Workshop PV

Thu 29th May, 2pm - 6pm
At InterAccess Electronic Media Arts Centre
9 Ossington Ave. Toronto.

Subtle Technologies Festival 2008
Toronto, Canada

By Bart Vandeput – with support of FoAM

“The Sun is the width of a human foot.” *Heraclitus*

Basic concepts & context

The photoelectric effect: is a quantum electronic phenomenon in which electrons are emitted from matter after the absorption of energy from electromagnetic radiation such as x-rays or visible light.

A solar cell or photovoltaic cell: is a device that converts solar energy into electricity by the photovoltaic effect. The efficiency of a solar cell is defined as the percentage of solar energy falling on its surface that is converted into electrical energy.

Photovoltaics: is a technology that converts light directly into electricity. It is also the field of technology and research related to the application of solar cells as solar energy.

(Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic cell is used when the source is unspecified.)

It is generally acclaimed that the photovoltaic effect -the physics behind the solar cell- was first discovered in 1839 by the French nature scientist Alexandre Edmond
Becquerel. In 1883, the American inventor Charles Fritts produced the first selenium-solar cell with an efficiency of only 0,1 %.

Distributed (power) Generation**:** generally refers to integrated or stand alone small electricity-generation power plants that are located near or at the site of the end user. ‘DG’ contrasts with centralised generation, a term that characterises conventional large-scale fossil fuel or nuclear power plant generation.
While photovoltaics can be installed in large, centralised systems equivalent in output to small or medium power plants, they are more commonly deployed in distributed systems that are integrated directly into the homes and buildings that they power.
Distributed generation has also been called on-site generation, dispersed generation, embedded generation, decentralised generation, decentralised energy or distributed energy.

The role of solar power is still negligible in the world’s overall energy system (<0.3 per cent) but this situation is changing rapidly. The cost of solar power has in recent years been dropping by around 5 per cent annually whilst prices of crude oil, natural gas and grid power have been rising steeply. Also, Silicon production capacity problems are being resolved and non-silicon technologies are emerging.

Scientific American's January 2008 edition proposed “A grand plan for Solar Energy. By 2050 it could free the US from foreign oil and slash greenhouse emissions...”

How it works

Photons - packets of electromagnetic energy radiating from the sun and moving along at around 300,000km/sec and reaching Earth in only 8,5 minutes- silently push electrons out of the solar cell and generate electricity. No moving parts come in to play.

“Here we have the first true quantum power device.” John Perlin

The radiation spreads over a wide spectrum of wavelengths, from the 'short-wave' infrared (longer than red light) to ultraviolet (shorter than violet). The intensity of the light is greatest in the visible portion of the spectrum and the warmth we feel on a sunny day is due to the absorption of the infrared radiation. The power output of the various solar cell technologies varies in function of the colour of the incoming light.

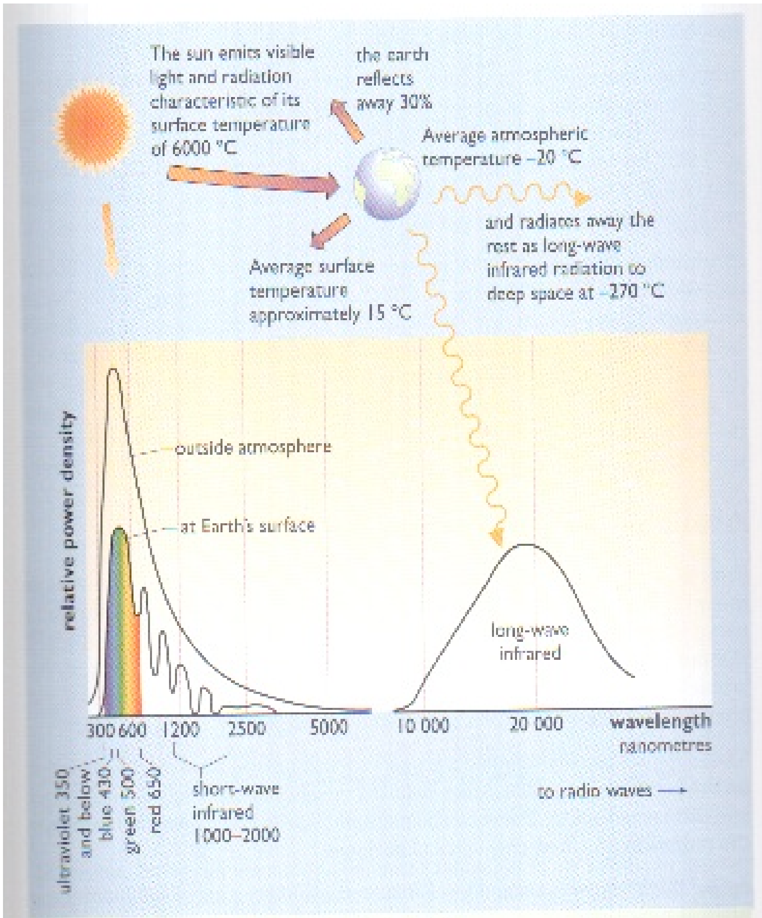


Figure 2.5 Radiation of energy to and from the earth

Differences due to time-of-day, season and latitude are largely controlled by earth-sun geometry and the weather (clouds). Planet earth is just at the right distance from the Sun but the greater the available solar resource at a given location the larger the quantity of electricity generated. Tropical regions offer a better resource than more temperate latitudes. The average irradiation in Europe is about 1,000 kWh per square meter, for example, compared with 1,800 kWh in the Middle East.

Source: Boyle, G. (2004) Renewable Energy. Power for a sustainable future. 2nd Ed. Oxford University Press. Oxford (UK). p.21.

Solar cells produce Direct Current (DC or "continuous current"): unidirectional flow of electric charge which is As opposed to Alternate Current. We have become comfortable -as in the early days of electricity- with DC technologies through the explosive growth of low consumption appliances such as cell phones, portable devices, and electronic gadgets. AC predominates when it comes to electricity transport but there exist a number of high to very-high-voltage DC transmission lines throughout the world. Power conditioners for low-voltage DC sources in Distributed Generation usually have two major functions: to boost the energy source output voltage and to convert it into an AC voltage. The voltage boost is usually done by a DC-DC converter (both imply conversion loss).

Technologies & Applications

All solar cells require a light absorbing material contained within the cell structure to absorb as many as photons as possible to generate as many electrons as possible via the photovoltaic effect. The materials can often be used in multiple physical configurations to take advantage of different light absorption and charge separation mechanisms. The original choices were motivated mainly by material availability and processing possibilities. The 'traditional' crystalline blue/grey Silicon-based PV accounts for more than 90 percent of the market and it is the most-researched and best documented technology in both bulk and thin-film configurations. The recent boost in interest for PV has also triggered a more systematic search for new materials and cell structures that may (also) fulfil the ultimate requirements of efficiency, cost, stability, and environmental effects. New discoveries from nanoscience f.i. contribute substantially to an increased diversity of PV-technologies as they lead to tinier, thinner, flexible, printable and sprayable solutions. This facilitates integration with other materials like glass, ceramic, fabric, etc., bringing the PV-technology into the realm of our day- to day, intimate life via building materials, consumer electronics and garments.

Many currently available solar cells are configured as bulk materials that are subsequently cut into wafers and treated in a "top-down" method of synthesis (inorganic silicon being the most prevalent bulk material). Other semi-conductors are configured as thin-films (inorganic layers, organic dyes, and organic polymers) that are deposited on supporting substrates, while a third group are used as quantum dots (electron-confined nano-particles) embedded in a supporting matrix in a "bottom-up" approach.

Kyosemi's 'Dome' Sphelar module

upcoming tech PV hard to get
The old-school (bleu/grey) solid state crystalline and polycrystalline solar cells are readily available on the (online) market as well as amorphous Si flexible PV. Some PV-tech is being produced but the order books are filled for a long period. it is difficult to almost impossible to acquire samples for the latter and for the technologies that are still in an experimental stage.

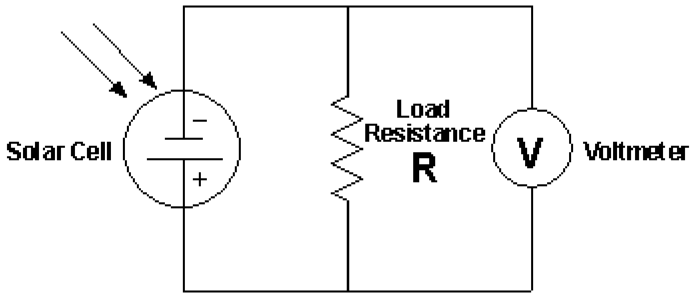
Exhibit I: Materials Used for PV

Material	Approximate Efficiency (Percent)	Use
Gallium Arsenide/Indium Phosphide/Germanium hybrid	35	In lab only
Gallium Arsenide	25	Not widely used, except perhaps in some aerospace applications and in other applications where weight rather than cost is an issue.
Indium Phosphide	22	In lab only
Crystalline silicon	25	The most common material used for PV today
Multi-crystalline silicon	20	Widely used
CIGS	20	Growing share of the thin-film market
Cadmium telluride	17	Significant and growing share of the thin-film market, but mostly comes from one firm
Amorphous silicon	10	The most common form of thin-film PV.
Organic materials	4 to 8 percent	Not in use, but several firms are actively trying to commercialize it

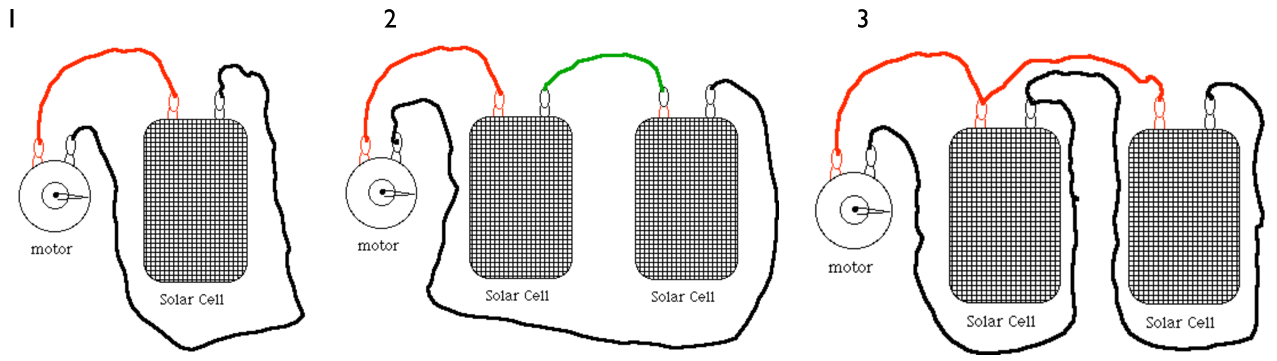
Source: EuroAsia semiconductor. Vol.30, Nr. 3. April 2008. p.38.

Connect Solar Cells & Measure

Basic Scheme



Basic set up PV-powered load (motor)



1. A solar cell is connected to a motor with clip leads.
2. 2 cells in series: the positive terminal of one connected to the negative terminal of the other. Series solar cells produce a higher output voltage.
3. 2 solar cells in parallel: the positive terminal of one connected to the positive terminal of the other, and also the negatives connected to each other. Observe the current (Amp).

Important:

– in case of the simple motor the direction of electrical flow can be reversed. When using an LED – a diode – this is not the case: the current can only go in one direction (diode): the positive side of the LED must be connected to the positive side of the solar cell.

Note: About electric current
A conventional electric current is defined as the flow of positive electric charges that produce the same effect as the actual flow in a circuit. In almost all circuits made of wires it is actually the negative charges that flow. The negative charge flow is in the opposite direction to the flow of positive charges that produces the same effect.

Measuring Voltage (V)
Use a multimeter to measure the voltage (make sure to turn the switch on V DC) across your solar cell in full sunlight then again in dimmer light. The black lead of the voltmeter goes to the black lead of the solar cell. The meter's red lead goes to the solar cells white (red) lead. The meter will have a very high resistance on the voltage scale so this is called the open circuit voltage of the solar cell, Voc. If you do not know which terminal of the solar cell is positive then notice that when the red, or positive lead of the meter is connected to the positive lead of the solar cell the meter will display a positive voltage.

Measuring Current (Amps)
Use a meter to measure the current (make sure the positive red lead is in the Amps-socket of the multimeter if it has one) through your solar cell in full sunlight then again in dimmer light. The meter will have a very low resistance on the current scale so this is called the short circuit current of the solar cell, Isc. When the meter reads a positive electric current then by definition an electric current is flowing into the red or positive lead of the meter.

Measuring to estimate the efficiencies of solar cells
Measure the power they produce while driving the motor by measuring the voltage across the terminals and the current through the solar cell. Multiply the voltage times the current to get the power of the solar cell Po.

Po = V x I (Power Law) = 0.6 x 0.5 = 0.3 W

Now estimate the power from the sun which hits the solar cell. To do this multiply the area of the solar cell, A, in square meters times the power of sunlight ,Ps, which is about 1000 watts per meter squared, W/m2. If your solar cell is 4 cm by 6 cm then its area is 0.04 m x 0.06 m = 2.4 x 10-3 m2. So the power input is

Pi = A * Ps = 2.4 x 10-3 * 1000 = 2.4 watts.

The ratio of the power delivered by the solar cell to the power input from the sun is the efficiency of the solar cell, e, which is usually expressed as a percent.

e = Po/Pi = 0.3/2.4 = 0.12 = 12%.

Important: Ohm's Law
Voltage (V), current (I), and resistance (R) are related by Ohm's Law. There are three different forms of the equation:

I = V/R   V = IR   R = V/I

Using ohm's law is easy. You pick an equation to use based on the value you're trying to find. Let's say you have a 9volt battery and you connect the + and - terminals through a 100 ohm resistor and you want to know how much current is flowing. You will use the I = V/R form:

V = 9   R = 100   I = V/R = 9/100   I = .09 amps (90 milliamps)

What if you want to limit the amount of current flowing through a circuit to say, 20mA, and you've got a 5v power supply. What size resistor would you need? We'll use the R = V/I form:

V = 5   I = .02   R = V/I = 5/.02   R = 250 ohms

So you can see that a given voltage across a given resistance will result in a proportional flow of current. If the resistance is too small (like 0 ohms!) You have a short circuit. That's what would happen if you just touched one terminal of a battery to the other. Looking at ohm's law again, you can see that if R = 0 then you've got a divide by zero problem...And so a super high current. That's bad. Short circuits tend to make the magic smoke come out of things. Don't do that.

"An architect who is as committed as an architect should work, i.e. answering the question of time in an artistic way, has to be a solar or ecological architect in today's world." *Georg M. Reinberg*

Quick start of a project using photovoltaics in 11 points

You want to realise a project that unavoidably requires electricity to work and you want to use solar cells/panels as the electrical power source?

The following scenario depicts a rational step-by-step way to get your project started.

1. Calculate the power requirements of your system (See: http://libarynth.org/_media/luminous/how_to_size_solarsyst.pdf). Try to think of ways to keep the power consumption as low as possible. (Unless fucking up the power to its extremes is your thing).

2. Determine when the electrical power is needed and verify what the light sources are (natural / artificial light).

3. Experiment with some ready available, cheap, small pv cells/panels.

4. Decide upon the technology
   - If It is readily available and fits in your budget – purchase and good luck.
   - is it too expensive?
   - do you want to customise the tech?

5. Look for a nearby company or research center dealing with this tech.

6. In case you decide to contact a manufacturer, look for the person responsible for R&D (gerneally NOT a marketing person)

7 . Send him/her a short, yet appealing description of your project including
   - your expectations of the pv-tech (if possible);
   - some 'hunch' that there's a budget.
   - project timing if possible.
   - pv-system sizing: it can be helpful for tehm to know how much electricty is required for your project.

8. If you've managed to get your foot in, always ask for a 'guided tour' (they might refuse, but its worth a try) and consequently ask a sample (por favor).

9 If you are convinced that this is what you want, and they are willing to make a customised solution according to your needs, ask them to help you with the testing and implementation in your system.

10. Check if they would consider sponsoring of the material.

11. Make it!

Sources

Basic concepts
http://en.wikipedia.org/wiki/Solar_cell
http://solar1.org/resources/photovoltaics/
http://www.renewableenergyworld.com/rea/news/reinsider/story?id=6780
http://www.leonardo-energy.org/drupal/node/2405
http://SciAm.com

Rifkin, J. (2002). The Hydrogen Economy: The Creation of the World-Wide Energy Web and the Redistribution of Power on Earth. Jeremy P. Tarcher/Penguin. New York (US). Pp. 195, 196.

Technologies http://www.kyosemi.co.jp/product/data/en2/dome_type_spphelar.html

Connect cells to power a motor http://www.exo.net/~pauld/activities/physics/solarcellf/solarcell.html#current

Further reading

Theory
Making Electricity Directly from Sunlight - John Perlin
http://www.renewableenergyworld.com/rea/news/reinsider/story?id=6780
- The science of the silicon solar cell. http://cs.sbcc.edu/physics/solar/sciencesegment/

Glossary: http://libarynth.org/luminous/glossary

– Technologies - Wikipedia and especially Peswiki provide an up-to-date overview of the main technologies in their photovoltaics sections: http://en.wikipedia.org/wiki/Photovoltaics , http://www.peswiki.org/DIY#Solar

Practice DIY - Electronic Circuit Simulator (recommended): http://www.falstad.com/circuit/directions.html

Market – Solar Panel price comparison
http://www.ecobusinesslinks.com/solar_panels.htm

Learning electricity & electronics: http://music.columbia.edu/~douglas/classes/electronics_workshop/
http://science.howstuffworks.com/question501.htm

Alternative Energy Storage Methods http://www.mpoweruk.com/alternatives.htm

Canada radiation data http://atlas.nrcan.gc.ca/site/english/maps/archives/5thedition/environment/climate/mcr4076

PhoEf - Photons & the electric kiss. A research project exploring the essence, use and abuse of the photovoltaic effect in science, industry, technology and the arts. By Bartaku, supported by http://fo.am - http://libarynth.org/luminous/phoef
Including:
- an overview of research centers, companies and PV-DIY:
http://libarynth.org/_media/luminous/080225_pv_overview.xls
- arts projects using PV: http://libarynth.org/_media/luminous/phoef_cases.pdf

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You're welcome to contribute to the Luminous Green wiki "Reflecting on the role of the arts, design and technology in an environment of turbulence." at http://libarynth.org/luminous/start