THE SOLAR SALT HEAT GRADIENT POND WITH BIOMASS FOR ETHANOL PRODUCTION AS A MEANS TO REMEDIATE SALT-AFFECTED AGRICULTURAL LAND.

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July 2003

SUMMARY: The major objective in this concept paper is to demonstrate the environmental sustainability and the plain economics in a plan to rejuvenate salt-affected areas of formerly productive agricultural land. Salt heat gradient ponds are not new nor is the practise of planting salt tolerant species of plants and trees on salt affected land or indeed saline soils. Currently salt-affected encroachment of formerly arable land is costing farmers dearly. With severe climatic changes predicted if we do not limit our emissions of greenhouse gases and the spectre of oil shortages and ultimately running out of indigenous oil it behoves us to look at several of these issues concurrently. The solar salt heat gradient pond generates "green" electricity, the biomass remediates the salt-affected land and halts its spread and the fuel ethanol, which is produced from the biomass produces a "green" alternative to petroleum.

KEYWORDS: Solar salt heat-gradient ponds, biomass, fuel ethanol, biodiesel, electrical power production, greenhouse gases, and climate change.

1. Introduction.

Solar heat gradient ponds are not new, in many places where salt ponds exist naturally and where seasonal rainfall can add fresh water to the upper layers, significant heating can occur in the lower more dense layer. It is believed that people collecting salt for human consumption and wading from pond to pond discovered this phenomenon around 80 years ago. Around 1960 Tabor and Block designed a small experimental heat gradient pond in Israel, which saw the base temperature rise to 90 degrees Celsius. Bryant at the University of New Mexico produced a base temperature of 109 degrees C. In Israel several large (7,500m2 and larger) solar heat gradient ponds are generating considerable electrical power. Solar heat gradient ponds are in operation in many countries including the US, Europe, India, Israel and Australia, (Alice Springs and Pyramid Hill in Victoria.) around 60 solar heat gradient ponds worldwide.

2. Design.

Solar heat gradient ponds are typically around 2-3m deep and consist of layers of water; the bottom layer is hypersaline containing typically 15-20% dissolved salt, above this layer the salt content diminishes until the water layer at the surface is almost salt-free. This arrangement is known as a non-convecting salt heat gradient solar pond. Periodically the upper fresh layer may need to be skimmed off to avoid the pond overflowing. Ponds are constructed using black polyethylene or similar durable polymers to contain the salts and to act as a solar absorber. Black polyethylene piping is usually attached to the base of the pond to facilitate the removal of heat without disturbing the salt gradient. Loss of the gradient is possible and the use of a transparent polymer such as Tedlar has been proposed to encapsulate the bottom hypersaline layer. A salt gradient pond can be operated with somewhat arbitrary upper layers but it is important to maintain the integrity of the lower layer for performance. The action of wind can cause considerable mixing of the fresh layer with the middle saline layer and devices are floated on the surface to prevent or reduce this surface effect.

3. Energy Production.

An Israeli Company (Ormat) operated an experimental 5 MW solar heat gradient pond from 1983 to 1990 near the Dead Sea. The ponds covered 250,000m2 and operated a 5 MW turbine, which equates to around 50m2 per kW generating capacity. Rankine Cycle Turbines are generally used as these can be used with the temperatures available from a solar pond. The organic Rankine Cycle turbine can use various organic working fluids to optimise by temperature and pressure the vaporisation and condensation of this fluid at temperatures below the boiling point of water. Whereas a steam turbine requires considerably higher temperatures to achieve the same results. The cost of power production has been estimated at less than $5/GJ (1981). The heat can also be used for absorption refrigeration, process heating and water desalination.

A typical salt-gradient solar pond can absorb around 10 kWh/m2/day and a 1-hectare (10,000m2) solar pond can absorb around 100,000 kWh of thermal energy per day. Conversion efficiencies of around 10% would realise 1.75 million-kilowatt hours annually. Greenhouse gas avoidance of 1,600 tonnes per annum would also be achieved.

4. Biomass for Saline Soils.

The deforestation of what is now our wheatbelt has contributed to the rising water table and the deposition of salt at the surface. It is now well known that the planting of trees can result in a reversal of the salinity if suitable salt-tolerant varieties are planted. However sometimes the salt levels are such that only species such as Saltbush (*Atriplex numularia*) are able to colonise such severely salinised land. In addition the soils in these areas are very poor in those nutrients necessary for optimal growth and need addition of both nutrients and humic material. This proposal suggests that the use of digested septic sludge from the local sewage works be used.

Sewage sludge contains valuable nutrients such as nitrogen, phosphorus and potassium as well as other micronutrients and humic material. The application of this material to an area as described in the proposal offers several benefits;

A. Valuable nutrients otherwise unavailable in the soil and would avoid purchase of commercial fertilisers to raise nutrient levels.
B. Carbonaceous material (humus), which not only aerates the soil but encourages the application of worms to aerate the soil and retain moisture.

The use of sewage sludge to arable land is proscribed by law because of the likelihood that certain undesirable elements may be present including bacteria and heavy metals. However saline water is antiseptic and the destruction of many bacterial species is likely. In this particular scenario the land will never again be used for agriculture for edible crops and as such any bacterial or heavy metal contamination will be of no consequence. The land set aside for this project (for the remediation of salt degradation) wherever it may occur will of necessity from agricultural, economic and salinisation reasons continue to be used for this purpose or run the risk of recurring salinisation. The salt encroachment will cease to spread and the farmer will be able to continue his grain production with confidence and will now have a viable new industry on his farm, increasing his economic viability.

Suitable salt-tolerant fast-growing trees include; *Eucalypts* such as *E. occidentalis, sargentii and camaldulensis.*

5. Ethanol Production from Cellulosic Material.

Ethanol production from lignocellulose and cellulosic crops has been carried out by various means for around 80 years particularly during times of petroleum shortages, generally during wartime. The oil boom of the 60's with abundant cheap oil effectively terminated ethanol production from lignocellulose as an additive to motor fuel although small plants continued in Russia for example. Ethanol from grain and molasses for addition to motor fuel has continued to varying degrees particularly in areas of high corn (United States) and sugar cane (Australia and Brazil) production utilising molasses.

The first reported lignocellulose to ethanol production plant was built in 1913 at Georgetown, South Carolina USA and utilised pine mill wastes and it produced 20,000 litres of ethanol per day.

The State of Hawaii in 1994 commissioned a study to investigate ethanol from biomass to offset the importation of petroleum fuels and to utilise the abundant biomass available on the islands. The biomass included sugarcane, cassava and biomass species.

The spectre of climate change caused by the increasing levels of carbon dioxide in the atmosphere and the increasing cost of and decreasing supply of petroleum has resulted in renewed interest in ethanol from lignocellulose.

More recently (1999) the California Energy Commission carried out a biomass to ethanol study in response to the phasing out of the fuel oxygenator, methyl tertiary butyl ether (MTBE). Petrol containing MTBE from leaking fuel tanks and pipes breaks down in soil to form methanol, a serious ground water toxic substance. Substitution of ethanol as ETBE (Ethyl tertiary butyl ether) would obviate this problem. Also the export of corn ethanol produced in the corn-belt across the Rocky Mountains was considered far too costly when a locally produced ethanol would benefit California's economy.

The production of ethanol from biomass is progressing in many countries worldwide however the production costs are still relatively high when compared to petrol. The environmental benefits coupled with the social benefits and economic benefits can be seen to have a dollar value offsetting the higher relative cost compared to petrol. (Otherwise known as the triple bottom line).

Ethanol / petrol blends used worldwide vary from 10% v/v as a general across the board addition to E-85 and E-95 blends used in specialised vehicles. Alcohol blends up to 20% v/v addition require practically no alterations to the engine, however at 20% blends air fuel rejetting will improve performance and economy.

E-85 and E-95 has been used in Brazil (E-95 is also known as hydrous ethanol). In the United States E-85 has been used in dedicated fleet vehicles and vehicles described as FFV's (flexible fueled vehicles) for many years.

Note; Hydrous ethanol is 95% ethanol, 5% water and 100ppm Bitrex® to deter human consumption. E-10 and E-85 are blends of ethanol (eg 10% or 85%) with the balance being unleaded petrol.

FFV's are fuel-injected engines that have the ability to detect the type of fuel and draw upon a computer program to optimise the air-fuel ratio.

Dedicated E-85 and hydrous engines as used in Brazil have features such as higher compression ratios (11.5-12.5:1) and specialised fuel system components to handle the fairly corrosive fuel. Because of the lower combustion energy of ethanol compared to petrol (27 MJ/Kg to 45 MJ/kg) less energy is available (around 60% that of petrol) and unless a higher compression ratio is used the fuel consumption will be poorer by around 10 to 40%. Modern fuel injected petrol engines use charge cooling to keep the pistons cool at wide-open throttle (WOT) and thus compromises real fuel efficiency. The higher latent heat of vaporisation of ethanol leads to lower piston temperatures and thus are capable of equal if not better fuel consumption than a straight ULP engine. This is because the higher thermal efficiency combined with the natural charge cooling of ethanol increases the overall efficiency.

6. Land Required for Proposed Demonstration Project.

A suitable area of agricultural land that has become saline is selected where the salt scour (an area much like an ulcer, on the land where agriculture has subsequently become impossible due to salinisation) and is around 300-500 metres in diameter. Although the concept diagram shows a square arrangement, in practise any shape will suffice.

A 1-hectare solar salt heat gradient pond is capable of running a 100kW generating system and by selecting a "suitable" 9-hectare square the following design is achieved.

7. Synthesis.

The area selected for this concept demonstration has been rendered by the rising salt levels to preclude any agricultural production and the salinity is inexorably spreading. Most farms receive electricity from feeder lines running off the main Muja to Kalgoorlie power grid and have significant line losses. The production of power from the solar pond being exported into the grid can offer reactive power improving the power factor.

The growth of the coloniser species eg, *Atriplex numularia* will be enhanced by the use of the sewage sludge and within 2-years the saltbush can be grazed by sheep, which will remove biomass and leave valuable manure. The tree belt, which must be at least 50 metres wide initially until salt levels in the *Atriplex* area have fallen to levels tolerable to the salt-tolerant trees, when the tree belt will be 200-300 metres wide. It is expected that within 5 years the entire area will be planted with trees available for cropping.

The drainage channels will allow harvesting of the salt in evaporating basins or by using heat from the solar heat gradient pond. The salt is not merely sodium chloride but a cocktail of salts, which may be sold to specialty manufacturers and which may contain valuable chemicals such as selenium, cobalt and molybdenum.

The biomass to ethanol conversion process will produce not only ethanol but also lignin, which has value in the manufacture of fibreboard. The black liquor from the distillation process coupled with the green residues is processed in an anaerobic digester, to produce biogas and to recycle the nutrients back to the tree field.

The power required to operate the various processes comes either from the solar heat gradient pond as thermal energy or from electricity generated by the solar pond or from the biogas produced from the anaerobic fermentation of the waste products. The process plant is therefore a net exporter of power and liquid fuel and is avoiding considerable tonnage of carbon dioxide production.

Atriplex numularia is a coloniser species used initially to effect a ground crop, which can be grazed by sheep whilst the salt levels drop. A salt tolerant oilseed crop can next be grown and 100% green biodiesel can be produced. Current biodiesel uses methanol produced from petroleum and renders biodiesel only 85% green. The use of locally produced anhydrous ethanol (100% as opposed to hydrous, which causes soap formation) used to trans esterify a vegetable oil renders the biodiesel 100% green. This can be sold locally through the town's fuel station or through a local cooperative, making the farmer completely self sufficient for agricultural diesel fuel.

8. Outcomes.

A. Regeneration of salt-affected land.
B. Halting the creep of salinisation of the land.
C. Improvement in the local grain crop due to enhanced tree effect.
D. Green electrical power production income.
E. Green motor fuel production income.
F. Specialty salt sales.
G. Employment opportunities.
H. Locally produced biodiesel.

9. Cost Benefit Analysis.

Typically a solar salt heat gradient pond can absorb around 10 kWh/m2/day particularly in the WA wheatbelt.

A 10,000 m2, (1-hectare) heat gradient pond can therefore absorb around 100,000 kWh of thermal energy per day and based on data from ORMAT (50m2/kW generating capacity, around 1.75 million-kilowatt hours will be generated annually realising around $223,000 in electricity sales per year at 12.75 cents per kWh. (The price Western Power will purchase it from the producer as renewable energy (2003 price).

Greenhouse gas reduction specifically CO_2, of around 1,600 tonnes would be achieved on an annual basis. Green credits or Carbon Credits are to be part of the carbon commerce of the early 21st Century and may be worth US$10 to 15 per tonne CO_2 avoided.

In this model I have selected a 9-hectare site for convenience and that it offers real-world output, however, in practise ponds of 10's of hectares are viable.

Additionally, the 7 surrounding hectares of land are planted with *Atriplex numularia* (Saltbush) and the salt tolerant oilseed *Carthamus tinctoria* (Safflower) or other high-yielding salt-tolerant biomass plants.

From the 7 hectares the biomass crop can potentially yield around 11,000 litres of fuel ethanol or biodiesel worth around $7,000 per annum if sold for 65 cents/litre or around $11,000 as direct substitute for diesel fuel. This may commence as soon as the second year after planting.

Tree harvesting for fuel alcohol may commence after around 5 years depending upon the species planted and how poor the soil and salt levels. Turning the trees into alcohol will return around $35-36,000 pa. As the salt levels are reduced the tree belt may be extended to around 500 metres each side of the salt pond and the processing facilities. The biodiesel crops may also be extended. From the commissioning of the solar salt heat gradient pond the farmer will be receiving income from what was useless land.

10 Estimated cost and return on investment (ROI).

The cost of construction of the solar salt heat gradient pond is estimated at around $40,000. A Rankine-cycle generator rated at 200kW is estimated to cost around $250,000. The oil-crop and lignocellulose processing plant with the alcohol production facility, wastewater treatment, salt harvesting and general infrastructure is estimated at least $1 million. The overall estimated cost is around $1.5million.

The return from electricity sales is estimated at $220,000 per annum, biofuels at around $45,000, with lignin, solar salt etc as yet uncalculated.

The salt harvested may contain some valuable additional elements (gold has been reported) as well as phosphate and molydate for example.

Potential returns could be in the vicinity of $300,000 per annum as a conservative estimate.

The ROI is expected therefore to be around 5 years.

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