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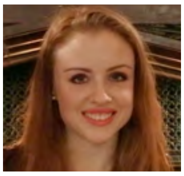

The Bright Future of Solar Energy

Claire Armstrong

Energy demand and consumption nowadays has lead to great interest in the research and development of renewable energies. The world's primary energy consumption is expected to grow by 1.6% per annum from 2010 to 2030, an overall increase of 39% [1]. Taking into account the proven reserves of fossil fuels and their daily production rate during 2005–2007, the estimated worldwide remaining supply of oil is 43 years, coal 148 years and natural gas 61 years [2]. These figures assume the daily production rate will remain constant over the years, however the reality is that worldwide consumption of fossil fuels has been increasing, and will continue to do so. In 2010, 87% of the world's total energy demand was met by fossil fuels, a figure which is expected to decrease to 81% by 2030 [1]. Predictions show that over the same period, the percentage for renewables will increase from 8% to 13% [1]. While this growth is encouraging, a larger growth rate is essential for future energy security and it is therefore vital that we continue to investigate alternative energy sources.

Despite several different green energies being necessary to meet global demands, solar energy is considered as one of the strongest alternatives to help replace finite resources. In one hour, the Earth receives more energy from the Sun than the global population currently consumes in one year [3]. Clearly, technologies which can harness even a fraction of this energy are worth researching. One of the most extensively researched solar technologies is the field of photovoltaics, more commonly known as solar cells. Photovoltaic (PV) technologies convert solar radiation directly into electricity using a 'p-n junction', which is the interface that forms when two types of semiconductor material are sandwiched together. These junctions are also crucial in many basic electronic devices, including transistors, LEDs and integrated circuits. Absorption of sunlight creates charge carriers which, thanks to the wonders of the p-n junction, can then be extracted from the solar cell as an electrical current.

Considering PV technology alone, covering only 0.1% of the Earth's surface with 10% efficient solar cells would provide enough energy to meet current demands [3]. Such an area is approximately the area of Spain – optimistic, however not impossible. All of these facts place solar energy as an ideal candidate to aid meeting energy demand by the end of this century.

So if the Sun is such a powerful source of energy, and mankind has already 'invented' the solar cell, why have we not given up on fossil fuels entirely and switched to solar energy? The answer, of course, is cost. The first practical solar cell, made from crystalline silicon, was developed in 1954 at Bell Laboratories. Due to their expense, however, their only widespread use in the next few decades was in space applications. Luckily, prices dropped as it was found that the cells could be made using cast-off silicon from the electronics industry without much sacrifice of efficiency, and in the years following the oil crisis in 1973, many oil companies branched out and formed solar divisions, making solar feasible for terrestrial energy applications.

Crystalline silicon is still the most commonly used material in PV applications, in either mono- or polycrystalline form. These cells are known as 1st generation cells, which comprise approximately 90% of the PV market, their dominance most likely due to their high efficiencies (27.6 % for a monocrystalline cell) and the technical know-how already developed by the semiconductor industry [4,5]. The maximum theoretical efficiency for these types of cells (crystalline silicon cells containing one p-n junction) is 33.7%, referred to as the Shockley-Queisser limit [6]. However, coming close to this value is not easy, as it is essential to use high purity (99.9999%) monocrystalline silicon. Ironically, producing these cells is a highly energy intensive process, with temperatures reaching as high as 1900°C at some stages. As an example, in order to manufacture enough of these cells to generate 4% of the energy produced worldwide in 2005, 10% of the worldwide energy would be needed. There is thus a fundamental limit to monocrystalline silicon solar cells [4].

The expense of these cells has lead to extensive research into alternative 2nd generation cells in an attempt to achieve a better cost-efficiency balance. These cells generally try to reduce costs by using thin film technologies and low temperature solution based processing, and are typically made from amorphous silicon or non-silicon materials such as cadmium telluride and CIGS (copper indium gallium selenide). Dye sensitized solar cells are also an alternative. Thin film cells are typically only micrometers thick, thus saving on material usage and resulting in a flexible structure that can be incorporated into various types of architecture. So far, CIGS solar cells have reached efficiencies of 20.3% and there are already several types of 2nd generation cells available in the market [5].

While the 30% theoretical efficiency limit for 1st generation solar cells sounds like an insurmountable barrier, it is possible to achieve efficiencies much higher than this through the development of new solar materials and cell designs. There are a variety of proposed cells that have this potential, all of which fall under the umbrella of 3rd generation cells. Multi-junction cells are 3rd generation cells which are already in commercial use, and by forming a cell made from several p-n junctions, efficiencies of 43.5 % have been shown to be possible using concentrated sunlight [5]. These cells use many layers of material to absorb a wider portion of the Sun's spectrum than traditional silicon solar cells, however the materials and processing methods required limit their use to space power applications where the desire for a high power-to-weight ratio is more important than cost. Extensive research into other types of cell within the 3rd generation category is also being carried out and while still at the pre-commercialisation stage, there are many promising options which, through continued materials research, are expected to become feasible within the next few decades.

Though the solar market is still young in comparison to that of the veteran fossil fuels, it is moving forward. Thanks to extensive research into PV materials and designs, in addition to lower production costs and higher production capacity, the solar industry is evolving and beginning to make its mark. From 2011 to 2012, photovoltaic installation in the US increased by 70% and market analysts predict a 30% increase in 2013 [7]. The US is actually just the tip of the iceberg. The true solar giant in the world right now is Germany. On the 15th April this year, Germany used its 1.3 million solar power systems to set a world record for power output [8]. The energy produced provided 12 % of the country's electricity consumption for that day, equivalent to 34,000 tons of oil or 8 nuclear reactors running non-stop for 24 hours. In fact, the peak power output at midday was 22.68 GW, enough energy for 19 trips in Back to the Future's De Lorian time machine. This figure clearly demonstrates the immense potential of solar power. If Germany, a cloudy northern European country, can make this much of a dent in its energy requirements, then the rest of the world should not be struggling so much to keep up. Turning now to look at the UK, we are far from reaching the PV capacity of Germany, however progress is being made. From 2011 to 2012, the UK's installed PV capacity grew from 980 to 1660 GW, and while this is vastly overshadowed by the German figures (25,100 to 32,700 GW), current growth projections look very promising [9]. It is predicted that, by the year 2020, 4 million households in the UK will have installed PV and the solar energy industry will have grown from 25,000 employees to 360,000. With today's electricity prices, the average three bedroom household in the UK could save as much as £800 annually by switching to PV and as energy prices are expected to continue to rise, could there be any other time where solar energy is more desirable [10]? Of course, to truly reap the benefits of solar energy, we must not take our eye off the ball. Only through continued materials research can we push the boundaries of photovoltaics and in order to take full advantage of this amazing technology, we must strive to rid ourselves of our dependence on fossil fuels. Solar energy has the potential to completely redefine electricity generation for the 21st century, and if we let it, the future of solar energy really is very bright.

References

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