

Better paradigms for our energy futures: from fossil fuels to phytofuels to photofuels

ROBERT L LEE

Robert E Lee was a Confederate general who fought for the right to enslave people of a different skin colour. He did not write this essay, being long dead.

The name Robert L Lee adopted here is an ironic pseudonym.

The author of this essay is a physician who has had (non-medical) essays on matters of practical philosophy published in the *Australian Skeptic* and *Australian Rationalist* journals.

Back in the 1950s, a geophysicist named M King Hubbert predicted that American peak oil production would occur in the early 1970s. He was proven absolutely correct. Since then, there has been a relentless decline in flow from the US oilwells — which now represent just three per cent of world reserves. Numerous scientists applying Dr Hubbert's analytical techniques have since determined that world peak petroleum production, the eponymous 'Hubbert Peak', will be reached before 2010 and indeed may well have been passed by now.

Given the mature state of the geological sciences, it is virtually certain that all reserves of readily extractable oil have already been identified — no more exist. It has been estimated that affordable petroleum will be depleted within forty years.¹

Thus we can expect an inevitable reduction of oil output from now on, even as there is a worldwide

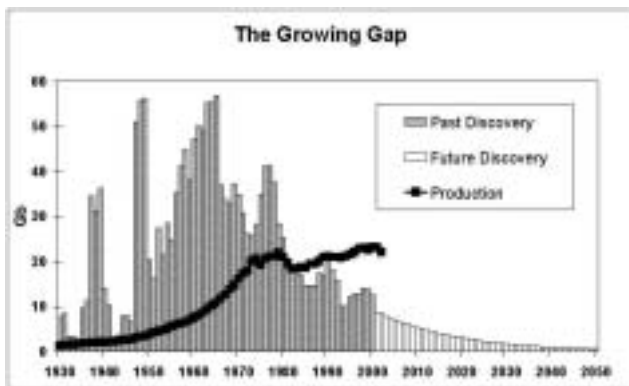
burgeoning demand for petroleum, particularly from the rapidly developing countries such as China and India. At the same time, America, representing less than five per cent of the world's population, continues to consume twenty-five per cent of all petroleum and remains the largest producer of carbon emissions, while officially casting doubt on the existence and/or importance of global warming. Political measures by the American automobile and oil companies to heavily and artificially subsidise gasoline for their consumers,

coupled with perverse government incentives to popularise gas guzzling vehicles such as sports utility vehicles (SUVs), serve to exacerbate a looming global crisis,² while America defiantly cocks a snook at the rest of the world.

Wars have been and are being fought over petroleum. The Japanese assert that Pearl Harbour was provoked by the American threat to cut off their oil.³

What was the real reason for America's invasion of Iraq? It had nothing to do with Al Qaeda or terrorism, nothing to do with weapons of mass destruction, nothing to do with liberating people from a brutal dictator and nothing to do with creating a better, safer life for the average Iraqi.⁴ (As of October 2004, the average Iraqi faced a fifty-eight-fold higher risk of violent death under American administration compared to when Saddam Hussein was in power.⁵)

There is no doubt the US invasion of Iraq was primarily related to America's sense of entitlement to 'energy security' and continued access to cheap oil; its belief in its God-given right to the profligate con-



Graph by: Dr Colin J Campbell, Oil Depletion Analysis Centre, London

sumption of petroleum irrespective of future global consequences.^{2,6} Of course, the Republican neo-conservatives will never admit to this — to do so will prove them to be the duplicitous, morally bankrupt characters they are.

The only connection between September 11, 2001 (in which fifteen of the nineteen airline hijackers were Saudi Arabian nationals⁷) and the US invasion of Iraq was the realisation by America that their continued access to cheap Saudi Arabian oil was far more precarious than they had hitherto suspected. The Saudi royal family is holding onto power by a thread and is deeply resented by the Saudi populace — they are perceived by many common Saudis as a corrupt, self-serving regime propped up by American self-interest.^{8,9}

Loss of access to cheap oil from Saudi Arabia, the country with the largest reserves in the world, was and is unacceptable to America. So how best to hedge their bets? Secure a supply from the country with the second largest reserves — Iraq.

Senator John Kerry, the Democratic presidential candidate in the 2004 US election campaign, highlighted energy independence and the pursuit of alternative (non-fossil fuel) energy sources as crucial issues, which was tantamount to admitting that the Iraqi invasion was all about oil.

At the Democratic Convention in July, Kerry said in his speech:

I want an America that relies on its own ingenuity and innovation — not on the Saudi royal family...and our energy plan for a stronger America will invest in new technologies and alternative fuels and the cars of the future — so that no young American in uniform will ever be held hostage to our dependence on oil from the Middle East.²

He failed in his presidential bid, suggesting to me, at least, that the average American couldn't care less about such matters.

Bush's agenda, however, involves the use of more fossil fuels, including a controversial proposal to begin drilling for oil in the Arctic National Wildlife Refuge.²

Australia is equally culpable and delinquent in supporting and emulating America's disingenuous policies. Our two nations alone remain defiant among developed nations in their refusal to sign the Kyoto Protocol, now that Russia has become a signatory.¹⁰

Surely globalisation of trade and profit opportunities also requires that responsibilities for a sustainable future and for environmental conservation are shared globally. Surely it is reasonable to expect that the nations which are the highest per capita consumers of fossil fuels (and the worst per capita pol-

luters) ought to bear the greatest responsibilities.

What scenarios may we anticipate for our energy future? Many paradigms have been advocated.

What is clearly unacceptable, however, is adoption of the American strategy of denial of scientific evidence, perverse incentives to encourage ongoing profligate oil consumption and unconscionable pollution, and illegitimate invasion of other countries to ensure one's own 'energy security'. Emulation of such despicable behaviour by other major powers will inevitably lead to wars over future energy resources.¹¹

There must be a better way.

Here is one suggestion: we should invest in scum. Confused? Read on and all will be revealed.

Advantages and disadvantages of the various energy sources

The drawbacks of the fossil fuels are well known: carbon emissions, the greenhouse effect and global warming, pollution by impurities or additives (sulphur dioxide, lead compounds), acid rain and especially the fact that they are a non-renewable resource.

Nuclear fission looked very promising in the past (before the Three Mile Island and Chernobyl disasters and concerns about terrorism) and provides a large proportion of energy for some countries, such as France and Korea.¹² In the short-term, it appeared to be non-polluting. Unfortunately, radioactive plutonium is a rather nasty substance. A single speck of plutonium dust has the potential to cause lung cancer in an individual who inhales it.^{13,14} The effects of radioactive caesium and iodine entering the food chain are well known. The use of so-called 'depleted' uranium warheads in Iraq has been associated with numerous adverse health effects in children and others^{15,16}, despite denials by the US government.¹⁷

Clearly, however, an option such as nuclear fission which allows a state with few alternative sources to be less dependent on oil and which has a 'petroleum sparing' effect will continue to remain attractive, despite the thorny unresolved issues of disposal of nuclear waste and decommissioning of old nuclear plants (which may end up being encased in concrete and cordoned off for decades at great expense). Furthermore, there is potential for the acquisition of materials by rogue states or terrorists for bomb building or just making 'dirty' conventional bombs to spread radioactive dust.

Renewable sources of energy, such as photovoltaic, wind, geothermal, hydroelectric or tidal energy, are tremendously appealing, but are applicable only to specific geographic areas and often with wide fluctuations in availability.

Petroleum products continue to be an indispensable source of energy for the transport industry and there are good reasons for this. Apart from the economic reasons, oil-based fuels are a near ideal chemical energy source for the following reasons:

1. High energy density

Biochemically, fats and oils are the most concentrated sources of energy per unit weight or volume. For instance, the calorific value of fats and oils is nine kcal/g as compared with four kcal/g for either carbohydrates or proteins and seven kcal/g for ethanol.¹⁸ With regard to transport/industrial fuels, energy density (by energy per unit volume in btu/cubic foot) is highest for diesel at 1,058, similar for biodiesel and gasoline at 950 and 922 respectively, lower for propane and liquid natural gas at 683 and 635 respectively, even lower for ethanol and methanol at 594 and 488 respectively, much lower for liquid hydrogen at 270 and pathetically poor for compressed hydrogen at 68.¹⁹

Liquid hydrogen may well be the most energy dense in terms of energy per unit weight (and thus suitable for rocket propulsion); however, to enable the same performance and range for more mundane vehicles such as cars or trucks, fuel tanks almost four times larger than normal diesel tanks will be required. This will of course represent loss of revenue in cargo space, and the larger pressurised tanks will also represent additional non-cargo weight to be carried about.

2. Advantages of the liquid medium

Gaseous fuels, e.g. compressed natural gas or methane, have low energy densities (per unit volume) and are difficult and bulky to transport and

contain, requiring pressurised containers. Solid fuels cannot be readily atomised to produce an air-fuel mixture to power internal combustion or jet engines. Liquid fuels (i.e. fuels which are liquid at normal temperatures and pressures) overcome both disadvantages, with the added benefit that they can take on the shape of any container (unlike solid fuels), such as the wing tanks of aircraft, resulting in space optimisation. The ideal fuel will remain liquid at extreme temperatures, even in the sub-zero Antarctic or the scorching Sahara.

3. Transportability and storage

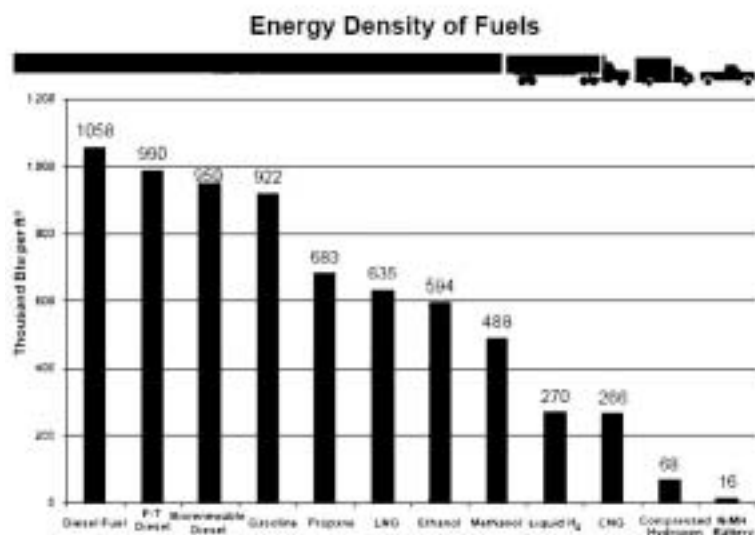
For electricity to be distributed, power lines, pylons and cables need to be set up and transformers/substations built. The electricity will be available only at fixed outlets and needs to be consumed directly. Petroleum products can be transported to any site unrestricted by fixed lines of delivery and can be stored for future utilisation at any date.

4. Aviation

There is no energy source at present which is superior to or can effectively substitute for petroleum products for aviation. Nuclear, hydro-electric, wind and geothermal power may generate electricity, but how may this electricity be stored on an aircraft and produce power to match that of a jet engine? Expensive hydrogen-powered space rockets and experimental planes exist but we have no precedent for a practical hydrogen-powered commercial transport plane. Furthermore, hydrogen combustion planes will produce water vapour which, although probably innocuous at ground level, represents a potent greenhouse gas when expelled into the upper atmosphere and will exacerbate global warming.²⁰ Without petroleum, the entire air transport industry will grind to a halt. One may conceive of alcohol- or LPG-powered planes, but again, due to the lower energy density of these fuels or bulky storage containers, the performance and range of such aircraft will be inferior.

Interim measures

What measures should we take now to minimise the shock of the upcoming oil crisis? Conservation will go a long way towards delaying the inevitable oil shortages. Cogeneration (burning waste to produce heat and electricity), better building construction (insulation, reflective glass etc.), more efficient engines, hybrid engines, use of alternative energy sources to 'spare' petroleum and so forth will help.



Graph by: Dr James J Eberhardt, 'Fuels for the future for cars and trucks', US Department of Energy, 2002

It has been estimated that 'if the United States became as energy-efficient as Germany, it would consume fifty per cent less energy, a reduction equivalent to more than twice the level of US imports of Saudi oil.'⁹

When the present oil fields run dry, there are other means of obtaining oil (from 'non-conventional sources'): from oil shale or oil sands, or by injecting detergents into previously tapped oil wells, or by synthesising oil from coal or natural gas. These methods exist now but are little utilised, not being generally cost competitive with good old crude.

But here is the other problem: in doing our utmost to extricate every last bit of energy from all the corpses of organisms accumulated underground over the past billion years, we will also ensure that every last bit of the carbon locked up in these fossils will have been released into the atmosphere.

No reasonable person these days can deny the truth of global warming or that it is the result of human activities.^{21,22}

There is merit to the idea of trading in carbon credits²³, now an approaching reality since the Kyoto Protocol was ratified. Pumping carbon dioxide underground into 'carbon sinks' has been advocated.²⁴ To me, this sounds like sweeping a problem under the carpet and is a diversion, a red herring — not a solution. There is no guarantee that the carbon dioxide will not leak out into the atmosphere eventually.

The above are all just temporising measures, however. After that, notwithstanding any breakthrough, air travel will all but disappear. Some might say the return to an agrarian lifestyle is the way to go.²⁵ This is unlikely to be acceptable to the majority of people used to a high standard of living. Furthermore, in a world of six billion people (possibly nine billion by mid-century), it will be impossible to revert to low productivity agricultural economies without mass starvation.

The nuclear fusion/hydrogen scenario

Let me now outline the future energy scenario that many physicists and some politicians will have us believe in — it is a big money scheme, and we're talking trillions of dollars:

A few (ten? fifty?) years from now, there is a major breakthrough in fusion research (research which has

already cost multiple billions to date) and electricity becomes laughably plentiful and essentially inexhaustible. So, powering our cities and many industries is no longer a problem and it is all pollution-free.

What of transportation? Overland, the electric vehicle will come into its own, whether by road or rail. Sea transport is a little trickier as it is unlikely that fusion generators (tokamaks?) may be reduced to a size that even a super tanker could contain in the near future, and even if they could, it may not be cost effective. Independent fusion units would certainly be out of the question for small craft. The need for a new aviation fuel will still remain and will not be solved by abundant electricity.

The answer to these issues, we are told, is hydrogen, derived from the electrolysis of water. And hydrogen is so wonderful because when you burn it (or utilise it in a fuel cell), all you get is nothing more than water again — no pollution. Thus we will have hydrogen-powered ships and jet aircraft. The only problem is, this will entail the complete redesign of current fuel storage, transportation and distribution facilities around the world, not to mention new engines and tanks on all these craft. Can liquid hydrogen be transported across thousands of miles by pipeline as oil is currently? Liquid hydrogen would be immensely more difficult to store and handle than current petroleum-based fuels. Bulky, pressurised and heavily insulated hermetic tanks will be necessary. Precautions must be taken in handling this intensely cold commodity; cryogenic technology must be introduced.

Another major problem will be the inevitable 'boil off' of liquid hydrogen if stored for any length of time,



which will represent a large waste and be dangerous if occurring in an enclosed environment. (Hydrogen is the smallest atom and thus the easiest to leak out of containers.) The potential for accidents will be ever present, hydrogen being more volatile than many petroleum products. (For instance — throw a burning match into a pool of cold kerosene or diesel and what do you get? An extinguished match.) The image of the burning Hindenburg may not be a fair one to conjure up but it is an inevitable one.

What if I were in the middle of a desert at night, or in a boat in the middle of the sea at night, and needed an energy source to run my generator or tractor or boat engine? Diesel or petrol are very convenient for this and it is difficult to conceive how hydrogen could supplant these fuels in small-scale, geographically isolated situations. Direct solar or wind generated electricity cannot provide sufficient power for many tasks.

In any case, the holy grail of fusion energy remains an unattainable illusion for now and the foreseeable future. As the joke goes, fusion energy is just forty years away from us — and always will be.²⁶

Better paradigms

There are more practical energy sources and technologies which are available right here and now. These sources are sustainable and renewable and do not result in a net increase of carbon dioxide in the atmosphere. Collectively we term this 'biomass energy'.

What do I mean by 'do not result in a net increase of carbon dioxide in the atmosphere'? Surely when one burns a piece of wood, carbon dioxide is released? The answer is simple: so long as a new tree is planted for every equivalent mass of wood burnt, there is no net increase in atmospheric carbon dioxide, as the growing tree will lock atmospheric carbon into its mass again. This is the attraction of all biomass energy, provided that we replenish everything we burn.

Is biomass energy just a fancy term for cow dung and wood and other organic matter which humans have used throughout history anyway? If so, what is the big deal?

New approaches to biomass energy were introduced last century. Small-scale methane-from-sewage projects are now widespread throughout China and India. One of the most ambitious schemes is the Brazilian National Alcohol Programme, where sugar cane is used to produce ethanol which, alone or mixed with gasoline, has gone a long way towards reducing their dependency on petroleum. Ethanol in Brazil now sells for about sixty to seventy per cent of the cost of petrol in the free market.²⁷

Other strategies to convert wood and plant waste to useable hydrocarbon fuels, whether aqueous (fermentation, chemical reduction) or thermochemical (pyrolysis, gasification, hydrogasification), have not proved to be practical or viable on a large scale.

Nevertheless, I believe modern methods can allow biomass energy to substitute for petroleum-based fuels, including aviation fuels. This has already been done in a limited manner.

Towards the end of World War II, when the Japanese ran out of oil, they resorted to pine resin to power their fighter planes for some missions. It worked to a degree, although the engines tended to gum up.²⁸ Few would be surprised at the suggestion that good old turpentine can be used as a fuel. Rudolf Diesel himself wrote in 1911 that 'the diesel engine can be fed with vegetable oil', a fact proven time and again at various times and places. Tractors were run on sunflower oil in South Africa many decades ago. During World War II, the Chinese developed an industrial process for cracking vegetable oils and turning them into motor fuels which did not clog engines.²⁹

Nowadays biodiesel is no longer considered experimental and is available at many roadside bowsters in Europe for use in ordinary diesel vehicles with minimal engine modification. (The Germans are particularly far-sighted in this respect.) Techniques have now advanced to the stage that private individuals can utilise kitchen-chemistry kits to convert their waste cooking oil to biodiesel to power their family cars. The exhaust apparently smells faintly of — french fries!³⁰

Modern diesel-powered piston aviation engines may well replace avgas- (leaded petrol) powered piston engines for light aircraft in the next few years for many practical reasons. (The Morane Renault company has been one pioneer in this respect.)

Diesel fuel is physically and chemically very similar to kerosene which is, of course, none other than jet fuel.

Let us now summarise the characteristics of the ideal fuel. It should have all the advantages of petroleum-based oils, i.e. have a high energy density and be a liquid over a wide range of ambient temperatures, and it (or its derivatives) should be a viable aviation fuel. It should have none of the disadvantages of fossil fuels, i.e. it should be renewable, should not add to the net carbon dioxide load in the atmosphere and should be minimally polluting. It should have none of the handling disadvantages of liquid hydrogen — which it will not if it has the physical characteristics of petroleum-based oils.

It should also have a minimal environmental impact in the event of a spill or leak and should be biodegradable. Additionally, it should be non-toxic.

Some hydrocarbon-based fuels are quite poisonous, e.g. methanol can induce metabolic acidosis and blindness and benzene is carcinogenic. Even diesel emissions contain carcinogenic polycyclic aromatic hydrocarbons. (There are far less of these in biodiesel emissions.) A major bonus would be if this fuel could be used in existing engines with no or minimal modification.

Now we come to the speculative, perhaps controversial part. I believe it is possible for us to create the ideal (or near ideal) fuel with existing technology.

Virtually all the chemical energy we use today is ultimately derived, directly or indirectly, from the photosynthetic process, and this is where I believe our efforts must be concentrated.

The question is, what is the most direct and most cost-effective way of converting sunlight into liquid hydrocarbons (preferably oil, although alcohol is also useful) rapidly and in volume?

Phytofuels

In the first instance we should strive to produce a plant-derived oil — what I term a ‘phytofuel’. The biggest obstacles to its development are economic and political. It will need to be price-competitive with petroleum-based oils and be able to meet current and future demands, i.e. will have to be produced cheaply on a large scale.

Growing sugar cane then converting it to alcohol (which has a lower energy density than oil) is a two-stage process. Furthermore, there is opportunity cost in that cane fields can be used for growing other crops, and sugar itself is a worthwhile commodity whose value may exceed that of the alcohol produced, depending on market circumstances. Similar issues hold for the vegetable oils, in that there is opportunity cost in the land utilisation and the oils themselves are useful commodities in non-fuel applications. The same applies to pine oils. Additionally, much of the solar energy, water and nutrients consumed during the growth of these crops goes into the formation of roots, stems or other plant parts which we would not primarily be interested in. This brings us to the characteristics of the ideal fuel crop.

The ideal fuel crop should:

1. Grow rapidly and be harvested easily;
2. Utilise land (or even lake or marine areas) not otherwise useful for other purposes;
3. Efficiently convert sunlight, water, CO₂ and nutrients to the end product, i.e. oil, with minimal diversion of energy into the formation of other plant parts — in the extreme situation, such a plant would consist of little more than chloroplasts and

oil-producing organelles surrounded by a cell membrane, namely, an algal species;

4. Not require a significant extraneous application of fertilisers, e.g. perhaps the nitrogen fixation ability of legumes can be spliced into the genome of the oil crop;
5. If fresh water is in short supply, be able to use sea or brackish or artesian water;
6. If it were to inadvertently escape the confines of the ‘fuel farms’, not proliferate rampantly and pose an ecological hazard — perhaps a self-destruct sequence could be built into its genes or it could be engineered to require an essential nutrient not normally found in the greater environment.

One inescapable criterion, however, will be that such a crop will require lots of sunshine. Perhaps areas like outback Australia or Arizona could prove to be just the place for such ‘fuel farms’.

Of course, such a plant does not exist. Not now, at any rate. Consider this, however: simple selective plant breeding has enabled humankind to exponentially increase the food yield of cereal crops, transforming grain-poor wild grasses into the highly productive staples of rice, wheat and maize we know today.³¹

We now have at our disposal a far more powerful and efficient tool than simple selective breeding: biotechnology. I believe biotechnology will enable us to create plants with far greater oil productivity than the current traditional bio-oil sources such as canola, soya bean or oil palm, dramatically increasing the economic competitiveness of such oils. But innovation and investment are required. The creation of economically viable ‘phytofuels’ will involve genetic engineering, the controversies surrounding which need to be discussed separately. Given the current state of biotechnology, it is entirely feasible to introduce an oil-producing gene into a rapidly growing algal species to produce such a plant. Some algae already have a very high lipid content, e.g. *botryococcus braunii* has been found to synthesise large amounts of hydrocarbons with oil contents of up to eighty-six per cent of dry weight.³² Some microalgae have a doubling time of less than a day.

Hence my initial suggestion — that we should invest in scum.

Other possibilities include bio-engineering seaweed or kelp for the same purpose. In all probability there will be no single ideal fuel crop but instead several different sorts, depending on the local environments where they will be grown, which will produce different sorts of oils for different uses.

Some preliminary research has already been done on the above, dating back several decades. However,

no breakthrough has occurred, largely, I believe, due to lack of funds and lack of interest, especially because of current, artificially cheap petroleum prices. Barring another petroleum crisis or John Howard being unexpectedly afflicted by an attack of decency, there is unlikely to be adequate government support for such a project.

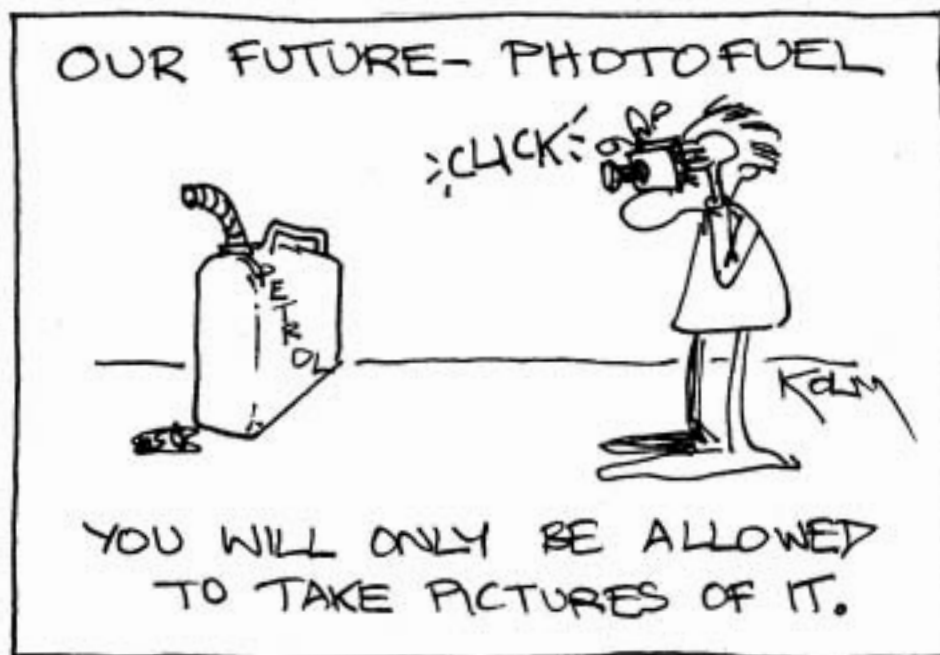
Biotechnology may also be the key to the production of new renewable polymers and plastics, which, after all, are presently derived from petroleum. But that is a whole other story.

Photofuels

Will the development of bio-engineered phytofuels solve all our energy problems? Almost certainly not. At the very least, however, my hope is that phytofuels will replace fossil fuels in the transport industry, and

1.2×10^{17} watts, or *twenty thousand times* the total rate of human consumption.³⁴ It is clear that there is huge potential to vastly increase our energy collection from the sun. By my own back-of-the-envelope calculation, a 100 per cent efficient solar energy collecting facility will need to be about ten per cent the area of the Nullabor Plain to meet *all* the world's energy needs — a tiny dot on the map of the world.³⁵ If we were able to develop a thirty-three per cent efficient solar process, a facility comprising thirty per cent the area of the Nullabor Plain (75,000 square kilometres) may be required (and much less if we can curb our present rampant profligate habits).

Certainly that represents a huge land area. However, we should compare that figure with the estimation by an Utrecht University team, that for *wind* power to meet the global *electricity* (not total



that vehicles with hybrid³³ phytofuel-electric engines will become the environmentally friendly standard.

It is likely that nuclear fission, hydro-electricity and, increasingly, wind power will be important sources for future electricity generation.

We do not know at this time the maximum volumes of oil which can feasibly be produced by bio-engineered plants. However, there may be another strategy which could far exceed the solar energy gathering efficiency of even the most wildly productive bio-engineered oil plant and utilise far less water.

The rate at which solar energy is delivered to the entire earth's surface, despite cloud cover, atmospheric attenuation (reflection, scattering, absorption), cosine effect (obliquity of rays at locations above or below the equator), rotation of the earth (day and night phases) and other factors, averages a total of

energy) demands of 2001, a land area of 2.4 million square kilometres (about the size of Saudi Arabia) will be required, which one science journalist considered an *upbeat* assessment!³⁶

Nevertheless, 75,000 square kilometres *is* a massive land area and a single such solar gathering facility will represent a monumental engineering feat far exceeding that of the Great Wall of China. A much more practical and likely scenario is that several hundred such facilities should be built around the world in areas of high insolation to collectively add up to such an area. What sort of solar energy collecting facilities are we talking about?

Let us revisit a question previously posed: What is the most direct and most cost-effective way of converting sunlight into liquid hydrocarbons rapidly and in volume?

I believe that, far more efficient than bio-engineered phytocombustibles, the direct conversion of light energy to hydrocarbons will ultimately be the way to go — in other words, artificial photosynthesis — to enable the production of what I term a 'photofuel'. The aim is to eliminate the biological middleman (the plant), to more efficiently produce a sustainable oil.

To me, artificial photosynthesis is the holy grail of renewable energy. Where do we currently stand on this matter? Surprisingly, hardly a word is mentioned about this topic in the popular science literature. It is an idea which deserves far wider publicity and a massive injection of funding.

A number of groups around the world are looking into this matter, including Lund University in Sweden, the Brookhaven National Laboratory in Arizona State, Boston Universities in the US, and our own CSIRO (among others) in Australia. The Australian Artificial Photosynthesis Network (AAPN) is a small multidisciplinary group of scientists in Australia and New Zealand who have a particular interest in this issue. I quote directly from their website:

The primary photochemical conversion processes in nature...are much more efficient (~ 4 times) than the best silicon based photovoltaic systems. They have been highly 'refined' by evolution to extract the most from the spectrum of solar light flux received at the earth's surface. For this reason, we regard a program to develop chemically robust, 'biomimetic' photoelectric conversion systems, as highly valuable.³⁷

To date progress has been modest, with the inefficient production of small volumes of hydrogen or methane at slow rates.

I believe, however, that research into artificial photosynthesis is much more likely to yield breakthroughs than the search for controlled nuclear fusion. After all, we have no precedent for the occurrence of controlled nuclear fusion under earth-like conditions and it may never be possible to achieve this. Plants, however, have been quietly performing photosynthesis under ambient conditions for billions



Map of areas of high solar insolation

of years. We just need to discover how to mimic them. Surely it is not beyond human ability to find out how a primitive unicellular blue-green alga works.

A metaphor

Let me use a metaphor to describe our present situation. We are rapidly steaming ahead through dense fog onboard a ship very much like the *Titanic*. Our radar indicates there is a huge iceberg directly in our path. (The iceberg represents the impending industrial and agricultural collapse consequent to petroleum depletion, as well as the dire effects of global warming.) The iceberg is half a mile away. Unfortunately, we need two miles of seaway to stop our ship and our rudder is jammed, hence we cannot change course. Our captain (who represents America) used to be a benevolent and helpful fellow, kind to children and animals, but has recently been gripped by an aggressive madness. An Arab crewmate named Saudi recently slapped the captain in the face (remember that in the September 11 hijackings, fifteen of the nineteen hijackers were Saudi nationals), so the captain did the natural thing and beat up *another* Arab crewmate named Iraq to a bloody pulp. Those Arabs all look alike anyway, he says, so he feels that he was fully justified. In any case, he needs Saudi to bring him his food.

We all know how to survive the impending collision with the iceberg: engage full reverse thrust to delay and lessen the impact, and lower the lifeboats to save the passengers.

The captain has at different times denied the existence of the iceberg on the radar or dismissed its importance — *We can crash through it no problem*, he says. *Stoke up the boilers and full-speed ahead*. He claims it is all a left-wing conspiracy, although he cannot explain how or why those shifty left wingers could or would fabricate such evidence.

We cannot overpower the captain and take command. He has adopted a Rambo mindset and carries knives, guns and grenades on his person which he will not hesitate to use. We are either with him or against him, he says. All we carry are tiny nail-clippers with spiky bits.

The first mate, Britain, who is currently stomping on Iraq's face with hobnail boots, has come to accept the existence of the iceberg but has done precious little about it except make a few token statements.

Some European crew members have begun to lower lifeboats and round up their favourite passengers.

Australia is a lowly midshipman who has always been loyal to the captain. Despite our tiny stature, we have had the dumb good fortune to be blessed with morbid obesity. Our exuberant rolls of fat (representing our coal and uranium resources) serve as insu-



lation and flotation, hence we will be able to survive much longer than anyone else in the frigid waters after the ship sinks. Complacency is thus the easy option for us. Let the others freeze and drown, why should we care? We'll be okay in the short-term. However, we also have at our fingertips the operating handbook for the largest lifeboat of all, one that may save most, if not all, the passengers. We just need to figure out the instructions for deployment.

What would you do?

Conclusion

At present, the only proven practical replacement for petroleum products in the transport industry is plant-derived oils. Oil-based fuels are infinitely more user-friendly than liquid hydrogen. We have the potential to greatly improve the economics of 'phytofuel' production with the application of biotechnology. With adequate support and funding, this can undoubtedly be achieved within a decade or two. Phytofuels alone, however, are unlikely to adequately meet our needs.

Success in artificial photosynthesis research is less certain, but it is much more likely to bear fruit than nuclear fusion research. Additionally, photosynthesis research can be undertaken without the need to construct multibillion-dollar infrastructure facilities such as tokamaks and is thus ideally suited for medium-sized but highly capable economies such as Australia. It may take thirty to forty years to achieve the breakthroughs in 'photofuel' development,

assuming we embark on a concerted effort right here and now.

As individuals, the task ahead seems insuperable.

Can we persuade right-wing governments and corporations with vested interests in fossil fuel consumption to acknowledge the truth and to do the right thing? Some companies, like BP, have seen the writing on the wall and are actively investing in alternative energy research. Automobile firms such as Toyota have achieved brilliant breakthroughs with hybrid engines. For others, however (in particular the Bush and Howard administrations), trying to reason with them is a waste of time — they are intransigent, duplicitous, self-serving and mutually support each other in powerful networks, as evidenced by past behaviour. They can be vindictive, bullying and resort to verbal gang bashing against those who may express an honest, valid but differing opinion.^{38,39}

John Howard said that developing nations such as India and China should be included in carbon emission agreements. Let us recall that America currently consumes *seven* times more fossil fuels per head of population than China (and Australia is not far behind). Advocating that *all* countries limit their emissions to 1990 levels (as per the Kyoto Protocol) amounts to insisting that poor countries should be condemned to perpetual poverty, while rich countries, having historically burnt off more than their fair share of fossil fuels in order to *become* developed, can continue to enjoy doing so. The impoverished of the

world must surely view John Howard as a sanctimonious hypocrite with an overweening sense of entitlement.

Fair-minded Americans do exist, even if they have been sidelined and are only able to express themselves indirectly. In the Emmy-award-winning (fictional) TV series *The West Wing*, the Nobel-prize-winning economist President Barlet says in one episode that a nation of SUVs has no moral right to lecture about reducing fossil fuel emissions to a nation of bicycles.

The methods adopted by Detroit, the fossil fuel industries and their government proxies to discredit and deny the evidence behind global warming is reminiscent of the way the tobacco lobby vigorously endeavoured to cast doubt on the link between smoking and lung cancer. Their tactics and moral standards are identical.

I believe our best strategy is public education. Democracy can only work if a critical mass of voters possess a reasoned understanding of issues. We need to build grassroots support for policies promoting sustainable futures. All adults and children from perhaps age twelve need to be taught to think critically and must realise that there is nothing less at stake here than their future living standards, employment prospects, risk of mass starvation and wars over resources. These ordinary folk are the ones we must recruit, and who we will ultimately depend on, to vote out useless lying rodent politicians and replace them with courageous visionaries.

Photocopy this essay or print it out from <www.rationalist.com.au> (edition 70) and give it to your friends. Teachers or lecturers can use it to prompt discussion between their students. If you discover any

inadvertent factual errors in your perusal, write to the author at the address below to have them corrected, then disseminate the corrected version.

Let us dream of a future where human beings live sustainably and have minimal impact on the environment. A future where our descendants will look back and shake their heads in amazement at how greed, short-term agendas, war mongering and wasteful practices dominated our lifestyles and feel thankful that they have found a better way.

A scenario describing a breakthrough in photofuel research which is ruthlessly suppressed by big business is depicted in the satirical novel *Icecubes in Rockets: A Future History of Human Folly*, available at the now-reduced price of \$20 per copy (plus \$3 postage and handling irrespective of number of copies ordered) from Iconoclast Press Australia, PO Box 791, Sunnybank, Queensland 4109.

A disk containing a booklet with annotations to the novel and this energy essay accompanies the novel. Excerpts of the novel can be read at <www.rationalist.com.au> (edition 67).

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