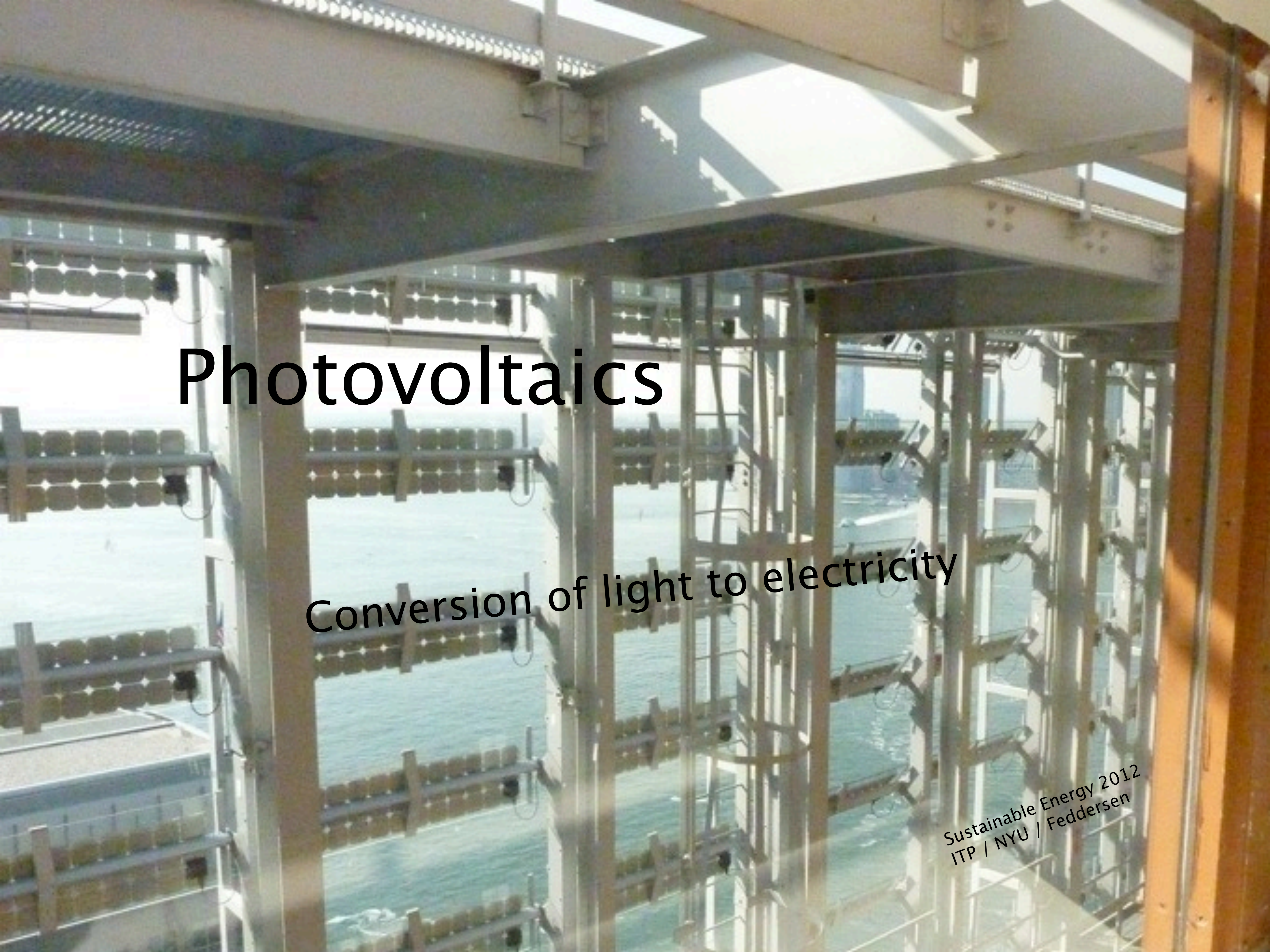
Photovoltaics

Conversion of light to electricity

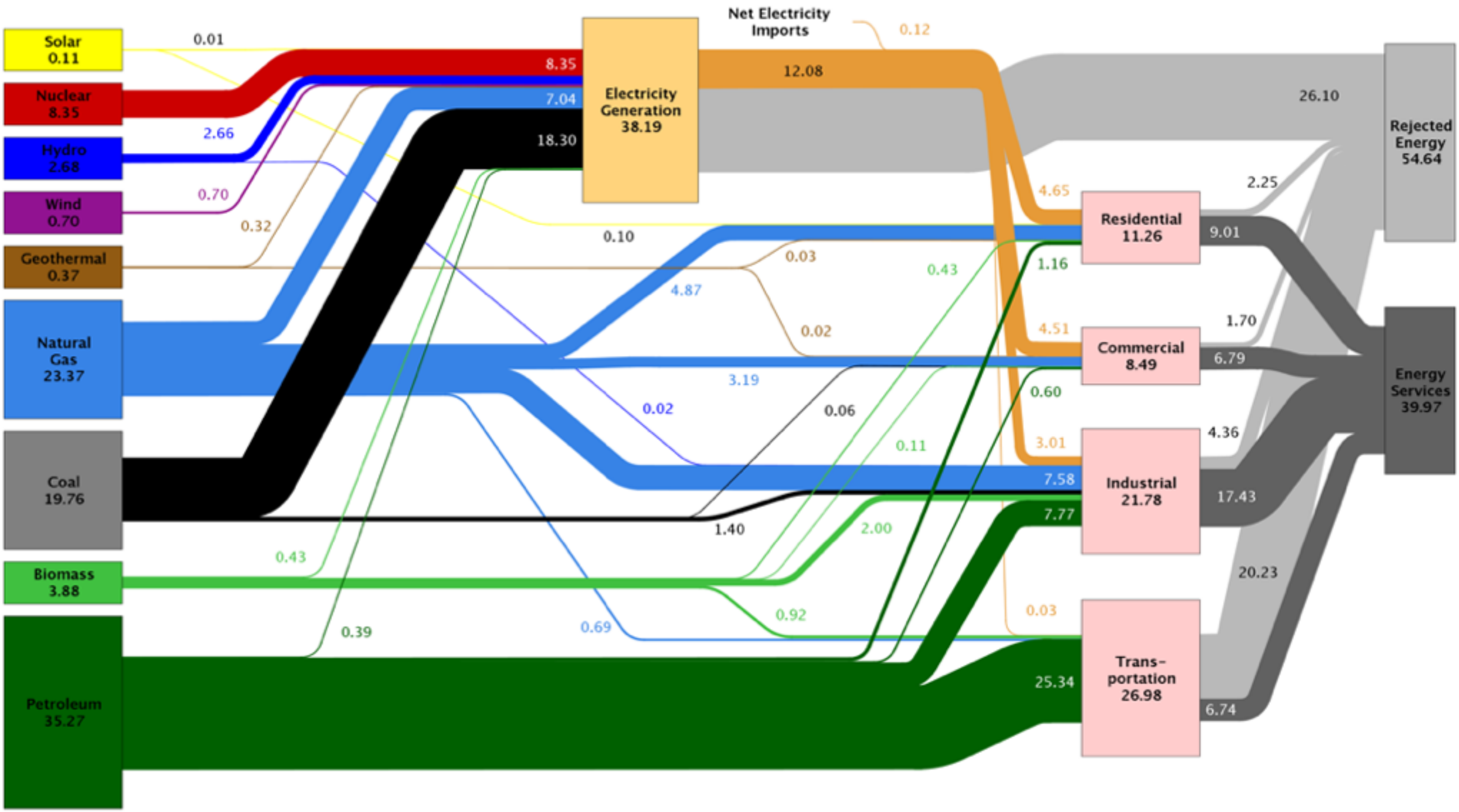


Sustainable Energy 2012
ITP / NYU / Feddersen

REVIEW

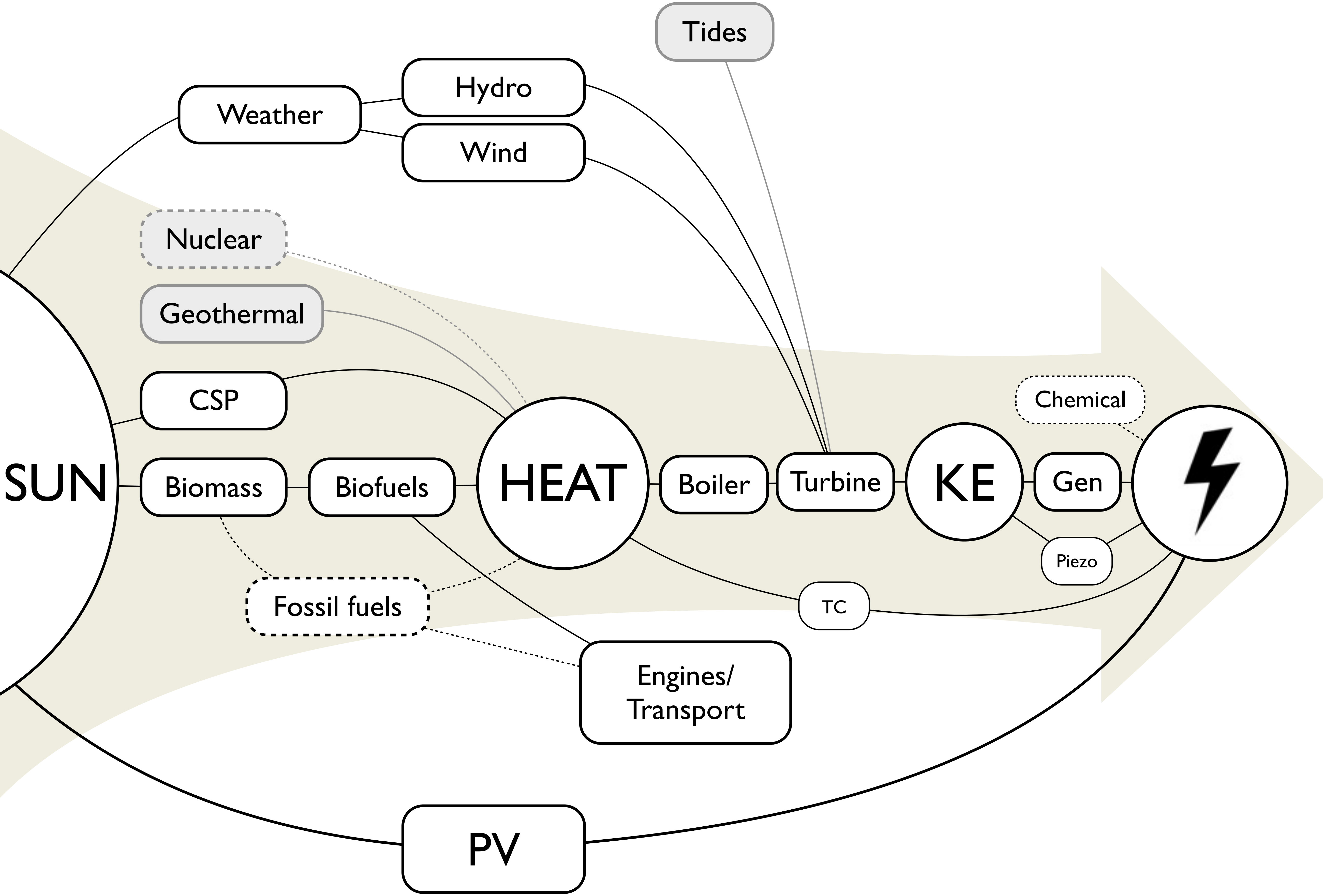
Estimated U.S. Energy Use in 2009: ~94.6 Quads

Lawrence Livermore National Laboratory



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



Tides
Hydro
Weather
Wind
Nuclear
Geothermal
CSP
Chemical
SUN
Biomass
Biofuels
HEAT
Boiler
Turbine
KE
Gen
Piezo
TC
Fossil fuels
Engines/
Transport
PV

Review

OVERVIEW

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

Solar constant in space at Earth locale:
1368 W/m^2

Distributed over Earth's sphere:
342 W/m^2

Average insolation (after reflection and absorption):
170 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

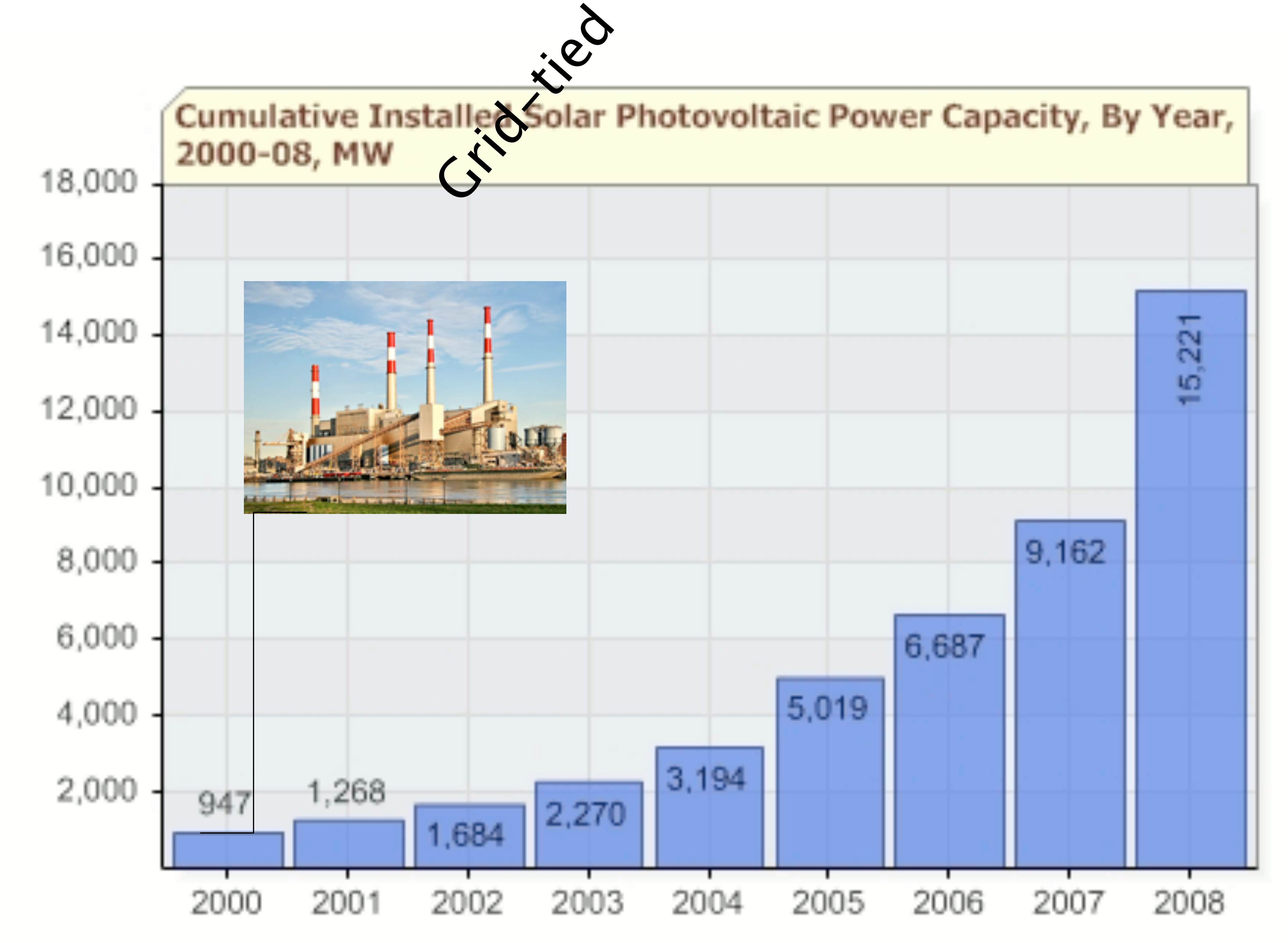
Overview

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

Overview

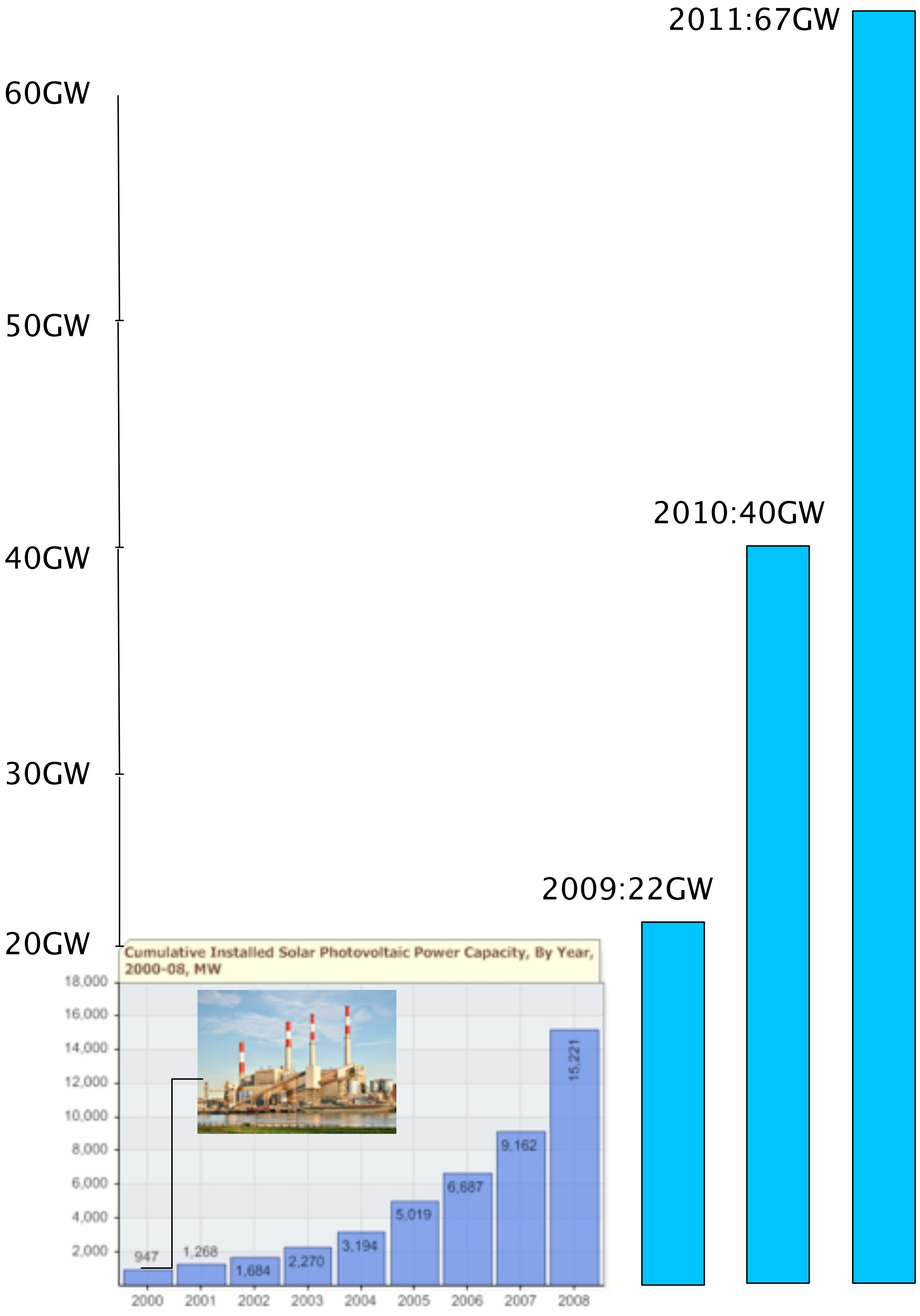
Small and large commercial applications

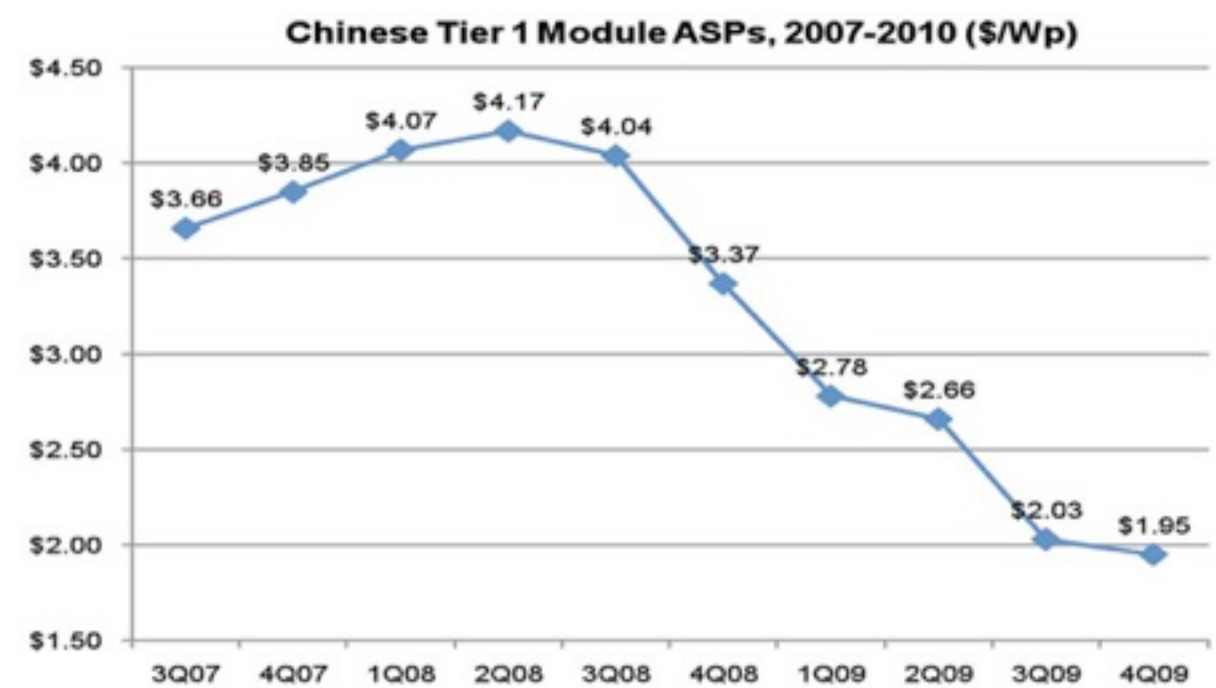
Overview



Source: http://www.energyandcapital.com/
Inset: Big Allis, first 1GW generator, in Queens.

Overview



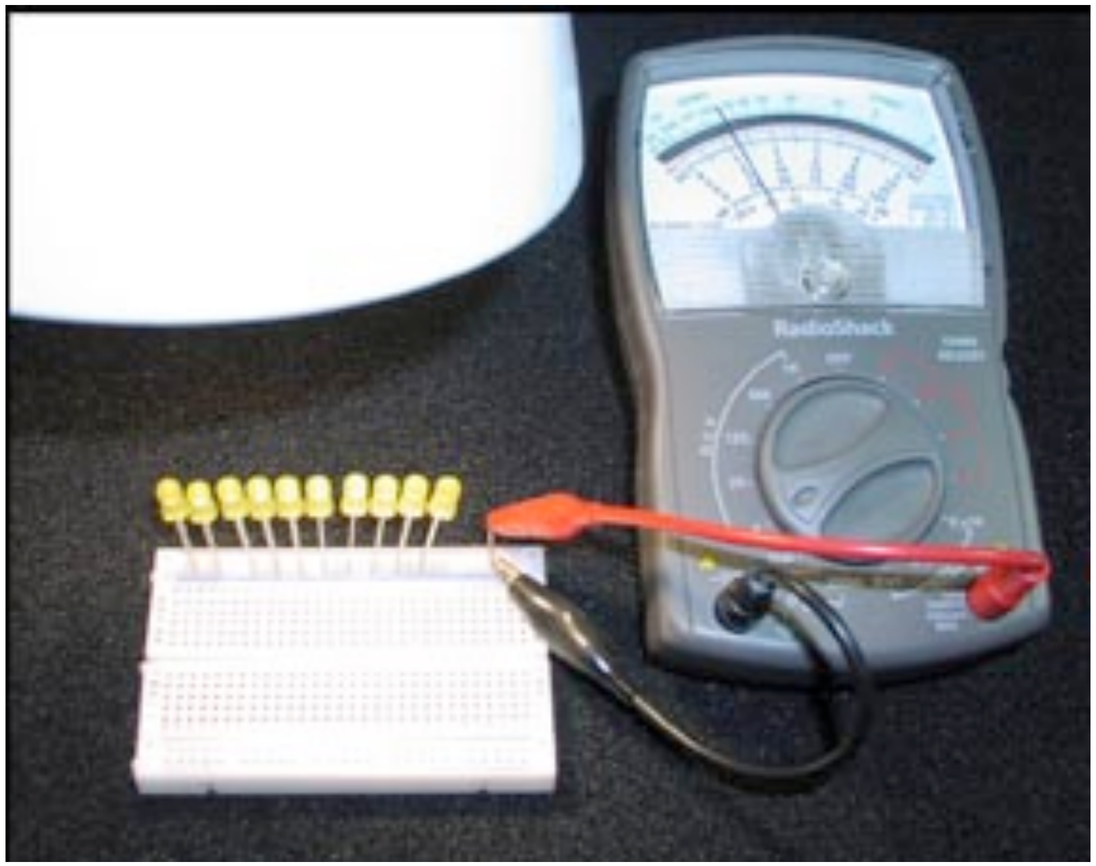


GTMedia, wikipedia

Overview

BASICS

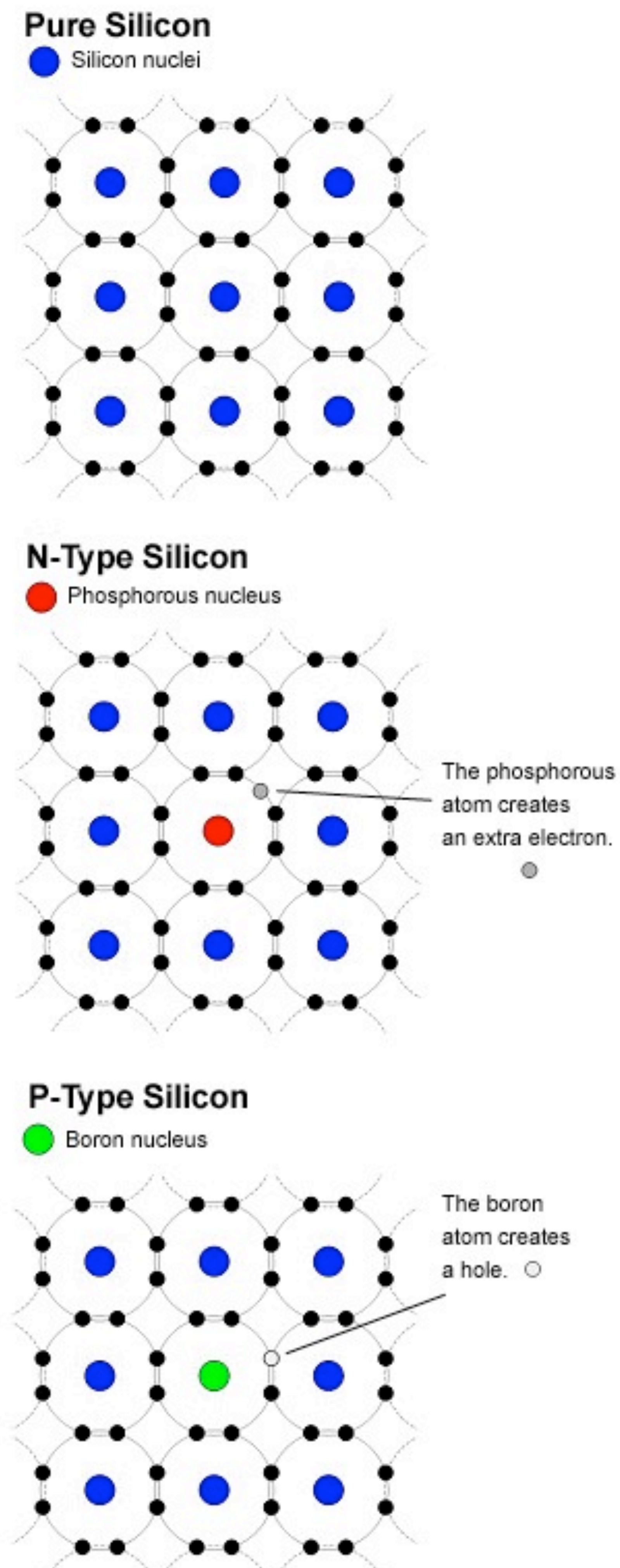
All PV is similar in that:



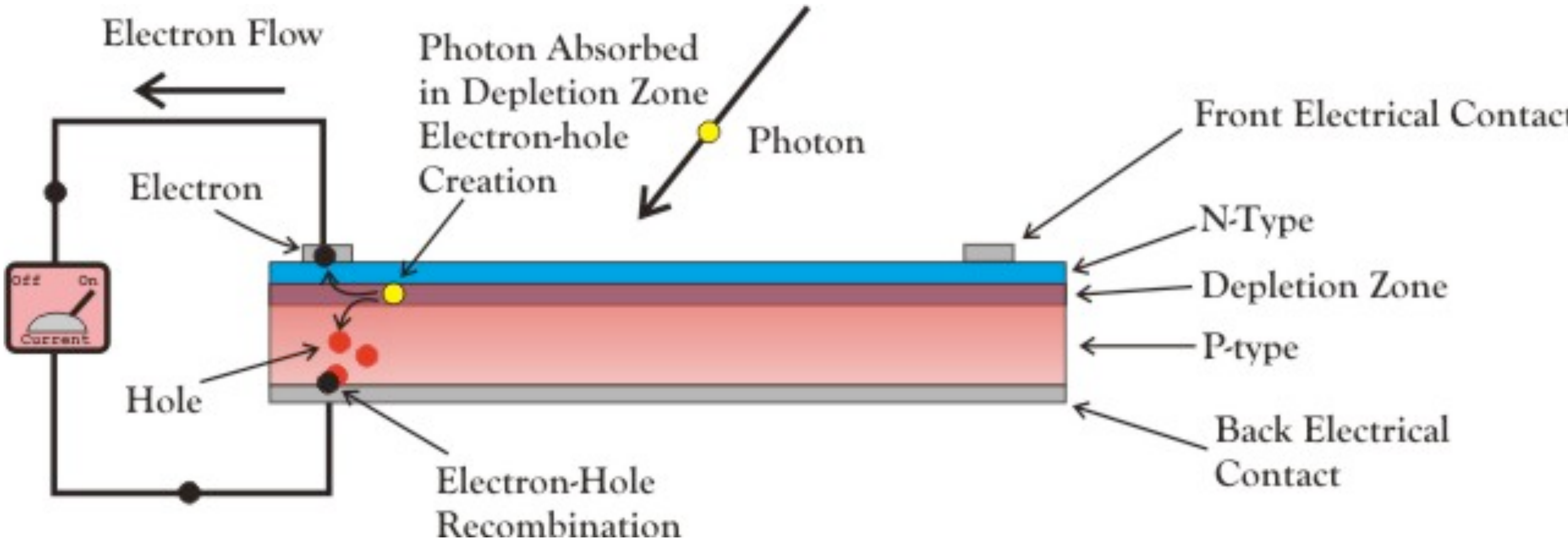
Photovoltaic materials directly convert light into electricity.

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

Source: http://www.imagesco.com/

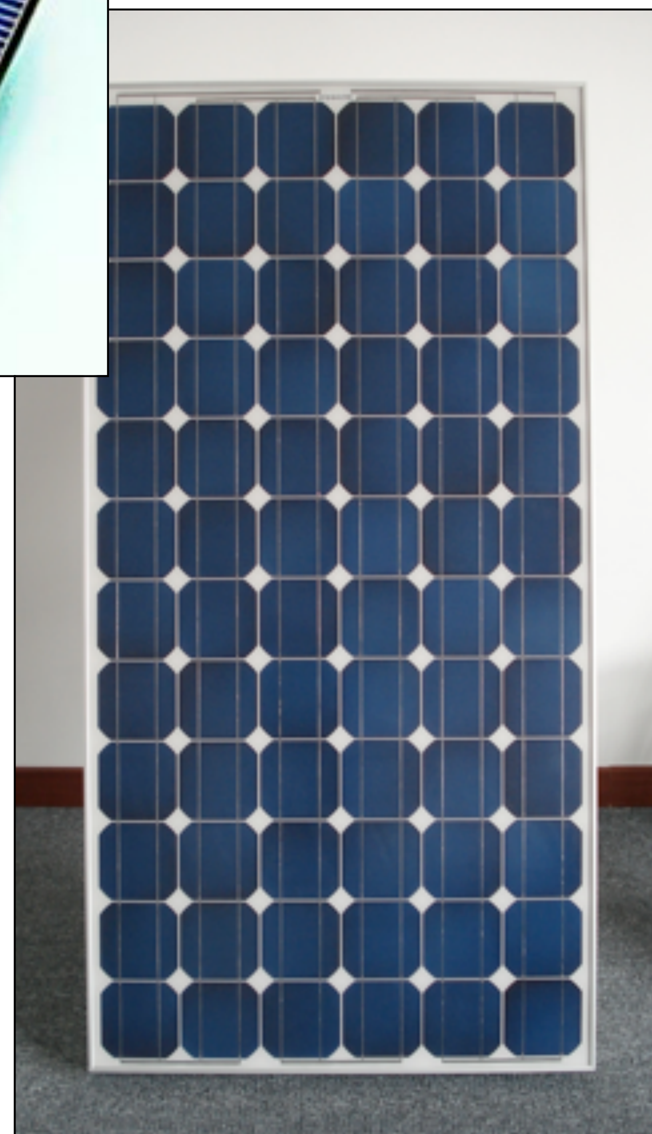


Source: http://www.techbites.com/



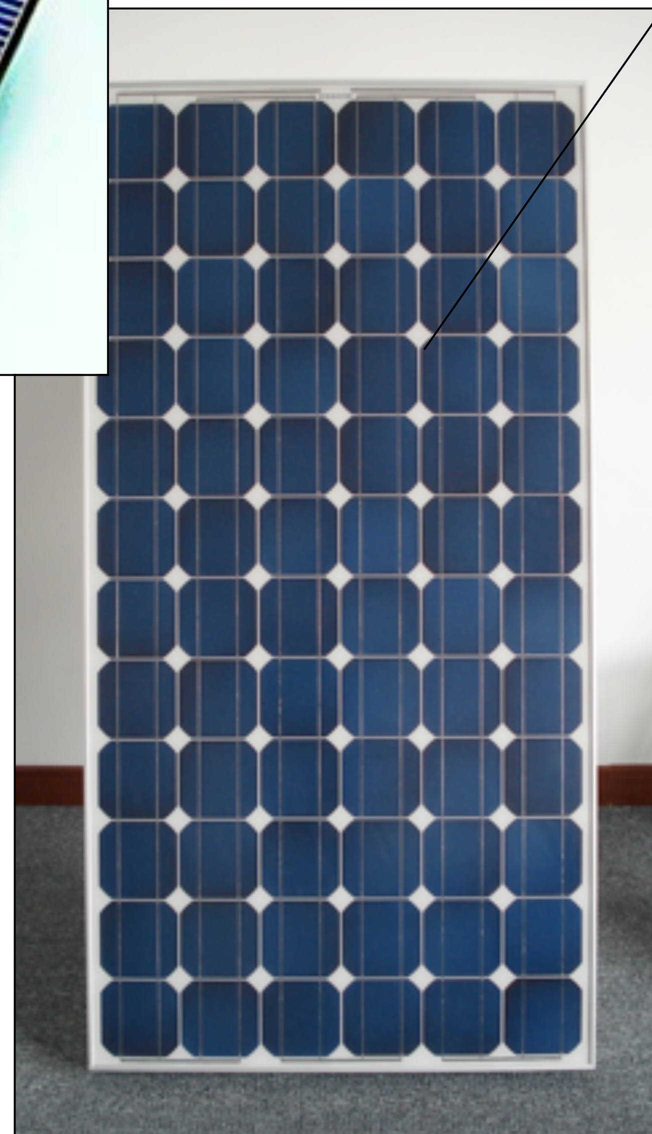
Source: http://www.imagesco.com/

Basics



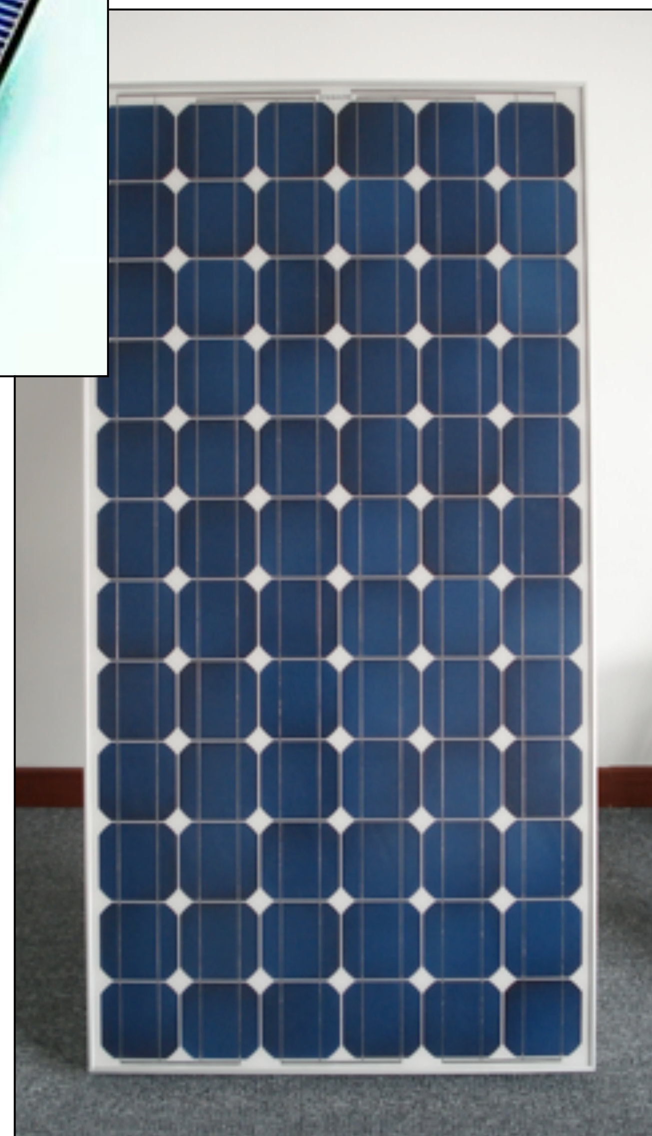
Cell:
Single piece of PV material. Voltage dependent on semiconductor type, current on surface area.

Basics



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

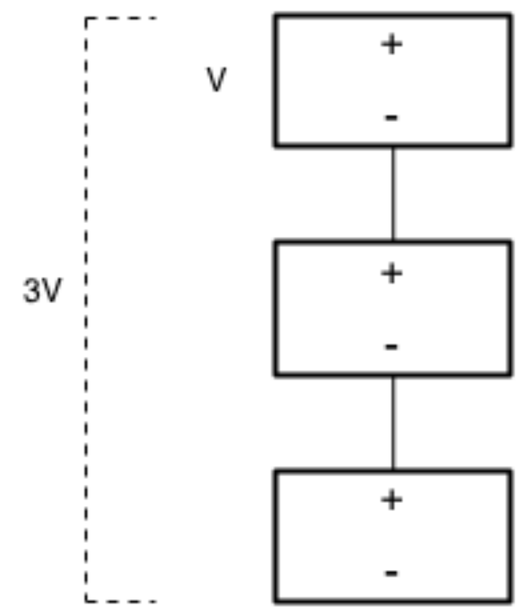
Basics



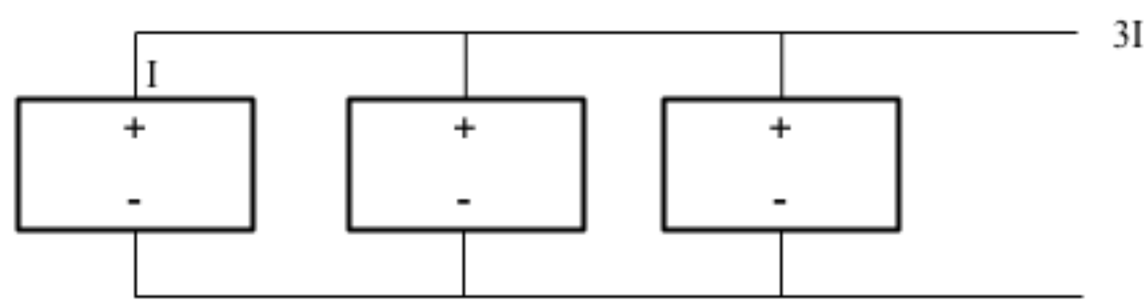
Array:
Multiple modules arranged in series and parallel groups to achieve desired voltage and current.

Basics

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



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



Basics

Metrics we care about are:

Rated performance
- “Watts-peak” under standardized conditions

Open Circuit (OC) Voltage
- voltage measured with no load

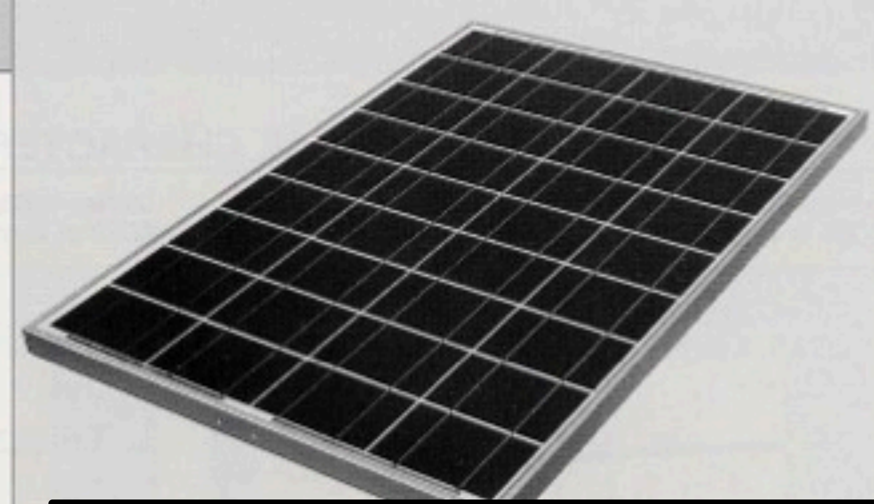
Short Circuit (SC) Current
- current through short circuit

And of course, cost...

KC80

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

TYPICAL OUTPUT 80 Wp



HIGHLIGHTS OF KYO

Kyocera's advanced cell processing technol
efficient multicrystal photovoltaic modules.
The conversion efficiency of the Kyocera sola
These cells are encapsulated between a tempe
maximum protection from the severest enviro
The entire laminate is installed in an anodized a

- 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 mon 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 1kW/m², Spectrum of 1.5 air mass and cell temperature of 25°C

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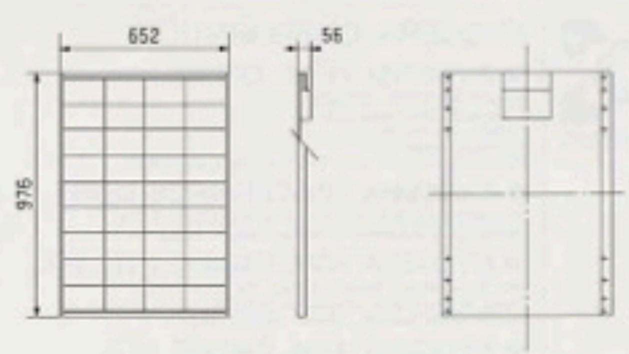


Basics

DIFFERENCES

Different types of PV are distinguished by:

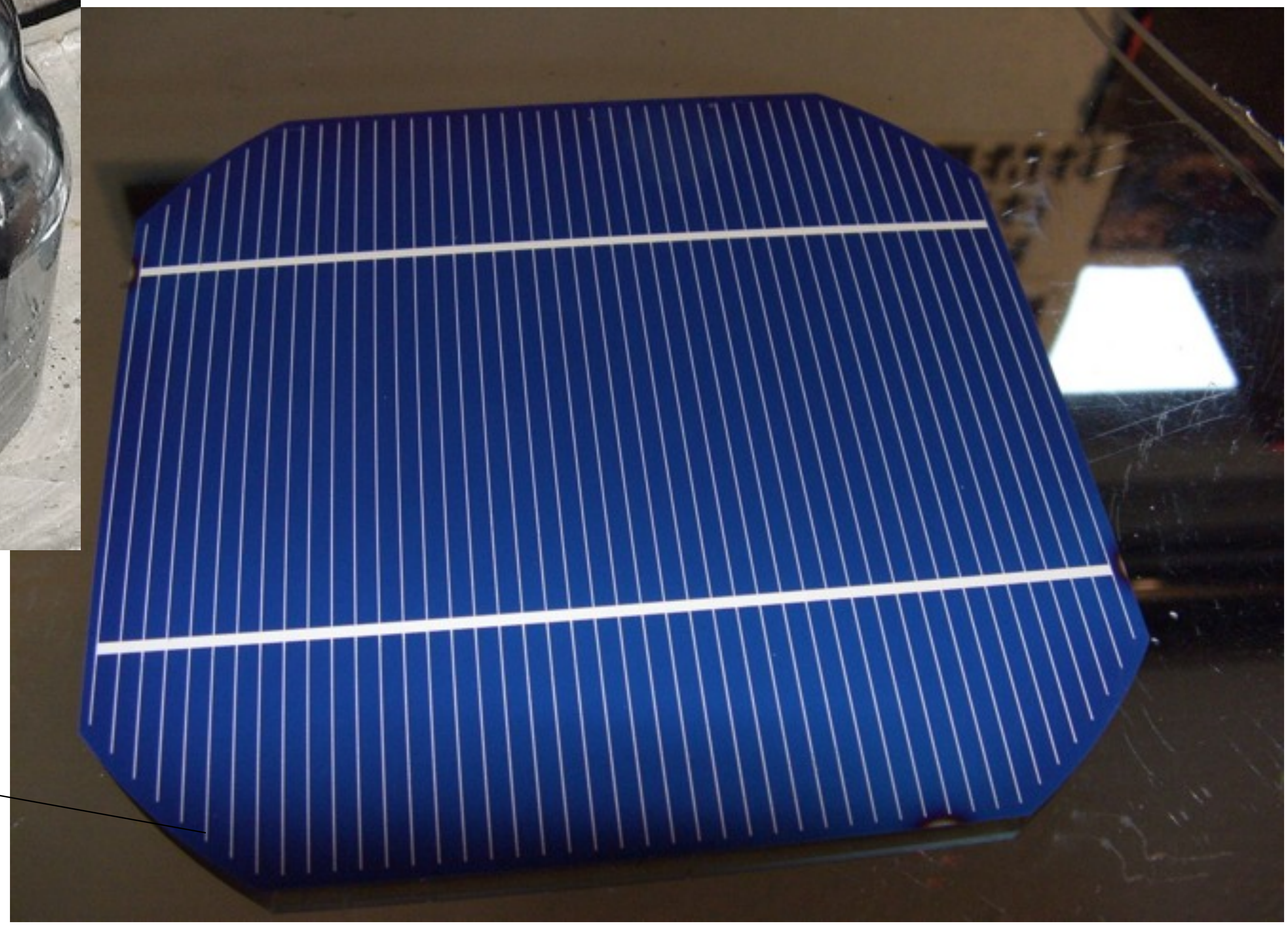
- Form of material (e.g. crystalline or thin film)

- 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 um thick
Si layer

Differences

Polycrystalline Si ingot and cell

Circa 300 um thick Si layer

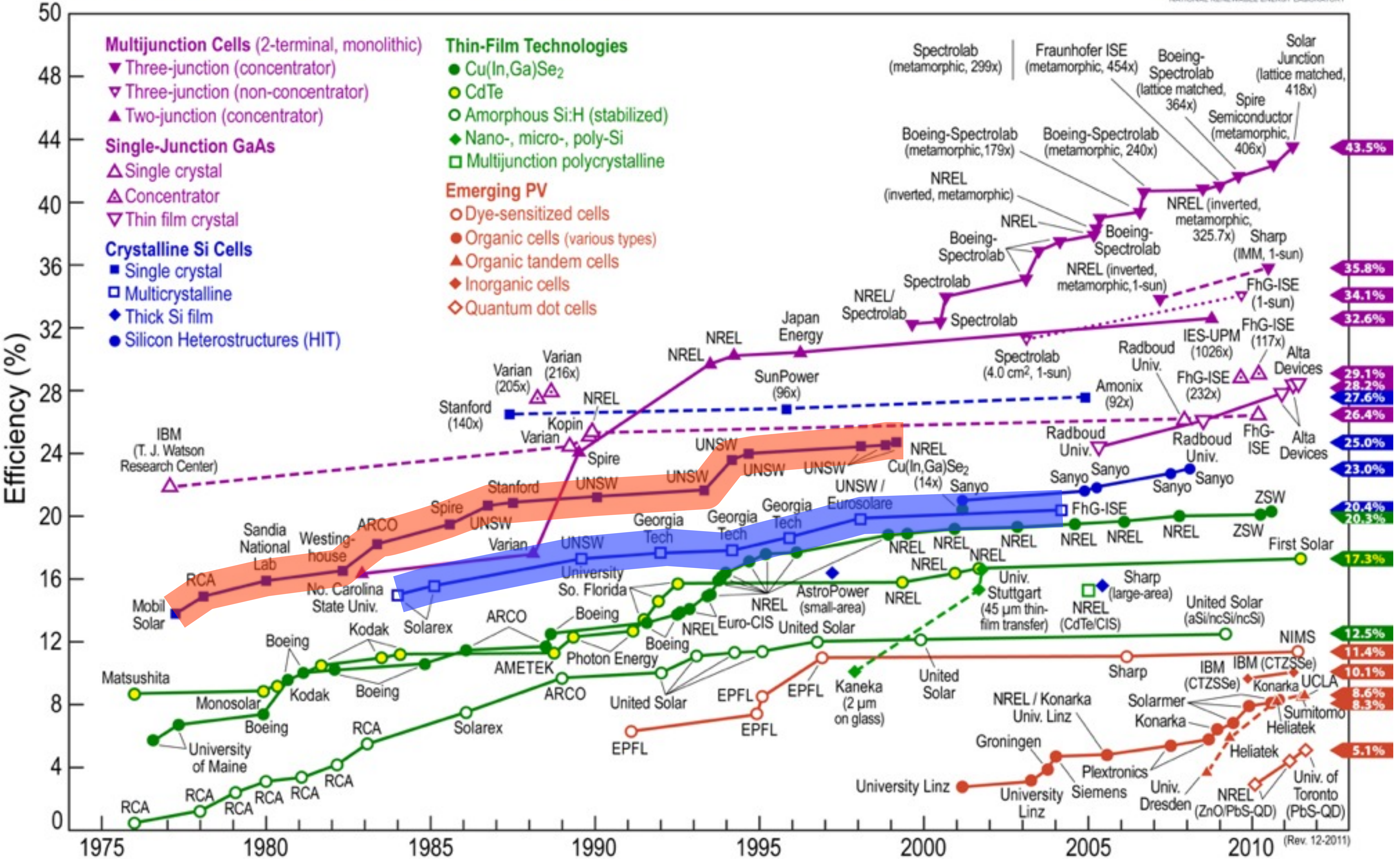
Differences

Amorphous or thin film PV

Circa 30 um thick
Si layer

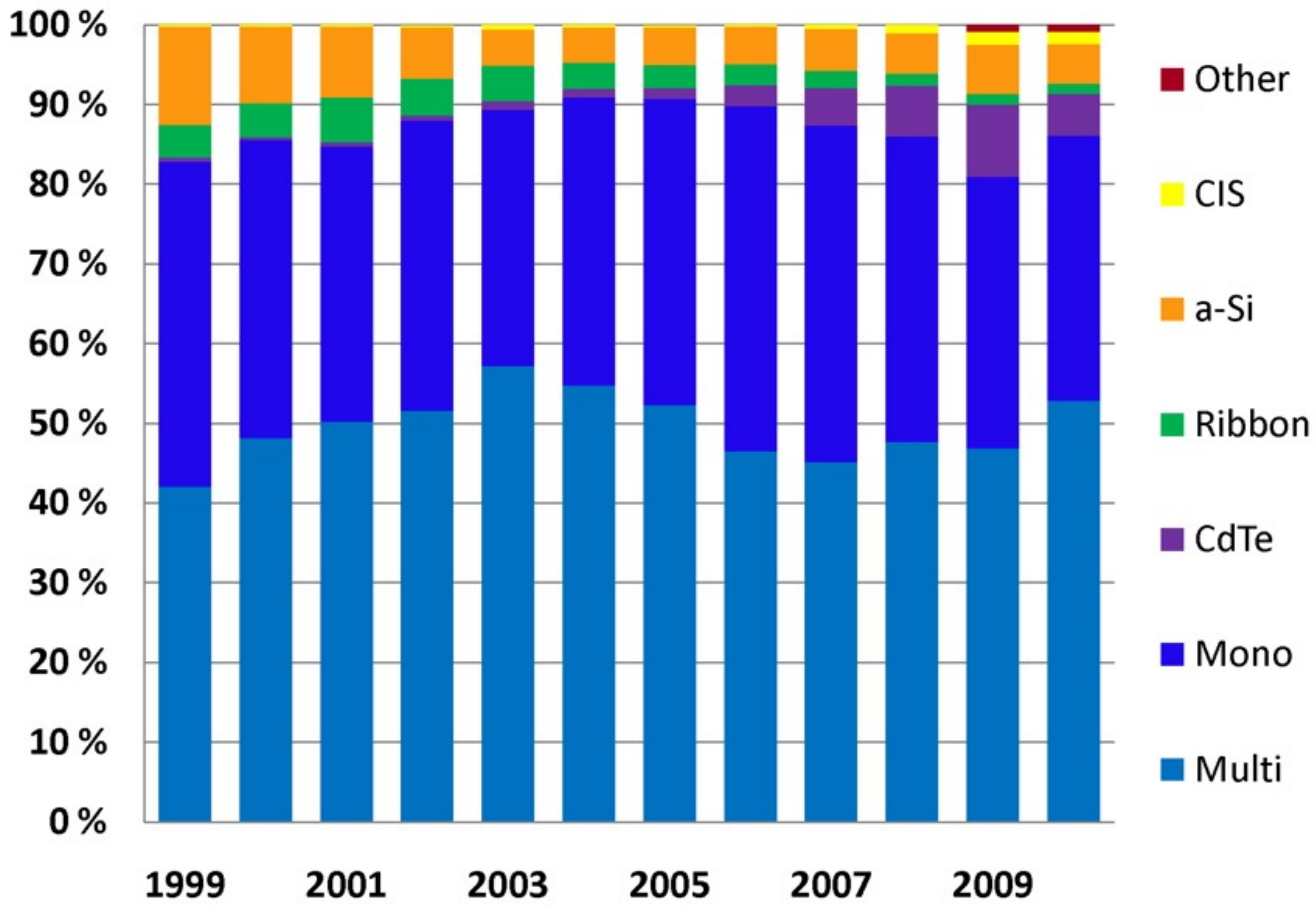
Differences

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

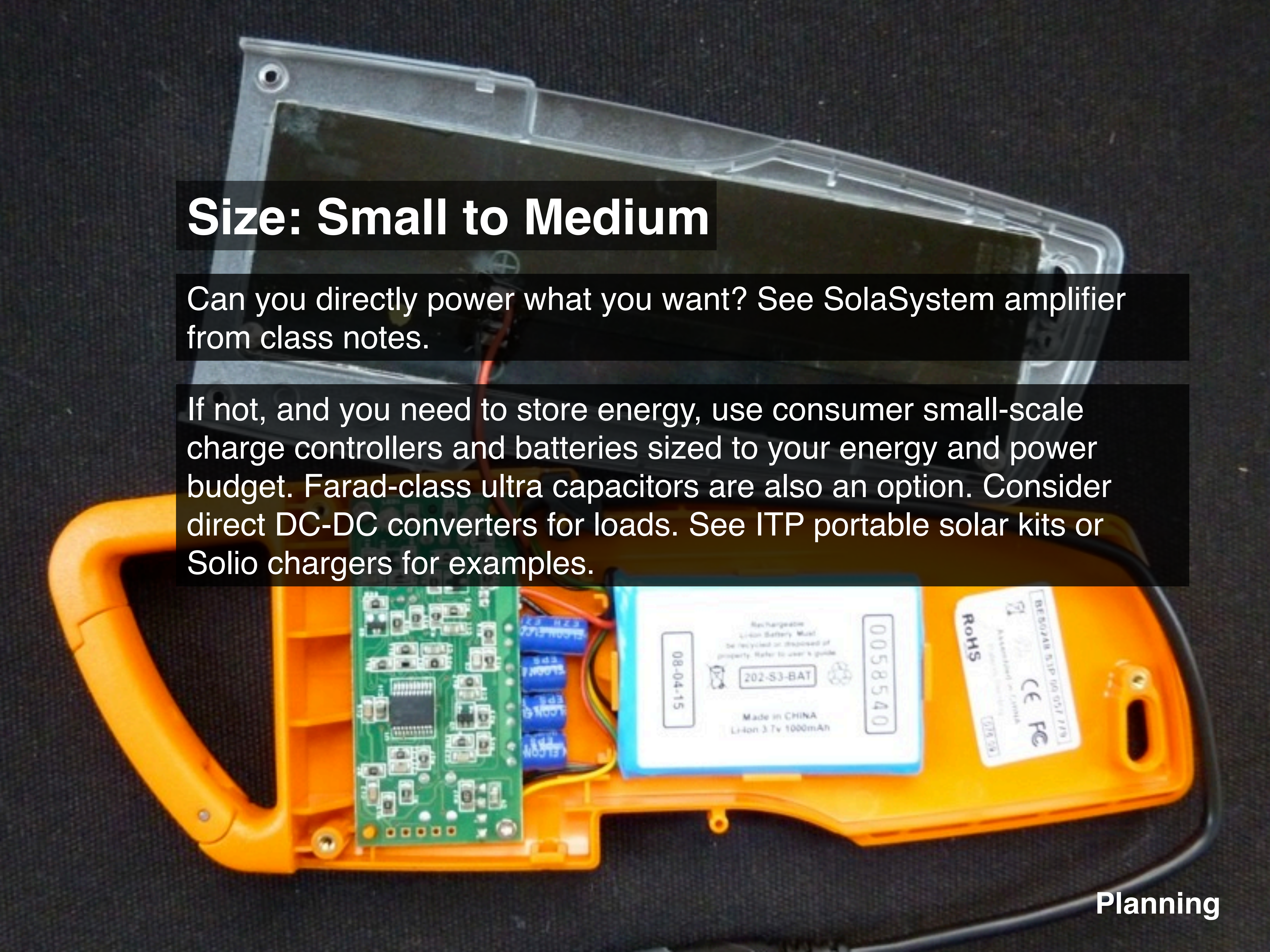
For now:

Planning a solar powered project

Size: Very Small

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

Solarbotics



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.

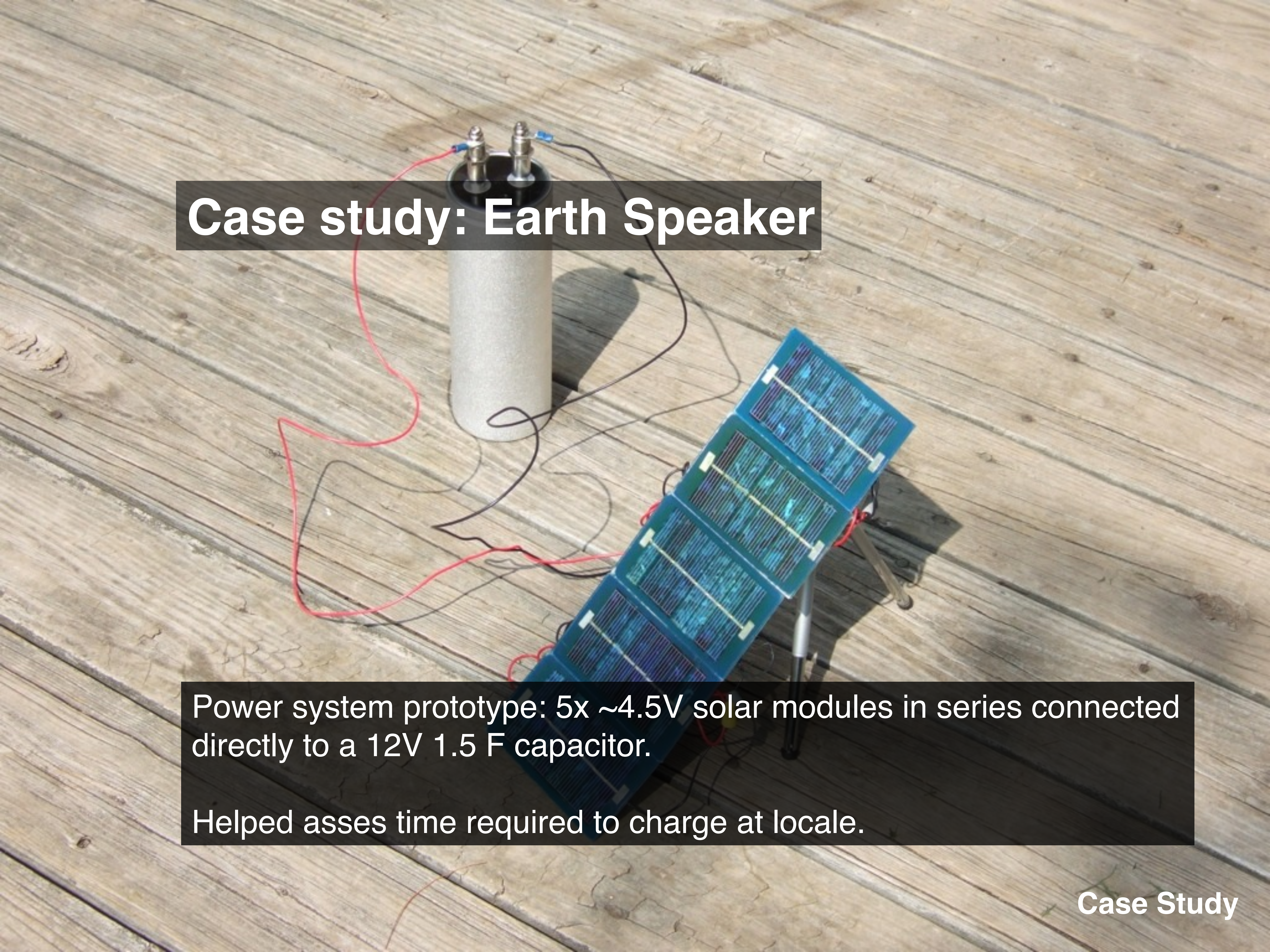
Size: Medium to large

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.

CASE STUDY

Case study: Earth Speaker

Solar powered sound installation



Case study: Earth Speaker

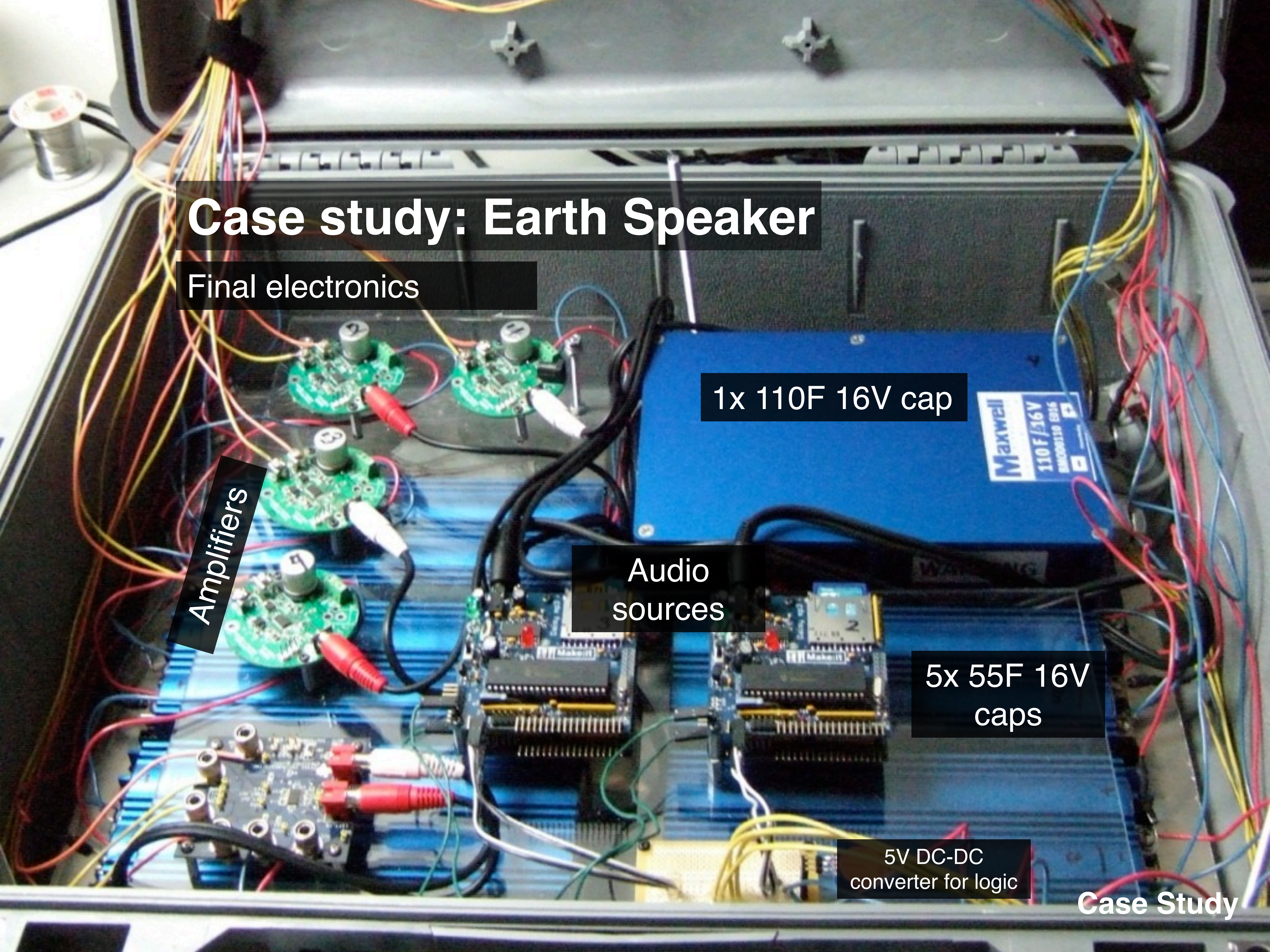
Power system prototype: 5x ~4.5V solar modules in series connected directly to a 12V 1.5 F capacitor.

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



What does this do to electricity use?