

Using a context-based approach to undergraduate chemistry teaching – a case study for introductory physical chemistry

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Appendix 2.

Student worksheets for the *Capital City* case study, Session 6, which addresses solar power as a potential energy source. The worksheets include e-mail correspondence, an extract from a report on solar power and a range of photochemical data in graphical form. Figure T-6.2 (taken from the tutor's guide) gives a suggestion for how the solar spectrum might be simplified and combined with the photovoltaic response curve.

From: <M Spark >
To: < Capital City Advisory Group >
Subject: solar power
Attach: solar brief.doc.2

Dear all

In view of the number of sunny days in the Los Verdes region, we shouldn't discount the possibilities that solar generation can offer.

Despite its 'alternative' status, there is a growing interest in the exploitation of this type of technology and the DEA seem particularly keen on it. There are two basic techniques of converting the sun's radiation into electricity:

1. Photovoltaic conversion – the energy of a photon is used to induce electron movement in a semiconductor (the solar cell), resulting in the generation of electrical work.
2. Thermodynamic conversion – photon energy is converted into heat (by absorption) and subsequently into electricity via a gas driven turbine (e.g. a solar power plant).

Take a look at the extract from an article I found recently – this will give you the basics and then we need to do some calculations together.

Thanks

M Spark
Account Director

It doesn't take blue sky research to demonstrate the promise of bringing the sun's energy down to earth, as *Ray Burn* reports

Sun trap

Solar cells

Photovoltaic devices (generally called solar cells) consist of semiconductor materials such as silicon (we will focus on Si here). When light hits the solar cell, some photon absorption occurs. If the photon energy is sufficiently high, electrons can be promoted from the valence band to the conduction band, into an external circuit, and work can be achieved. In a semiconductor material, the energy required for an electron to transfer from the valence band into the conduction band is called the bandgap. The conversion efficiency of a PV cell is the proportion of sunlight energy that the cell converts to electrical energy (Figure 6.1).

The solar power plant

This type of plant can be divided into a *collector*, and a thermodynamic *converter* (Carnot cycle). The collector works in such a way that part of the sun's rays are reflected into a *receiver* by *reflectors*, with a net concentration of the solar radiation. The energy absorbed by the receiver is transferred to a gas driving a turbine, which in turn drives an electric generator. The total efficiency of the solar power plant is therefore given in the equation :

Total efficiency = Collector efficiency x Thermodynamic efficiency (steam plant efficiency)

As the temperature of the receiver increases, its ability to absorb heat decreases due to convection losses and emission of infra red light. In contrast, the thermodynamic efficiency is enhanced when the difference between the turbine temperature and cooling temperature is high (*cf* Carnot cycle; $\epsilon = (1 - (T_C/T_H))$). The plant is therefore operated at a receiver temperature (which is also the temperature of the turbine gas), which maximises the total efficiency. The dependencies of the two efficiencies on the receiver's surface temperature are shown in Figure 6.3

Costs

The costs of solar power exploitation can be highly variable. This is due in part to the highly variable nature of the energy source, the evolutionary nature of the technology and the need for application specific needs. For large-scale operations, and in terms of basic running costs, it is estimated that PV cells are more expensive than solar power plants by a factor of about 4 due to the greater technological investment. However, solar power plants generally have a higher plant cost which can offset (in part) these differences. Clearly, individual cases need careful examination.

From: < M Spark >
To: < Capital City Advisory Group >
Subject: solar power

Dear All



Task 1

Solar energy is certainly an option we should seriously consider and I'd like to get a feel for your thoughts on it. Let's meet later today to discuss what factors might affect the conversion efficiency of solar energy into electricity. Please bring an outline of some benefits and potential drawbacks of using solar electricity.



Task 2

We'll need to come up with some numbers for the DEA so please use the diagrams from the article to estimate the maximum theoretical efficiency (mid-day, clear sky) using the two methods, assuming that the reflectors / PV cells are tracking the sun in two axes. For the PV method in particular, consider an 'ideal' way of calculating the efficiency, whether this is achievable given the data available, and if some approximations or estimations may facilitate the calculation.



Task 3

Remember that Los Verdes is located in a hot and dry area in South-West, USA at about 35DegN. Cloud cover reduces the effective irradiance by 85%. A typical solar irradiation spectrum is shown in Figure 6.2. Estimate the average daily Irradiance for Los Verdes considering that the sky is cloudless 60% of the time. You may find the data in Figs. 6.4 and 6.5 useful.

Let's bring all our results together to come up with some ideas for DEA – please prepare to present your results to the group.

Incidentally, the diagrams from the article are attached too.

Thanks

M Spark
Account Director



Task 4

Figure 6.1 Photon response curve for Si

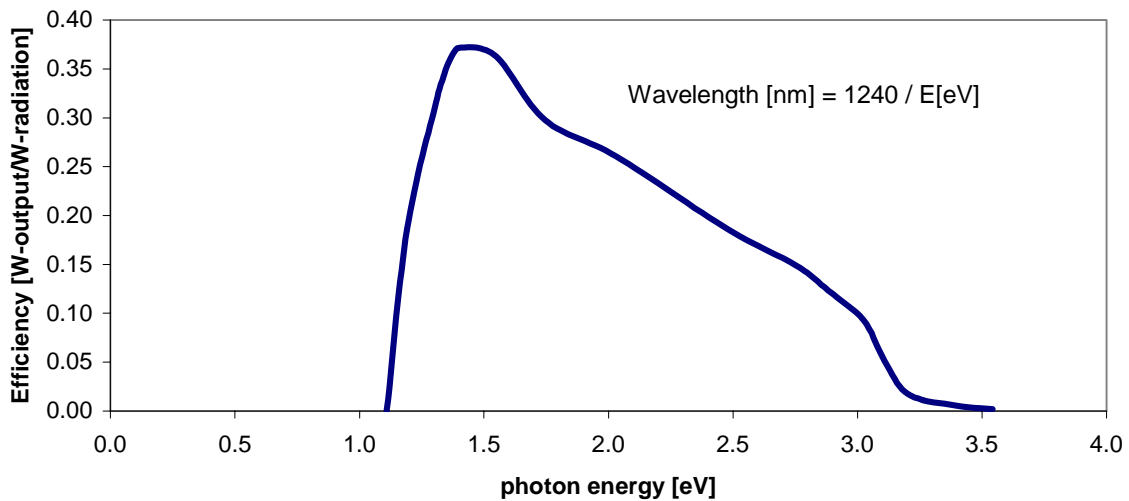


Figure 6.2 Typical solar irradiation spectrum at 35 degN for a clear sky at mid-day in March

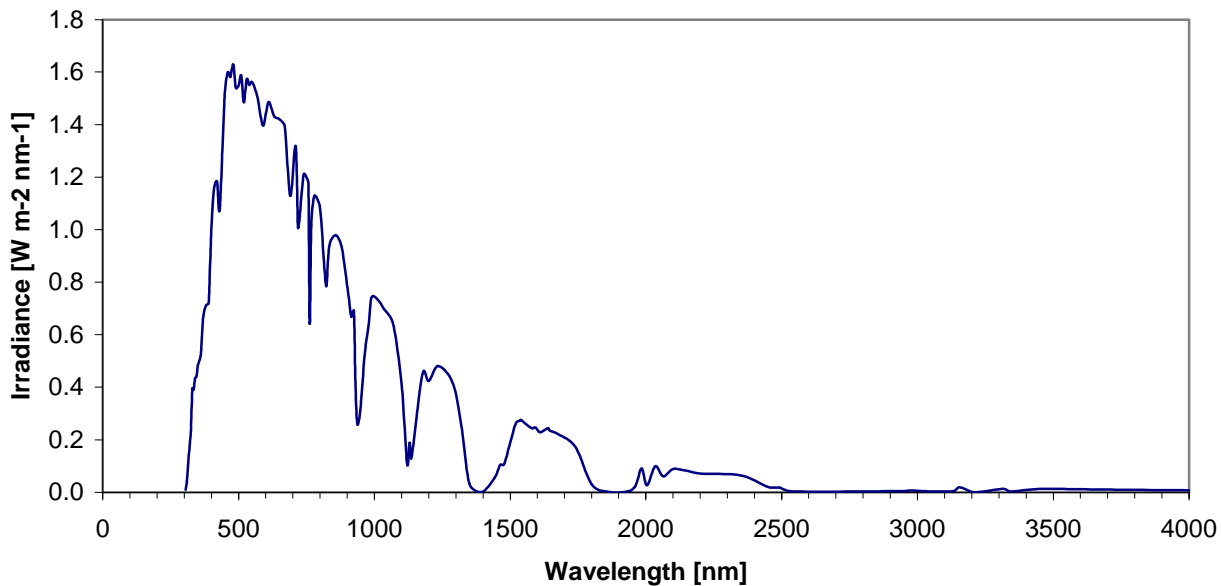


Figure 6.3 Efficiencies for a solar power plant as a function of the receiver's surface temperature

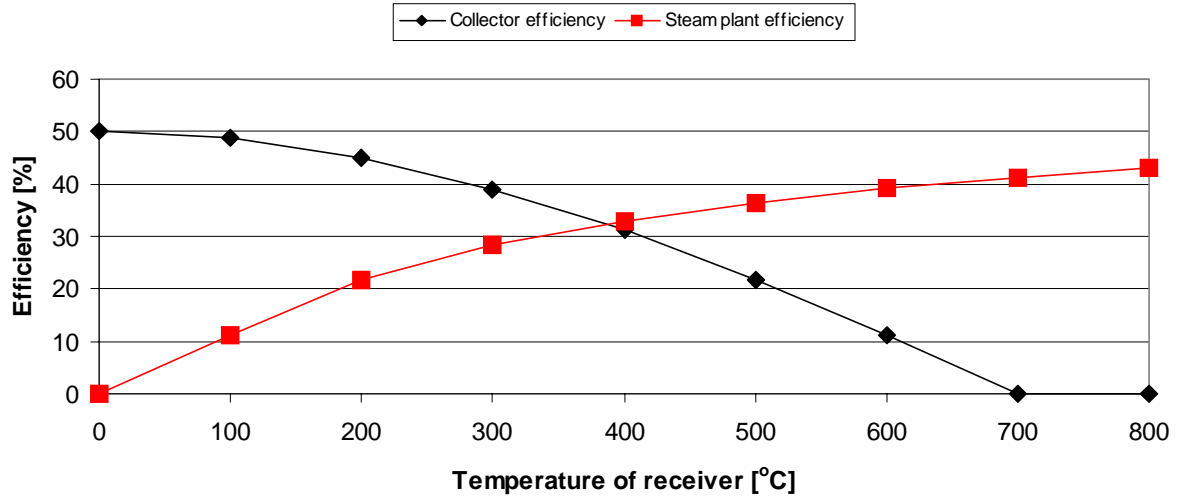


Figure 6.4 Typical monthly Irradiance (clear sky conditions) at 35 DegN

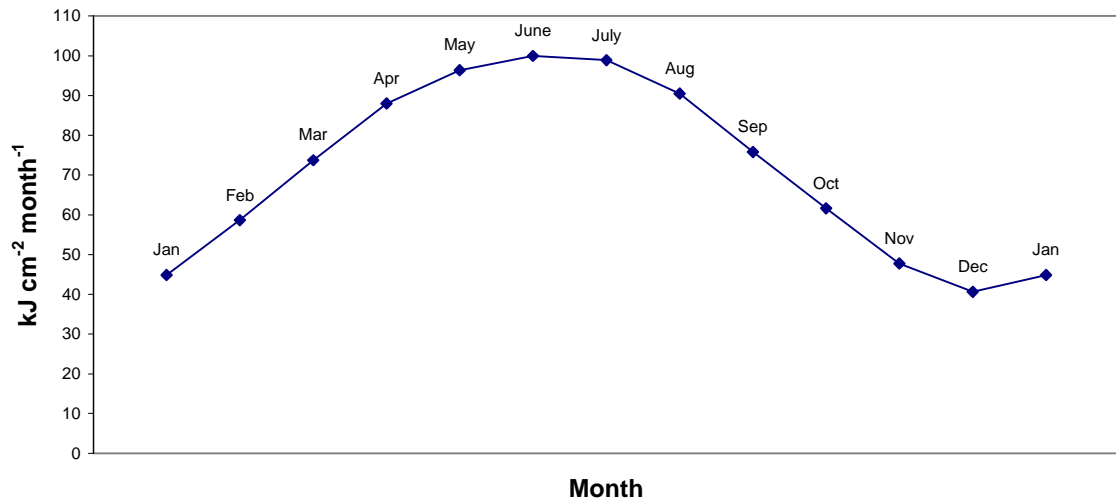


Figure 6.5 Solar Irradiance as a function of time of day in March at 35 DegN

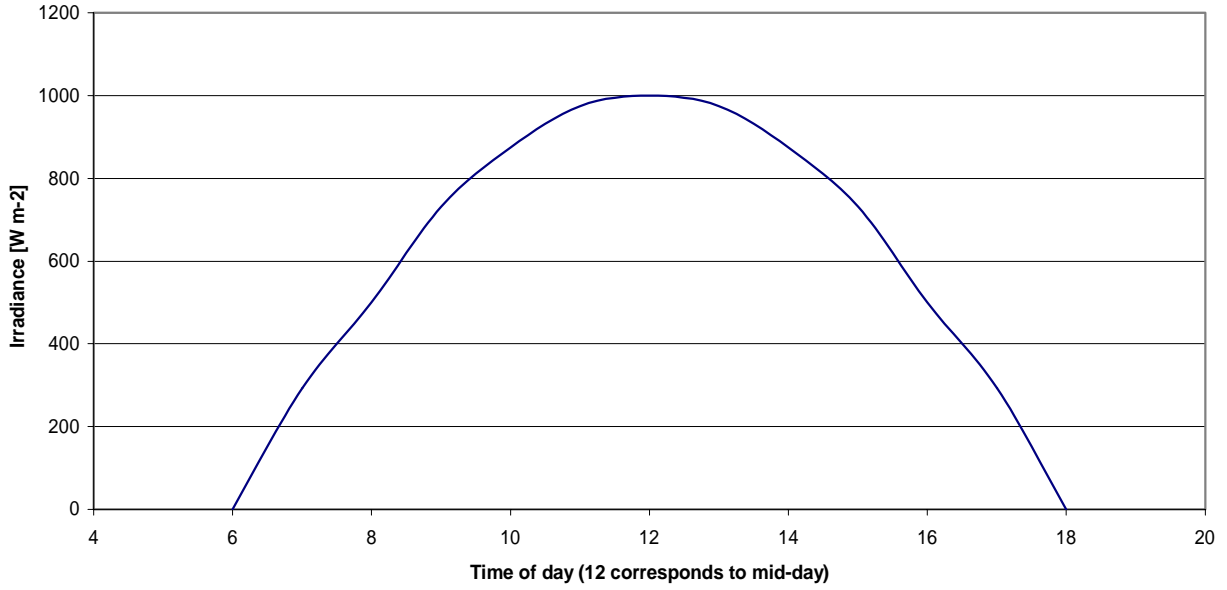


Figure T-6.2 Overlay of solar spectrum at 35 degN for March with Si response curve (an indication of how the solar spectrum may be approximated is also shown).

