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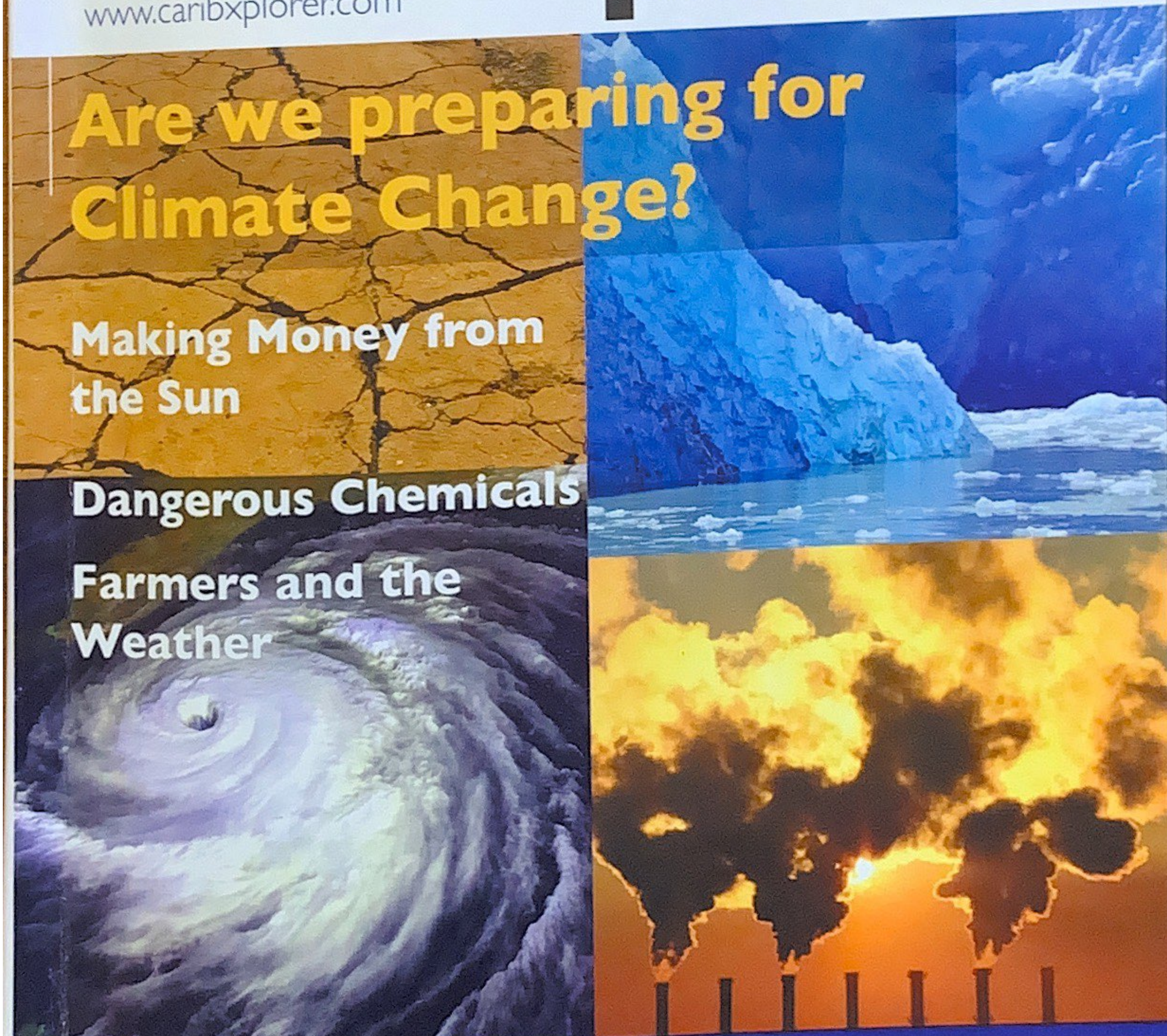

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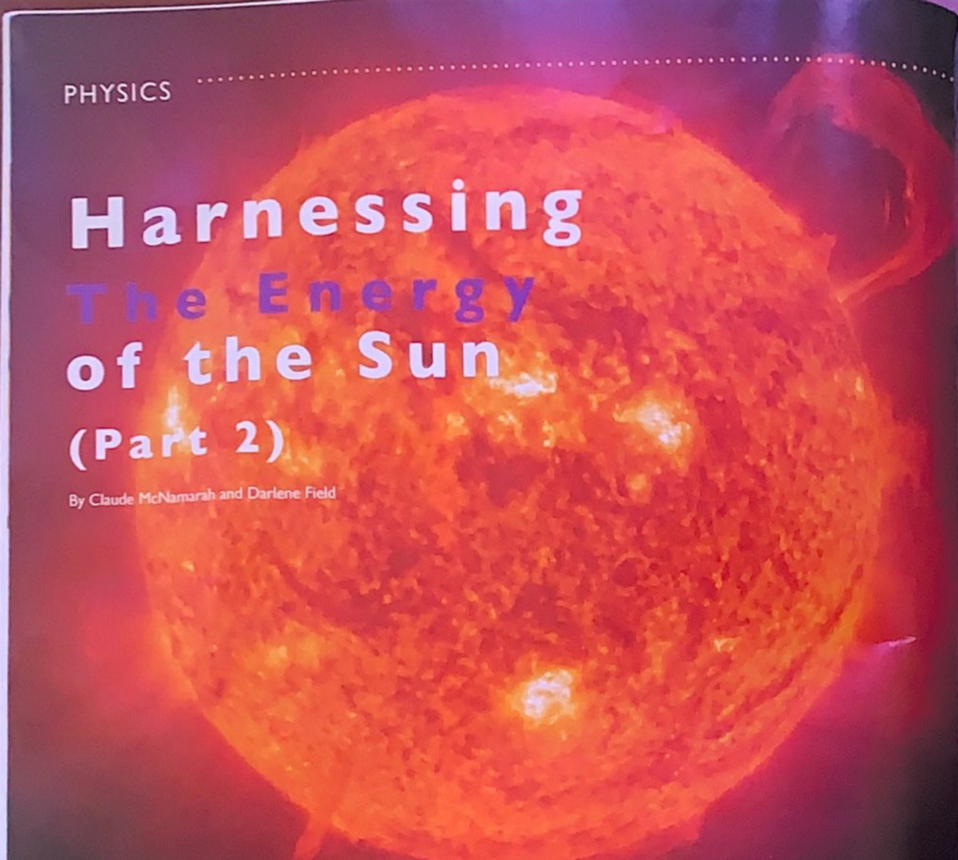

Harnessing The Energy of the Sun (Part 2)

By Claude McNamarah and Darlene Field

The popular technologies used to harness the energy of the sun are solar thermal and photovoltaics (solar cells). In Part 1 of this article that was carried in the 3rd issue of this magazine, solar thermal and organic solar cells technologies were discussed. We now continue our discussion on solar cell technology, its development and application.

What are Photovoltaics?

Photovoltaics (PVs) are devices which convert sunlight directly into electrical energy. PVs are alternatives to the traditional means of energy generation using fossil fuels. Since the sun is the resource of PV cells, and that resource cannot be depleted, then PVs are grouped as renewable methods of energy generation.

Photovoltaics made their debut with the discovery of the photoelectric effect by Edmund Becquerel in 1839. He observed that a voltage developed within two metals when they were exposed to light. At that time, however, the use of the photoelectric effect for power generation was not considered since efficiencies obtained were less that 1%. The development of the first operational semiconductor PV cell in 1954 at Bell Laboratories[1] with efficiency six times the maximum efficiency gained by previous methods[2] resulted in an increased interest in PVs as a source for power generation. Due to high capital costs and relatively low efficiencies, PVs were only used for space applications where the requirement of having light-weight, static power generators superseded the cost factor.

Space applications prompted more research into increasing the efficiencies. This resulted in PVs being made from different materials and being more resistant to extreme radiation.

Considerations of PVs for terrestrial applications were due to the oil crisis in the 1970s. Research into reducing the cost of PVs became the focus. In the 1980s, photovoltaics became a popular power source for consumer electronic devices such as calculators, watches and other small battery charging applications. Other PV technologies also emerged on the commercial market. Today PV technologies can vary from the base material to manufacture process with efficiencies varying rom 5.4% for organic PVs to 41% for concentrator PVs.[3]

How PVs Work

A PV cell utilizes a p-n junction during the direct conversion of sunlight into electricity. Semiconductor materials are usually used to make the p-n junction. The p-n junction is formed when a p-type semiconductor (one with a greater concentration of positive mobile charges) and an n-type semiconductor (one with a greater number of negative mobile charges) are connected together. The different concentrations will cause migration of the positive and negative mobile charges to the n-type and p-type semiconductors, respectively. This creates an electric field within the p-n junction which will direct mobile charges across the junction in one specific direction based on their charge.

Light energy, when shone on the PV cell, is absorbed and the energy is transferred to the electrons of the p-n junction. These electrons gain enough energy to escape the bound state and become mobile. The electric field within the p-n junction forces these mobile charges in one direction resulting in current flowing through an external load and back to the cell as illustrated by Figure 1. Once the charges are back in the PV cell the process begins again: a charge absorbs light and gains energy thus becoming mobile, the mobile charge is collected by the p-n junction, it leaves the device to dissipate its energy as they travel through a load and then re-enters the solar cell.

Photovoltaic cells can be connected to form the photovoltaic module (solar panel) to produce a combined electric current. Silicon was the first and is still the most popular semiconductor material used to make PVs.

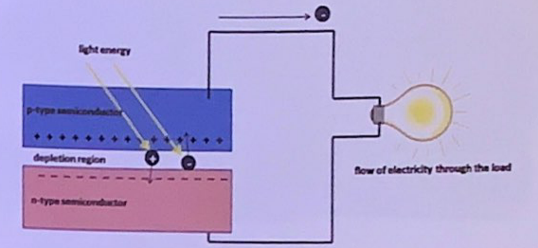

Figure 1: The action of the p-n junction of a PV cell. The positive and negative charges move across the p-n junction generating electricity to light a bulb

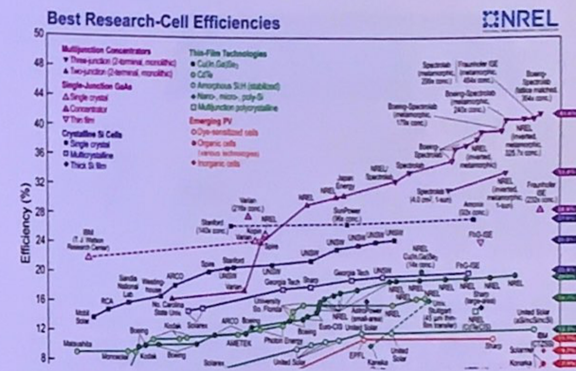

Figure 2: A thirty-year evolution of solar cell efficiency obtained from the National Renewable Energy Laboratory, Boulder, Colorado (SRoeCo Solar, Solar Cell Efficiency vs Solar Panel Efficiency 2011. http://sroeco.com/solar/)

PV Technologies and Performance Ratings

In order to make PVs economically competitive, different types of raw materials as well as different manufacturing processes are used. Cheaper raw materials with the ability to effectively absorb sunlight were investigated. Also different manufacturing processes were used to reduce the high production costs. This has resulted in various PV technologies becoming available on the market.

Commercially available photovoltaics are now classified based on the raw materials used and the manufacturing processes involved. There are three main types of PVs: crystalline, thin film and most recent organic PVs. Each PV technology has its own unique response to different operating environments, such as solar irradiance and temperature. As a result, PV performance is quoted while operating under a reference operating environment, namely the internationally accepted "Standard Test Conditions (STC) of solar irradiance of 1000 Watts per square metre (1000 Wm^2)," module temperature of 25°C and air mass(AM) of 1.5. Figure 2 shows the best efficiencies of PV technologies obtained at STC. One should note that even though the operational conditions are the same, efficiencies vary with technology.

The STC reference environment was obtained from the combination of the seasons throughout the year; that is the irradiance on a clear summer day, the module temperature on a clear winter day and the air mass during a clear spring day.[4] This statement clearly indicates that STC rarely occur under local operational conditions. Jamaica, for example, whose average daytime irradiance is 519 Wm-2 has average daytime ambient temperatures of 29°C, far greater than the STC module temperature of 25°C. PV performance therefore varies based on not only the technology but also on the operating environment.

Applications of Photovoltaics

PV modules can be connected together (see Figures 3-5) to generate the desired power output to satisfy a particular need. Photovoltaic cells and modules are used for both small-scale applications such as powering calculators, radios, gate openers and telecommunication equipment, and mid and large-scale applications such as powering residential homes or industrial offices and solar plants.[3]