Energy From Salt Lakes: A Primer on Salt Gradient (Solar) Ponds

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INTRODUCTION

Any lake absorbs heat from the sun. Normally, heat is lost as warmed water rises to the surface and cools by evaporation. But water is a VERY poor conductor of heat and if this circulation can be stopped, the heat can be trapped in the bottom of the lake. A salt lake, (ideally about 3m deep), managed so that the water on top is of relatively low salinity (density ~1.0g/cc) and the water on the bottom is of very high salinity (density ~1.2g/cc), will not circulate to release heat because the water on the bottom is so heavy with salt it cannot rise—even at quite high temperatures. The deeper water gets very hot—in the right circumstances (the record is 114°C)—70°C degrees is common in even temperate climates. In Southern Australia 50°C is easily achievable—even in winter.

Run like this, such ponds are called 'Salt Gradient Solar Ponds' or just 'Solar Ponds'.

There are other ways of setting up the necessary gradients in a pond and collecting the heat—one of which is to cover the pond surface with a plastic 'honeycomb' to absorb heat and prevent circulation. But this article will concentrate on the salt gradient type.

Effectively, the pond acts as a very large, quite low cost, collector of solar heat.

As a form of solar energy collector, the solar pond has major advantages:

- The heat storage is massive, so energy can be extracted day and night, and continue into moderate periods of cold, cloudy weather—hence it is a source of 'base load' energy—no batteries or other storage needed !
- Solar ponds can have very large heat collection area at relatively low cost.

- The major production potential is during peak electrical power demand (and price) in mid- summer
- The technology and scientific principles for collection and extraction of heat and its conversion to electricity are well understood and well documented in scientific papers.
- A solar pond for heat collection could be built by a careful amateur. Being a refrigeration engineer would be useful if you wanted to build a Rankine engine and produce electricity.

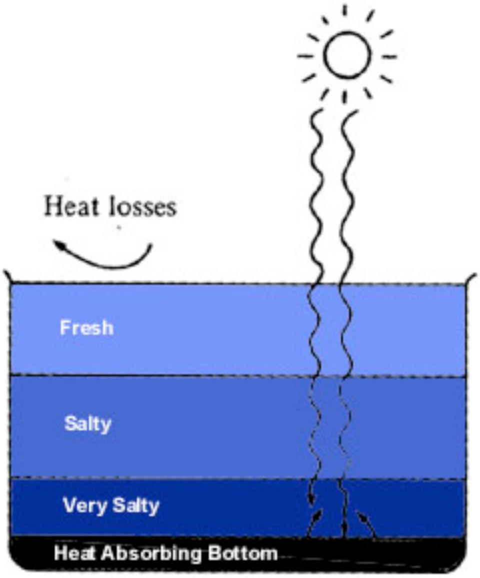

Figure 1. Diagram illustrating the principles of operation of a salt gradient solar pond.

USING A SOLAR POND FOR INDUSTRIAL GRADE HEAT SUPPLIES

In the right environment, solar ponds can provide the cheapest form of solar water heating on a commercial scale. They have been used to provide cheap heat for warming municipal buildings and swimming pools, as well as glass house production, and aquaculture and a number of agricultural and industrial production processes.

To use the heat, it is necessary to remove it from the pond. This presents some difficulty as, any attempt to pump the water from the hot layers at the base of the pond can set up a disturbance which may cause the pond layers to mix—a disaster requiring months to rectify! The heat is extracted either by very carefully extracting hot hypersaline water from the bottom of the pond and circulating it to the glasshouse (or other application), then (with great care) replacing the cooled liquid back into the pond afterwards. This is not a trivial task—the ElPaso site tried several methods of doing this with only limited success over a period of many years (www.utep.edu)

The alternative is to use an 'in pond' heat exchanger. This is a network of pipes passing through the hottest layer of the pond, though which a coolant liquid is passed. The fluid may be fresh water, but since it is recycled, a radiator coolant is preferred as it is less corrosive on the pipes and pumps. This method has the advantage that there is no disturbance to the pond as heat is extracted, but has the disadvantage that there is a loss in efficiency making the output fluid a few degrees cooler.

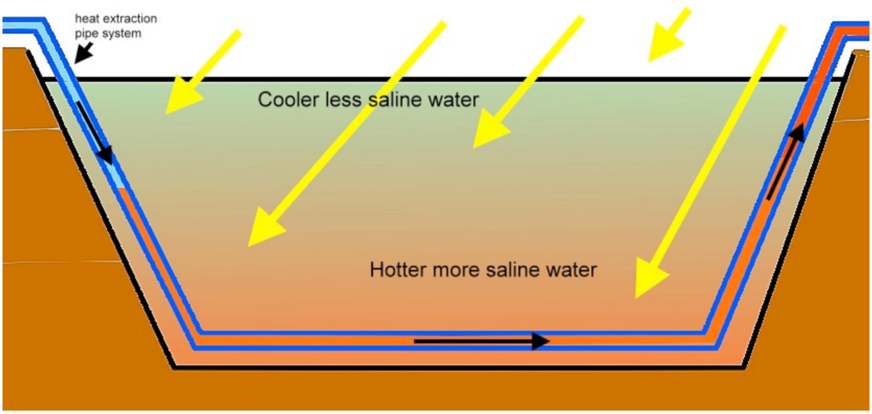

Figure 2. Heat extraction from a solar pond by means of a heat exchanger.

ELECTRICITY FROM SOLAR PONDS!

The hot water from a solar pond can be converted into electricity.

The device are called 'Organic Rankine Cycle Engine'—an ORC engine for short—named after a 19th century engineer. This is the same process used to extract energy from deep ocean temperature gradients. There are several more sophisticated technologies than the Rankine engine—but they all work in a similar way.

A Rankine engine is similar to a steam engine and it is used to convert waste heat from a solar pond (or any other source—such as industrial waste heat) into energy to drive a rotating shaft—which is used to drive a conventional alternator to make electricity.

The Organic Rankine engine works by using the hot water to evaporate an 'organic' fluid, a low boiling point chemical, such as those used in refrigerators. For solar ponds, the fluid often chosen is pentane (C_5H_{12}). The vapor created by the boiling liquid then becomes a high pressure gas which can be used to drive a turbine and produce electricity. Once used, the gas is recirculated, cooled, condensed and recycled—same as in a refrigerator.

In fact, a low cost version of a Rankine engine can be built using 'off the shelf' industrial scale air conditioner parts. Rankine units at Alice Springs and Birdsville in Australia were built this way in the 1970's. See Fig. 3. Like refrigeration technology they are very robust and reliable. The Rankine unit at Birdsville—is still converting hot ground water into power after 30 years.

ARE SOLAR PONDS A NEW TECHNOLOGY?

No. A large solar pond was set up in Israel in the 1950's for electrical power generation. However, the power produced was much less than expected and the project was discontinued after a few years. One of the companies—Ormat technologies is still a major producer of Rankine type technology for converting waste heat to electricity. Solar pond technology has been used in the USA, Israel, Australia Europe, and India The USA had a pond operating at El Paso in Texas for many years—operating both as a research facility and to supply heat to a nearby textile mill. A South Australian company set up an experimental solar pond at Alice Springs in the 1970's. Royal Melbourne Institute of Technology constructed a solar pond at Kerang in Victoria in 1999—it has since been operated by the Pyramid Hill Salt Co—to heat air to flash dry 'gourmet' table salt.

Enersalt P/L is currently operating a research pond near Murray Bridge in South Australia.

Figure 3. The solar pond built at Alice Springs in central Australia (left) in the 1970's and (right) the Organic Rankine engine used to generate power from the pond's hot water.

ENERGY PRODUCTION FROM A SOLAR POND AND COSTS.

Note: $ values supplied here are in Australian Dollars (AUD) and refer to sites in rural areas but not extremely remote from service—note that the AUD is currently much the same as the USD.

Like most forms of solar energy, the running cost of a solar pond is negligible—in this case just the cost of moving the coolant water.

However, the capital cost can be high.

The costs fall into five groups:

1. The cost of digging the pond—this is usually done by digging a hole 1m deep and using the spoil to build a 2m high wall—thus making a 3m deep pond. The heat collection and storage is then in the bottom 1m of the pond ($\$10/m^3$).

2. The cost of lining the pond. Clay is not a suitable material for lining saline lakes—the salt alters clay so that it eventually leaks—badly! The pond must be lined with heat resistant plastic—we recommend at least 0.5 mm thick polyethylene. This requires that plastic sheets be welded on site—a task for professionals. There are many companies set up to do this as it is a routine requirement for effluent dams for many industries. If the soil around the base of the pond is dry and likely to remain so, then insulation should not be necessary. However, if the soil is likely to get moist, then the efficiency of the pond will be greatly increased if it is insulated. There are a number of 'bubble wrap' style materials which will do the job ($\$25/m^2$).

3. Making the hypersaline brine. This would seem to be a trivial task, but when you need to dissolve 0.5 ton of salt per m^2 of dam both the cost of salt and the cost of labor are significant. While it might be assumed that salt is a cheap commodity, salt is in great demand for a number of industries and the price continues to rise. Price at the time of writing this article is at least $80/ton plus transport costs. If there are salt lakes around the area where the pond is to be built, then the economics are much more attractive ($\$50/m^2$). (plus salt transport if necessary!)

4. The pond must be protected from the 'sloshing' effects of wind—so either a mesh above the pond or a floating grid is needed ($\$5/m^2$). See Figure 4.

5. The heat exchanger—usually a grid of welded plastic pipes. ($\$15/m^2$.)

This makes a total of about $\$105/m^2$.

Because of the need for wind control (Figure 4), the effective maximum module size for a solar pond is 0.5 ha (about 5000 sq yards). This

Figure 4. Solar pond at Kerang (Northern Victoria, Australia) showing the plastic rings used for wind control and pipes crossing the pond -used as heat exchanger.

will cost around $520,000. You will need to add some more pipes and pumps to get the hot water to where you want it.

A typical figure for solar insolation in winter in a temperate climate is around 4..5 kWh/day/m^2 (16MJ/day/m^2) (Figures for your area for each season are usually available from the local meteorology office.) The pond captures about 25% of the incident energy and typically you can extract about 60% of that—about 12 kWh/day or 12Mj/day from a 0.5Ha pond.

Amortizing the investment over 30 years gives a price to the heat produced at about 5c/kWh—about 30% of the cost of electricity or gas in many areas.

A pond run to provide low level heat (<40°C) for glasshouses requires only that the heat gain is balanced with the heat extracted. The pond needs to be kept transparent –i.e. kept free of algae.

Neither of these tasks requires attention of more than a few hours a week.

Using the Pond is to Produce Electricity

The hot water can be converted to electricity, but at the cost of additional investment and considerably higher level of management.

You will need to build or purchase of a Rankine engine, alternator and associated heat exchangers. The 0.5 ha pond should be able to produce around 25kW and the equipment will cost around $200,000. But that is not all. The conversion efficiency depends vitally on the difference in temperature between the hot water from the pond and the cold water used to cool the working fluid in the Rankine engine. To get reasonable output, you will need to run the pond at close to 90°C. While this is possible, it is a much more demanding management task than running it at 40°C, as the pond must be kept close to its 'turnover' or mixing point. To run such a system would require either some quite sophisticated computer controls or 'hands on' daily testing of salt and temperature gradients.

The Rankine engine will need annual servicing—mainly replacement of the special refrigeration oil—which costs about $10,000/year. The good news is that the supply of hot water—for glasshouses or whatever, is still available—the Rankine engine will only drop the temperature a degree or two.

The cost (excluding management costs) amortized over 30 years prices the power produces at 15-20c/kWh—in South Australia that is about the retail price of power. However, for an enterprise needing power but located a long way from the grid, the capital costs are far more attractive than solar panels and batteries which need replacing every 10 years or so.

Are Solar Ponds Viable?

The large land area and salt and water requirement of solar ponds precludes their use in built up areas for any purpose at all. However, they are usually commercially viable (even economically attractive) in applications to produce low grade (<60°C) heat for rural industries where a supply of saline water is readily available—especially in areas with saline land degradation or where saline water is being produced by another industry (e.g. coal seam de-gassing or where a reverse osmosis plant needs to dispose of saline water). Low grade heat is used for warming animal pens, wash down water for abattoirs and dairies, and aquaculture, as well as heating glass houses and buildings.

The use of solar ponds for producing electricity is probably not commercially viable at current power prices except in special cases where a power supply is needed in a remote area with lots of salt lakes and a long way off the power grid. The big advantage of solar ponds as a remote area power supply is that the supply is 24/7 and no high cost batteries are needed.

SEEING IS BELIEVING

The University of Texas, el Paso, conducts active research in this area. See a man standing on a frozen solar pond which is still generating electricity from hot water at 154 degree F below the surface: http://ece.utep.edu/research/Energy/Pond/pond.html

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ABOUT THE AUTHOR

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Enersalt also maintains the website www.solarponds.com.