The storage of solar heat

N. S. Sigurdarson, G. N. Jacobsen, K. Bjarklev, B. Johansen¹, and E. R. Møller²

¹DTU Design & Innovation, Technical University of Denmark
²DTU Chemical Engineering, Technical University of Denmark

One of the main issues in incorporating weather dependent sustainable energy sources such as solar- and wind power, into the electrical grid, is the irregularity of power production. The peak hours of power consumption in society, rarely coincide with the peak hours of generation of sustainable energy. The full potential of sustainable energy sources is therefore seldom utilized.

In this concern, solar thermal collectors are quite problematic. The need for heating and hot water is largest during the least radiant parts of the day – in the morning, evening and during the night. Most residential solar thermal collectors are connected to large water tanks, in which hot water is stored. These can however, rarely cover an entire households’ heating needs, and are most often only useful to cover hot water needs. The problem is even more obvious when observing the difference in the heat required and heat generated for an average danish house (built in the 1990’s) during an average year, using 25 m² of solar thermal collectors.

Our hope is to prove, that it is possible create a system, which stores large quantities of surplus heat from daytime hours - and from periods with very varying weather conditions, which is more effective than systems using water as a heat storing medium. This is possible by utilizing phase changing materials, which can contain large amounts of latent heat energy, as mediums of heat storage. Using large tanks of for instance lauric acid (which is a naturally occurring lipid that melts at app. 44 ºC) could potentially store approximately 2.5 times more usable thermal energy than equivalent water tanks. These tanks would be able to store some of the excess heat energy during peak hours, and provide heat energy when it is needed. In effect, a system such as this could be able to store more energy than water, thereby reducing the amount of wasted heat energy, available during peak hours, considerably.

These systems could be effective in areas with large consumptions of residential hot water, such as Scandinavia, or in areas with very varying temperatures, such as deserts, mountain regions etc, ultimately making solar thermal collectors a more viable source of residential heating, reducing the amount of fossil fuels used for heating.

A solar power revolution

Solar power has always had a reputation for being expensive and a niche market. However in recent years developments in innovation and manufacturing mean that we could be on the threshold of a mass market breakthrough. Solar power could viably provide 20-25% of the world’s electricity supplies by 2050 according to a report published by the International Energy Agency in 2010 [1]. Back in May 2011 Mark M. Little, global research director for General Electric Co., said that solar power may be cheaper than electricity generated by fossil fuels and nuclear reactors within three to five years because of innovations [2]. And perhaps most importantly, fresh figures from Bloomberg New Energy Finance show that the price of solar panels fell by almost 50 percent in 2011 – and they are now almost a quarter of what they were in 2008 [3]. In fact, solar power is now the fastest growing industry in America [4]. Being a clean, safe, sustainable energy source, this all makes solar power a technology that can hardly be ignored by all the nations and organizations that has set ambitious goals for green energy.

The future of solar power may be curved and 3-dimensional

In 2011 MIT Engineering Professor Jeffrey Grossman and his team set out to investigate the potential of 3D solar panels, inspired by the way trees spread their leaves [5]. Using a computer algorithm the research team “evolved” 3D solar panels all designed to take up the same base area [6]. The efficiency of these dynamic shapes was greater and much less affected by cloudy weather than regular flat panels using the same amount of ground space. And ubiquitous, 3D solar panels are exactly what the maturing industry of thin-film solar cells may be making possible.

Mathematical model, optimization and methods of flux calculation

Our presentation is based on a 3-week project from the 1st-year introductory course in “Advanced Engineering Mathematics” (Mat1). For a given configuration of curvilinear solar panels (perhaps on a building), which will be the optimal orientation for gathering solar energy over day cycle? What is the total energy absorption over a whole day? What problems exist in calculating the flux of energy in a solar panels and which methods exists for different types of surfaces? In designing a curved solar panel, what is the relationship between the curvatures and the efficiency? What things matter and doesn’t matter? We have addressed these questions of these kinds in our project by using a simplified model of energy absorption on a limited set of surfaces, namely planar surfaces, convex single-curved surfaces and convex surfaces of revolution, represented by parametric equations. We have investigated several methods, some of which are very specific to certain kinds of surfaces and lead to analytic expressions that yield mathematical insight, and some of which are more numerically inclined but generally applicable to a wider class of surfaces.

References