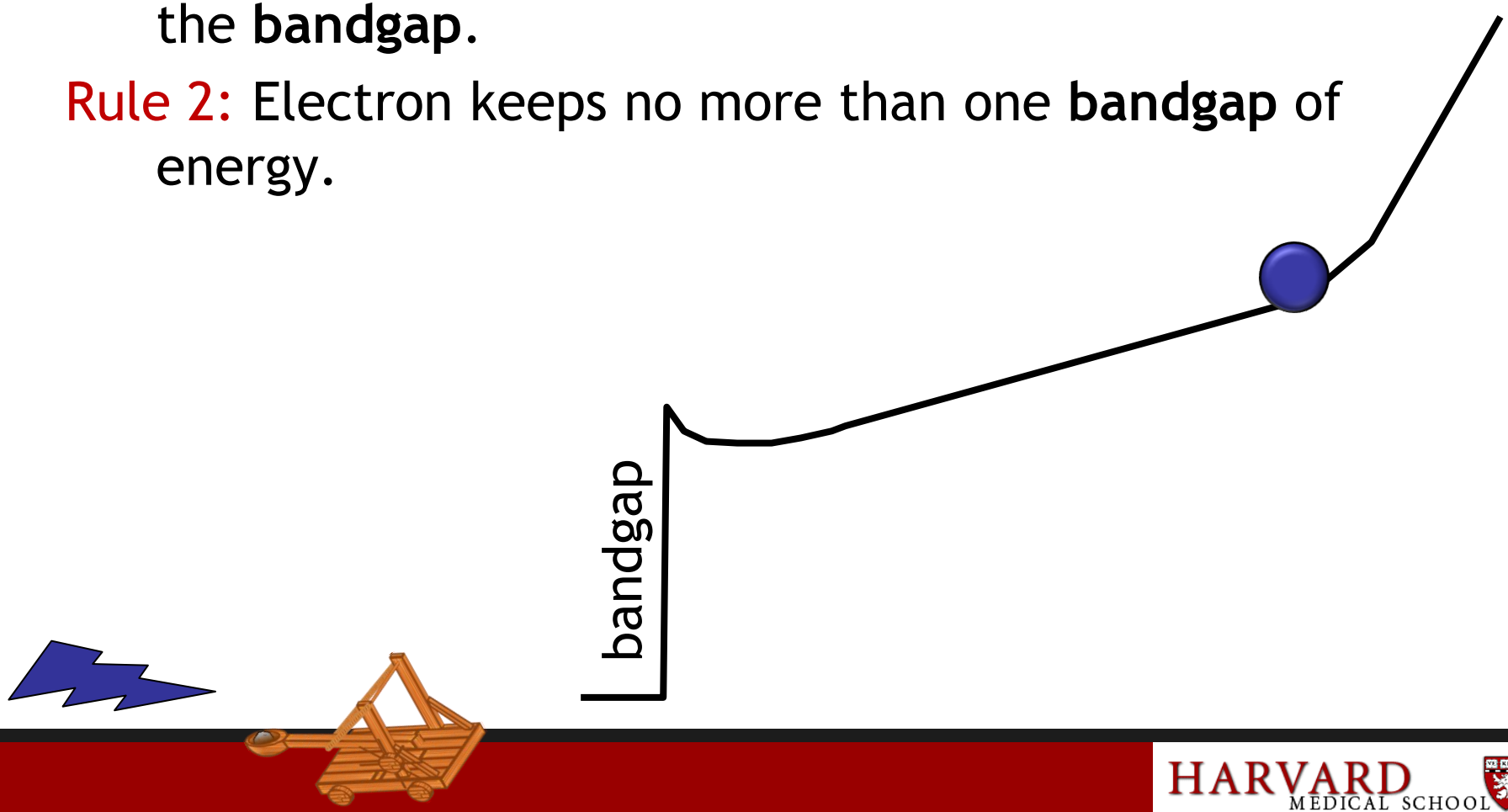

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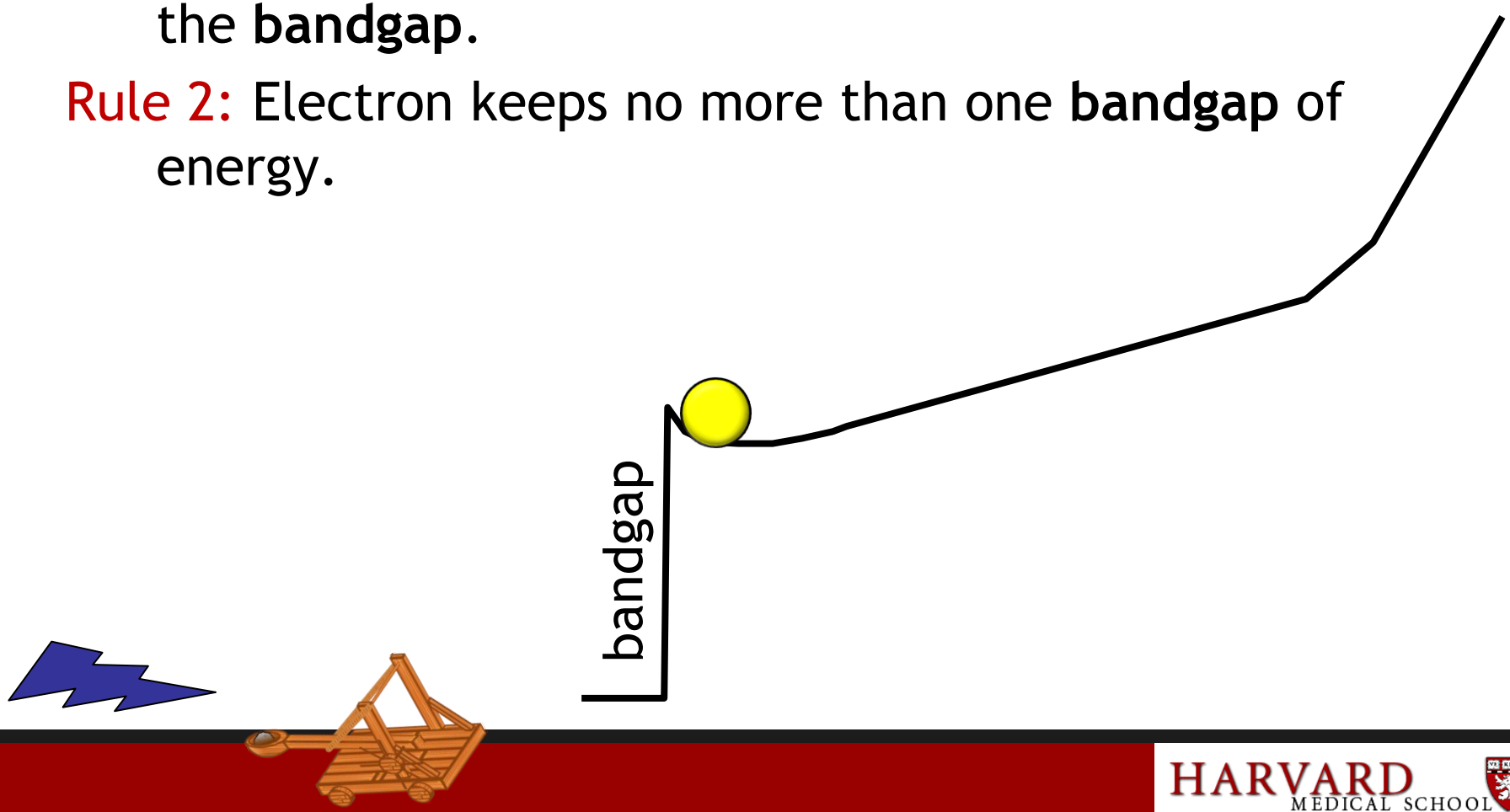
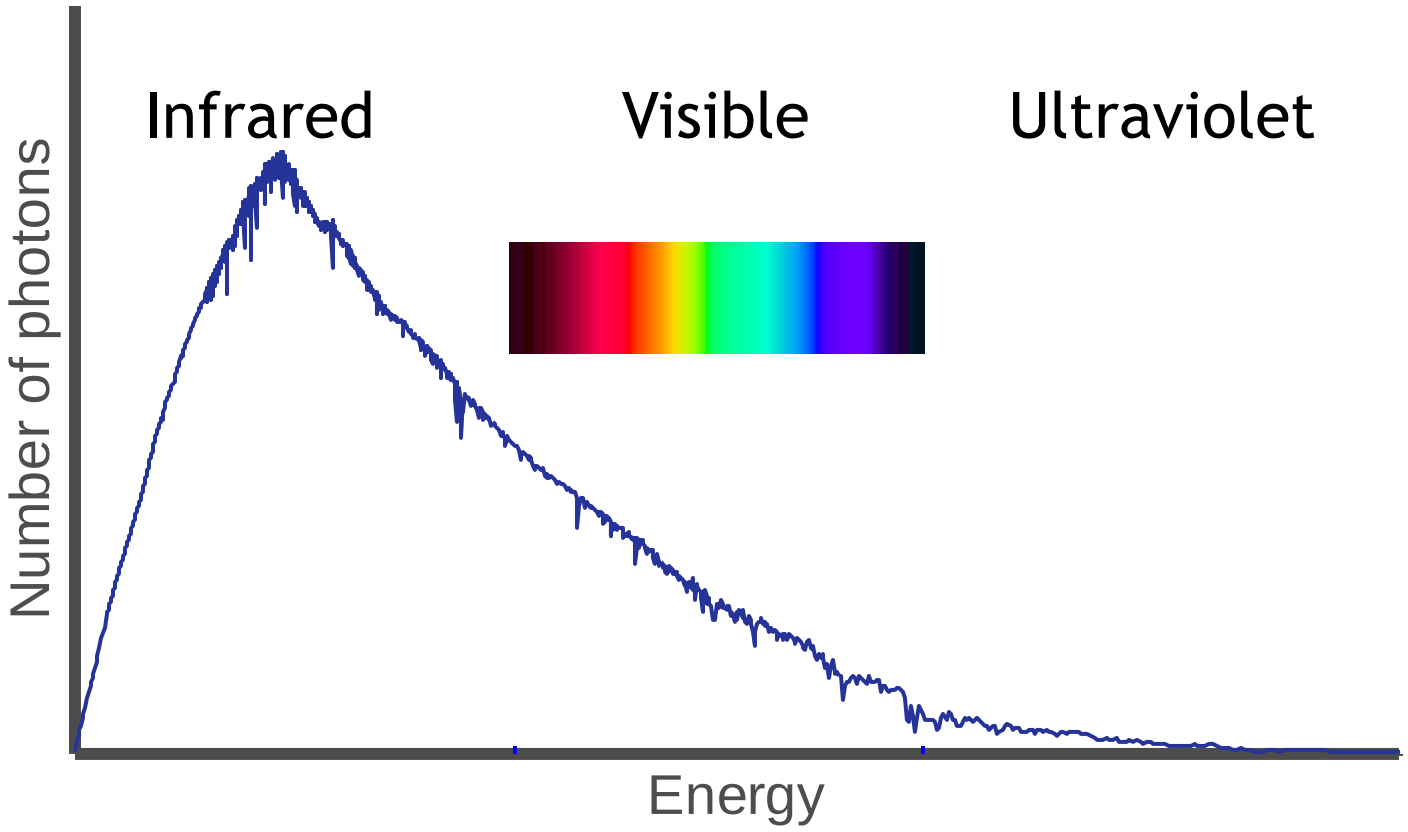
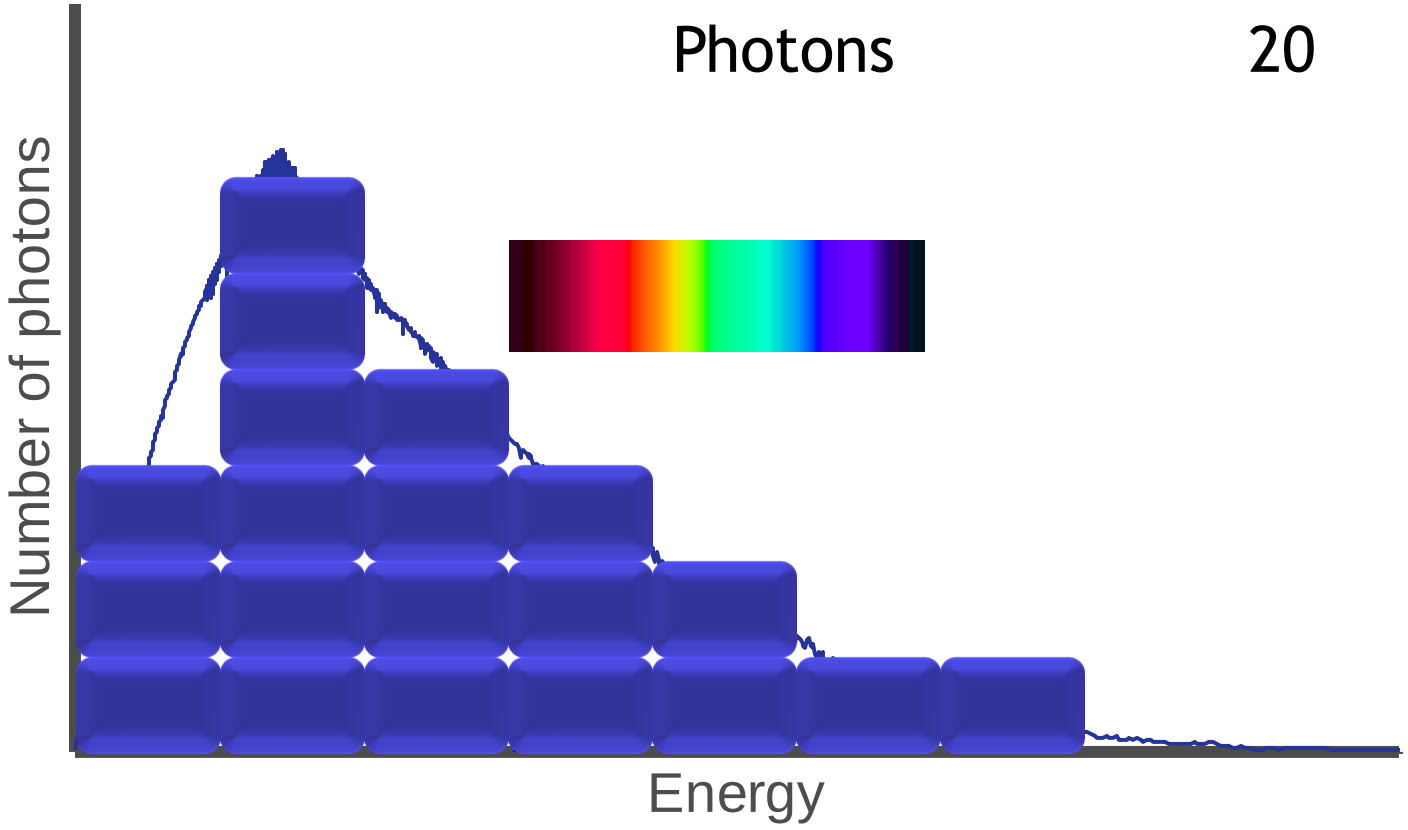
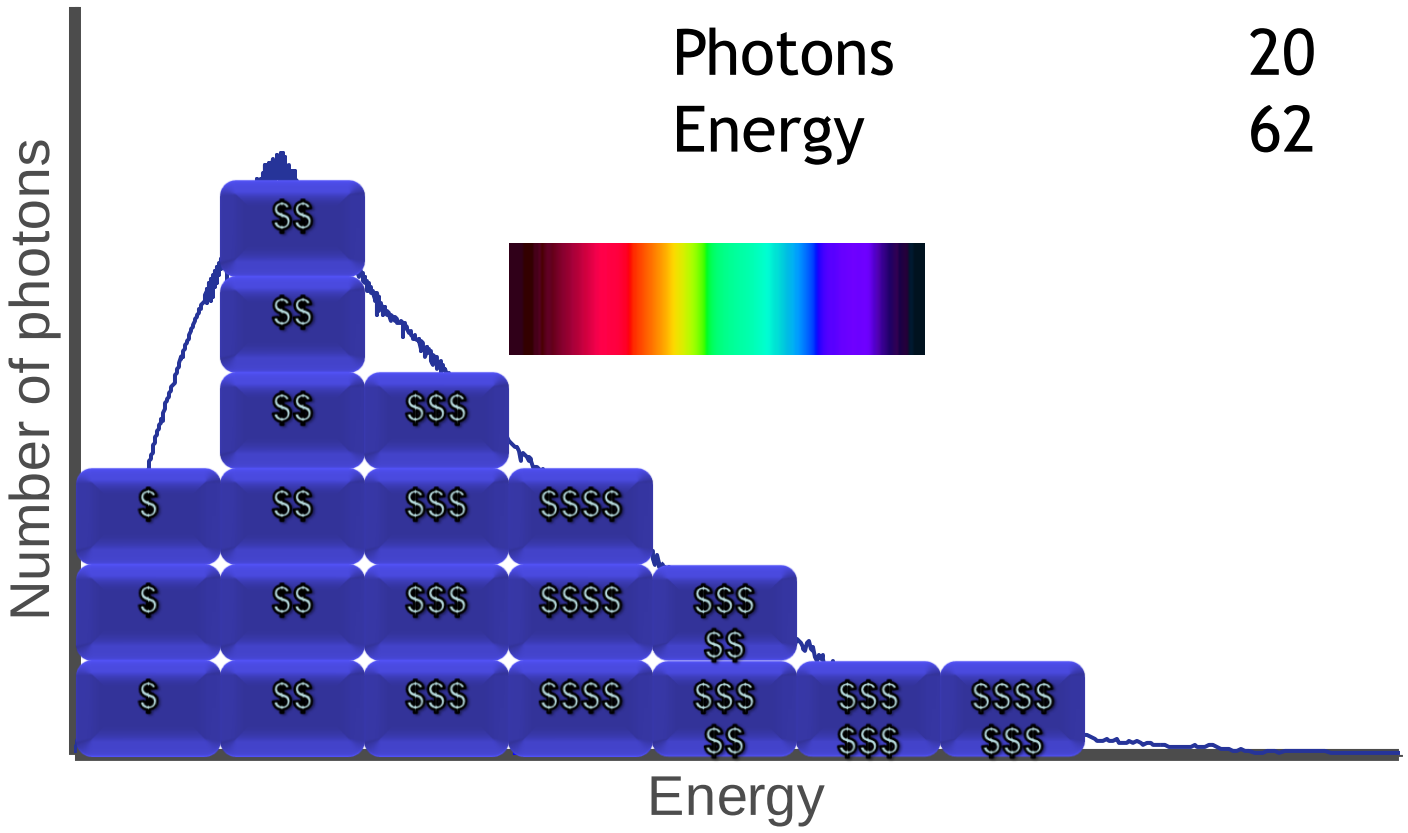
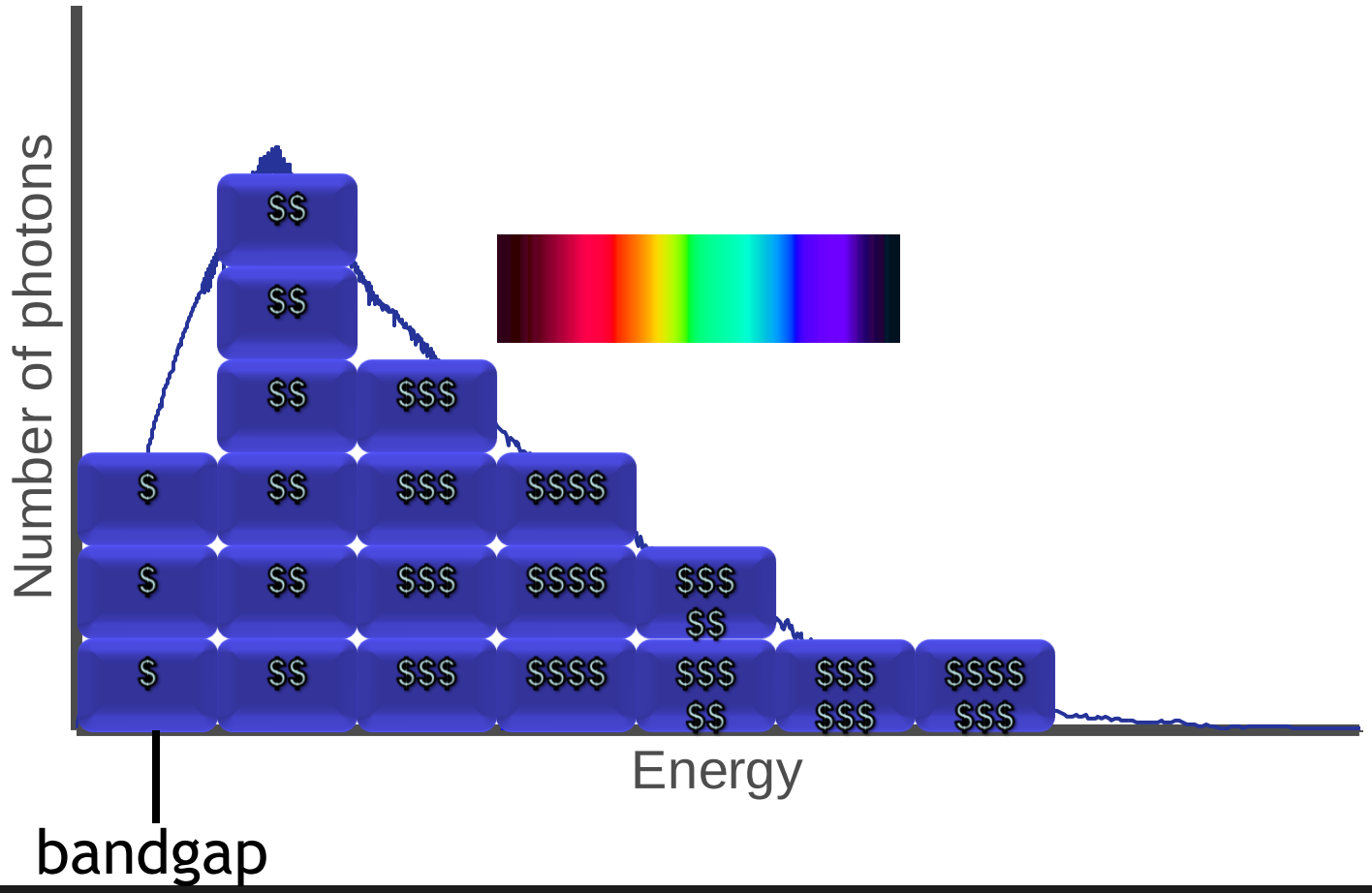


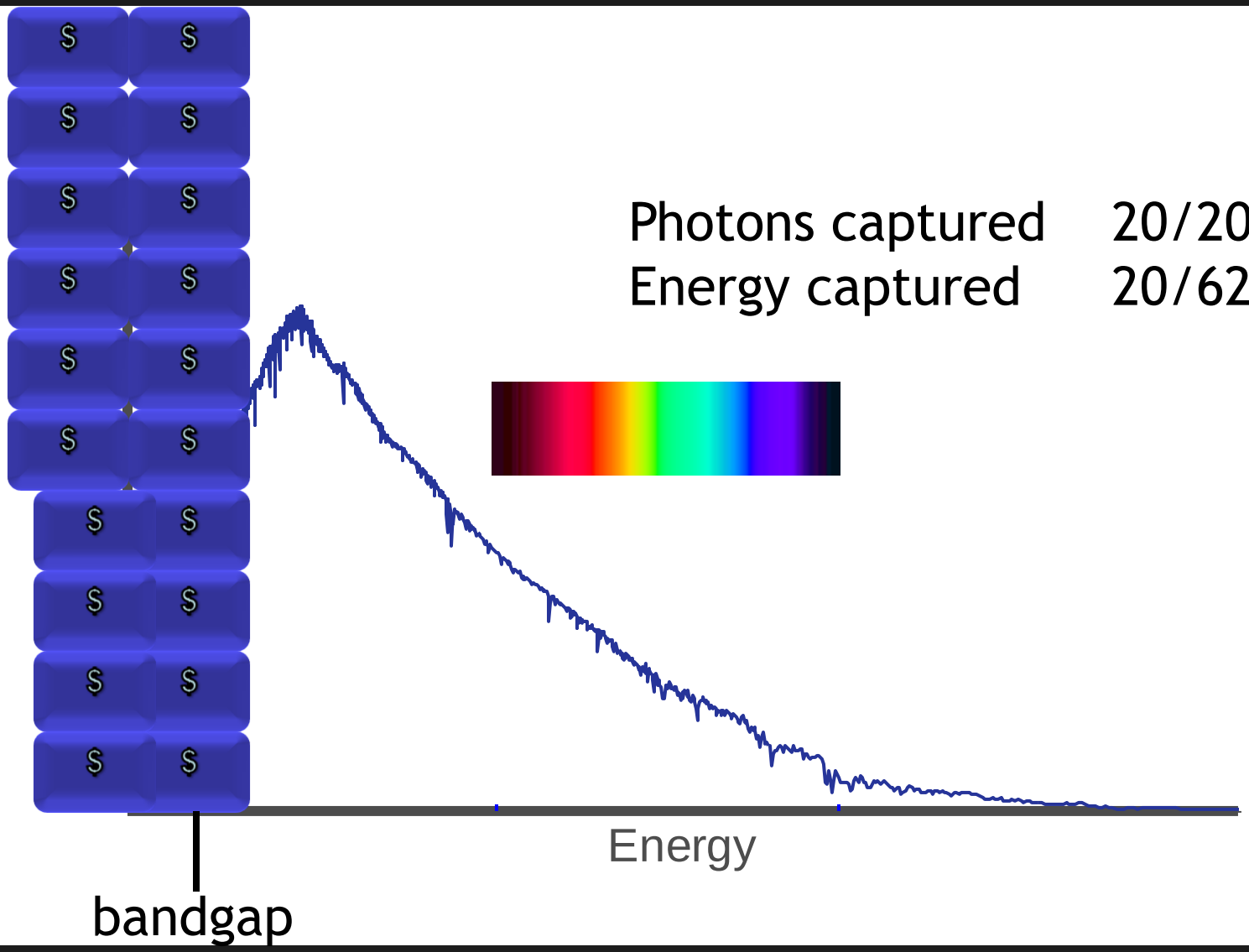
Solar spectrum

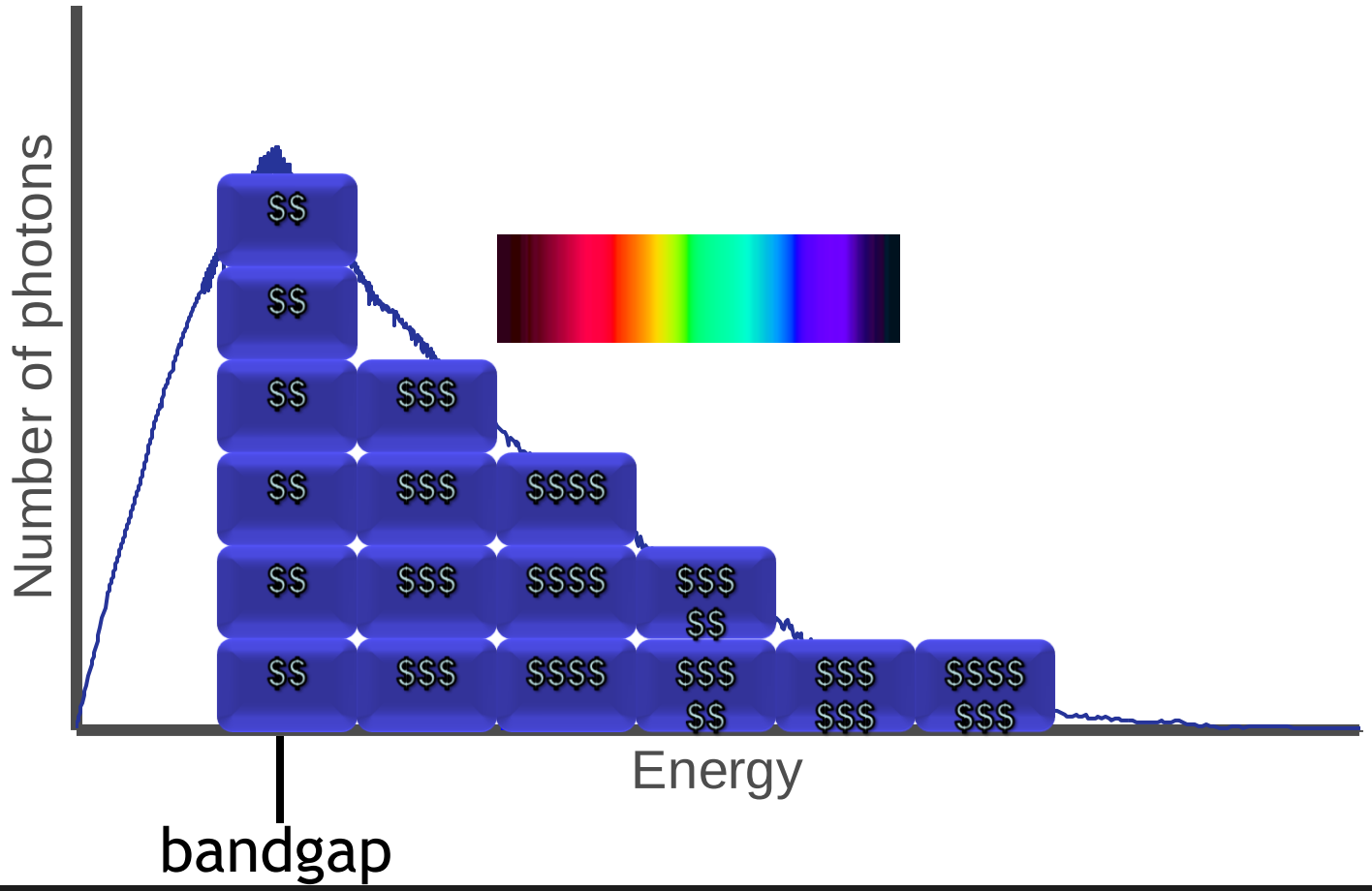


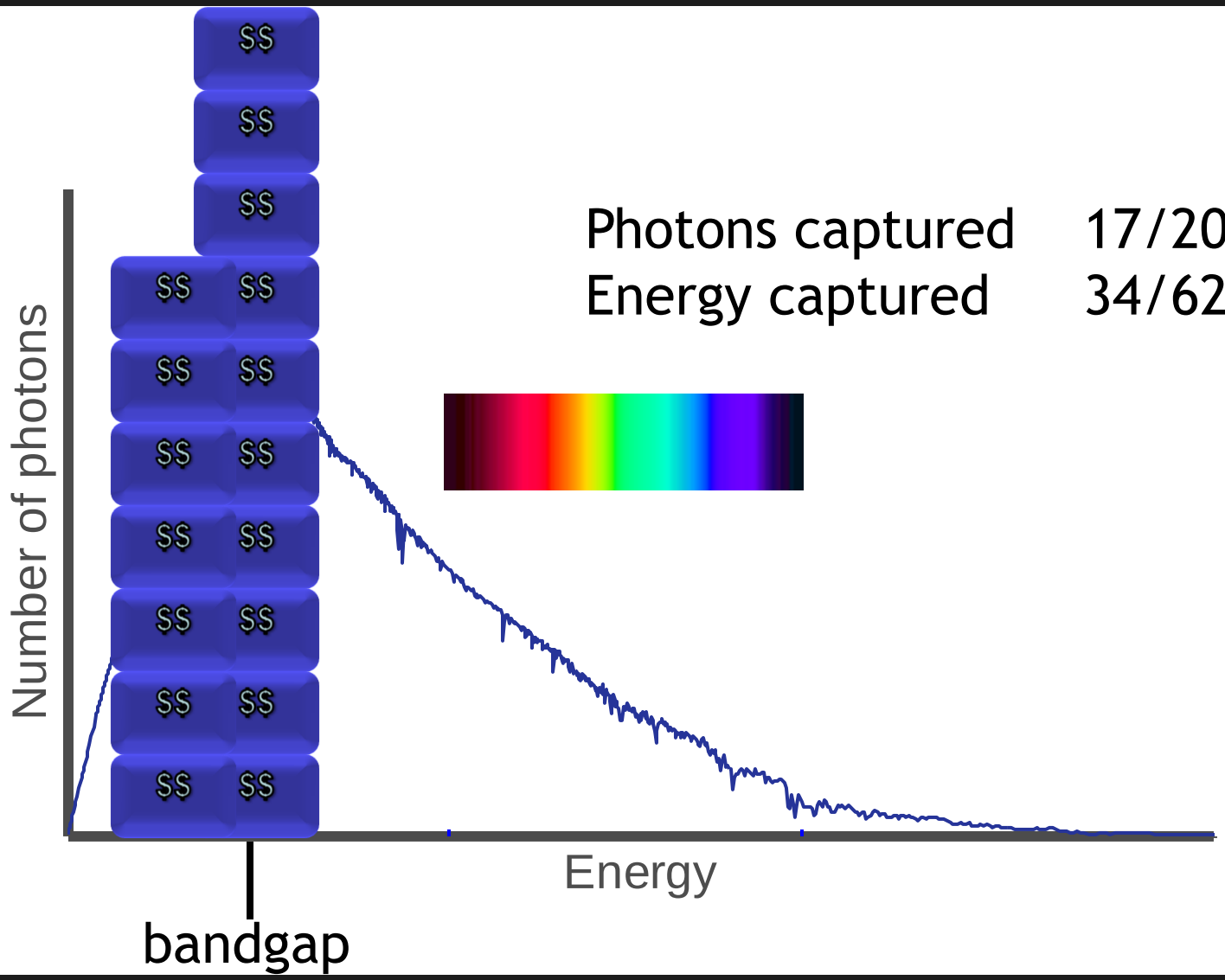

Photons
20
Number of photons
Energy



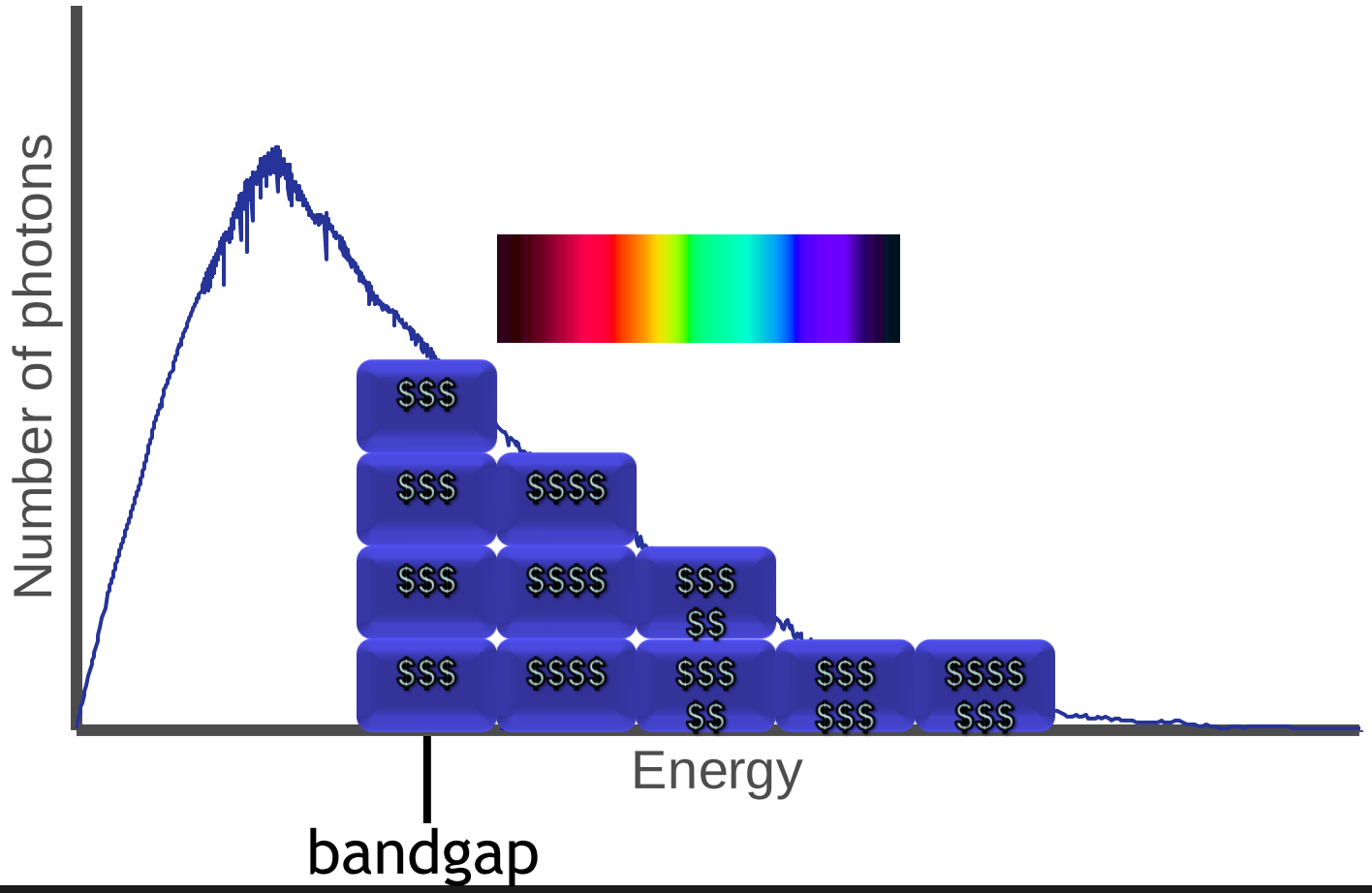


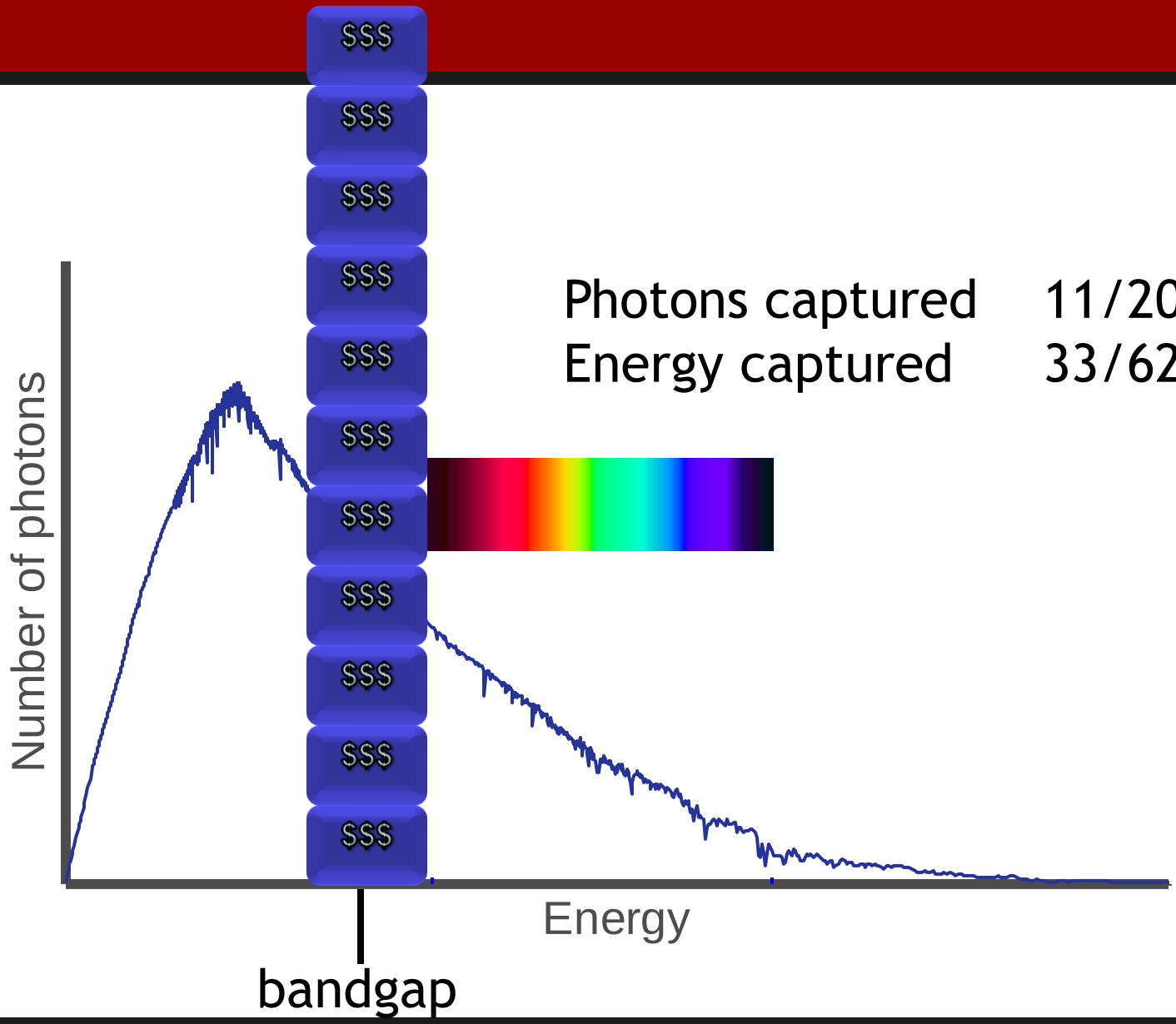

Photons captured 20/20 (100%)
Energy captured 20/62 (32%)
Energy
bandgap


Number of photons
Energy
bandgap

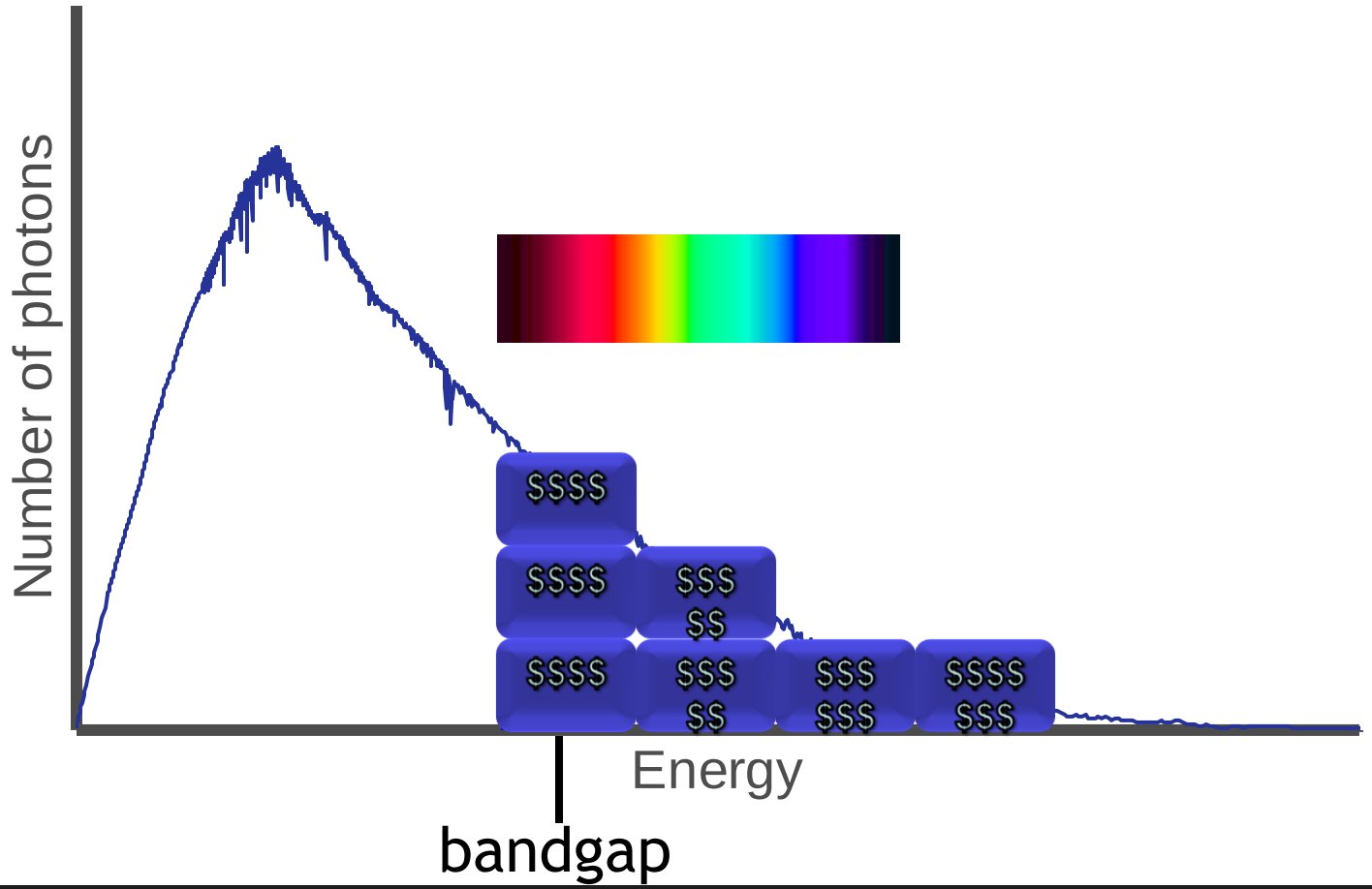


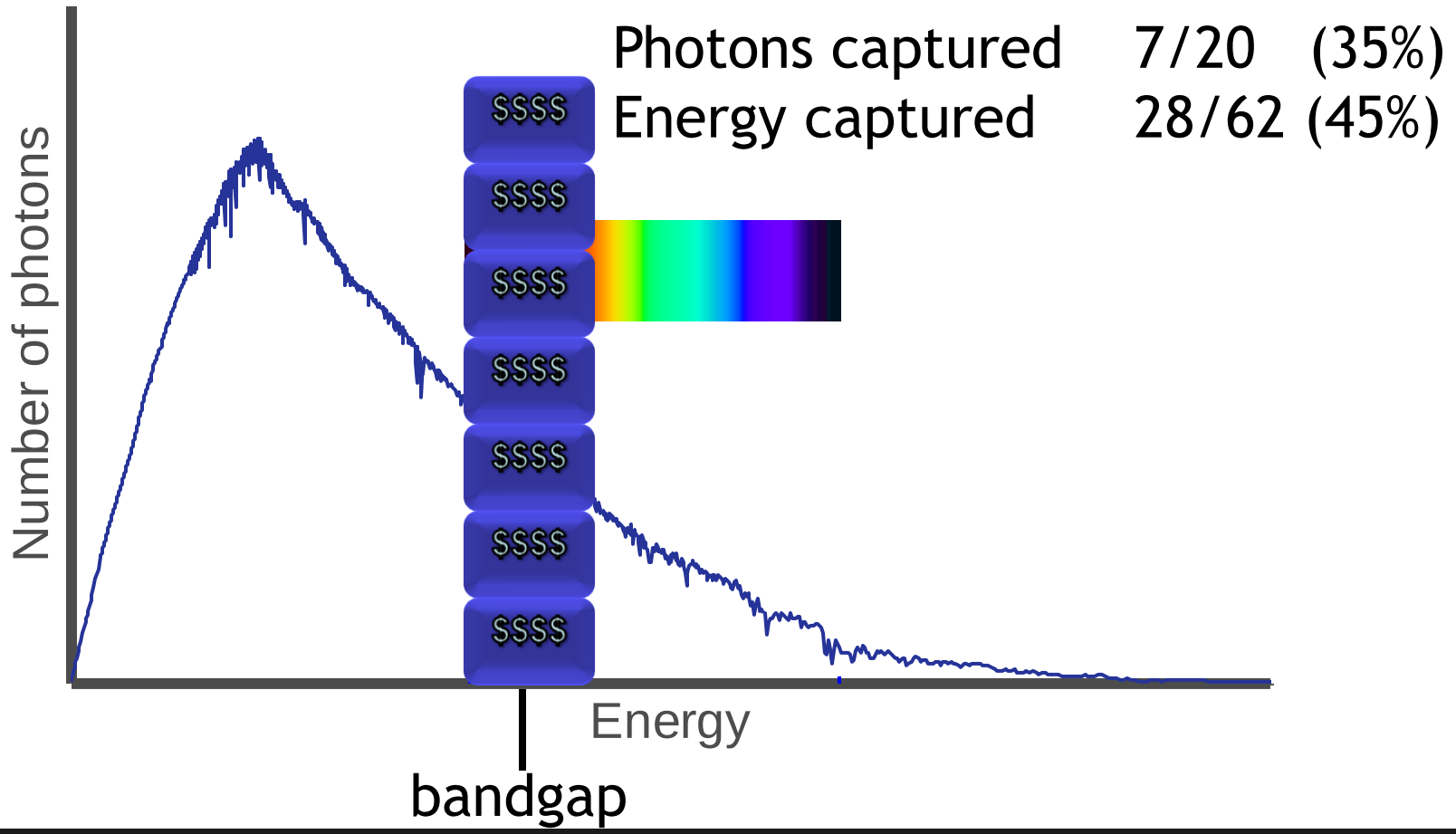
Photons captured 17/20 (85%)
Energy captured 34/62 (55%)


Number of photons
$$$
$$$
$$$$
$$$
$$$$
$$$
$$
$$$
$$$$
$$$
$$$
$$$
$$$
Energy
bandgap



Photons captured 11/20 (55%)
Energy captured 33/62 (53%)


Number of photons
$$$$
$$$$
$$$
$$
$$$$
$$$
$$
$$$
$$$
$$$$
$$$
Energy
bandgap



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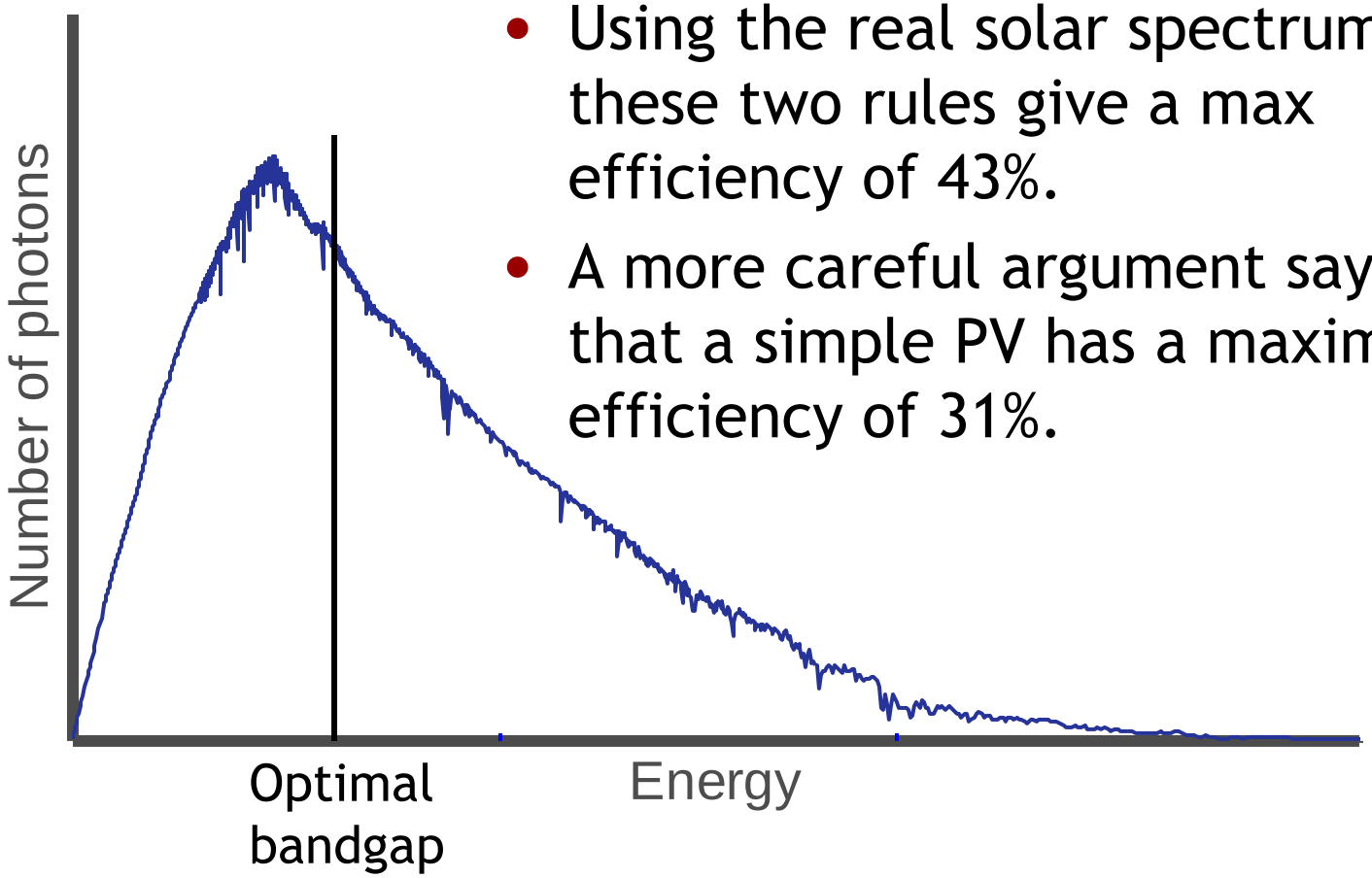


- Using the real solar spectrum, these two rules give a max efficiency of 43%.
- A more careful argument says that a simple PV has a maximum efficiency of 31%.

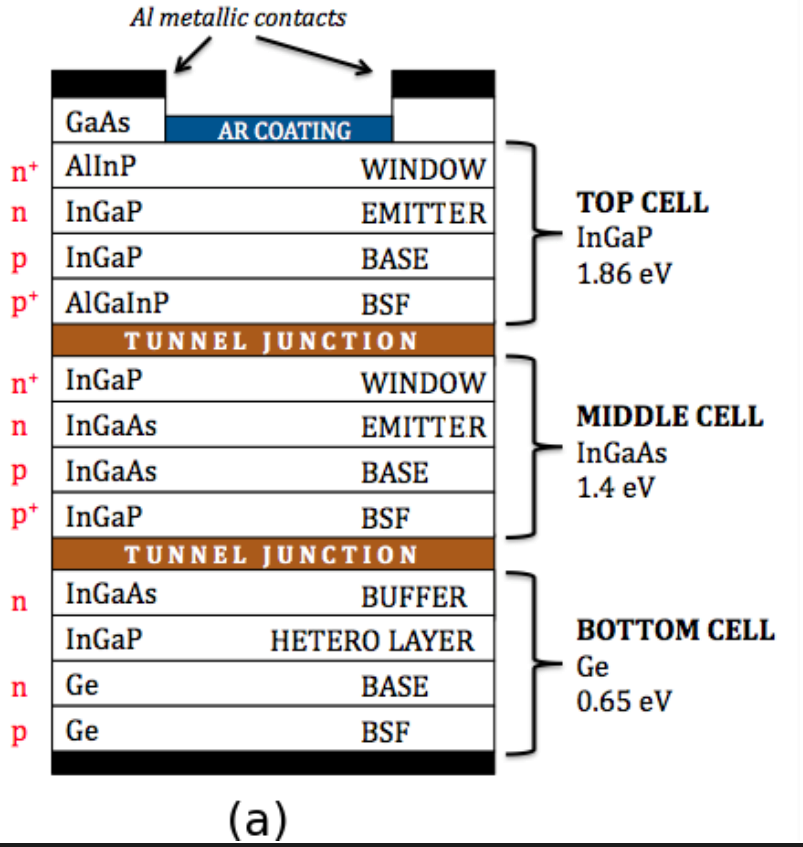
Breaking the limits

- Highest recorded efficiency is 44%. How'd they do it?

http://en.wikipedia.org/wiki/File:StructureMJetspectre.png

Breaking the limits

- Highest recorded efficiency is 44%. How'd they do it?
- Three solar cells in a stack. Each gets different colors.



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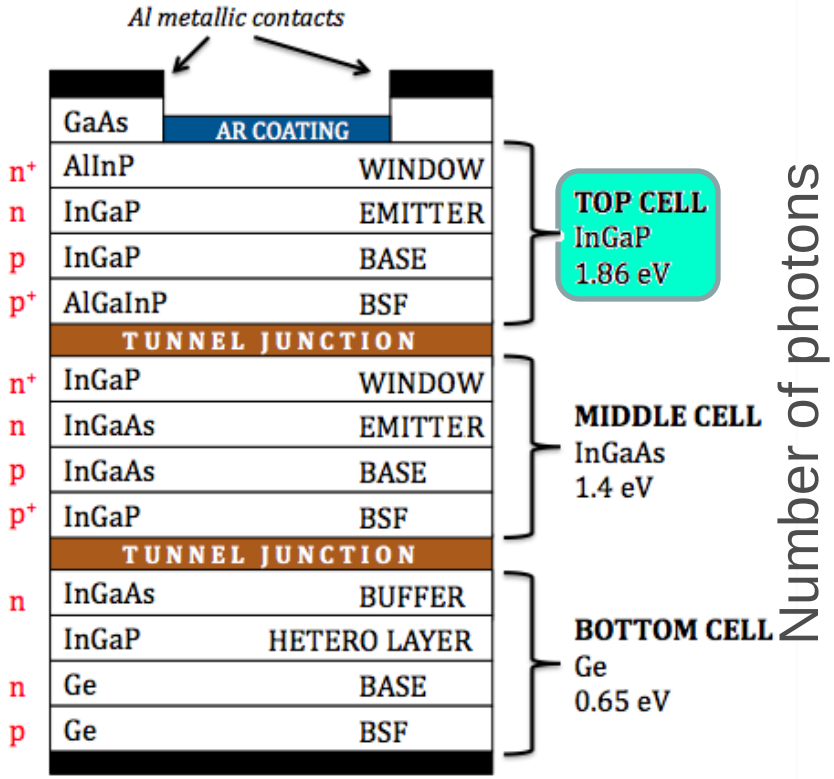
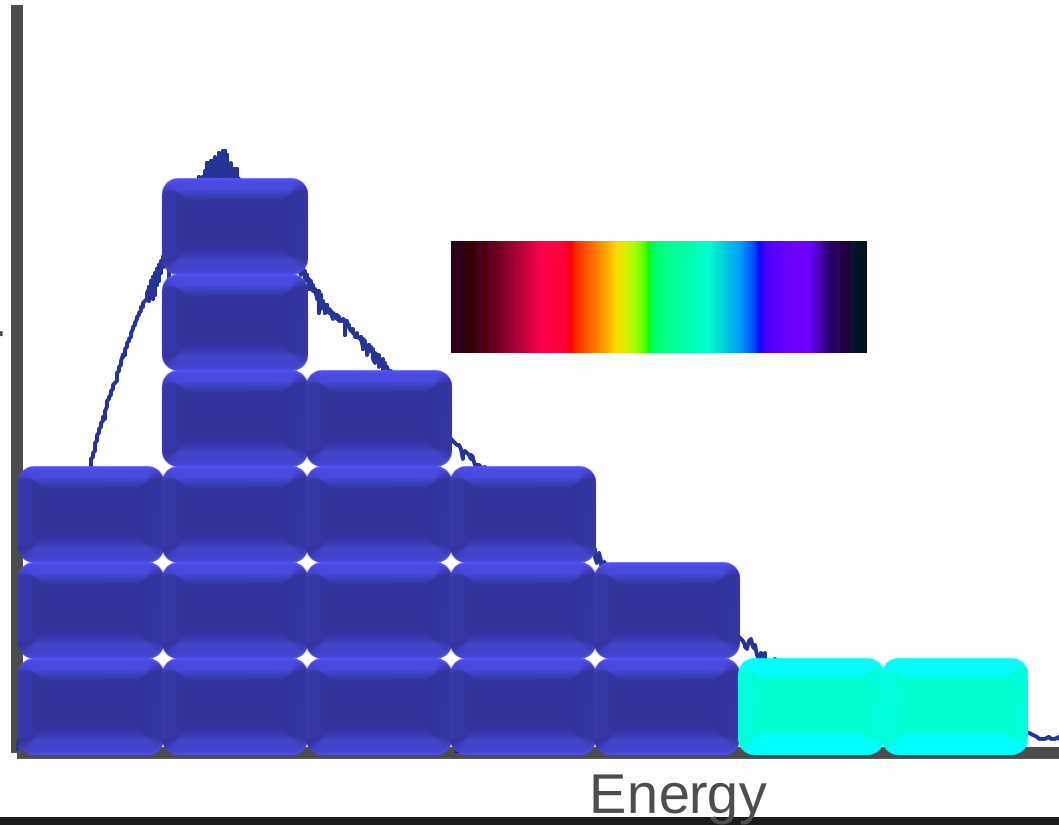


(a)



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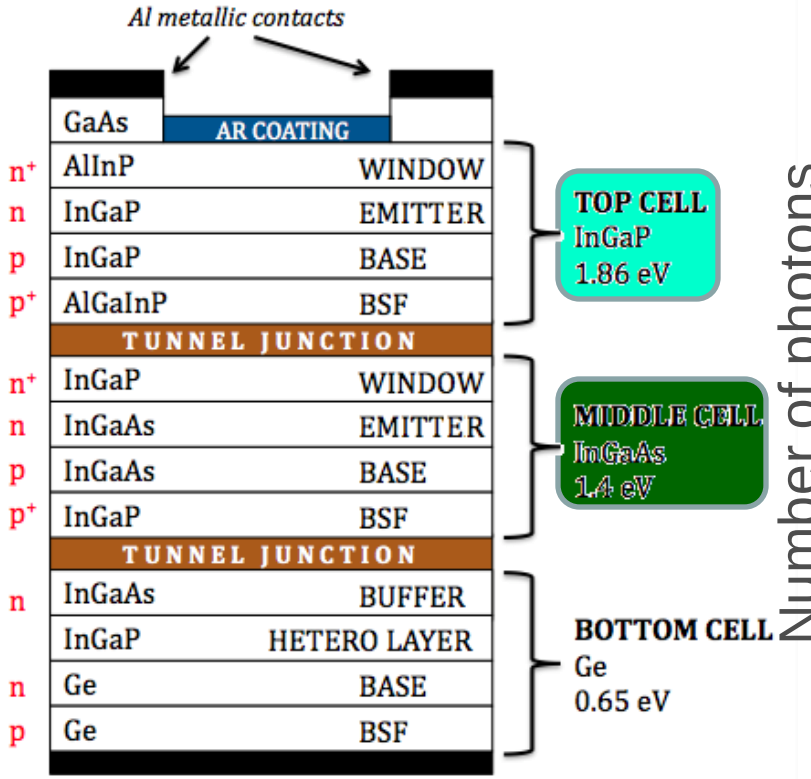

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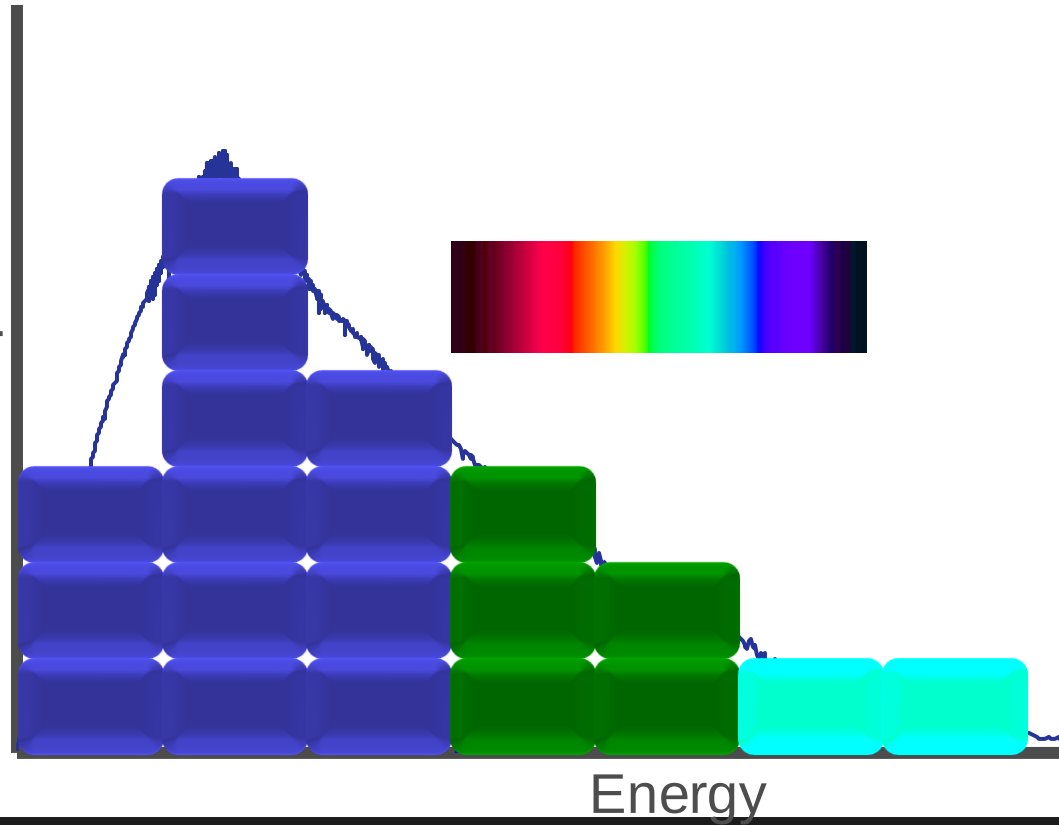

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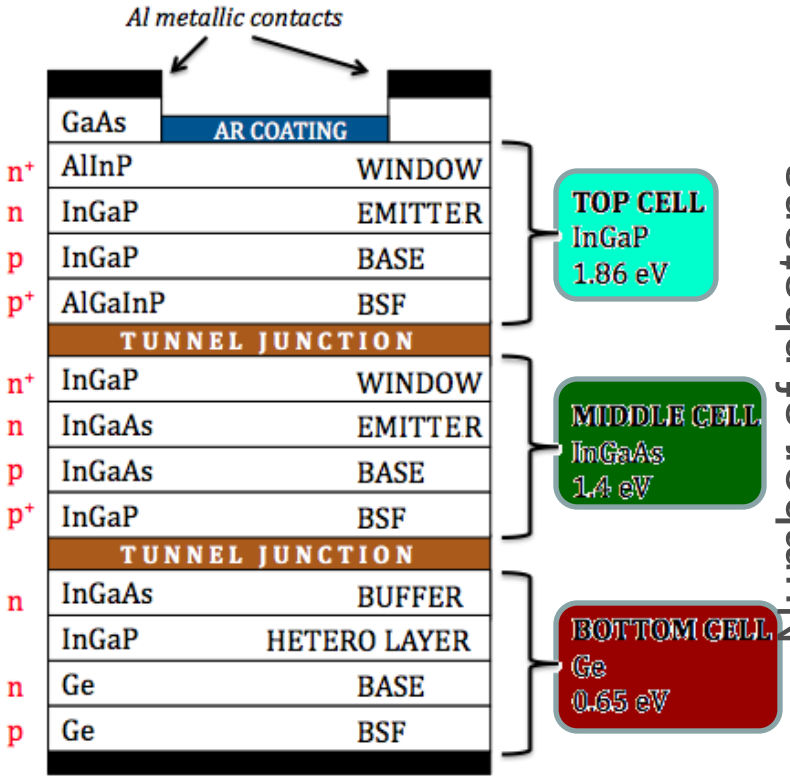

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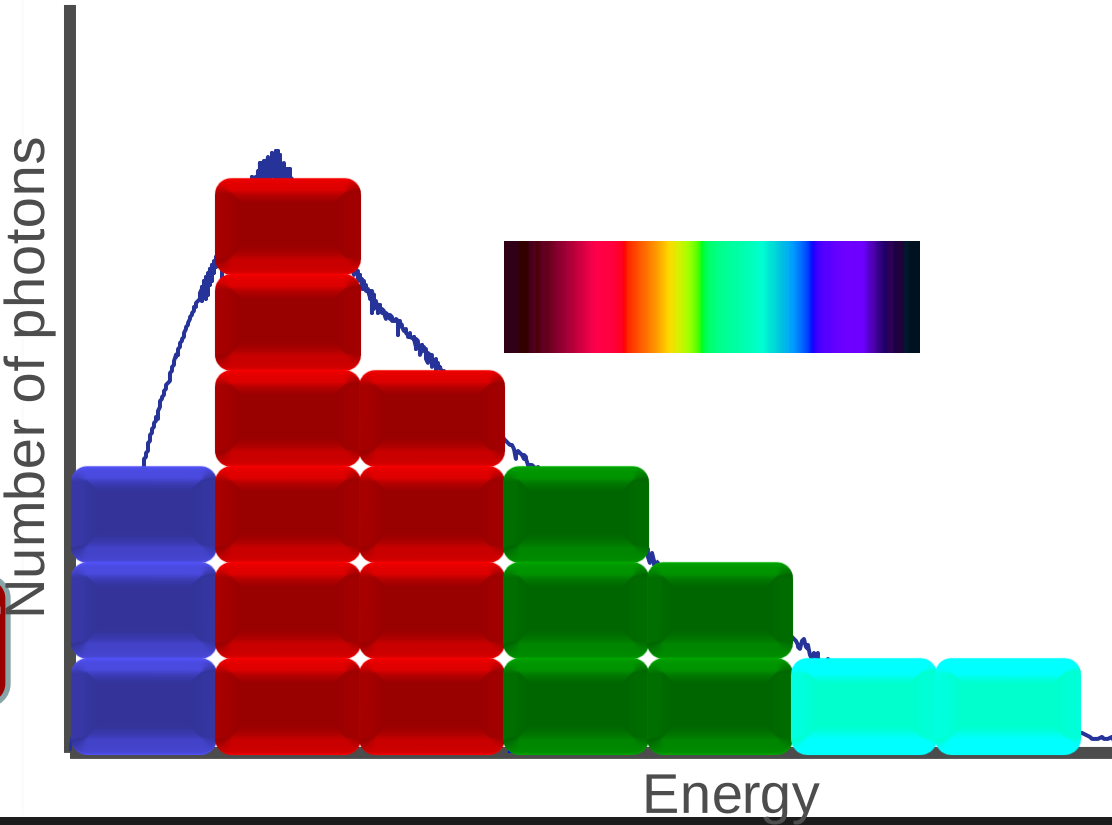

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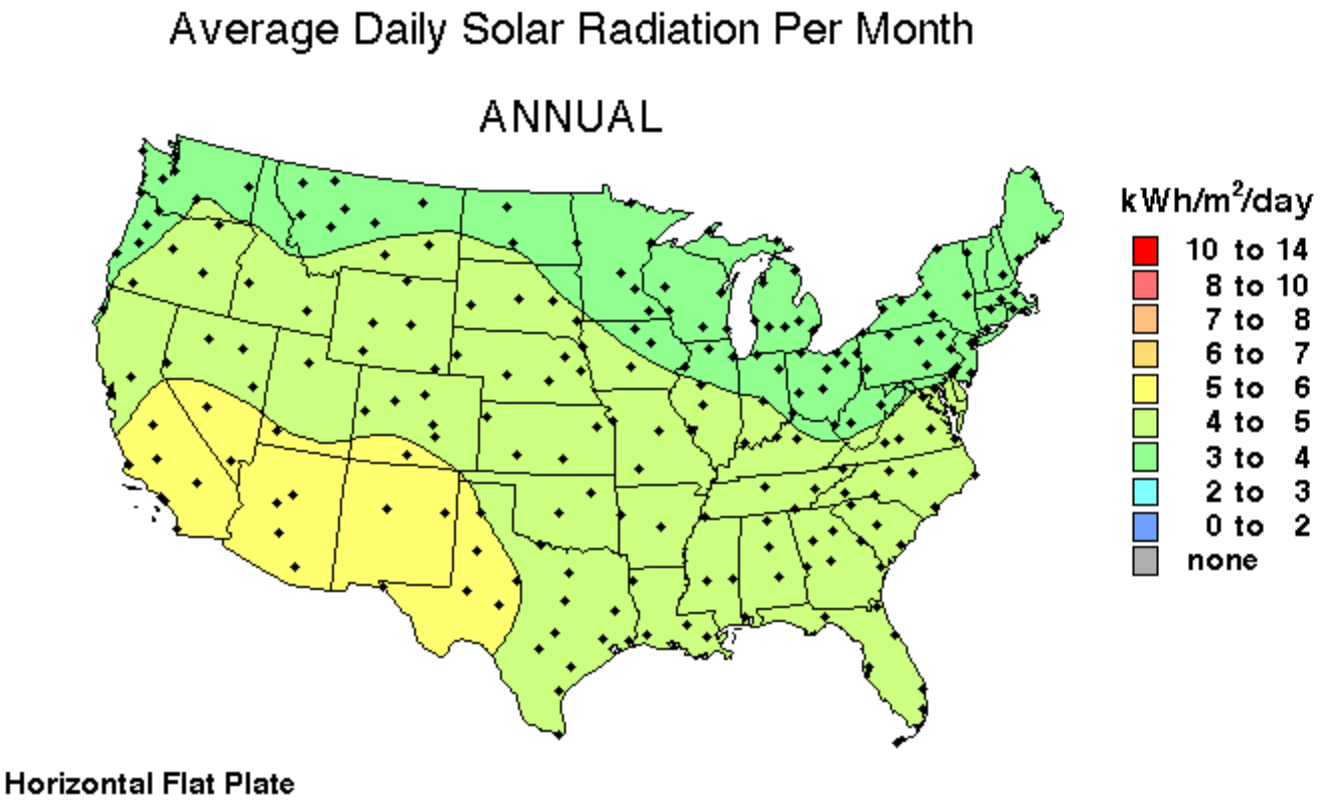
Where should we put solar?

More sunlight falls on the south than the north.

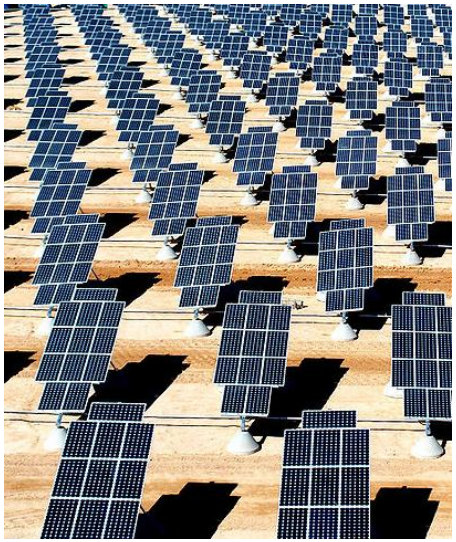


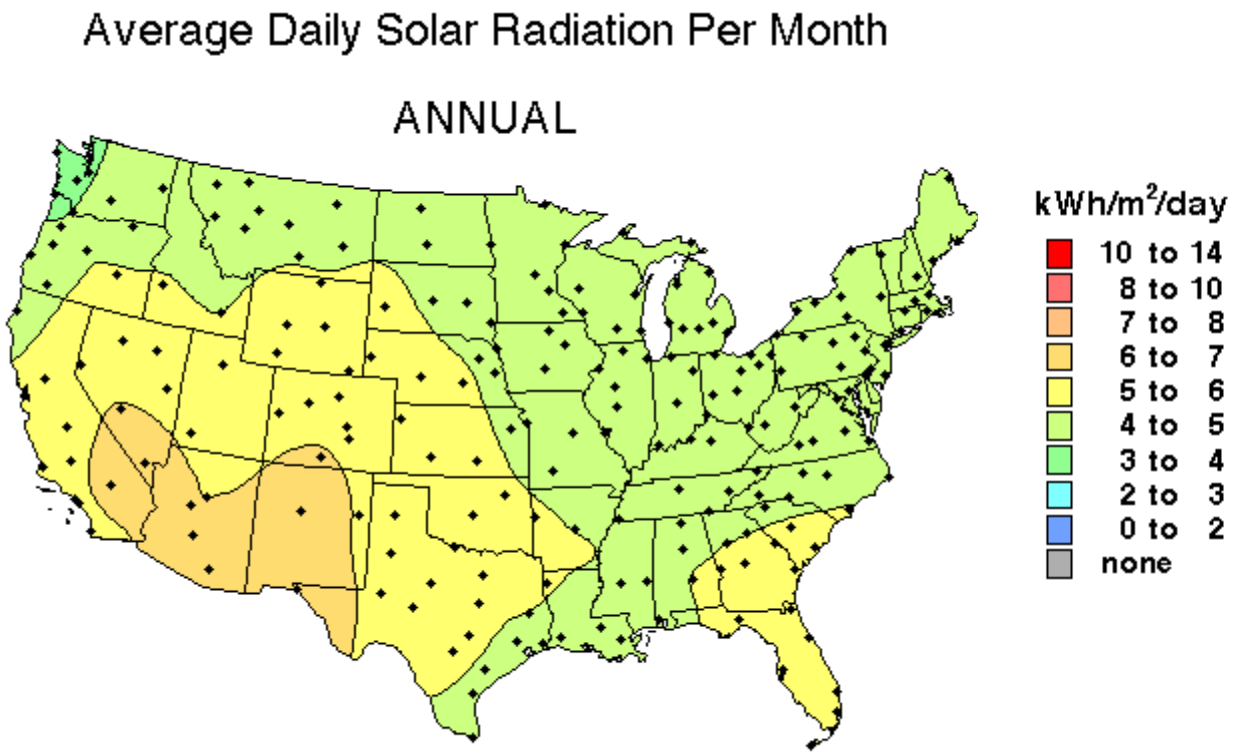
http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/

Where should we put solar?

More sunlight falls on the south than the north.

But we can tilt the panels.



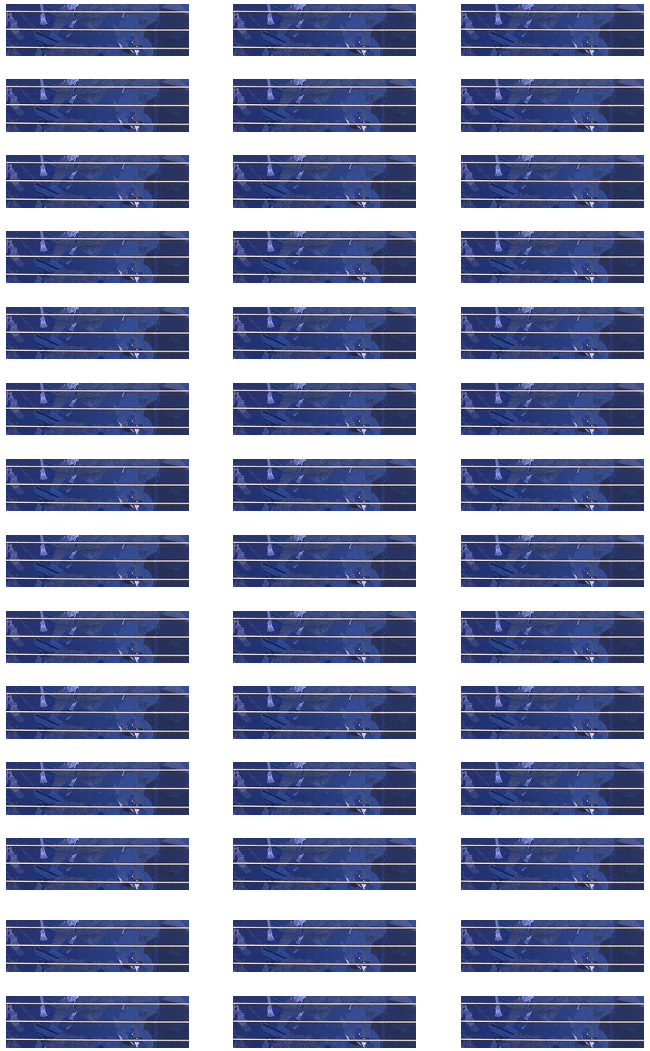


Flat Plate Tilted South at Latitude

http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/
http://commons.wikimedia.org/wiki/File:Giant_photovoltaic_array.jpg

Solar modules do not like shade

- Solar modules are often wired in **series**.
- Shading one cell blocks a disproportionate amount of current.
- Keep your solar panels 100% unshaded.



Shaded cells	Current (mA)	Percent shaded	Percent decrease in current
0	8	0%	0%
1	7.2	2%	10%
2	5.6	**5%**	**30%**
14	1.5	**33%**	**81%**

Summary

- Photovoltaics cannot convert all the sun's energy.
- Two simple rules tell us that the maximum efficiency of standard photovoltaics is about 30%.
  Much research is being done to break this limit.
- It can make sense to put photovoltaics in Boston.
- Keep them out of the shade.

Star Power

1: Introduction to energy

2: Photovoltaics (Jacob)

3: Solar Thermal applications (Dan)