


# Kinetic and Solar energy

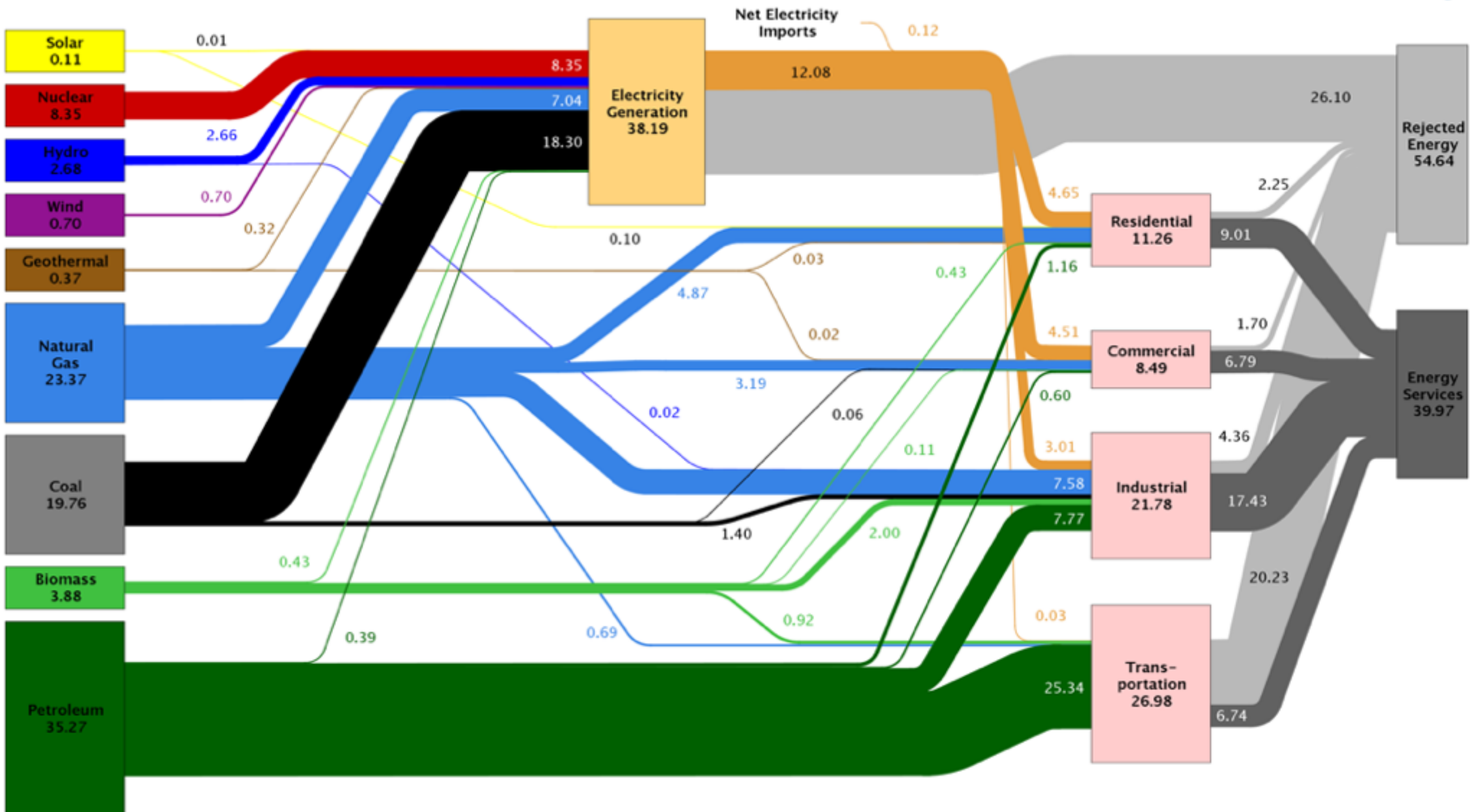
The image shows a wide-angle view of a tidal energy farm, likely the Bennington Energy project. The scene is captured from an elevated position, possibly a walkway or observation deck, looking down at the water. The water is a light blue-grey color. In the foreground and middle ground, there are several rows of tidal turbines. Each turbine consists of a vertical support structure with a horizontal arm extending into the water, which holds a large, dark, rectangular blade. The turbines are arranged in a grid-like pattern across the water. The background shows more turbines extending towards the horizon. The sky is bright and clear. The overall structure of the farm is made of metal, with visible beams and supports. The image is taken during the day, with sunlight reflecting off the water and the metal surfaces.

Bennington Energy 2012  
Feddersen

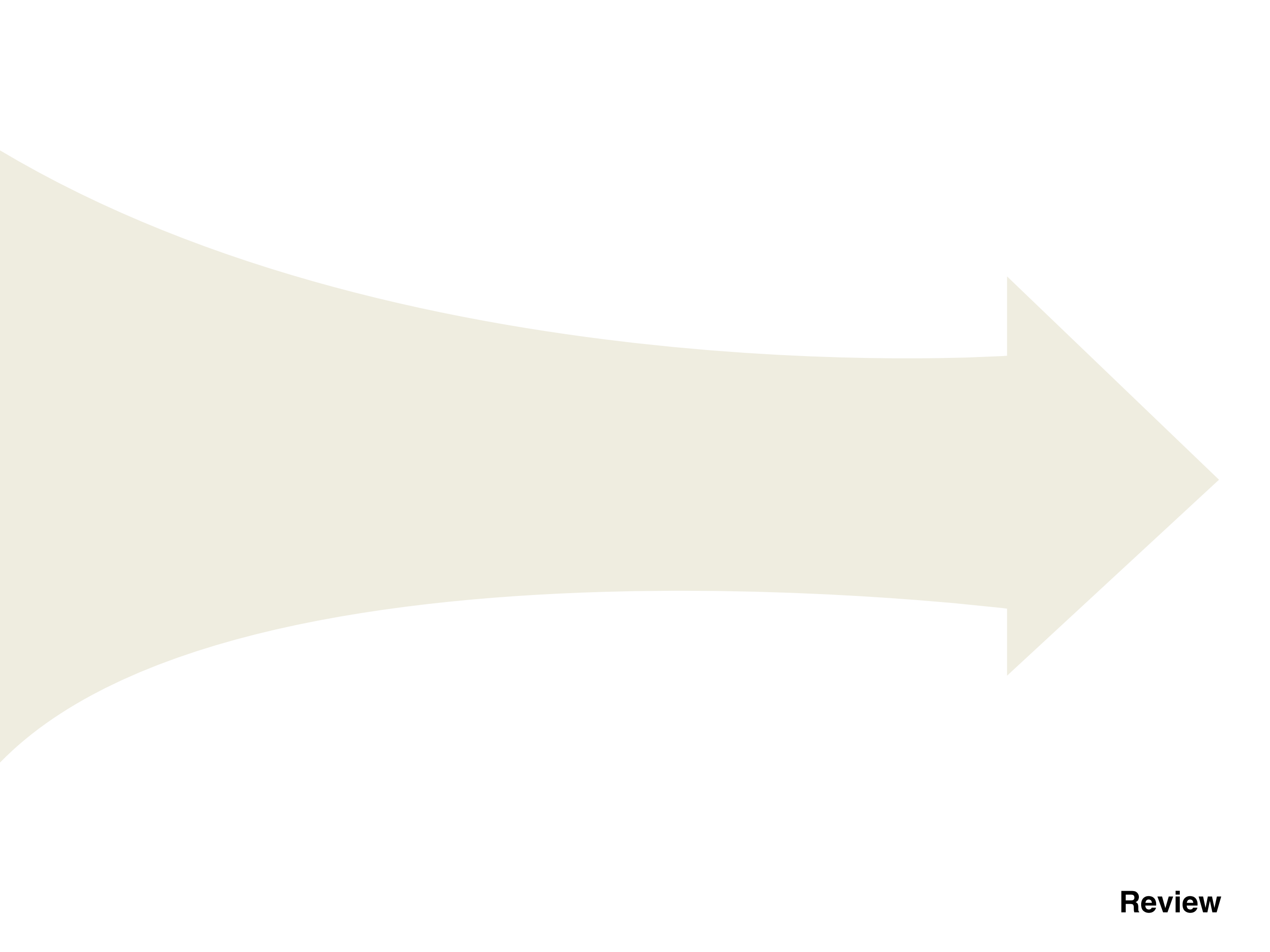


**REVIEW**

# Estimated U.S. Energy Use in 2009: ~94.6 Quads

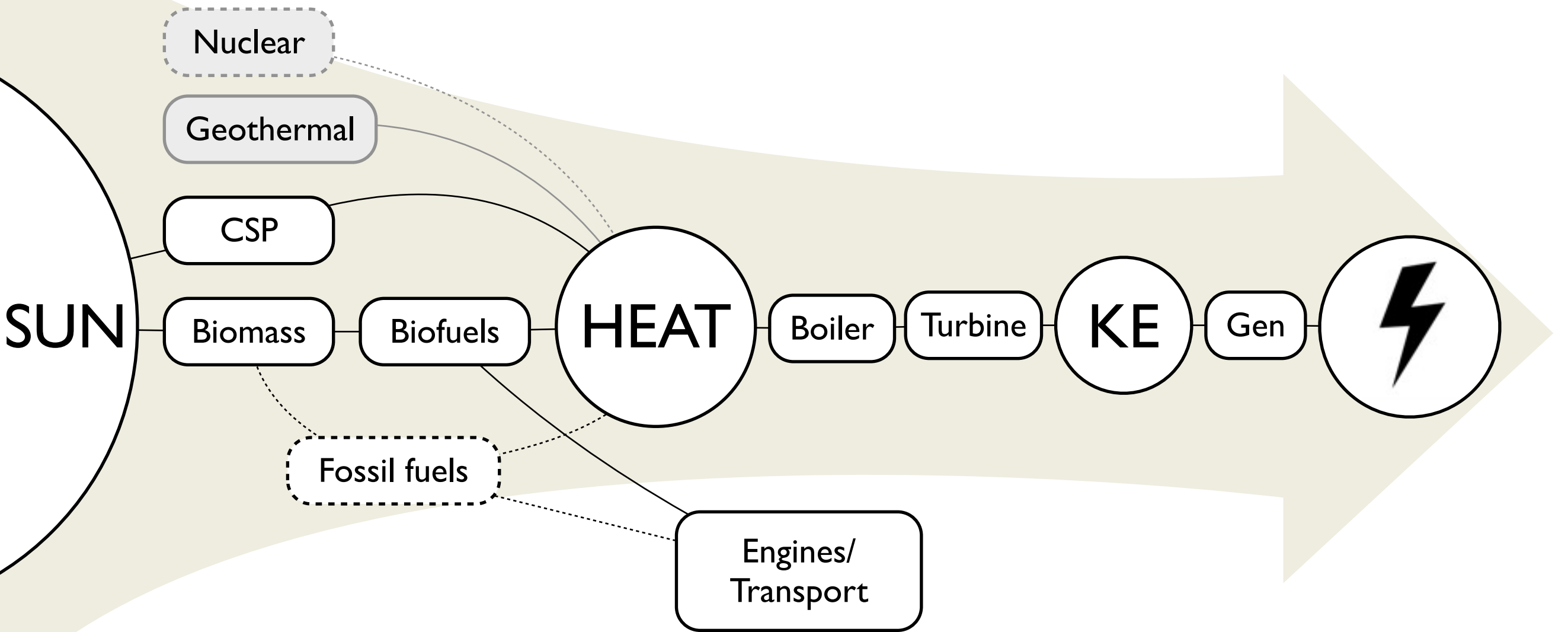


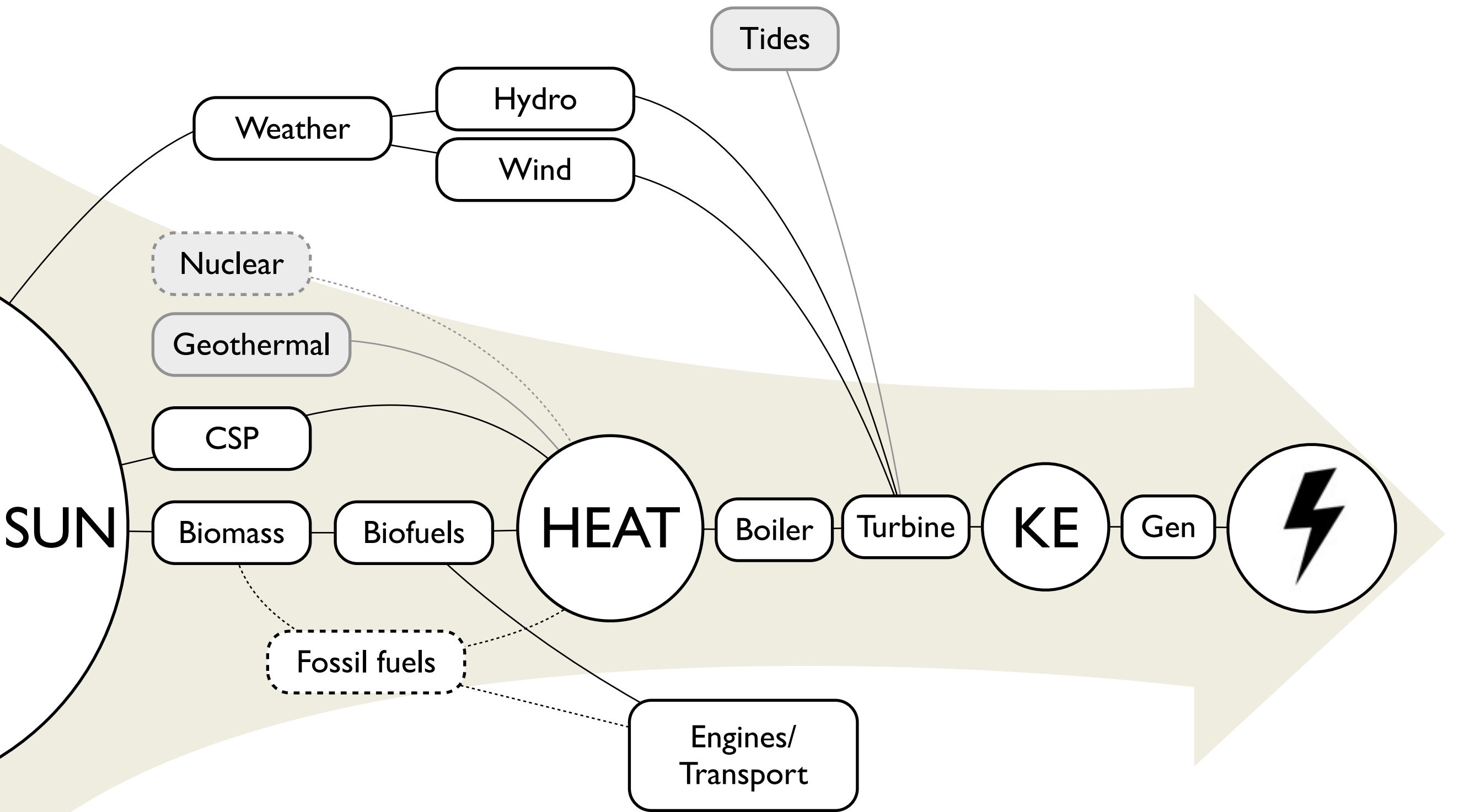
Source: LLNL 2010. Data is based on DOE/EIA-0384(2009), August 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527



**Review**

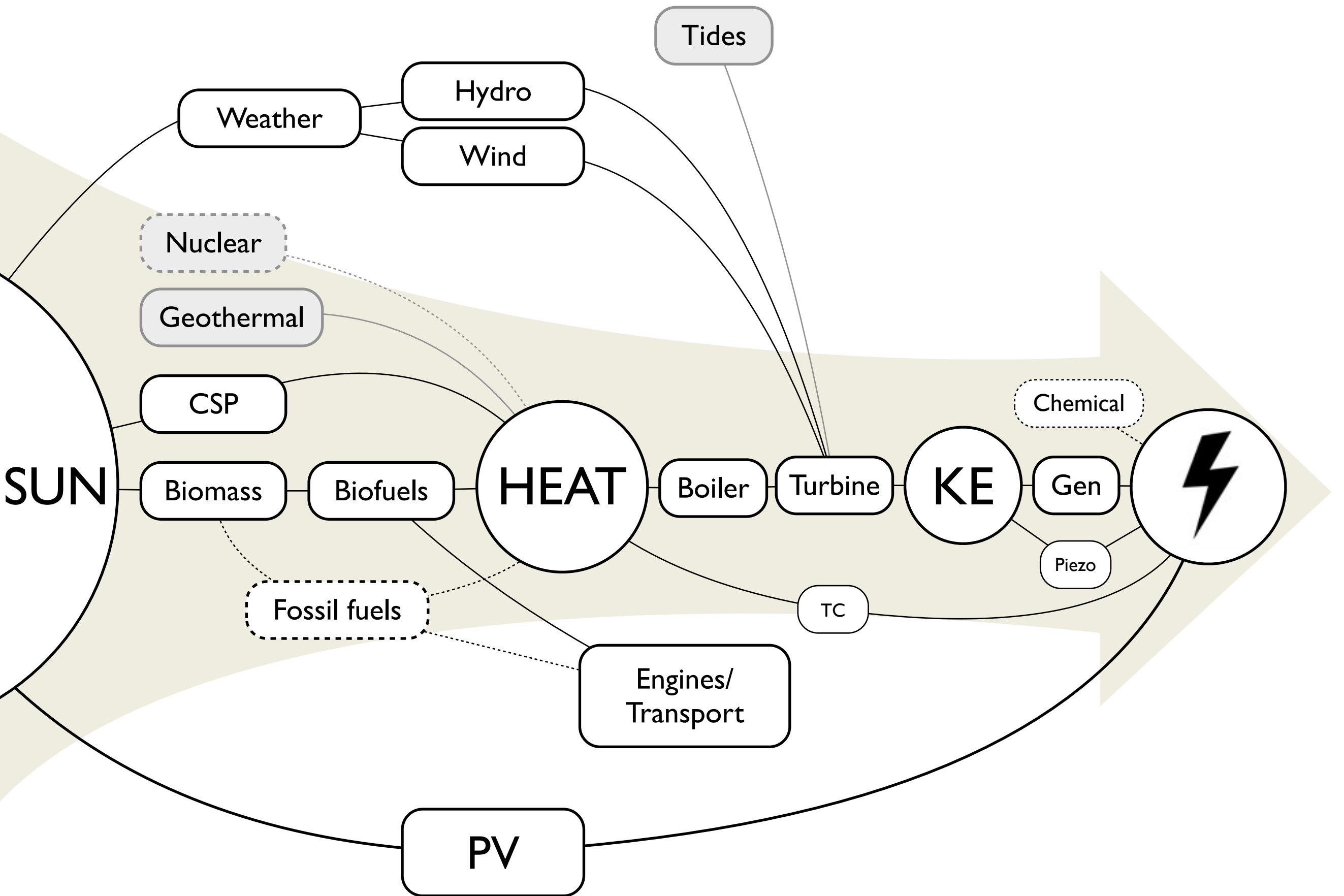




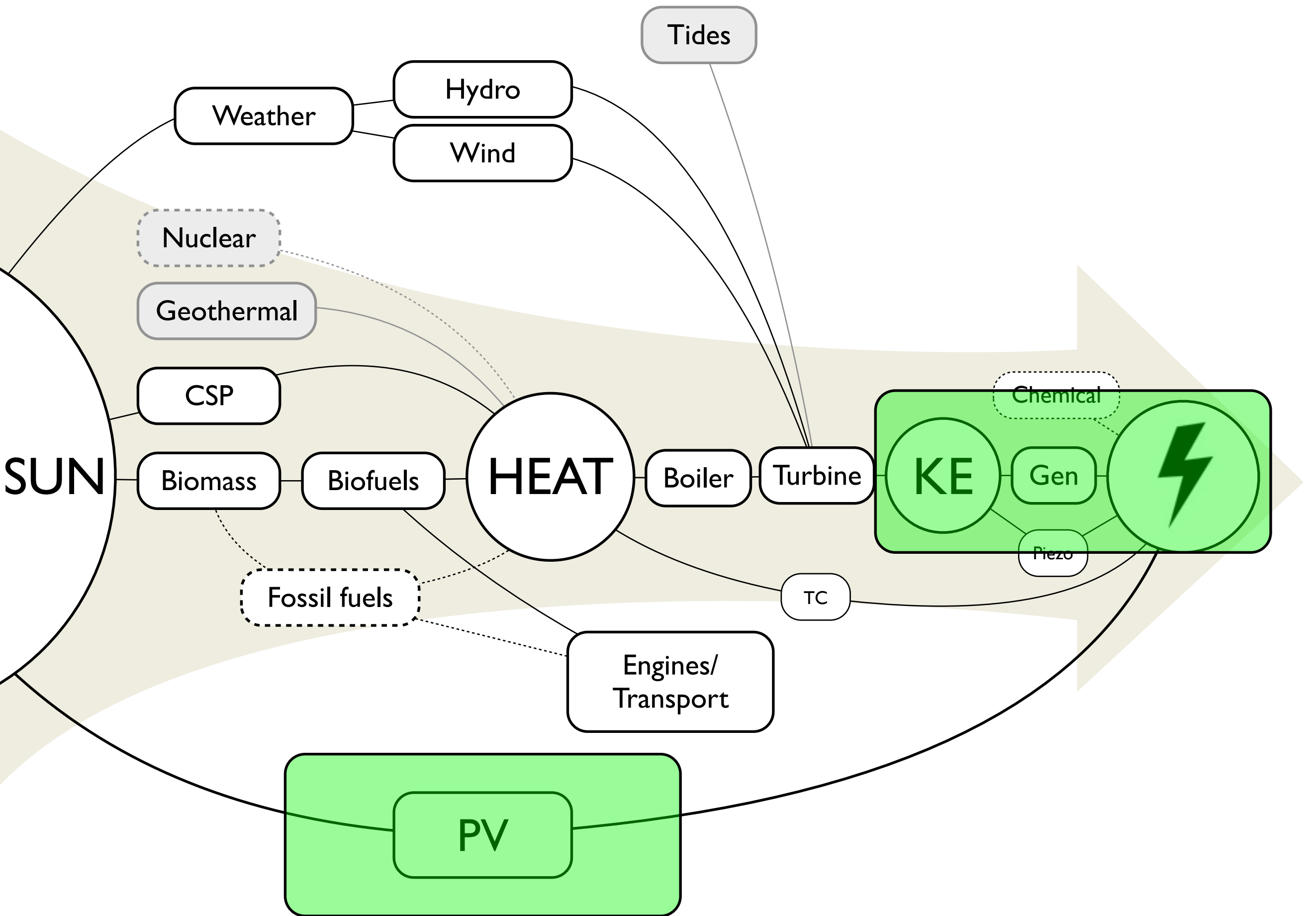










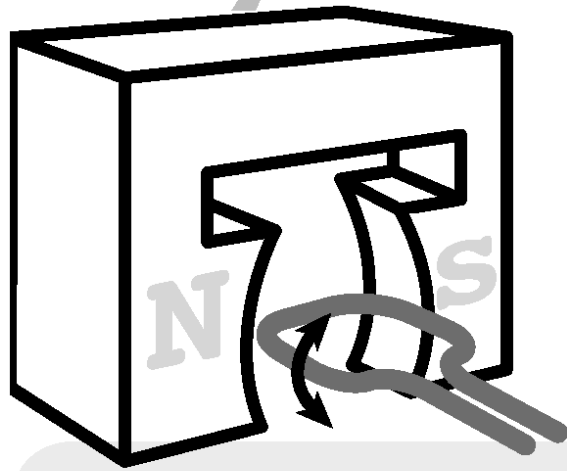


**Review**

# **KINETIC OVERVIEW**



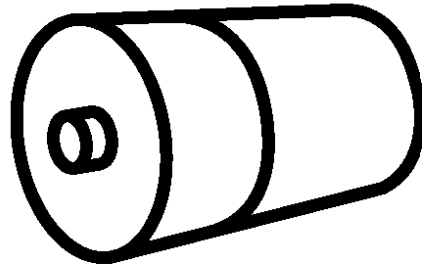
# (some) Ways of generating electricity:



## Electromagnetic Induction

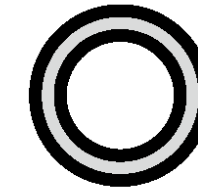
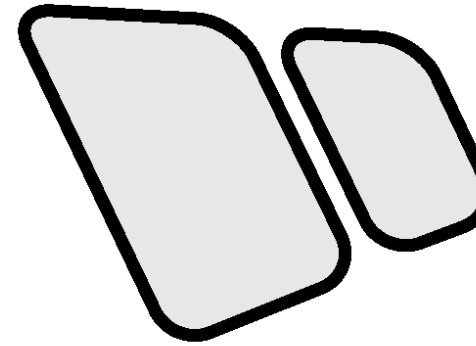
Moving conductors past magnets (or vice versa) causes electrons to move. This turns kinetic energy (the energy of moving things) into electrical energy (the energy of moving electrons).

This is the principle behind most large-scale electricity generation. Thermal power plants (coal, natural gas, nuclear, etc.) heat steam to move turbines to spin generators; hydropower dams and wind turbines spin generators with falling water and moving air. PV, the only large non-induction means of electricity generation, is a fraction of the "other renewables" slice at right.



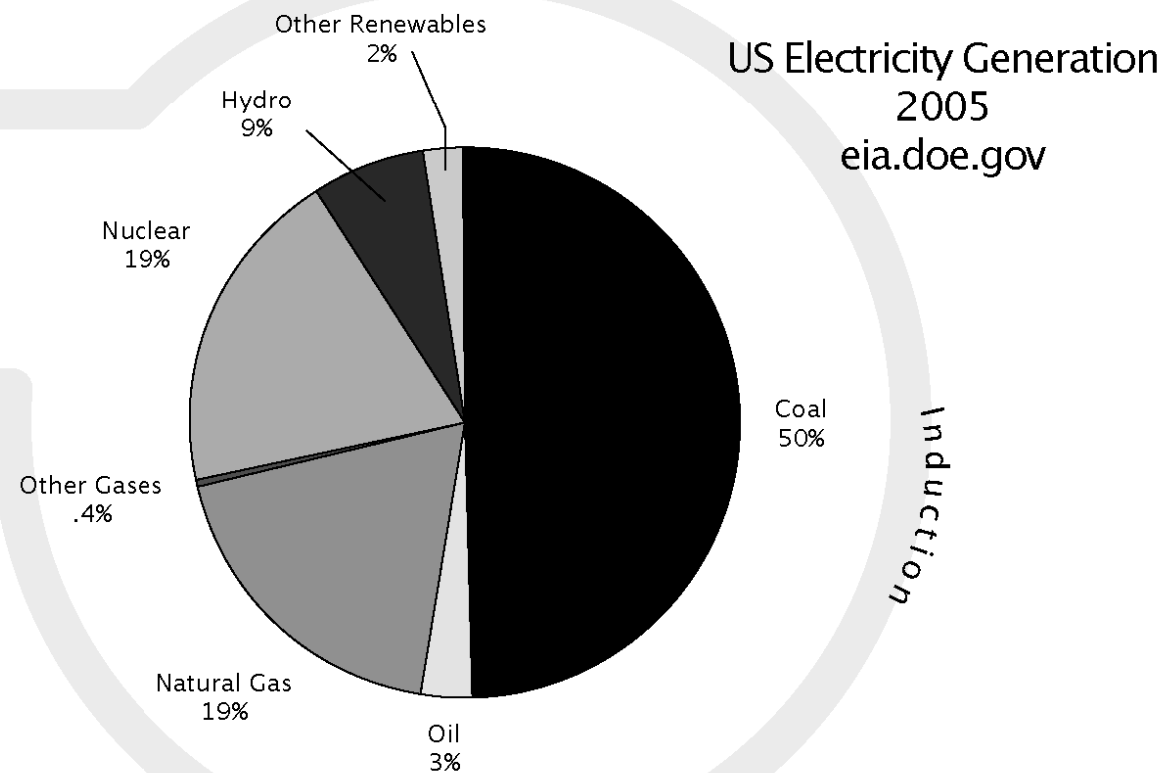
## Batteries + Fuel Cells

Chemical reactions can move electrons. If the reactions are reversible, electricity from other sources can be stored this way, too.

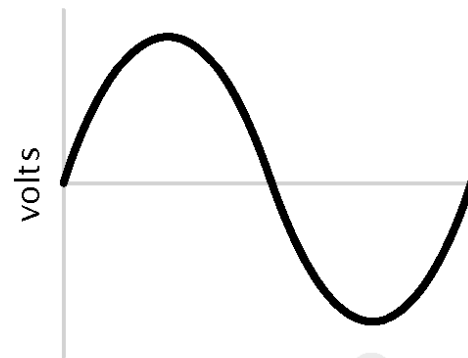
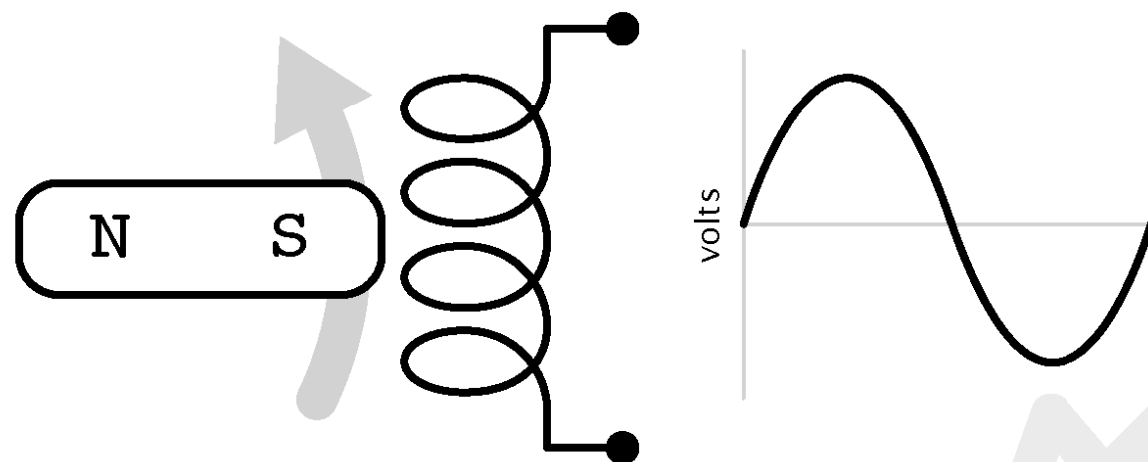


## Photovoltaics, Piezo, and Thermal

Semiconductors can directly convert light (via photovoltaics) or heat (via peltier junctions) into electricity. Certain materials exhibit the piezo effect, where pressure or stress generates electricity.



Induction also works in reverse – moving electricity makes a magnetic field. This is how electric motors work. In fact, most electric motors can work backwards as perfectly good generators (this is exploited by regenerative braking in electric or hybrid vehicles).

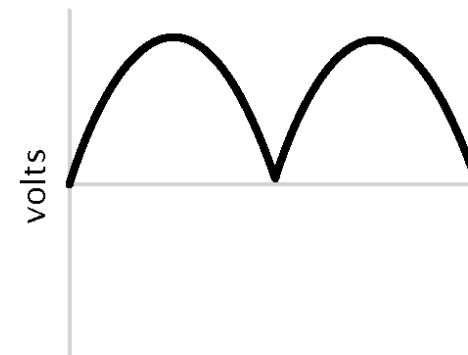
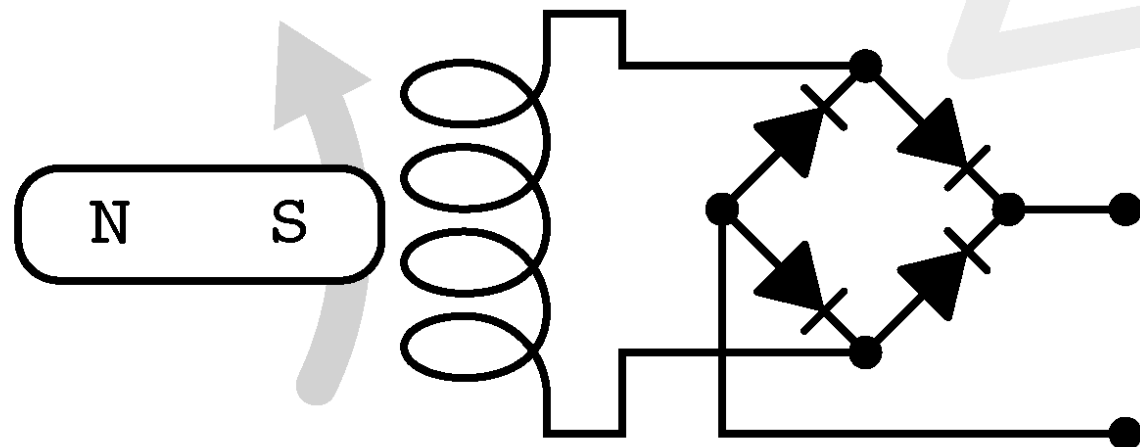


A magnet moving past a coil will produce electricity moving first in one direction and then the other – alternating current, or AC.

A diode is an electrical component that only lets electricity flow one way.



This arrangement of four diodes (called a bridge rectifier) will make AC into direct current, or DC.





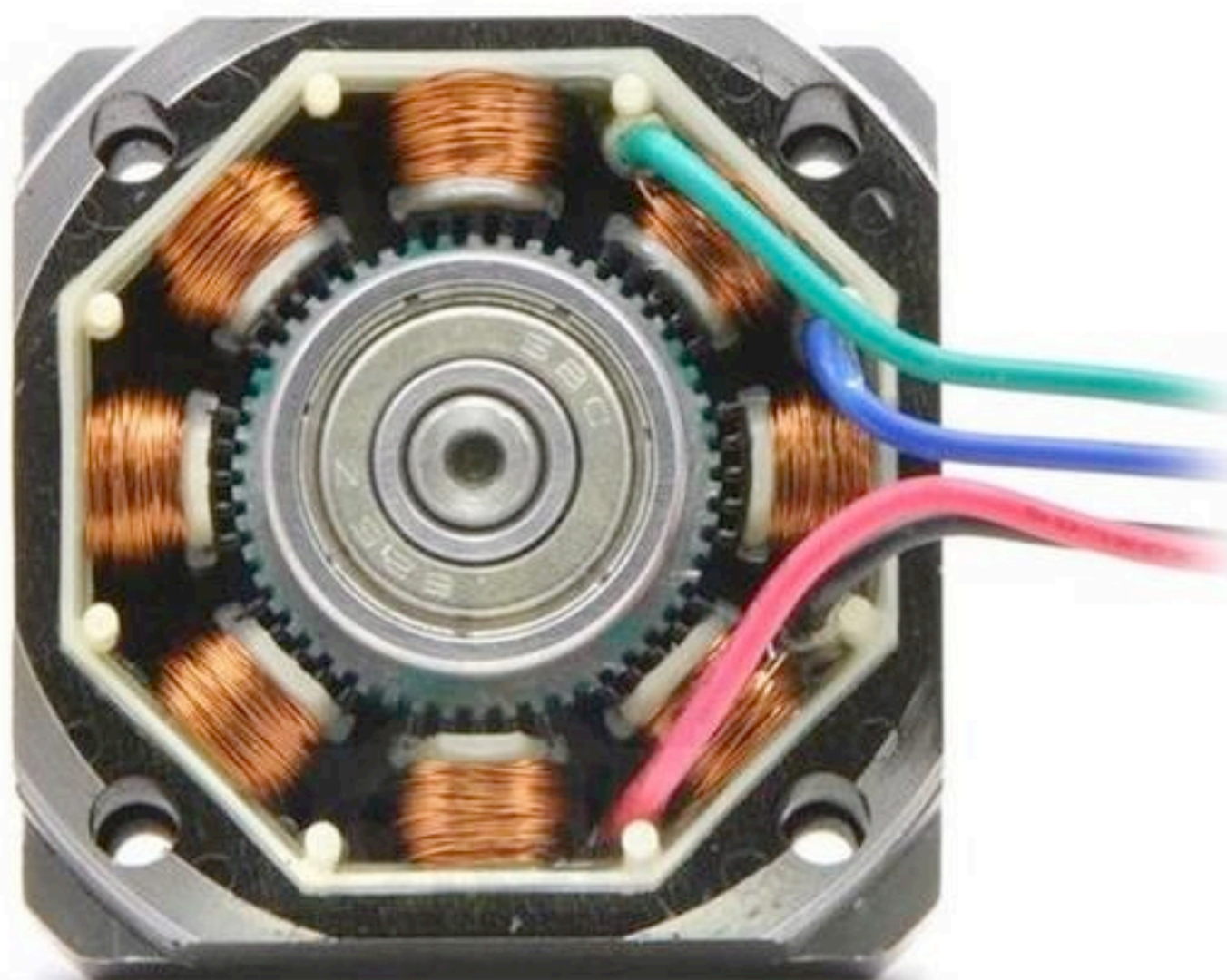
Stepper motor



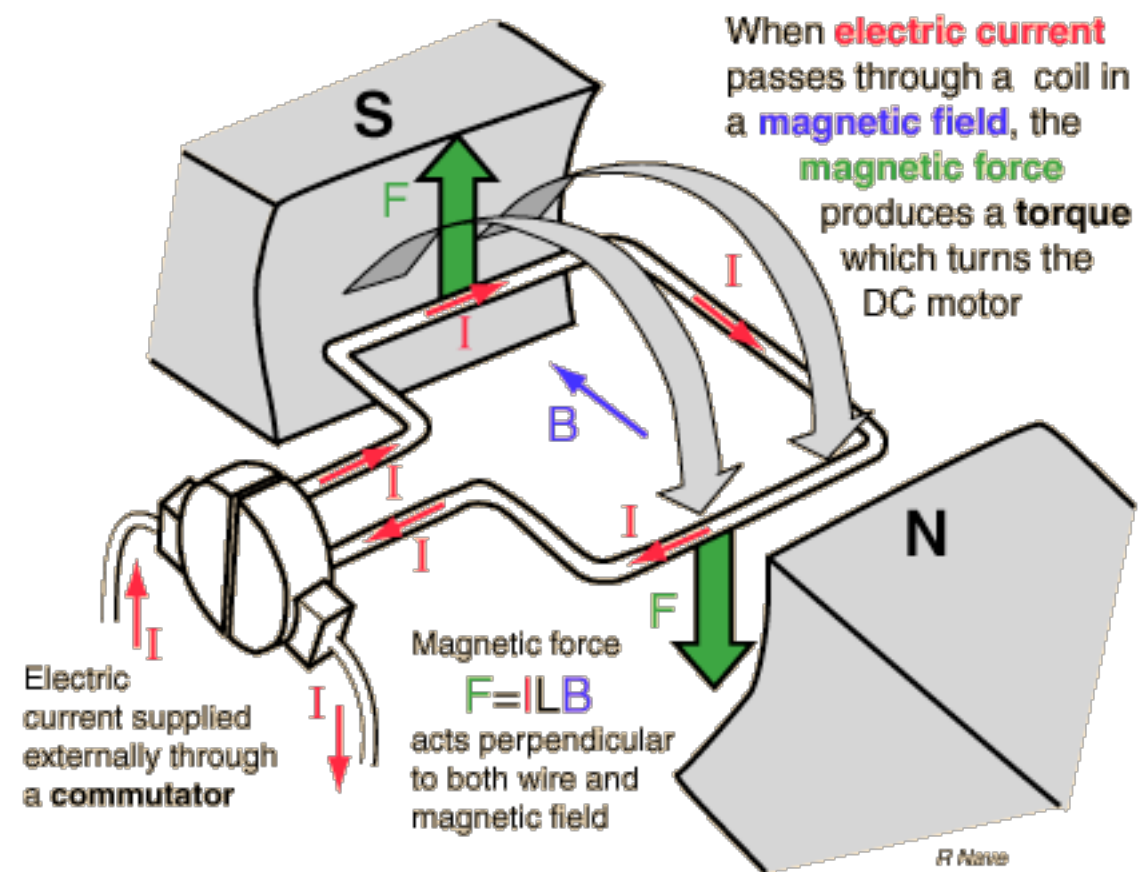
DC Motor

DC Motor  
w/ gearbox





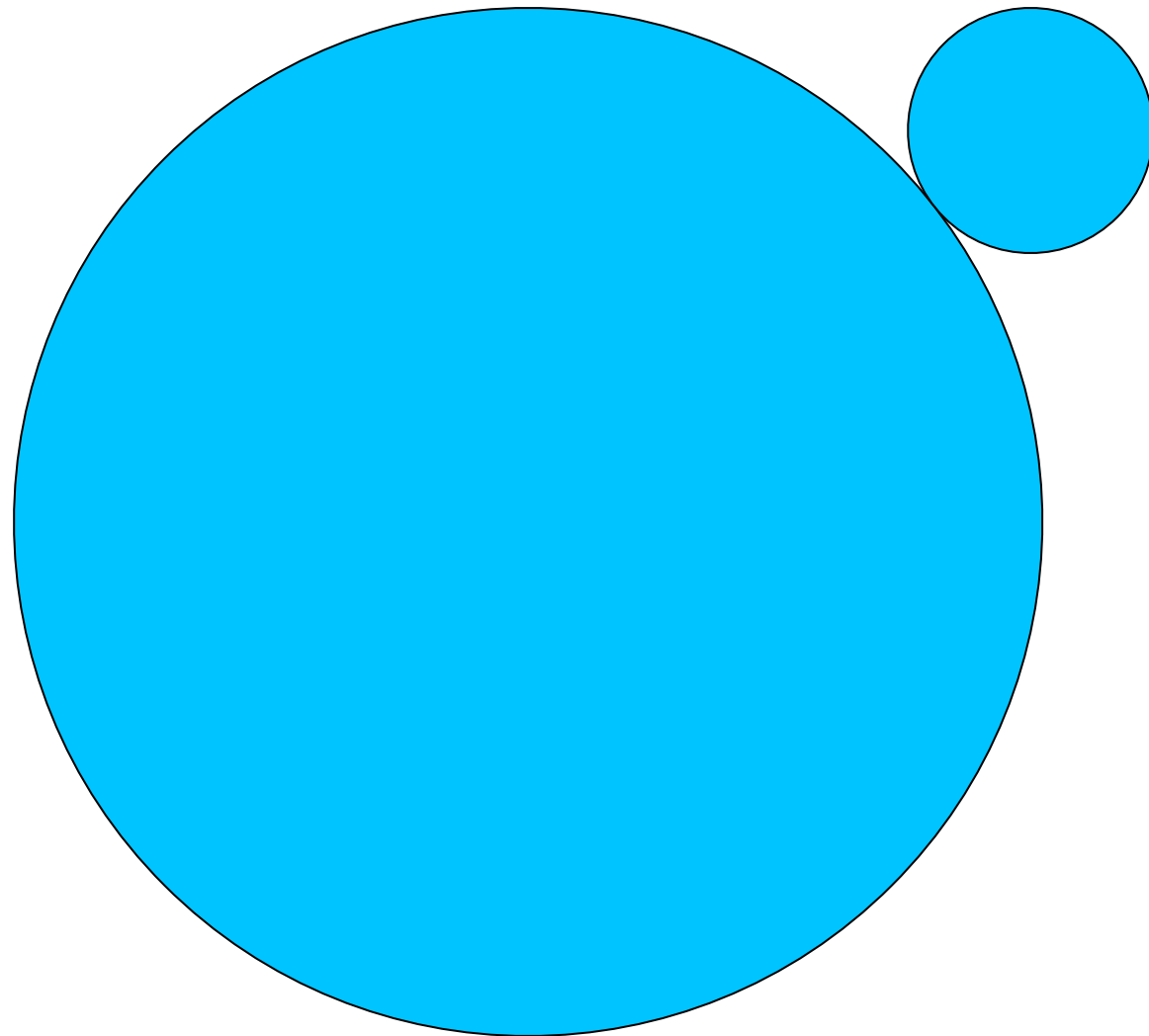
[www.pololu.com](http://www.pololu.com)





Gears/pullys/etc. – KE  
conversion

High speed, low torque



Low speed, high torque

# **SOLAR OVERVIEW**

4.2 billion kg of H -> Energy / second  
so  $3.85 \times 10^{26}$  Watts (385 yottawatts!)

Solar constant in space at Earth locale:  
 $1368 \text{ W/m}^2$

Distributed over Earth's sphere:  
 $342 \text{ W/m}^2$

Average insolation (after reflection and absorption):  
 $170 \text{ W/m}^2$

Global solar energy input:  
87 PW (~7000x fossil fuel use)

source: Smil



## **PV works!**

Enabling technology for telecom  
and space exploration

MER originally planned for  
~90 sols, have operated for  
over 2000.

140W GaAs/Ge cells





Terrestrial applications



Overview





Fishermen in Kenya attracting shrimp w/ solar-charged lights (photo:Siemens)

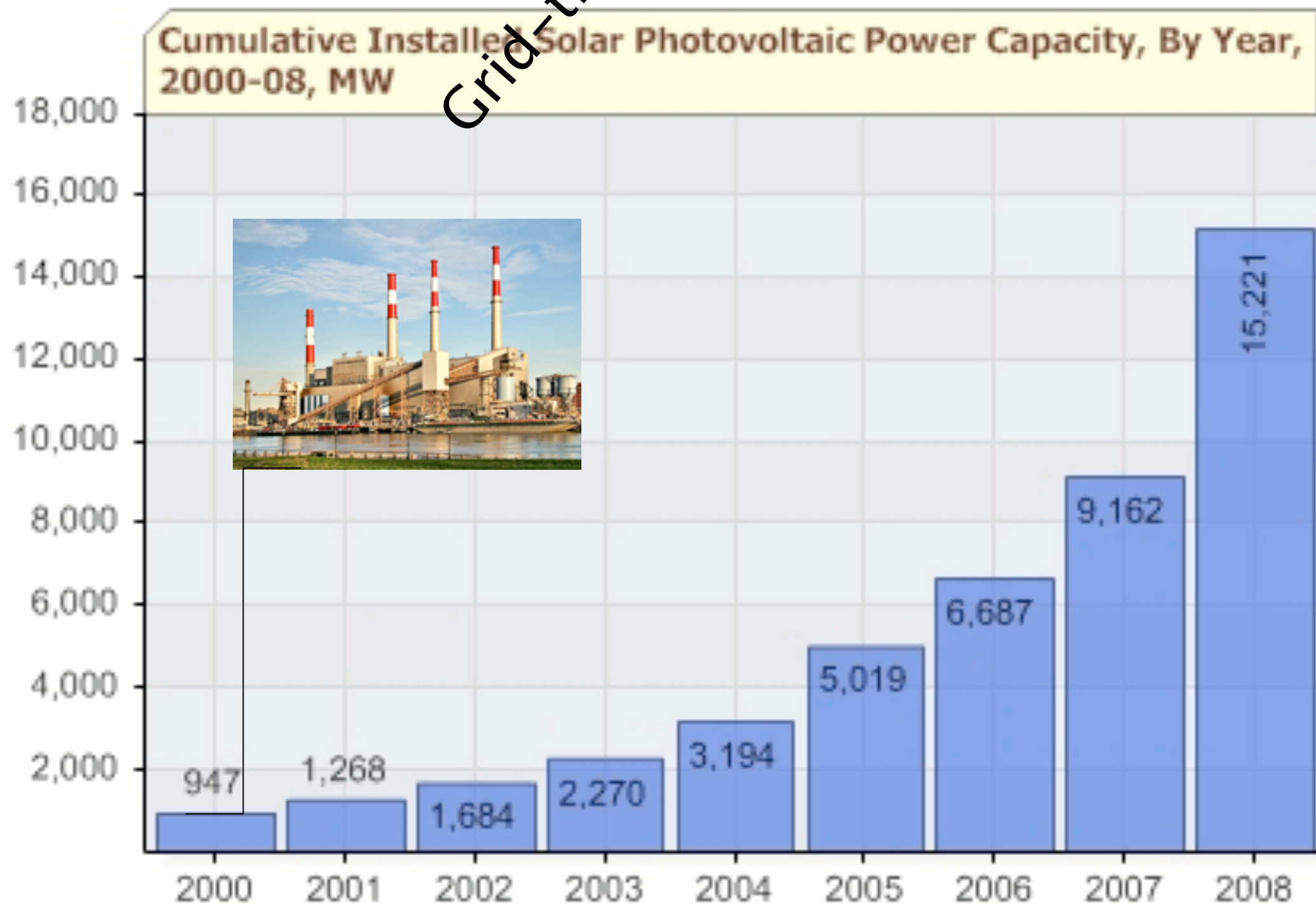
Overview





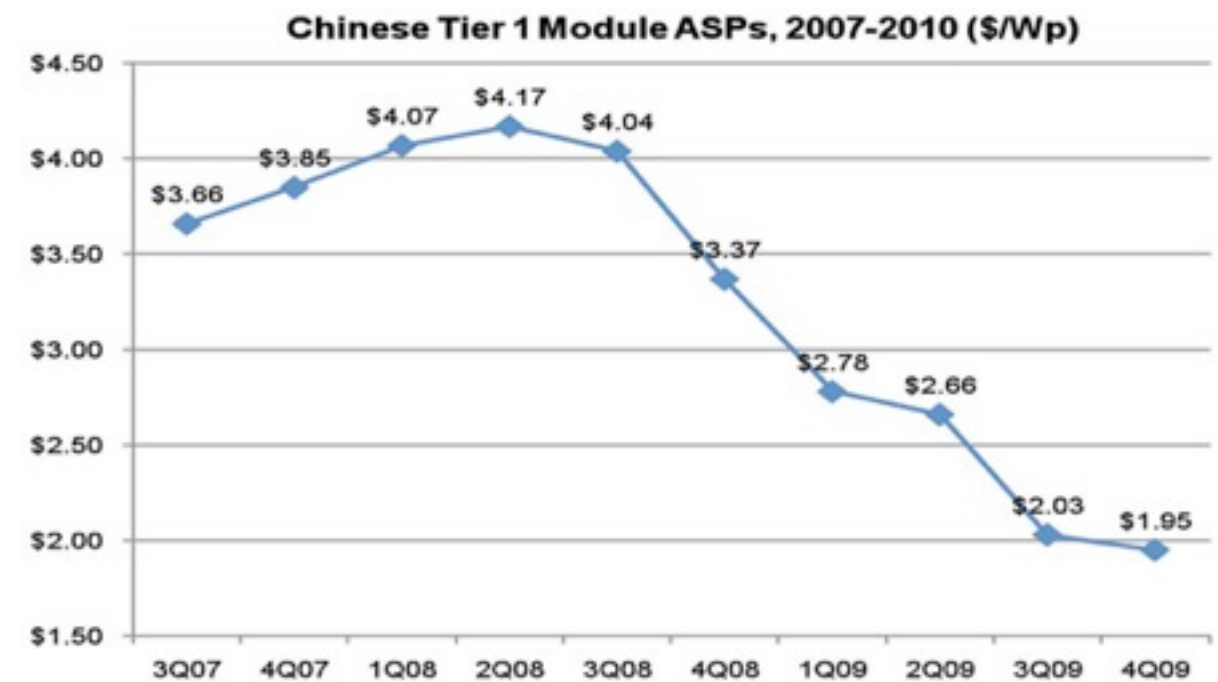
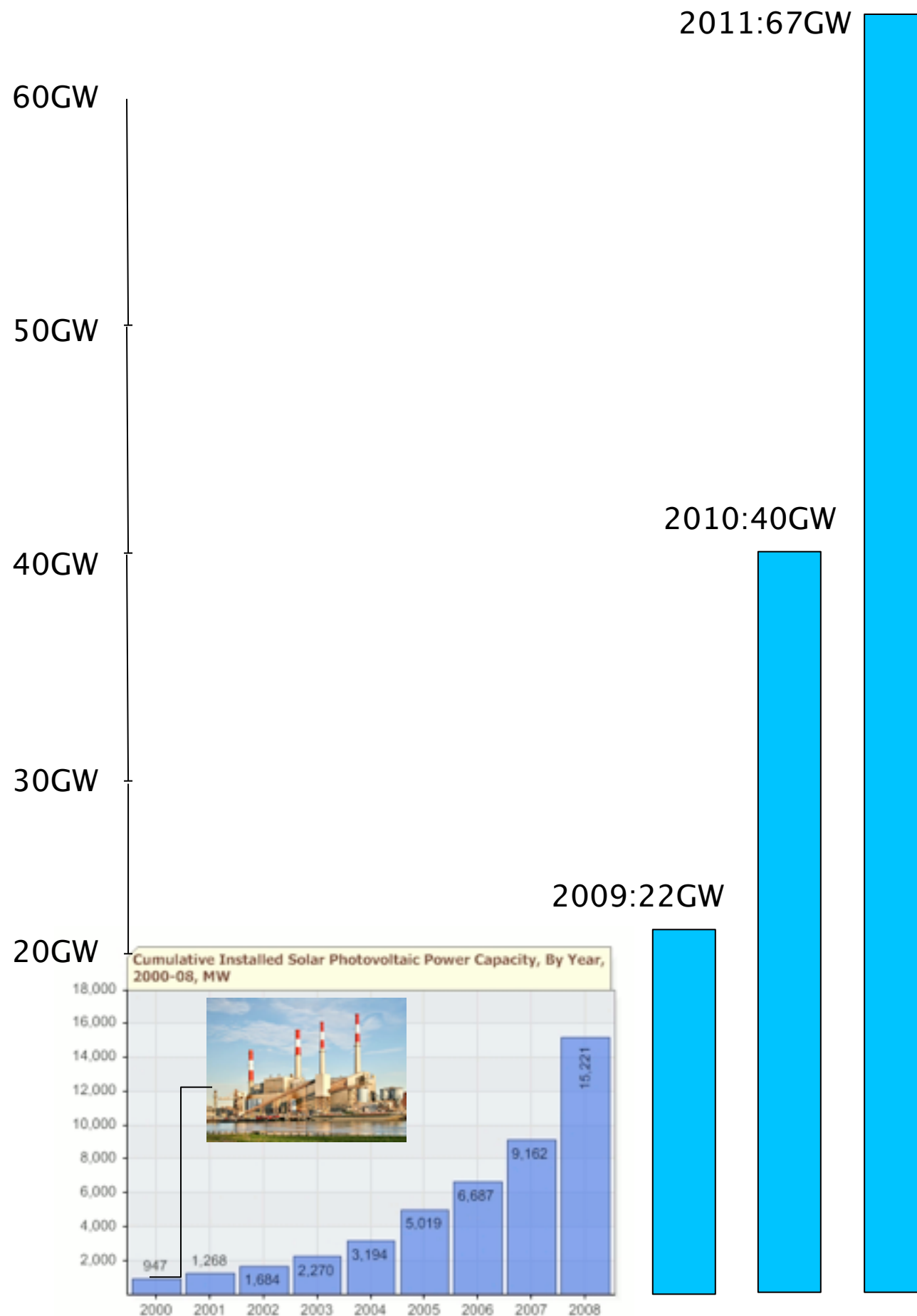
Small and large commercial applications

**Overview**



Source: <http://www.energyandcapital.com/>

Inset: Big Allis, first 1GW generator, in Queens.



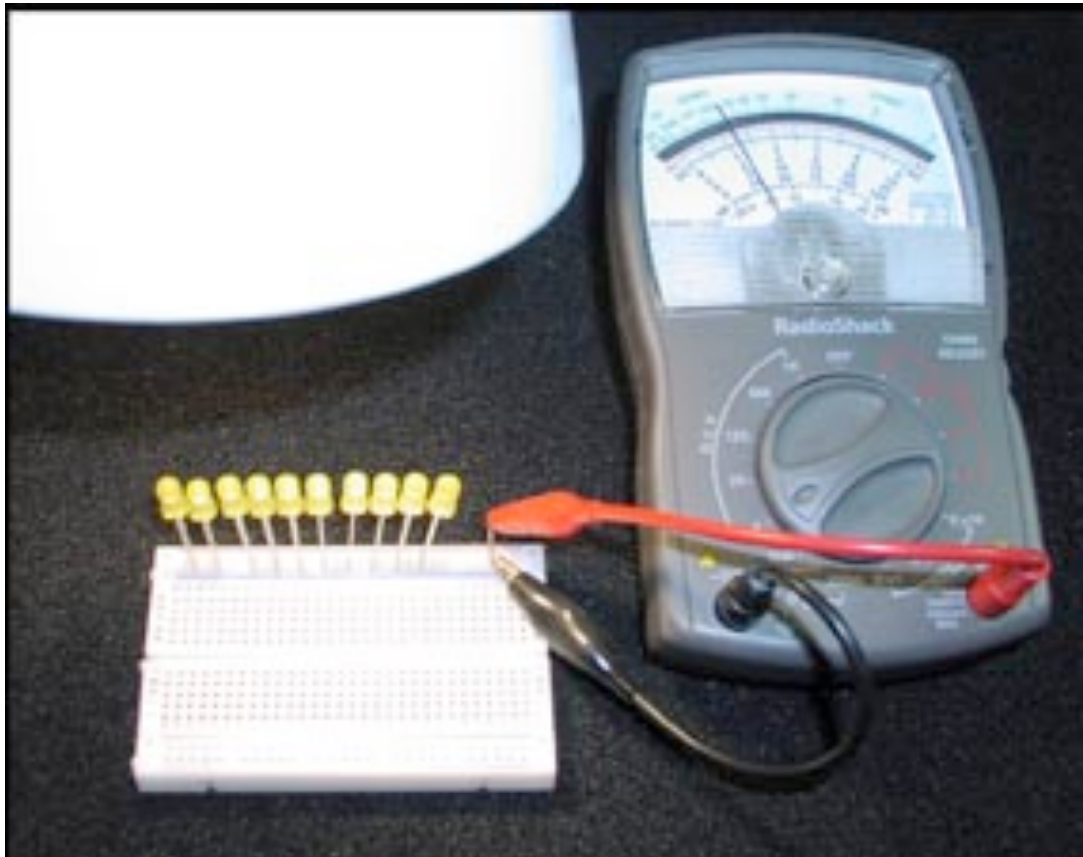
# **BASICS**



# All PV is similar in that:

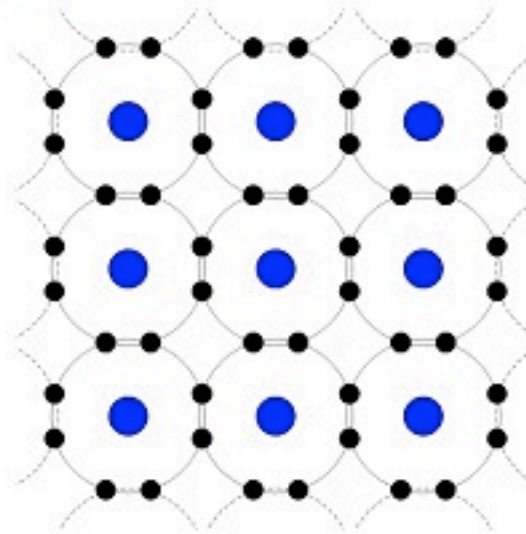
Photovoltaic materials directly convert light into electricity.

Most semiconductors (including LEDs) do this to some extent.



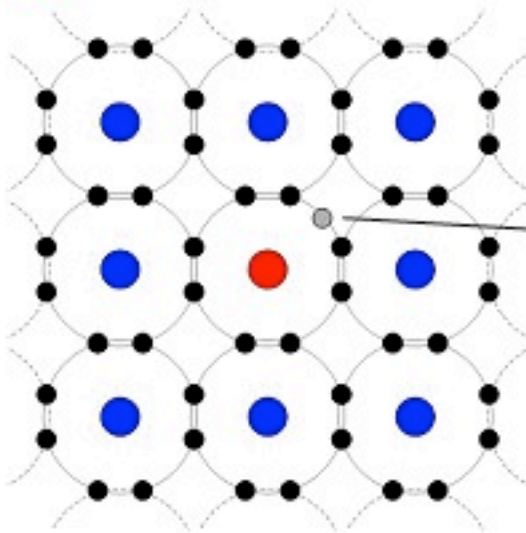
### Pure Silicon

● Silicon nuclei



### N-Type Silicon

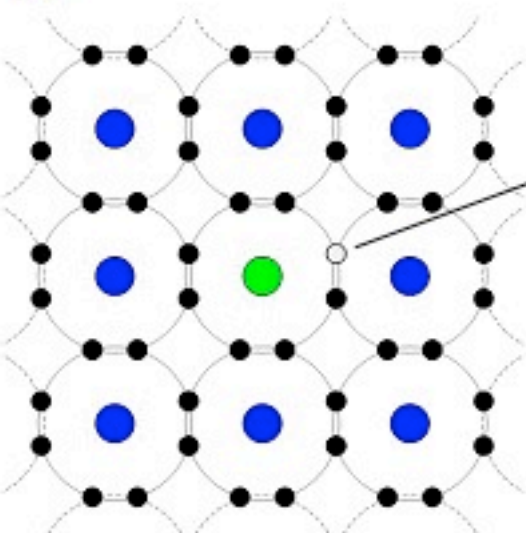
● Phosphorous nucleus



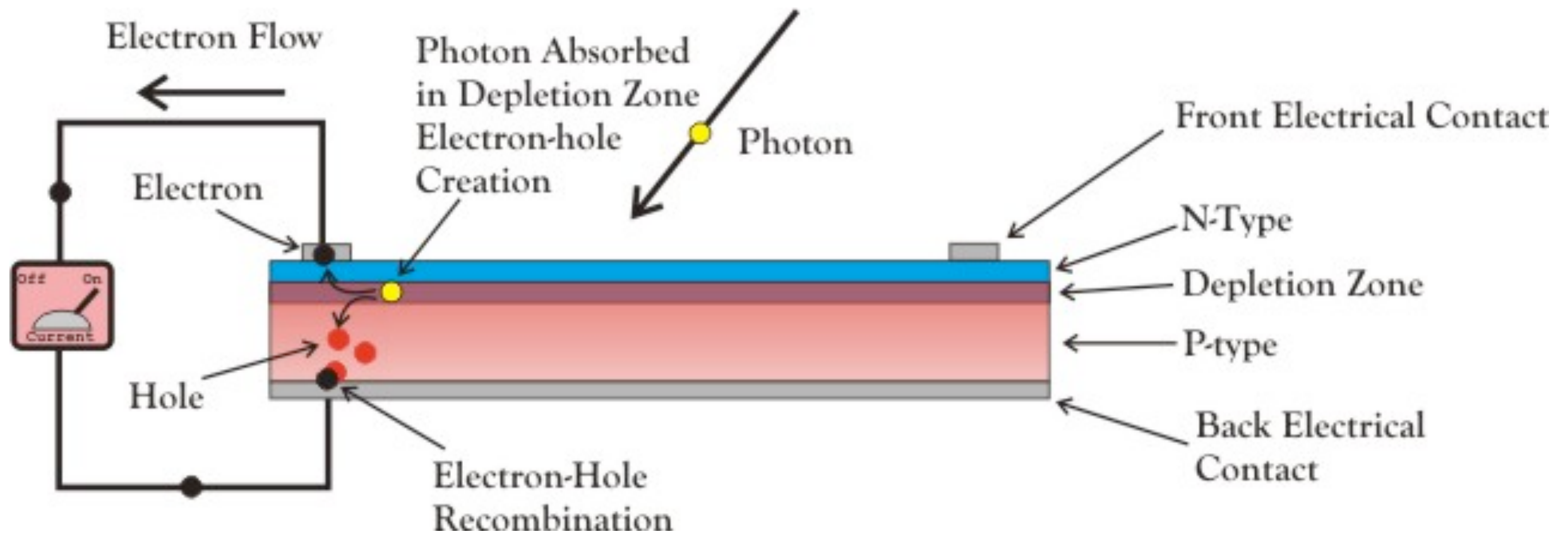
The phosphorous atom creates an extra electron.

### P-Type Silicon

● Boron nucleus



The boron atom creates a hole. ○

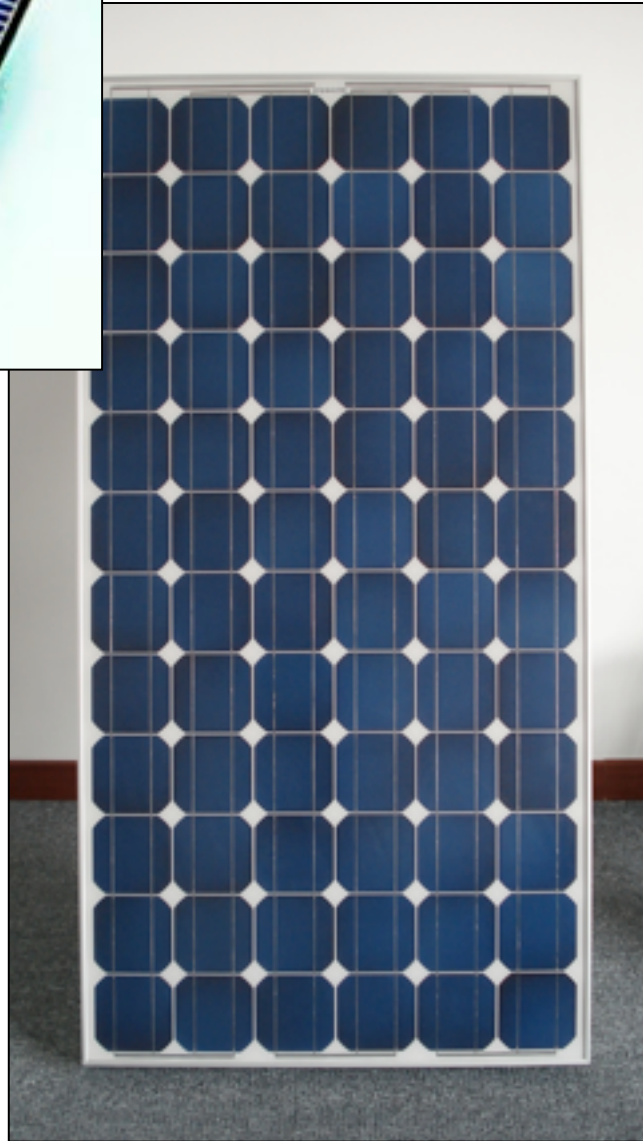




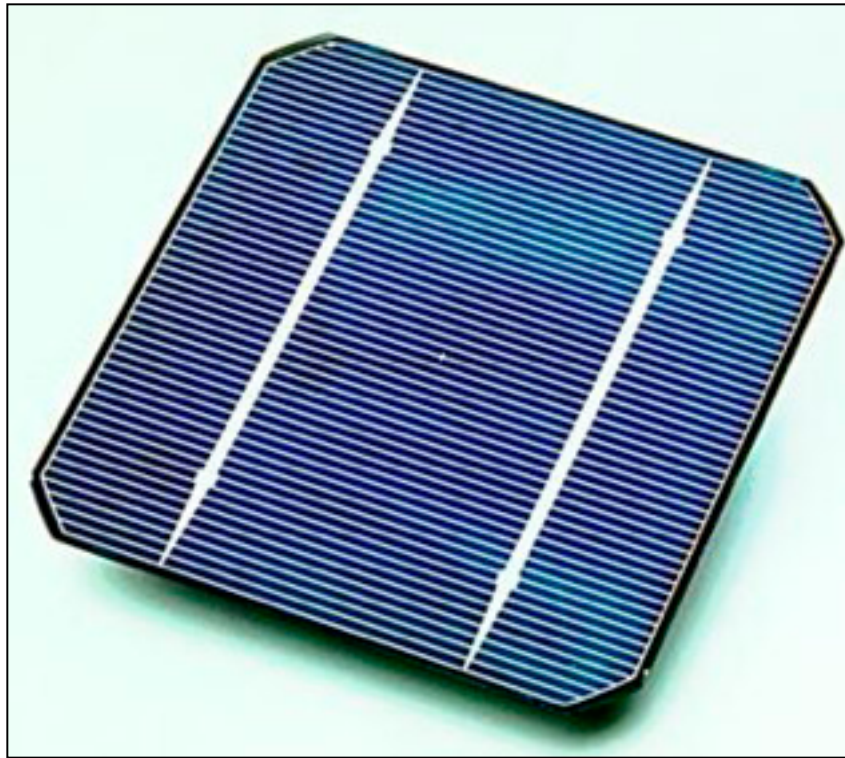


### **Cell:**

Single piece of PV material.  
Voltage dependent on  
semiconductor type, current on  
surface area.







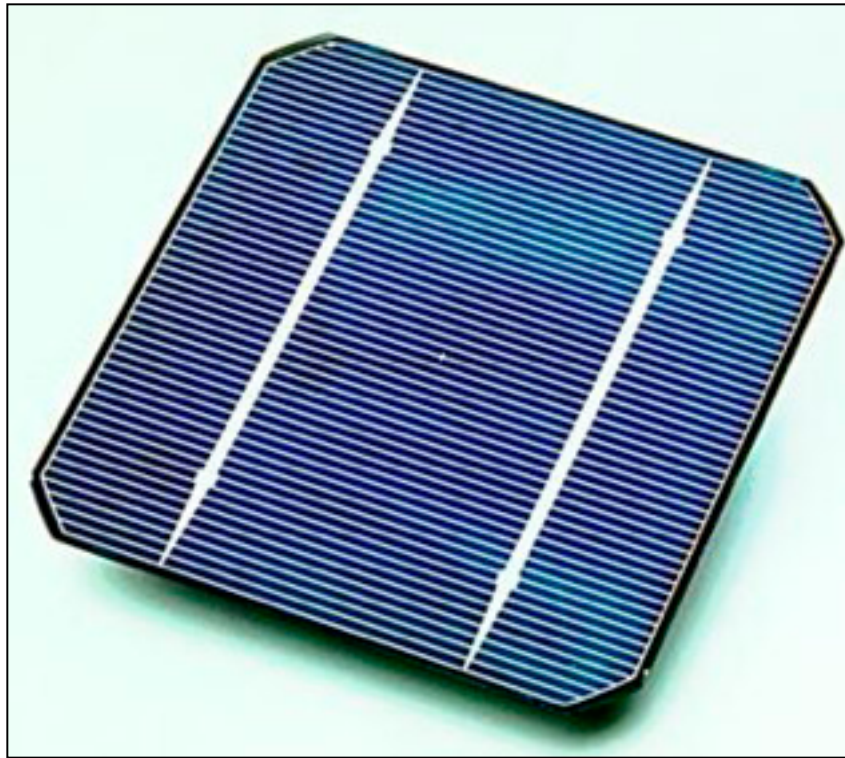
## **Module:**

Multiple cells arranged in series and parallel groups to achieve desired voltage and current.



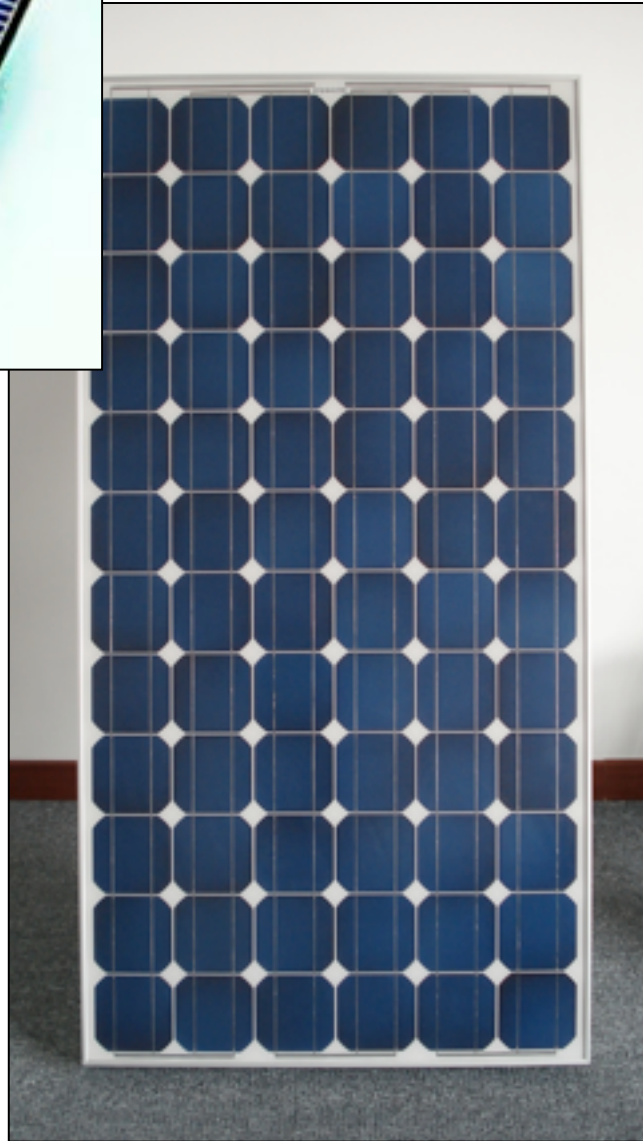
**Basics**





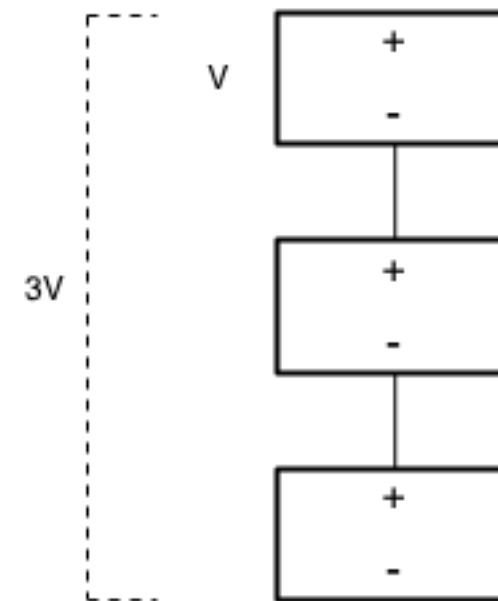
## **Array:**

Multiple modules arranged in series and parallel groups to achieve desired voltage and current.

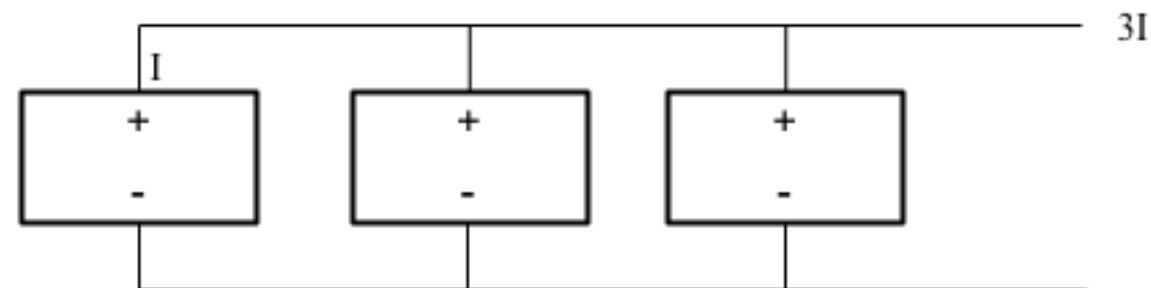


**Basics**

In **series**: Voltage  
sums, current  
remains the same



In **parallel**: Voltage  
stays the same,  
current sums



# Metrics we care about are:

## **Rated performance**

- “Watts-peak” under standardized conditions

## **Open Circuit (OC) Voltage**

- voltage measured with no load

## **Short Circuit (SC) Current**

- current through short circuit

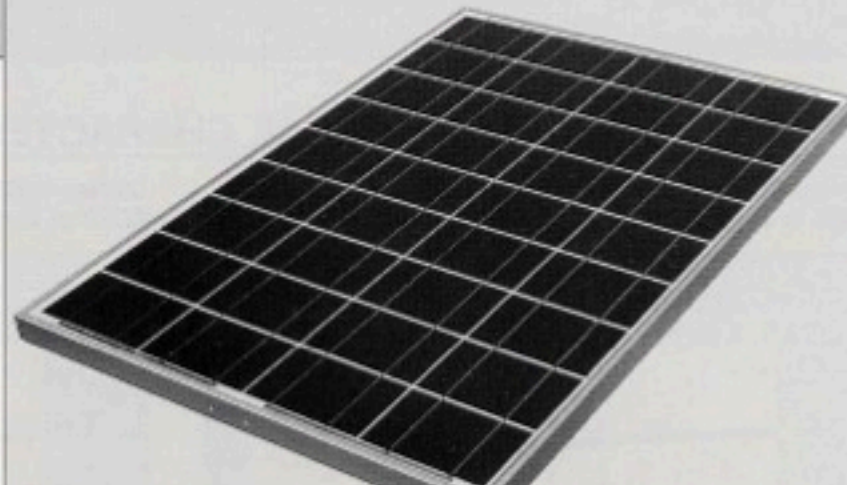
And of course, cost...



# KC80

## HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

TYPICAL OUTPUT 80 Wp



### HIGHLIGHTS OF KYOCERA

Kyocera's advanced cell processing technology produces efficient multicrystal photovoltaic modules. The conversion efficiency of the Kyocera solar cells is high. These cells are encapsulated between a tempered glass and a high-strength polymer film for maximum protection from the severest environment. The entire laminate is installed in an anodized aluminum frame.

- Microwave/Radio repeater stations
- Electrification of villages in remote areas
- Medical facilities in rural areas
- Power source for summer vacation homes
- Emergency communication systems
- Water quality and environmental data monitoring systems
- Navigation lighthouses, and ocean buoys

### ■ Electrical Specifications

MODEL	KC80
Maximum Power	80 Watts
Maximum Power Voltage	16.9 Volts
Maximum Power Current	4.73 Amps
Open Circuit Voltage	21.5 Volts
Short-Circuit Current	4.97 Amps
Length	976mm (38.4in.)
Width	652mm (25.7in.)
Depth	56mm (2.2in.)
Weight	8.0kg (17.7lbs.)

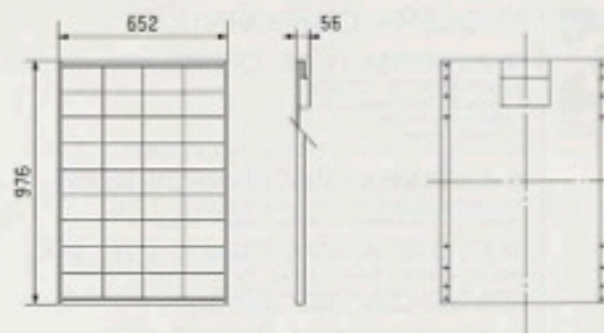
Note: The electrical specifications are under test conditions of Irradiance of  $1\text{kW/m}^2$ , Spectrum of 1.5 air mass and cell temperature of  $25^\circ\text{C}$

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Kyocera reserves the right to modify these specifications without notice.



**DIFFERENCES**



## Different types of PV are distinguished by:

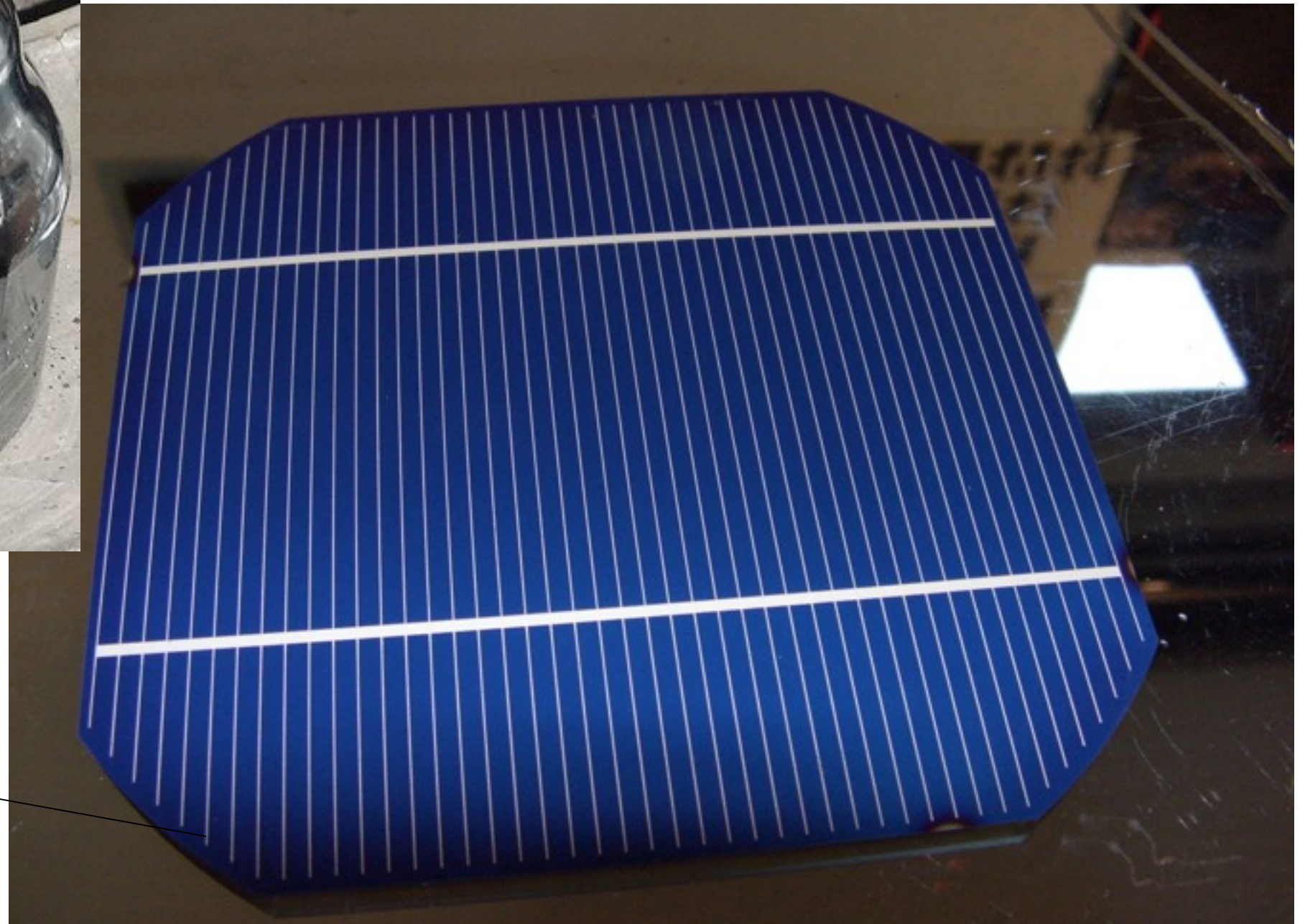
- Form of material (e.g. crystalline or thin film)
- Type of material (Si vs. CIGS vs...)
- Number of layers (“junctions”)

Different types will have varying **efficiencies** under different **conditions**, and widely-ranging associated **costs**.

## Monocrystalline Si ingot and cell



Circa 300  $\mu\text{m}$  thick  
Si layer



**Differences**



Polycrystalline Si  
ingot and cell



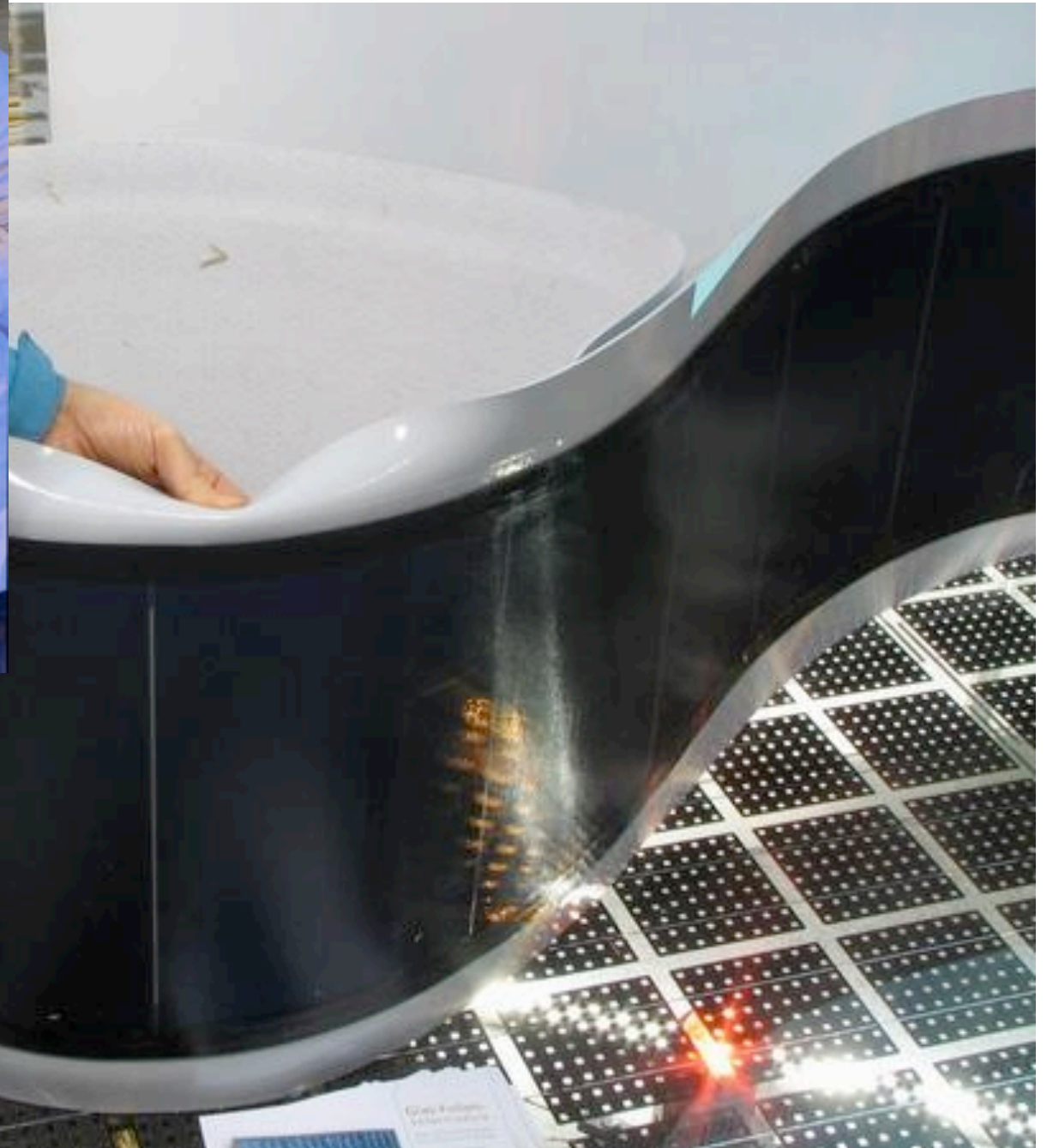
Circa 300 um thick  
Si layer



**Differences**



## Amorphous or thin film PV

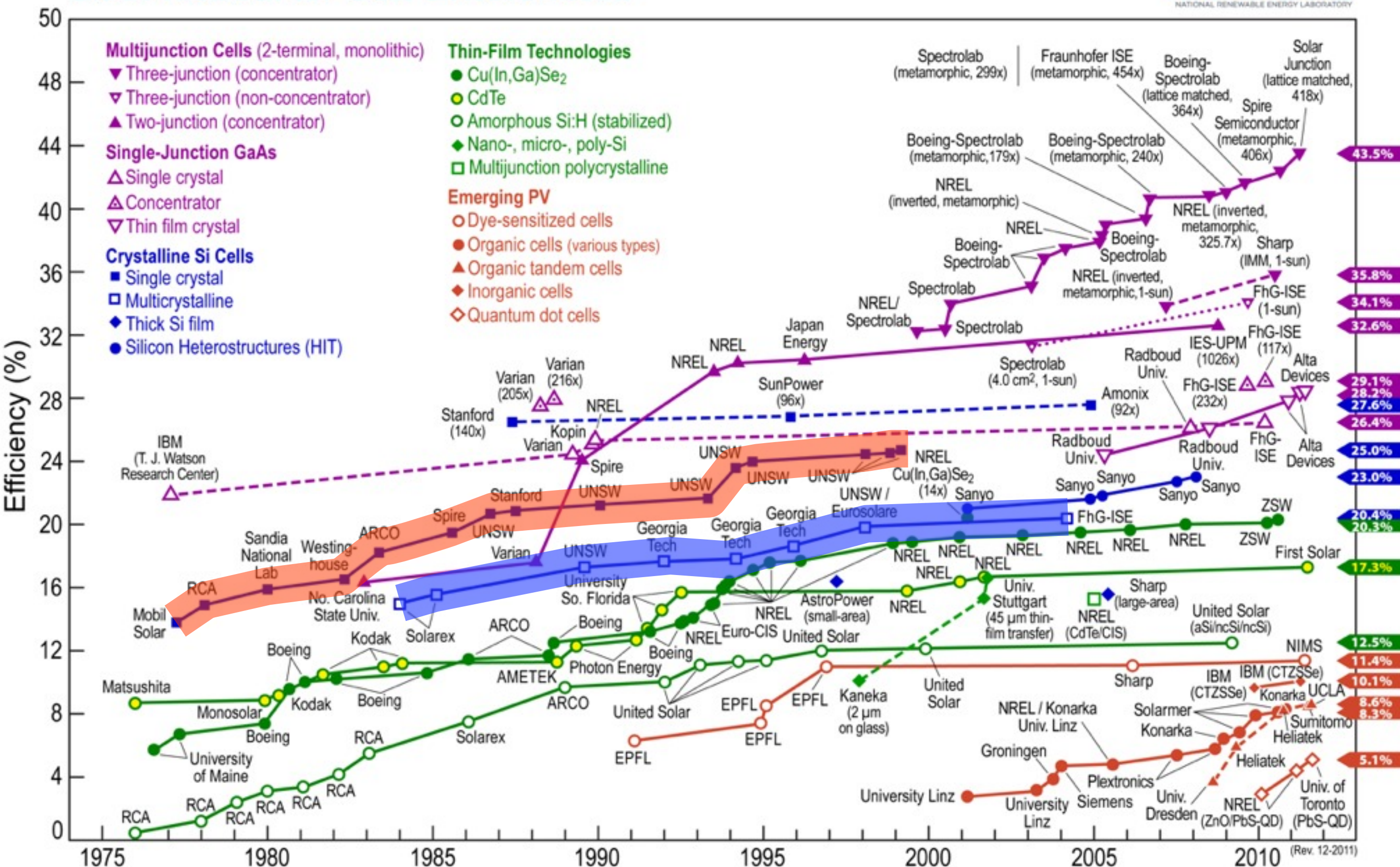


Circa 30 um thick  
Si layer

**Differences**

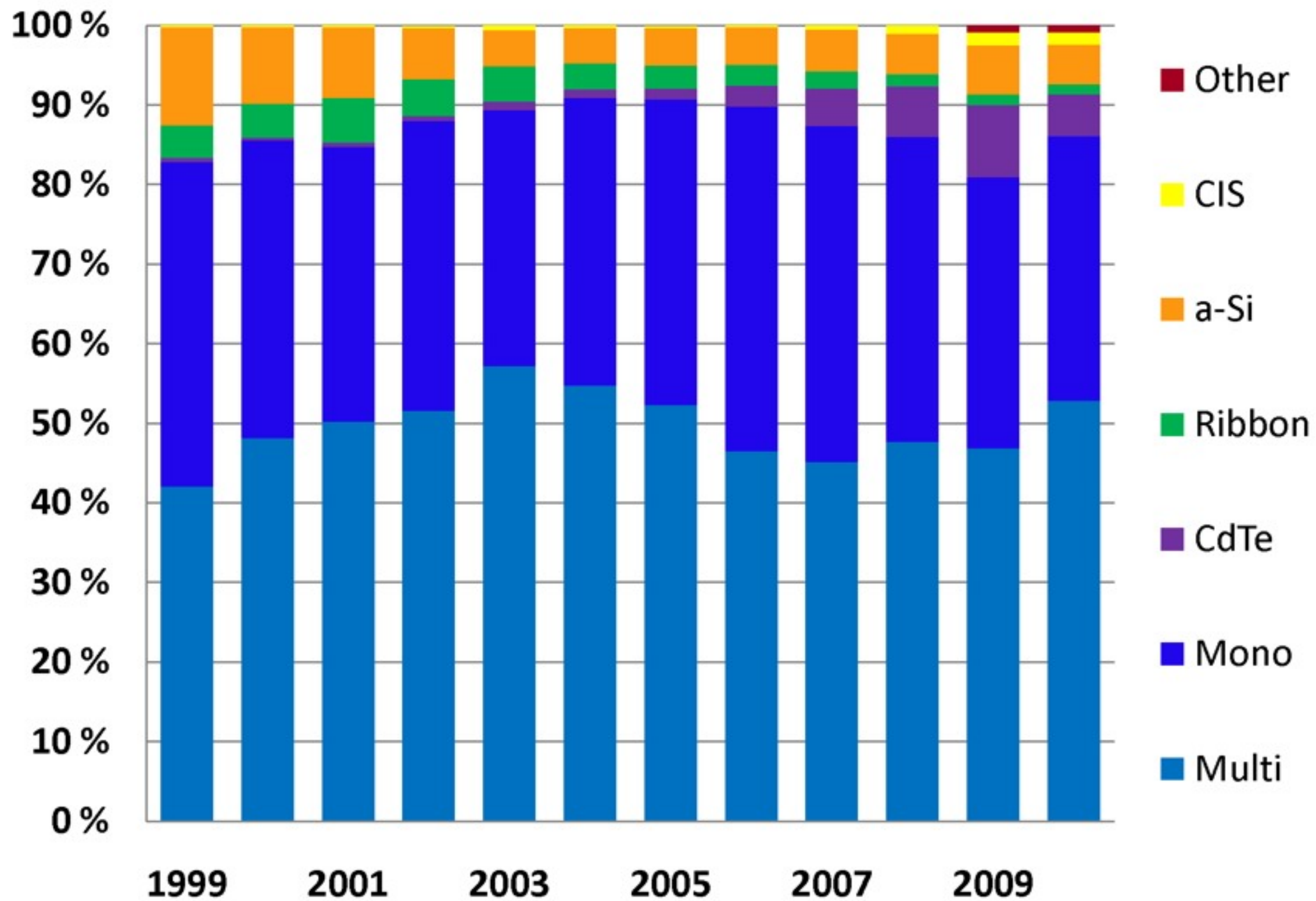


# Best Research-Cell Efficiencies



Source: DOE NREL

Differences



Source: Cleanenergy

**Differences**



## **For later:**

Balance of system

Tracking methods

Concentrating systems

Solar lighting

Solar thermal

also:

Kardashev scale

Space based solar power

Dyson swarms

**For now:**

Planning a solar powered project

## Size: Very Small

BEAM circuits.  $<1\text{W}$  PVs charge capacitors, discharged through resistive loads by voltage monitor ICs. Can be extended to power microcontrollers and other circuits.





## Size: Small to Medium

Can you directly power what you want? See SolaSystem amplifier from class notes.

If not, and you need to store energy, use consumer small-scale charge controllers and batteries sized to your energy and power budget. Farad-class ultra capacitors are also an option. Consider direct DC-DC converters for loads. See ITP portable solar kits or Solio chargers for examples.





A large, rectangular solar panel is mounted on a light-colored wall. The panel is tilted upwards and is supported by a metal frame with several adjustable arms and bolts, suggesting it can track the sun. To the left of the panel, a silver cylindrical device, possibly a sensor or part of the tracking system, is mounted on the wall. A black cable runs down the wall from the panel area. In the background, there are green vines climbing the wall and a clear blue sky with some clouds.

**Size: Medium to large**

Use commercial grade modules, battery chargers and batteries. Mature products exist for off-grid markets. Use inverter as de facto common interface for AC loads.

**Planning**

# **CASE STUDY**



# Case study: Earth Speaker

Solar powered sound installation

Case Study



## Case study: Earth Speaker

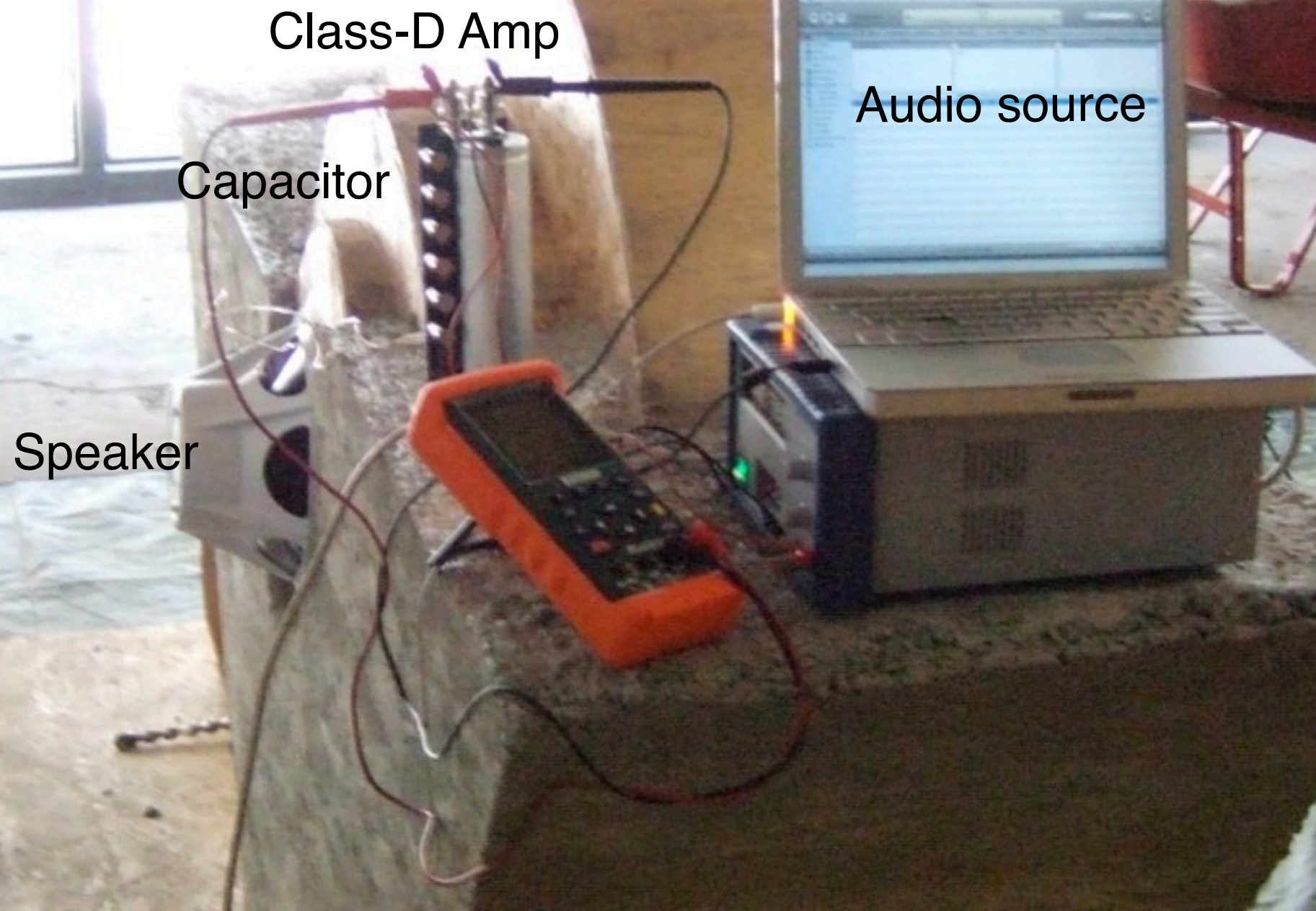
Power system prototype: 5x ~4.5V solar modules in series connected directly to a 12V 1.5 F capacitor.

Helped asses time required to charge at locale.



# Case study: Earth Speaker

Load prototype. Tested run-time / energy stored for different frequencies, amplifiers, and speaker configurations.





# Case study: Earth Speaker

Final electronics

Amplifiers

1x 110F 16V cap

Audio  
sources

5x 55F 16V  
caps

5V DC-DC  
converter for logic

Case Study





What does this do to electricity use?