Saline algae farming for biodiesel production and carbon capture (Potential for saline sites to grow algae for biofuel in central west New South Wales)

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Introduction

Feasibility of growing algae for oil to replace petroleum transport fuel is examined to stimulate interest and investment in algae farming in Central Western NSW. An attempt is made to answer:

- How much liquid fuel is used for vehicles overseas, in Australia, within a region and locally?
- If algae farming using saline water could grow oil for biofuel how much land is needed?
- How could a saline site be assessed as feasible for algae farming?
- Is Central Western NSW well suited to growing algae for oil and other productive uses?
- Can farming algae be used capture and store atmospheric CO2?

The NSW Central West Catchment covers an area of about 92,000 km2 of which 58,880 km2 are estimated to be high risk salinity landscapes (CWCMA 2007, Humphries 2000). The Catchment Action Plan (CAP) developed by the community and the Central West Catchment Authority website shows targets set to manage and reduce salinity hazards (CWCMA 2007).

Petroleum fuels are non-renewable and contribute significant fossil carbon to the atmosphere. Petroleum prices have risen dramatically since 2002 as 'peak oil' has approached (RIRDC 2007). Fuel crops compete with food for agricultural land. Freshwater to grow food crops for is now in shorter supply due to climate change and prolonged droughts. Dwindling petroleum fuel is causing rising prices for vegetable crops such as corn grown for ethanol. In 2007 in Mexico the price of corn, a major basic food rose 30% causing local strikes and protests (Wilkinson 2007).

Indonesia and Malaysia supply 80% of the worlds palm oil, where forest is cleared and burnt to grow palm oil plantations for biodiesel. Palm oil plantations have grown from 600,000ha in 1985 to 6.4 million in 2006. Ecologists estimate that up to 50 orang-utangs die each week due to this forest clearing. National Fuels Australia Limited estimated "You can get 4,000 to 5000 litres of oil per hectare per year" from palm oil (Wilkinson 2007). The separate problems of salinity, dwindling oil supplies, release of fossil carbon, competition between biofuel, food production and habitat presents a complex array of resource issues.

When viewed as a whole, the combination of: plentiful sunlight, CO2, warm arid climate, saline groundwater, low productivity land, excess nutrients, rising fuel prices emerge as resources for algae farming. Abundance of saline water, large areas of land and high average sunlight offers great opportunity to produce biofuel from algae in much of Australia (Qin 2005). A combination these conditions of sunlight, salinity and land exists in Central Western NSW.

High oil-producing algae grow slower than species that produce simpler carbohydrates. Technical issues are being explored to keep out or manage non-oil species from contaminating and competing with oil producing algae (Murdoch University 2007, UNH 2007). Open ponds are low cost to set up but enclosed systems called bioreactors better exclude undesirable species. Bio-reactors range from covering ponds with plastic to enclosing the algae and medium in plastic or glass. Enclosed systems obviously are more expensive than open ponds (UNH 2007).

The World Aquaculture Society states that algal farming could produce more than 100 metric tons of biomass per hectare per year and considering the technological issues that need to be resolved to lower the costs of producing useful algae (WAS 2007)

An example of a problem saline site affecting urban and rural land near Dubbo in Central

West New South Wales is considered for extraction and use of saline groundwater to grow oil-producing algae.

This assessment is presented as a demonstration of potential from a known salinity site. No discussion or proposal has been actually considered for this Dubbo site with landholders or possible partners at this stage.

Study method

Research from Australia, USA and elsewhere is used to demonstrate potential for algae farming in regional NSW. Firstly the volume of biodiesel needed to replace petroleum for Australia, Central West NSW and Dubbo is estimated from an assumption that per capita vehicle fuel is similar for Australia and the United States. The area estimated for growing algae for biodiesel in the USA is also used to estimate algal-farming areas for Australia. These volume and area estimates are listed in Table 1.

Secondly an assessment table is developed to indicate saline site potential for algal farming. A reported Dubbo site with a high saline water table has recommended extracting the saline groundwater as one solution for reducing the impacts of salinity. A concept is considered to assess potential for the Dubbo location and other sites for algae farming.

The following criteria are suggested for assessing local saline sites for growing algae:

1. Average positive or negative hydraulic depth of saline groundwater (SGW);
2. Is the volume of SGW likely to be sufficient for algae farm considered?;
3. How much salt affected or low productivity land area is available for algae farming?;
4. Is the landowner interested in an algal farming?;
5. What products could come from the considered algal farm?;
6. Is a nutrient source available?;
7. What local, regional and global benefits could come from the algal farm?;
8. What partners could have an interest in the algal farm?;
9. What are the anions and cations and saline concentration of the groundwater?;
10. What is the saline concentration of the groundwater?;
11. List productive algal species suited to the site; and
12. Where they can be sourced in Australia;
13. What physical and chemical barriers needed to limit or exclude non-desirable algae?

Table 2 shows some results for a site near Dubbo reported in a NSW State government salinity report.

Results and discussion

Professor Michael Briggs from the University of New Hampshire (UNH 2007) estimates that if high oil producing algae was grown over 38,500 km2 located in high sunlight areas then 533 billion litres, being the total volume of petroleum consumed in the United States could be replaced by biodiesel. The population of the USA is about 303,000,000, so the annual per capita vehicle fuel requirement is 1760 litres. These US figures are used for Australian, regional and local estimates shown in Table 1.

Studies and publications in Australia and elsewhere show there is potential to grow and extract significant volumes of oil for biofuel from algae from relatively small areas of land. (Murdoch University 2007, Pahl 2005, Qin 2005, UNH2007, WAS 2006).

Table 1 Vehicle fuel volume and area required to grow algae biofuel replacement extrapolated from USA (UNH) to estimate volumes and areas for Australia, Central West NSW & Dubbo

Annual vehicle fuel usage (population)	litres (L)	megalitres (ML)	Area to grow algae for biodiesel	km2	ha
USA (303 million)	533 billion	533,000	USA	38,500	3,850,000
Per capita	1,760	0.002	Per capita	0.0001	0.013 (130 m2)
Australia (21.2 million)	37.3 billion	37,300	Australia	2,790	279,000
Per 1,000	1,800,000	1.8	Per 1,000	0.13	12.7
Dubbo (39,500)	71 million	71	Dubbo	5	502
Central West NSW (240,000)	422 million	422	Central West Catchment (92,000km2)	30.5	3049

Newspaper advertisements for many small to medium diesel vehicles show fuel consumption can currently be as low as 5 litre per 100km, which is about half the consumption of more common petrol vehicles. With an average travel distance of 20,000km per year, these fuel efficient diesel vehicles consume about as little as 1,000 litres per year. Halving fuel consumption, driving in air-conditioned comfort and using biodiesel sourced from algae that recycles atmospheric CO2 should be an acceptable alternative to releasing fossil carbon and escalating petroleum prices.

The U.S. Department of Energy funded a program through the National Renewable Laboratory (NREL) from 1976 to 1998 and over 300 species and strains of algae were identified as high producers of oil, up to 40%. The program called "Aquatic Species Program: Biodiesel from Algae" also focused on producing oil from algae using CO2 from coal-fired power plants. University of New Hampshire is continuing investigation to link CO2 from coal fired power stations and directing into oil producing algae (UNH 2007). Storing solid biomass or liquid oil above ground seams to be far simpler than attempting to pumps CO2 gas underground and hoping it stays there.

There are many useful products from algae including aquaculture food, cosmetics, and edible algae. Some species such as *Dunelia salina* are already being commercially grown in ponds up to 250ha near the coastline in Western Australia (Murdoch Uni 2007). Murdoch University in Western Australia ia developing types of photobioreactors for producing algae. Several pure strains of oil producing algae species are now available in Australia (CSIRO 2007, Qin 2005)

The Department of Natural Resources produced a report titled *Urban Salinity Hydrogeological Investigations 1995 to 2006, Troy Creek Catchment, Dubbo NSW.* Information from this report and other studies on growing algae in saline water are used to assess potential of Troy Creek for algal farming. The shallow confined groundwater flow system at this site is likely to be suited to extraction of water to reduce local impacts (Smithson et al 2004)

This assessment exercise has been developed from reports and publications to develop assessment criteria for saline groundwater sites for algal farming. No discussions, commitments or assurances with any parties associated with the Troy Creek catchment occurred for any algal farming proposal. Some actual information was taken from the Troy Gully report (Smithson 2006). Any assumed data in Table 2 regarding landowner or potential partners is fictitious and in *italics* for the purpose of demonstrating the assessment process only.

Table 2 Initial Potential Saline Algae Farming Assessment for Troy Gully near Dubbo:

1 Depth of saline groundwater (SGW) (+/-m):	10 m, less in wetter years	2. Sufficient volume of SGW available:	Yes	3.Low-productivity land area nearby (ha)	*Possibly low hundreds hectares due to known salinity issues*
4. Landowner/s interest in algae farming:	*To be asked*	5. Products:	biofuel, biomass, feedstock for fish & livestock, cosmetics, medicinal	6. Nutrient source:	*Treated effluent – availability?*
7. Local benefits:	*new industry, local jobs*	Regional benefits:	*Secure fuel source, regional industry network*	Global benefits:	*Reduced CO2 emmission, secure transport fuel*
8. Potential partners:	*Local, State & Federal Government* *Local and regional farmers & processors* *Major fuel and biofuel companies*				
9. Major salinity ions:	Na, Mg, Cl and some Ca, HCO_3	10. Saline concentration:	mean 7,450µS/cm; Range 2,500 to 24,200µS/cm		
11. Useful algal species:	*Botryococcus braunii*		12 Useful algae pure strain source:		Australia - CSIRO
13.Algae farm infrastructure economic drivers:	CO2 reduction; road & building saline damage; rising fuel costs; competition between land & water for food, biofuel, habitat				

Central West NSW is centrally located to the bulk of Australia's population centres of Brisbane, Sydney, Melbourne and Adelaide. A Cluster of associated oil-producing algae farms within the Central West could contribute significantly to biofuels in Australia.

There are many other regions of Australia that have significant areas of salinity and some of these have similar ideal conditions of sunlight as Central West NSW. These areas would benefit from a study of feasibility for algae farming. some of these sites could also be within reasonable distance from coal fired power stations to collect and sequester CO2 into a useful and storable form to ameliorate climate change.

There are many economic drivers emerging that favour algae farming for biofuel and other benefits including: reduction of atmospheric CO2; road & building saline damage expenses; rising fuel costs; land & water competition between food, biofuel and habitat.

Troy Gully saline groundwater is shallow enough to be extracted. There could be many hectares of land available if landholders were interested and local government approved the landuse. A discussion focussed an algal farming could show if local landholders and government were interested.

Local, State and Federal Government may have an interest in promoting regional employment and new industries and reducing CO2 emissions. Urban areas such as growing cities like Dubbo have ongoing effluent treatment that could be assessed for suitability as a nutrient source for algae.

The average salinity of Troy Gully is too high for most landuses and affects local infrastructure, but is in a range useful as a medium for algal farming. Many useful species can grow well in water as saline as seawater.

There is so much promise in growing algae including CO2 capture, as well as managing local saline outbreaks that getting started while technical problems with oil species are solved is an imperative. In USA CO2 is being captured directly from coal-fired power stations and delivered directly to algae ponds to grow oil for biodiesel production on arid land in the United States (UNH) in a similar climate to areas of western NSW.

Professor Steve Halls from Murdoch University said "…when oil prices are above US$25 a barrel, biofuels are cheaper", in 2007 oil prices are hovering around US$100.

Conclusions

- Central West NSW has ideal preconditions and resources for producing biodiesel from algae.
- An inventory of potential for saline sites in Central West NSW algae farming would provide datato more fully assess potential for algae farming enterprises in Central West NSW.
- The suggested assessment for productive algal farming needs to be refined and applied to known saline groundwater site in Central west NSW.
- A comprehensive feasibility study for algae farming could be considered for Troy Creek after consultation with interested local interests.
- Some successful pilot algae farms located in Central West NSW could to encourage economic oil producing algae farming with several local and regional benefits.

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