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CHALLENGES OF TOURISM AND BUSINESS LOGISTICS IN THE 21ST CENTURY

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PREFACE

The Faculty of Tourism and Business Logistics in Gevgelija, at the Goce Delcev University - Stip, hosted the First International Scientific Conference, "Challenges of Tourism and Business Logistics in the 21st Century".
The conference was held on 24 and 25 October 2017 in Gevgelija with an optional visit to Dojran - Dojran Lake.
32 works of 60 authors from Serbia, Latvia, Turkey, Poland, Bulgaria, Kosovo and Macedonia were presented at the Conference.
The purpose of the Conference is exchange of ideas and experiences of the participants coming from Macedonia and abroad, and establishment of cooperation for further development of tourism and business logistics in Macedonia and beyond.

The results of the Conference are visible through publication in a collection of papers, which is presented to a wider scientific audience and the public.

In this way, we want to promote the Faculty of Tourism and Business Logistics, to promote Gevgelija and Dojran as the most visited settlements in the south-eastern part of Macedonia.

Gevgelija - Stip,
December 2017

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C O N T E N T S:

PLENARY SESSION

TOURISM

ECONOMICS AND BUSINESS

NEW GENERATION OF PV CELLS AND THEIR POTENTIAL APPLICATION IN TOURISM AND HOTEL INDUSTRY

Vlatko Cingoski1; Biljana Petrevska 2; Saso Gelev 3

Abstract

Photovoltaics (PV) have started replacing fossil fuels as major energy generation roadmaps, targeting higher efficiencies and/or lower costs are aggressively pursued to bring PV to cost parity with grid electricity. Staring with first generation semiconducting p-n junctions and the second generation thin film cells, the third generation PV technologies may overcome the fundamental limitations of photon to electron conversion in single-junction devices and, thus, improve both their efficiency and cost. Even more, recently developed "inorganics-to-organics" 4G polymer solar cells, brought new challenges for development, investigation and application of such sophisticated energy resources in various fields. This paper presents some notable advances in these technologies, namely organic, nanostructures, polymer and dye-sensitized solar cells and their potential applications in the tourism and hotel industry.

Key Words: *photovoltaic, energy efficiency, smart windows, hotel management*

JEL classification: Q49, Q56, Q59

Introduction

Recently, mostly due to exhaustion of other conventional energy resources, especially fossil-based fuels, various alternative renewable energy sources including those obtained by solar cells have attracted much attention. Fossil fuels lead to high emissions of CO2 and other pollutants and consequently have aggravating influence on human health due to adverse environmental conditions. On the other hand, the photovoltaic (PV) energy generated using various types of solar cells, is one of the cleanest, most applicable and promising alternative energy using limitless sun light as raw energy source (Kumar & Rosen, 2011; Singh, 2011).

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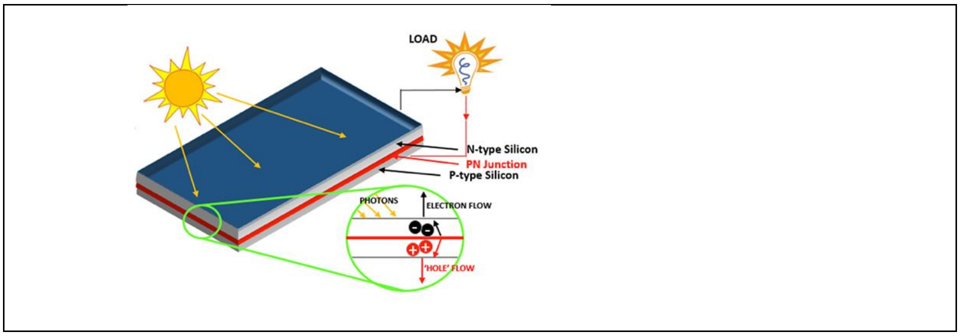
From the physical viewpoint, the PV conversion represents the direct conversion of sunlight into electricity without any heat engine to interfere. Photovoltaic devices are rugged and simple in design requiring very little maintenance and their biggest advantage being their construction as stand-alone systems to give outputs from microwatts to megawatts. Hence, they have wide implementation range used as power source, water pumping, remote buildings, solar home systems, communications, satellites and space vehicles, and for even megawatt scale power plants (Parida et al., 2011).

The historical development of solar cells usually is divided into several major deployment stages, called generations, the silicon-based solar cells being the so-called first generation (1G) of solar cells. Second generation (2G) of PV or solar cells is usually closely associated with the emerging of the thin-film solar cells, while the third generation (3G), currently widely analyzed and full of potential generation, is so-called "tandem" or "organic" PV cells.Thus, although the inorganic solar cells (generally silicon-based solar cells) still dominate in today's world photovoltaic market, organic solar cells as the new emerging PV cells has explored new possibilities for different smart applications with their advanced properties including flexibility, light-weight, and graded transparency. In addition, the low cost production and easy processing of organic solar cells comparing to conventional silicon-based solar cells make them interesting and worth employing for personal use and large scale applications (Anctil & Fthenakis, 2012; Bedeloglu, 2011; Galagan & Andriessen, 2012; Sohrabi et al., 2013).Today, the smart textiles as the part of technical textiles using smart materials including photoactive materials, conductive polymers, shape memory materials, etc. are developed to mimic the nature in order to form novel materials with a variety of functions. These new solar cell-based textiles have found its application in various novel fields and promising development obtaining new features. The photovoltaic textile materials can be used to manufacture power wearable, mobile and stationary electronic devices to communicate, lighten, cool and heat, etc. by converting sun light into electrical energy. The photovoltaic materials can be integrated onto the textile structures especially on clothes, however, the best promising results from an efficient photovoltaic fiber has to be come which can constitute a variety of smart textile structures and related products (Singh, 2011).

In this paper, we will get acquainted with a so-called new kind of materials, including textiles that exhibit photovoltaic qualities, i.e. they have the capacity to produce energy. Firstly, we are going to take a closer look at the mechanism of energy generation by means of solar cells that are used today. Next, we will briefly elaborate on some of the newly developed 3G PV cells. We will get to know what they are made of, their production process, work characteristics, mechanical characteristics, some of their positive and negative traits as materials and most common uses. Finally, we would also discuss some potential application of such PV cells in hotel industry and in general in tourism industry as energy sources either for increasing energy efficiency or as additional renewable and environmentally friendly energy resource, followed by some final remarks and conclusions.

Photovoltaic effect, photovoltaic cells, and their classificationThe basic physical process within solar cells is the process called photovoltaic effect. It generates voltage or electric current in specially designed physical materials when they are exposed to sunlight, i.e. process of conversion of sunlight into electrical energy.

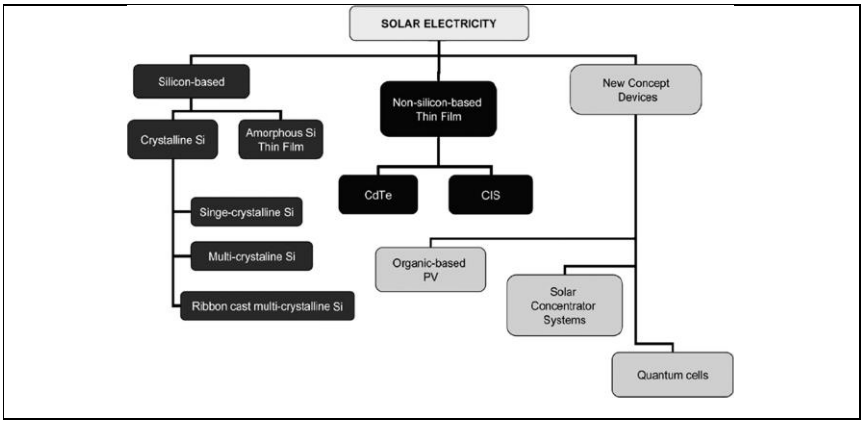
Figure 1: Photovoltaic effect and the basics for operation of a solar cell



Source: http://www.eworkzpower.pk/how-solar-works.php

A key feature of photovoltaic systems is their ability to provide direct and instantaneous conversion of solar energy into electricity without complicated mechanical parts or integration. These specially designed materials with photovoltaic properties are commonly called photovoltaic (PV) or solar cells. They are composed of two different types of semiconductors, a p-type and an n-type semiconductors that are joined together to create a so-called p-n junction. By joining these two types of semiconductors, an electric potential field is formed in the region of the junction as electrons move to the positive p-side and holes move to the negative n-side. This electric potential field causes negatively charged particles to move in one direction and positively charged particles in the other direction, thus enables flow of electric current, as shown in Figure 1.

Figure 2: Classification of PV cells



Source: Akarslan, 2012

Photovoltaic systems can be further distinguished based on the solar cell technology as shown in Figure 2. Silicon (Si) based technologies can be categorized as a crystalline silicon and amorphous silicon or thin film, and are considered the most mature. Crystalline silicon cells can have different crystalline structures: mono-crystalline (mono-crystalline) silicon, multi-crystalline silicon and ribbon cast multi-crystalline silicon (Kumar & Rosen, 2011).

The 1G of PV technologies was made of crystalline structure which used silicon (Si) to produce the solar cells that are combined to make PV modules. However, this technology even today is not obsolete rather it is constantly being developed to improve its capability and efficiency. Mono-crystalline, multi-crystalline, and emitter wrap through (EWT) are cells under the umbrella of silicon crystalline structures and are still widely used as solar cells in various applications.

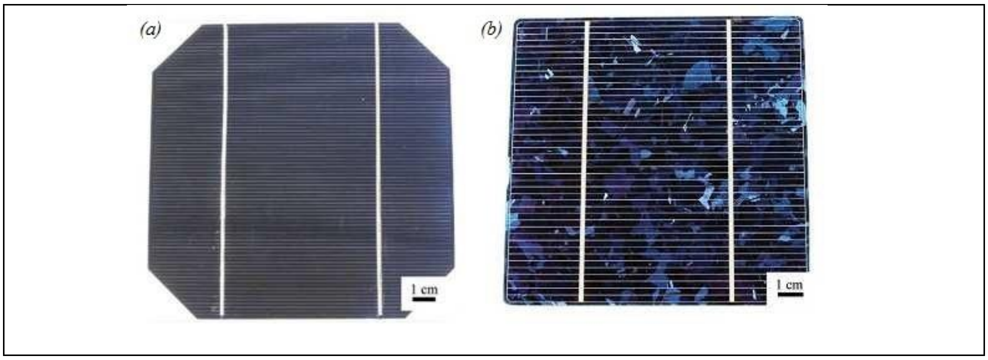
Mono (single)-crystalline photovoltaic cells/panels

This type of a cell is the most commonly used, constitutes about 80% of the market recently and will continue to be used until a more efficient and cost-effective PV technology is developed (Chaar et al., 2011). Because these cells essentially use crystalline Si p–n junctions, current attempts to enhance the efficiency are limited by the amount of energy produced by the photons since it decreases at higher wavelengths. The maximum efficiency of mono-crystalline silicon solar cell has reached around 23%, but the highest recorded was 24.7%. However, module efficiencies always tend to be lower than the actual cell and Sun power recently announced 20.4% full panel efficiency. These types of mono-junction, silicon-wafer devices are now commonly referred to as the first generation (1G) technology, the majority of which is based on a screen printing-based device.

Multi (poly)-crystalline photovoltaic cells/panels

The efforts of the photovoltaic industry to reduce costs and increase production level have led to the development of new crystallization techniques (Chaar et al., 2011). Initially, multi-crystalline was the dominant and more attractive in the solar industry because manufacturing cost is lower even though these cells are slightly less efficient (15%) than mono-crystalline. The advantage of converting the production of crystalline solar cells from mono-silicon to multi-silicon is to decrease the flaws in metal contamination and crystal structure. Multi-crystalline cell manufacturing is initiated by melting silicon and solidifying it to orient crystals in a fixed direction producing rectangular ingot of multi-crystalline silicon to be sliced into blocks and finally into thin wafers (Figure 3).

Figure 3: Photographs of (a) crystalline, and (b) multi-crystalline Si solar cells



Source: Akarslan, F. (2012)

Thin film technology

The second generation (2G) of solar cells is usually named as thin-film solar cells. A thin-film solar cell is made by depositing one or more thin layers or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous thin-film silicon (a-Si, TF-Si). Thin films greatly reduce the amount of semiconductor material required for each cell when compared to silicon wafers and hence lowers the cost of production of photovoltaic cells (Parida et al., 2011).

Unlike crystalline forms of solar cells, thin film panels are created by depositing thin layers of certain materials on glass or stainless steel (SS) substrates, using sputtering tools. The advantage of this methodology lies in the fact that the thickness of the deposited layers which are barely a few micron (smaller than 10 µm) thick allows the creation of flexible PV modules. Technically, the fact that the layers are much thinner, results in less photovoltaic material to absorb incoming solar radiation, hence the efficiency of thin film solar modules are lower than crystalline.

Third Generation of solar cells

With further research, various improvements and inclusion of new materials in the existing 2G of thin film solar cells, recently a new so-called emerging or third generation photovoltaic cells (3G) has become commercially available. Among them the most promising are the organic, dye-sensitized (“Grätzel cell”), and polymer solar cells, as well as quantum dot, copper zinc tin sulfide (CZTS), nanocrystal, micromorph, and Perovskite solar cells (Chaar et al., 2011).

The main aim of third generation solar cell is obtaining high efficiency. To achieve such efficiency improvements, devices aim to circumvent the Shockley-Queisser limit for single bandgap devices that limits efficiencies to either 31% or 41%, depending on concentration ratio (Sohrabi et al., 2013). Researchers showed that it is possible to greatly improve on a single-junction cell by stacking thin layers of material with varying energy barriers on top of each other and creating so-called "tandem cell" or "multi-junction” cell (Figure 4a).

Traditional silicon preparation methods do not lend themselves to this approach. Most tandem-cell structures are based on higher performance semiconductors, notably gallium arsenide (GaAs). Three-layer GaAs cells achieved 41.6% efficiency for experimental examples, while on September 2013, a four-layer cell reached 44.7 percent efficiency. A theoretical "infinity-layer" cell would have a theoretical efficiency of 68.2% for diffuse light. The second benefit of this type of solar cells is decreasing the losses, especially the lattice thermalization loss that could be achieved by capturing carriers before thermalization (Figure 4b).

Finally, the 4G of solar cells which are still not commercially widely available are organic cells with polymer binding having donor and acceptor pair. The concept of these 4G solar cells has been developed with the aim of realizing both improved charge transport and an improvement in the optical coupling, in polymer solar cells through the incorporation of inorganic nanostructures into the device architecture. In addition to the optical and electronic benefits of incorporation of inorganic systems within active materials, certain inorganic materials are also known to improve the device's lifetime as well.

Figure 4: Efficiency projections and loss processes

Figure 4a: Efficiency and cost projections for first- (I), second- (II), and third generation (III) PV technologies

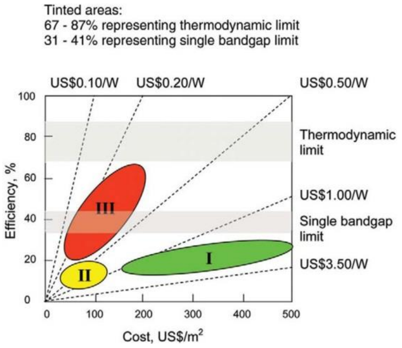
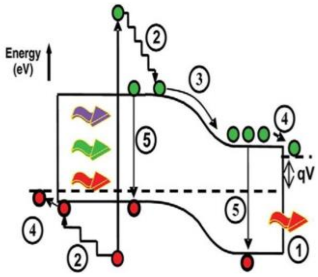


Figure 4b: Loss processes in a standard solar cell: (1) non absorption of below bandgap photons; (2) lattice thermalization loss; (3); (4) junction and contact voltage losses; (5) recombination loss



Source: Sohrabi et al., 2013

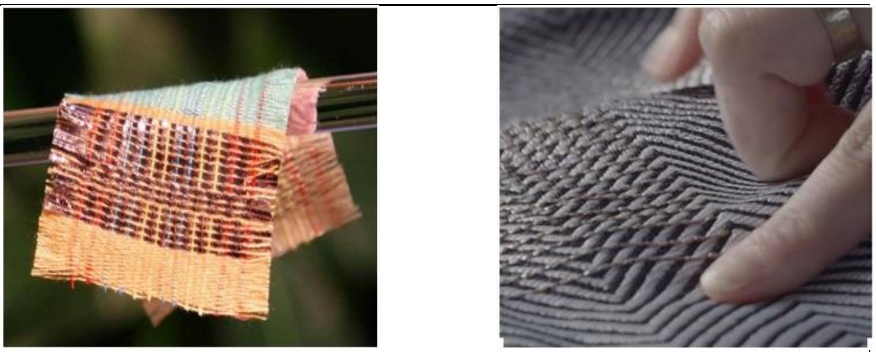
In addition to classification based on the solar cell technology, solar cells could be classified on the basis of their installations into four main types: grid-tied centralized (large power plants); grid-tied distributed (roof/ground mounted small installations); off-grid commercial (power plants and industrial installations in remote areas); and off-grid (mainly stand-alone roof/ground based systems for houses and isolated applications). The balance-of-system requirements of each installation differ significantly, e.g. off-grid stand-alone applications often require a battery bank or alternative electrical storage capacity (Kumar & Rosen, 2011).

Flexible Photovoltaic Textiles

The solar cell-based textiles are very good example of so-called organic solar cells. The photovoltaic textile materials can be used to manufacture power wearable, mobile and stationary electronic devices to communicate, lighten, cool and heat, etc. by converting sun light into electrical energy. They can be integrated onto the textile structures especially on clothes, however, the best promising results from an efficient photovoltaic fiber have to become which can constitute a variety of smart textile structures and related products (Singh, 2011).

Various photovoltaic materials and devices similar to solar cells integrated with textile fabrics can harvest power by translating photon energy into electrical energy. Some examples of textile with PV properties are shown on Figure 5.

Figure 5: Examples of textile with PV properties



Source: Singh, 2011

Some applications of the new generations of PV cells

The triggering point into wider commercial utilization and production of PV cells (solar cells) was their ability to convert the sunlight into electricity. Thus, they soon became alternative, renewable and almost inexhaustible energy sources to the existing fossil-based energy sources. However, as the time passed, the research in this field increased and certain advances were made in this field, the focus of interest gradually shifted to further exploration of cost advantages and application flexibilities.

Today the solar cells of all generations are widely used for various applications. The electricity produced by solar cells can be utilized in many applications such as cooling, heating, lighting, charging of batteries and providing power for different electrical devices (Curran et al., 2009). Solar cells using first generation technology have high areal production costs and moderate efficiency. Although with modest efficiency, the second-generation solar cells, so-called thin-film solar cells have advantages such as increased size of the unit of manufacturing and reduction in material costs. Consequently, third generation technology concept has been developed to eliminate disadvantages of earlier photovoltaic technologies mostly into two directions: to achieve very high efficiencies and second one, to achieve cost per watt balance via moderate efficiency at low cost. Finally, this third-generation solar cells, mostly renowned as organic solar cells, provides large flexibility of the cells enabling wide range of applications that were almost impossible with previous generations of solar cells. Furthermore, we briefly address some applications that might be of interest especially in modern tourism and hotel industry.

Building-integrated photovoltaic (BIPV) systems

The widely used solar technology application is during the building of the new hotel and tourism facilities. Using modular approach, a set of solar cells, mostly of the first generation could be used mainly for generation of additional power for the facility, increasing the energy efficiency and improving their environmental footprint, which leads towards development of co-called “green-tourism” (Petrevska & Cingoski, 2016 and 2017; Petrevska et al., 2016).

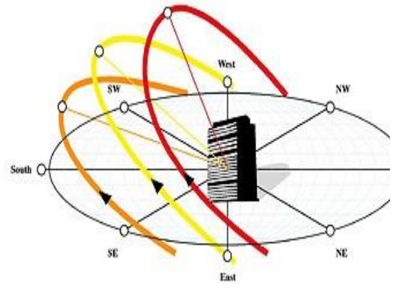
Figure 6: Examples of Building-integrated photovoltaic (BIPV) systems

Source: Cingoski, 2017

BIPV systems incorporate photovoltaic properties into building materials such as roofing, siding, and glass and thus offer advantages in cost and appearance as they are substituted for conventional materials in new construction (Cingoski, 2017). Moreover, the BIPV installations are architecturally more appealing than roof-mounted PV structures. Additionally, some architects proposed a building design to have the PV modules shade the building in summer, so as to reduce cooling loads, while at the same time allowing solar energy to enter the building during the heating season to provide daylight and conducted an analysis of the system performance, evaluation of the system efficiency and the power output. This nowadays classical approach for solar cells application could be seen almost everywhere for hotel facilities located at the costal or high-mountain resorts with significant amount of sunny days per year (Figure 6).

In case of already constructed facilities, usually it is not feasible to make changes in the construction or doing any other large reconstruction works. However, the solar cell technology provides solution even for such cases, such as installation of solar shades, solar window glazing and/or solar windows.

Figure 7: Solar shading basics and example in hotel industry



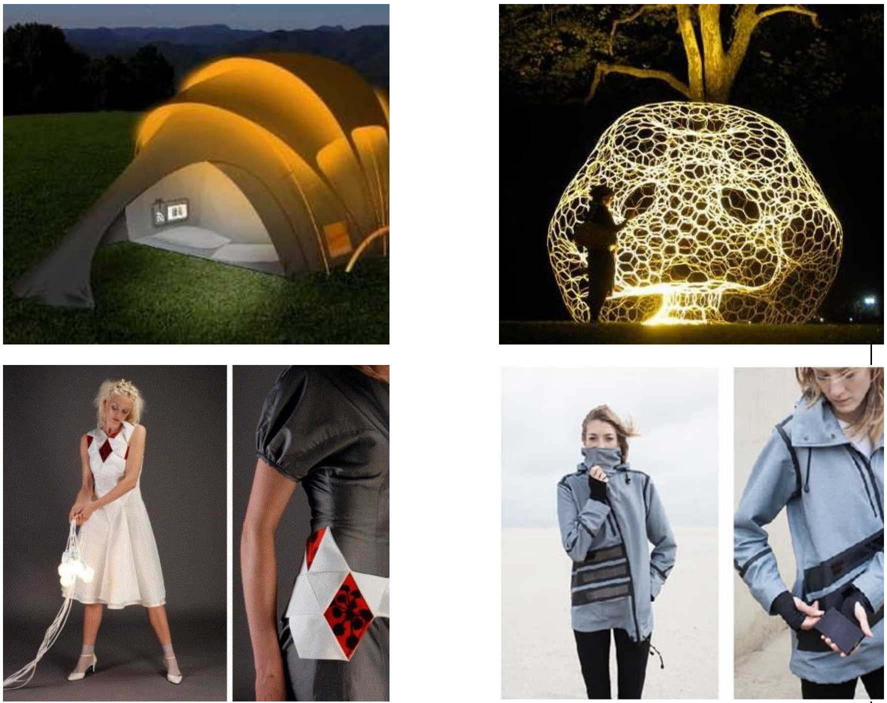
Source: https://www.coltinfo.co.uk/

Solar shading is one of the easiest methods for decreasing the cost for HVAC in any modern hotel facilities. It is based on the physical properties of the sun which moves on the sky at different angle towards the buildings as show in Figure 7. By installing solar shades at the appropriate angle, one could allow direct sunlight during the winter period for additional heating and in the same time shade direct sun during summer period and avoid unwanted heating of the space.

Conclusions

In this paper, a brief review of major solar photovoltaic technologies comprising of photovoltaic systems, performance and reliability of PV system, environmental aspects and PV applications is presented. The different applications of solar PV system such as building-integrated photovoltaic (BIPV) systems, solar shading, solar glazing and transparent solar windows, and few applications of flexible textile solar cells, with special aspect to the tourism and hotel industry, are also presented. Electricity produced from photovoltaic (PV) systems has several benefits over other mostly fossil fuels power sources such as need no fuel, give off no atmospheric or water pollutants and require no cooling, thus they do not contribute to global warming or acid rain problems. The use of PV systems is not constrained by material or land shortages and the sun is a virtually endless energy source. Various alternatives have been designed for building-integrated PV systems, including roof-top, facade and sun-shield systems. Most recently developed flexible organic textile solar cells even further broaden application area of such modern energy devices for application previously unrealistic using older solar cell generations (Figure 8).

Figure 8: Some recent application of textile (organic) solar cell technology



Source: Singh, 2011

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