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An assessment of the viability and benefits of using vegetable oil fuels and of more fundamental ways to offset the impending fossil fuel dilemma

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Abstract: The first part of this work involved performing a literature review and a 45,000km on-road trial using a 50/50 blend of vegetable oil and diesel fuel. It was first presented at the 5th International Conference on Sustainable Automotive Technologies in Ingolstadt, Bavaria in 2013 [1]. The second part addresses the potential increased safety of using vegetable oil fuels and blends, the availability of non-food oil-producing species and land, and the sociological and environmental aspects associated with growing biofuels. It was first presented at the 6th International Conference on Sustainable Automotive Technologies in Gothenburg, Sweden in 2014 [2]. Costs of growing, extracting, purifying and transporting vegetable oil fuel are lower than any alternatives given the simplicity of processes involved, the fact that almost anyone can perform them and the fact that the fuel can be grown and processed close to point of use by small, non-monopolistic enterprises. A comparison of alternative fuel costings is contained in reports by the European Community Joint Research Commission and the International Energy Agency (IEA) [3, 4]. This work shows that providing the world's current energy needs without fossil fuels unless humanity is prepared to reduce its population to a sustainable level, is essentially impossible. Consequently, the authors also address the broader sociological and philosophical questions posed by our current and impending demise. Evidently, the human race is destined to catastrophe or even to extinction if we do not collectively address issues such as population control, climate change, species extinctions, equality for all people and elimination of greed with its associated mantra of infinite growth at all costs.

Keywords: Waste vegetable oil (WVO), straight vegetable oil (SVO); pure plant oil (PPO); High-flashpoint fuel; oil-producing species; land availability; land-grabbing; population; explosion; fire; degrowth; chrematistics; oikonomia

1 Introduction

Vegetable oil based fuels are one of many sustainable energy sources which can be used when fossil fuels run out. Others are for example, biomass, wind-power, wave-power, geothermal energy, solar-voltaic & solar-thermal power. Vegetable oils may be transesterified or hydrotreated to produce volatile, conventional hydrocarbon fuels. This work considers unprocessed vegetable oil used either in neat form or in blends with other fuels such as conventional diesel fuel. In so doing, the higher cost and risk of processing is avoided while at the same time gaining a significant safety advantage in transport, storage and use consequent upon the higher flashpoints of vegetable oils.

The compression ignition engine (oil engine) was invented by Herbert Akroyd Stuart and patented in 1886. The oil engine was very successful and 32,417 were manufactured (Figures 1,2) [5-7]. This was before Rudolf Diesel developed and patented his improved, higher pressure design (Figures 3, 4). An engine designed specifically for running on vegetable oil was developed by Ludwig Elsbett in 1977 (Figures 3,4) [8]. It contains three cylinders, a two-part piston, bowl-in-piston swirl chamber and a novel method of cooling. Production ceased following progressive re-application of fuel tax in Germany from 2008 to 2012. Now that governments are beginning to realise the importance of sustainability however, vegetable oil fuel is again being considered.

Figure 1: Hornsby-Akroyd vapourising oil engine: Richardhornsbyvaporizing oilengine.jpg

Figure 2: Herbert Akroyd Stuart: Tractor & Construction Plant Wiki, http://tractors.wikia.com/wiki/Herbert_Akroyd_Stuart

Figure 3 : Rudolf Christian Karl Diesel: http://en.wikipedia.org/wiki/Rudolf_Diesel#/

Figure 4 : Diesel's compression ignition engine: http://en.wikipedia.org/wiki/Diesel_engine

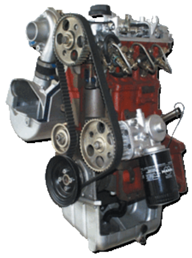


Figure 5: The Elsbett Motor: http://de.wikipedia.org/wiki/Elsbett-Motor

Figure 6: Ludwig Elsbett: http://en.wikipedia.org/wiki/Ludwig_Elsbett

2 The literature review

139 papers by authors from 32 countries (see Table 1) have been reviewed covering the period 1980-2014.

Table 1 : Papers reviewed by country

Country	Papers
USA	21
India	24
Turkey	12
Greece	7
Germany	7
France	6
Spain	6
China	6
Brazil	4
Burkina Faso	4
UK	4
Jordan	3
Romania	3
Nigeria	2
Australia	2
Italy	2
Czech Republic	2
Canada	1
Denmark	1
Egypt	1
Finland	1
Ghana	1
Indonesia	1
Japan	1
Lithuania	1
Netherlands	1
South Africa	1
South Korea	1
Slovak Republic	1
Switzerland	1
Ukraine	1
Yugoslavia (fmr)	1
	139

For 80 of these papers, equipment details and engine performance were recorded some of which are shown in Table 2.

Of 499 data points from 48 of these papers, exhaust emissions for vegetable oil are improved or the same as diesel fuel in 314 instances and worse in 185 instances (see sample Table 3). NOx, Smoke, PM and Noise are generally improved relative to diesel fuel and CO_2, CO and HC are inconsistent. Poon, Mahua, Linseed, Soybean, Palm, Rapeseed, Orangeskin, Karanja, Cottonseed, Corn, Putranjiva and Jatropha oils performed best.

Of 210 data points from the same 48 papers, engine performance for vegetable oil is improved or the same as diesel fuel in 132 instances and worse in 78 instances (see sample Table 4). Brake thermal efficiency (BTE) is improved in 85% of instances for food oils and 74% for non-food oils. Torque is improved in 53% of instances for food oils and 63% for non-food oils. Power is greater in 59% of instances for food oils and 63% for non-foods oils. Brake Specific Fuel Consumption (BSFC) is improved for 39% of instances for food oils and 59% for non-food oils. Brake Specific Energy Consumption (BSEC) is worse in the one instance assessed for food oil and is improved for 57% of instances for non-food oils.

Several researchers describe adverse impacts of the use of vegetable oil fuels on the engine and its componentry caused by high viscosity, presence of free fatty acids and propensity to polymerise, particularly where 100% vegetable oil is used. They suspect that this will prejudice use of vegetable oil particularly in the long term. Saturated oils are less likely to polymerise but tend also to be higher in viscosity and more likely to be solid at room temperature. Chemical properties affecting cetane number, presence of hazardous emissions and late combustion enhancement are the aromatic/aliphatic compound balance and the amount of combined oxygen present [9]. The Czech Republic has operated fleets of dual-fuelled vehicles successfully since 1977 [10]. Few long-term trials have been conducted in other countries. On balance research to date indicates that there appears to be wisdom in using vegetable oil either alone or in blends with more volatile fuels, for both automotive and stationary engine applications.

Table 2 : Sample of the equipment details and performance summary (full table of 7 x A4 landscape pages is available on request)

Fuel	Purpose	Engine	Cylinders	Comp Ratio	Inj press bar	Engine mods	Performance vs diesel
Jatropha	Auto	DI	-	-	-	Preheat	Viable
Karanja	Agric	Kirloskar	1	-	180-200		Better up to 50% oil
Pistacia	-	Lister 8/1, 6kW, IDI	1	17.5:1	-	-	bte, power down; bsfc up
Rapeseed 100%	Boiler	Roca AR/25GT	-	-	-	-	Viable
Sapodilla/Teitai oils	-	-	-	-	-	-	Viable @ 10% oil
Sunflr/Cotton/diesel	Auto	Rainbow 186	1	18:1	196	ZrO_2 coated	all fuels viable; SFO better
Karanja	Auto	6kW, 4-stroke	1	-	-	-	10% oil; bte up; BSEC down
Karanja oil, prod gas	All	Apex Kirloskar	1	17.5:1	200-225	-	Brake thermal efficiency
100% WVO run for 500 hrs	Agric power	Listeroid c/w generator	-	6:1	-	75% ld 650rpm	500hr trial; Oil-change every 110 hours.

Table 3 : Sample of emission and noise findings; red (Up), green (Down), white (Same). (Full table 6 x A4 pages available on request)

Species	Reference	CO	CO_2	HC	PM	NOx	Smoke	Noise	Oil type etc
Animal Fat	Mormino	-	-	Up	Same	Down	-	-	Animal fat, torque 138 & 277 Nm
Animal Fat	Mormino	-	-	Same	Up	Same	-	-	Animal fat, torque 415 Nm
Cashewnut shell	Kasiraman	Up	Down	Up	-	Down	Up	-	Cashew nut shell oil (CNSO), 100%
Cashew/Camphor	Kasiraman	Same	Up	Same	-	Down	Same	-	CNSO/Camphor oil (CMPRO) 30%
Cashew/Camphor	Kasiraman	Up	Down	Up	-	Down	Up	-	CNSO/Camphor oil (CMPRO) 10-20%
Chicken fat	Kleinova	Same	-	Up	-	Down	Up	Down	Chicken fat, Skoda Octavia 1.9TDI, 850bar
Chicken fat	Kleinova	Same	-	Down	-	Up	Down	Down	Chicken fat, VW Touareg R5 2.5UI 2050bar
Coconut oil	Machacon	-	-	-	-	Down	Down	-	Coconut oil, 0-100%
Coconut oil	Nettles-Anderson	Same	-	-	-	Down	-	-	Coconut oil, DI engine

Table 4 : Sample of performance findings; red (Worse), green (Better), white (Same) . (Full table 4 x A4 pages available on request)

Species	Reference	BTE %	BSFC g/kWh	BSEC MJ/kWh	Torque Nm	Power kW	Fuel details
Karanja	Agarwal	Same	Same	Same	-	-	Karanja oil/diesel, 10-100% VO, w/o preheat
Lard	Kleinova	-	Worse	-	Worse	-	Lard, Skoda Octavia 1.9TDI 850bar
Lin/D/Eth	Kumar	-	Same	Same	-	-	Diesel/linseed oil/ethanol, 60/35/5, A2
Lin/D/Eth	Kumar	-	Same	Same	-	-	Diesel/linseed oil/ethanol, 60/30/10, B2
Lin/D/Me	Kumar	-	Same	Better	-	-	Diesel/linseed oil/methanol, 60/35/5, A1
Lin/D/Me	Kumar	-	Worse	Better	-	-	Diesel/linseed oil/methanol, 60/30/10, B1
Linseed	Cheng	-	-	-	Same	Same	Linseed oil, 2000 bar
Linseed	Cheng	-	-	-	Same	Same	Linseed oil, 3000 bar
Mah/D/Eth	Kumar	-	Same	Better	-	-	Diesel/mahua oil/ethanol, 60/35/5, A4

3 The on-road trial

Two instances have been found where on-road trials have been conducted by others [11], [9]. The first involved a Euro 2 Volkswagen Golf 1.9L Tdi over a distance of 20,000km and a Euro 3 Renault Laguna 1.9L dCi common-rail vehicle driven for 14,000km. Both vehicles fuelled with a 10% cottonseed oil/diesel blend, met EU Emissions Directive 2003/30/EC. The second involved two second-hand Euro 2 compliant vehicles, a 1.9L DI vehicle with 52,000km odometer reading at commencement and a 1.5L IDI vehicle with a reading of 21,000km. Each was fitted with a fuel preheating kit and driven on 100% Canola (low-acid Rapeseed) oil which complied with the German Rapeseed Fuel Standard, for multiple 200 mile runs. Both of these groups of workers conducted extensive engine performance and exhaust emission testing. They urged others to perform further tests in view of the potential importance of SVO and of blends with diesel fuel as future fuels.

The present work used a mechanically injected, pre-Euro 2, 1996 model Mitsubishi Triton utility vehicle, equipped with a 2.5L In-Direct Injection (IDI) turbocharged diesel engine. This model as sold in the UK was required to comply with the Euro 3 standard. Current light diesel vehicles in Australia are Direct Injection (DI) common-rail, complying with Euro 5. All diesel vehicles will comply with Euro 5 in 2016 and Euro 6 in 2017/18. The test vehicle was powered using 100% waste vegetable oil for a 1000km pre-trial period in 2004. The vehicle ran well until a 5mm wire mesh filter inside the fuel injector pump became partially blocked with paint particles from the drums that the waste oil was stored in and would not travel above 80km/hr. The fuel injector pump was repaired, injectors refurbished and the vehicle operated on conventional diesel fuel for a year. Trials were recommenced in November 2005 using a 10% blend of vegetable oil with conventional diesel fuel. Following successful operation, the oil concentration was progressively increased to 50%. The reported thirty trials consisted of seven diesel fuel control runs, four 50/50 blend runs and a total of nineteen runs comprising 50/50 blend with an additive. Additives used were isopropanol, ethanol, ethyl acetate and a range of industrial perfumes. Trials were conducted over 21 months from April 2008 to January 2010, covering a total distance of 42,269km. They were not without fault. The fuel filter blocked regularly leading to loss of power and excessive exhaust smoke. The cause was fuel containing a dispersion of finely divided solid fats and high melting point oils. Problems reported by others such as fuel acidity, injector fouling and fuel polymerisation were not experienced. On completion, the engine was found to have suffered extremely low cylinder head and cylinder bore wear and no acidity was evident in the lubricating oil (pH 7.0). Fuel consumption was measured for all trials, country runs and city runs. Average speed was also measured for country runs. Measuring other variables such as vehicle condition, wind, temperature, power, torque and traffic conditions required more resources than were available. This was offset by using two principal routes with relatively constant journey times :- *Williamstown-Kilsyth-Brooklyn-Williamstown 116km city runs, twice per week in off-peak traffic; Williamstown-Bahgallah-Williamstown, 750km country runs, approximately eight times per year.* Other variables such as vehicle performance (apparent power) and smoke emission were noted in the trial log.

Fuel used

Standard diesel fuel in Australia complies with Fuel Standard (Automotive Diesel) Determination 2001. This permits up to 10mg/kg sulphur and requires a minimum Cetane Index of 46, a viscosity range of 2.0-4.5 cSt at 40°C, a minimum flashpoint of 61.5°C and maximum of 11% PAHs mass/mass. Australia also has a biodiesel fuel standard but unlike Europe [11] does not yet have a vegetable oil fuel standard. 50/50 vegetable oil/diesel fuel was the basis for all formal trials performed. The purpose of using additives was to assess whether they would improve performance. Principal examples used were a range of industrial grade perfumes formulated as additives for disinfectant, detergent and bleach formulations comprising complex proprietary mixtures of both natural and synthesised fragrances such as eucalyptus oil, terpineol, 2-phenoxy ethanol, 2-octanol-2,6 dimethyl acetate, benzyl benzoate, and 6-acetyl-1,1,2,4,4,7-hexamethyltetraline, each dissolved in ethanol. The blending technique was to mix 10L each of diesel fuel and decanted waste vegetable oil in a calibrated container. For trials involving an additive, 2L was added to the 20L blend. Additive blends were therefore 45.5% WVO, 45.5% diesel fuel and 9% additive. The mixed fuel was filtered using Nital 9 monofilament filter cloth. The fuel gauge was calibrated by draining the tank and noting gauge readings following addition of a series of 10L increments. Fuel consumption was measured either by filling the fuel tank with a measured amount and running until empty or more commonly, by adjusting for the fuel gauge reading at the start and finish of a run and adding any fuel additions made during the trial. Some trials with additives were grouped together for the purpose of analysing results.

Results

The suppliers of WVO purchased cooking oils comprising Canola (six sources), Sunflower (two), a Canola/Sunflower blend (one) and Cottonseed (one source). Their calorific values are Canola 34-36 MJ/L, Sunflower 37 MJ/L and Cottonseed 42 MJ/L [12-15]. Slightly lower values for vegetable oils compared with diesel fuel (45-46 MJ/L), are expected to cause higher fuel usage than diesel fuel for the same energy consumption. Trial duration and fuel consumption are presented for each type of fuel used in Figures 7 and 8.

All trials

KEY TO FUELS USED

Diesel	Conventional diesel fuel alone.	Citrus	50/50 blend with citrus perfume.
50/50	50% waste vegetable oil & 50% conventional diesel.	Lemon	50/50 blend with lemon perfume.
IPA	50/50 blend with isopropyl alcohol.	Lem/Euc	50/50 blend with lemon or eucalyptus perfume.
WKR	50/50 blend with white king regular perfume	Euc	50/50 blend with eucalyptus perfume.
Brn Euc	50/50 blend with brown eucalyptus perfume	D+Euc	50/50 blend with eucalyptus perfume.
Et/EtAc	50/50 blend with ethanol and ethyl acetate		

Figure 7: Trial distance (km) vs fuel type

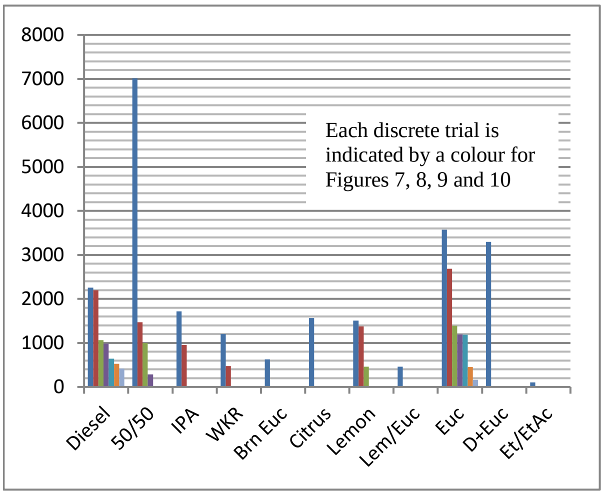


Figure 8 : L/100km vs fuel type

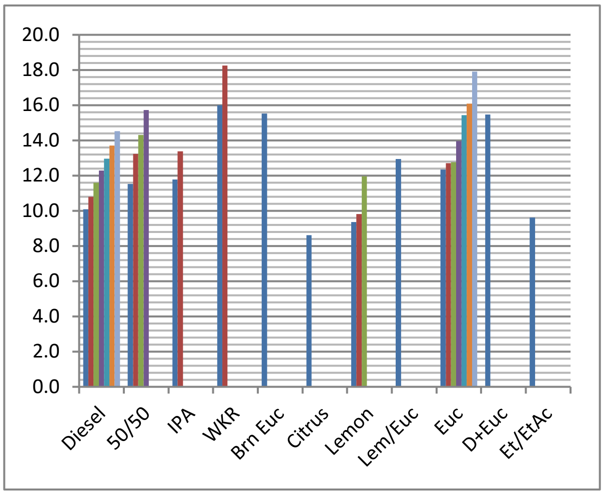


Figure 7 shows that the most tested fuel was the 50/50 blend without additive. Figure 8 shows that the lowest fuel consumption was achieved using 50/50 blend with Citrus perfume (8.6L/100km). Second lowest was the 50/50 blend with lemon perfume (9.4L/100km) and one of the straight diesel fuel runs was fifth best (10.1L/100km).

Country runs

The range of average speeds achieved for outbound and return runs is similar (outbound 66.6 to 92.0 km/hr; return 64.6 to 90.6 km/hr). Outbound runs were against the prevailing westerly wind and the vehicle was heavily laden. Return runs were with the wind and the vehicle was lightly laden. The route had few built-up areas, limited traffic, substantially no road works and few traffic lights. Outbound run average fuel consumption was 17.3 L/100km and return run average, 15.3 L/100km indicating that to achieve similar journey times, more fuel was consumed outbound. There was no diesel fuel control outbound and so comparisons have been made with the 86/14 diesel/WVO blend. Figures 9 and 10 show fuel consumption versus fuel type. The best performing outbound fuel was 50/50 blend with lemon perfume (12.2 L/100km). Second best was 50/50 blend with citrus perfume (14.1 L/100km) and third best was 50/50 blend with IPA (16.0 L/100km). Worst performing was one of the blends with eucalyptus perfume (20.4 L/100km), followed closely by the 86/14 diesel surrogate, one of the 50/50 blends and a WKR blend (18.7 L/100km). Return runs showed 50/50 with lemon perfume to fare best (12.0 L/100km). Second was citrus blend (12.3 L/100km). Third and fourth were a 50/50 blend and a lemon blend (13.3 and 13.4 L/100km). Diesel fuel was fifth at 13.9 L/100km.

Figure 9: L/100km vs fuel type outbound

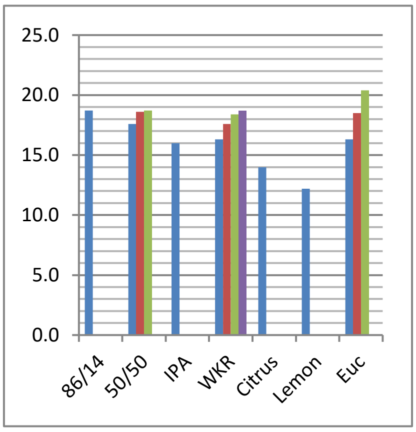
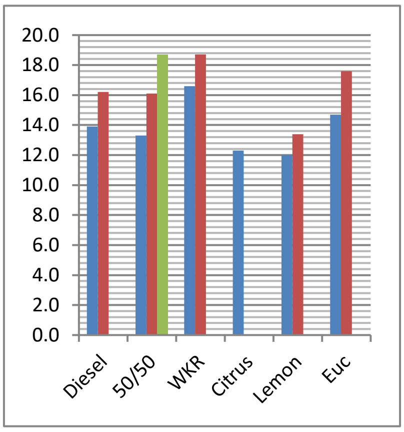


Figure 10: L/100km vs fuel type



Statistical analysis

Table 5 : Statistical analysis

Student t-test outcomes		L/100km		No of samples		Significant (@ 95%)
1st variable	2nd variable	1st mean†	2nd mean†	1st	2nd	
All trials						
Diesel	All other	12.3+/-1.5	13.4+/-1.1	7	23	No
Diesel	Citrus/Lemon	12.3+/-1.5	9.9+/-2.3	7	4	Yes
Diesel	Cit/Lem/LemEuc	12.3+/-1.5	10.5+/-2.3	7	5	No
Diesel	IPA/C/L/Et-EtAc	12.3+/-1.5	10.6+/-1.6	7	7	No
Diesel	W/L-Eu/Eu/D-Eu	12.3+/-1.5	14.9+/-1.4	7	11	Yes
Diesel	50/50	12.3+/-1.5	13.7+/-2.8	7	4	No
Diesel	Euc	12.3+/-1.5	14.5+/-1.9	7	7	Yes
Outbound country runs						
86/14**	WKR	18.7	17.8+/-1.7	1	4	No
86/14**	All other	18.7	17.2+/-1.3	1	13	No
86/14**	All additives	18.7	16.8+/-1.7	1	10	No
Return country runs						
Diesel	All other	15.0+/-14.5	15.3+/-1.8	2	10	No
Diesel	All additives	15.0+/-14.5	15.1+/-2.4	2	7	No
All country runs						
D+86/14	50/50	16.2+/-5.9	17.2+/-2.2	3	6	No
D+86/14	Lemon	16.2+/-5.9	12.6+/-1.9	3	3	No (Yes @ 90%)
D+86/14	WKR	16.2+/-5.9	17.7+/-1.1	3	6	No
D+86/14	Euc	16.2+/-5.9	17.5+/-2.7	3	5	No
D+86/14	All other	16.2+/-5.9	16.4+/-1.1	3	23	No
D+86/14	All additives	16.2+/-5.9	16.1+/-1.3	3	17	No
All outbound vs All return country runs						
Outbound	Return	17.3+/-1.2	15.3+/-1.5	14	12	Yes
City runs						
Diesel	50/50	12.2+/-1.4	13.2+/-2.7	7	5	No
Diesel	Euc/B Euc/D+Eu	12.2+/-1.4	13.3+/-2.2	7	5	No
Diesel	All other	12.2+/-1.4	13.0+/-1.1	7	18	No
Diesel	All additives	12.2+/-1.4	12.9+/-1.4	7	13	No

Findings are contained in Table 5. Trial categories are coloured blue, and signi-ficant results green. For sets of more than four results for the test fuels (except for D+86/14 vs lemon for com-bined country runs), two-sample Student t-test fin-dings at 95% confidence level are reported. Results are presented in six blocks, (a) all trials, (b) outbound country runs, (c) return country runs (d) all country runs, (e) all outbound vs all return country runs and (f) all city runs. There was insufficient data for two of the return country runs. For all trials, 50/50 blends containing eucalyptus perfume perfor-med significantly worse than diesel fuel. Conversely, 50/50 blends containing citrus or lemon perfumes were signif-cantly better than diesel fuel. An equally important finding, is that there was no significant difference between diesel fuel and the most tested experimental 50/50 diesel/WVO blend. Country runs saw no significant differences apart from between all outbound runs and all return runs where the impact of the different prevailing conditions is borne out. Notwithstanding this, one of the best performing experimental fuels, 50/50 blend with lemon perfume when assessed for all country runs, was close to presenting a significant difference (t-stat [2.5] not > t-critical [2.8] and P two-tail [0.06] not < alpha [0.05]). This run showed significant difference at the lower, 90% confidence level. City runs showed no significant differences between fuel types.

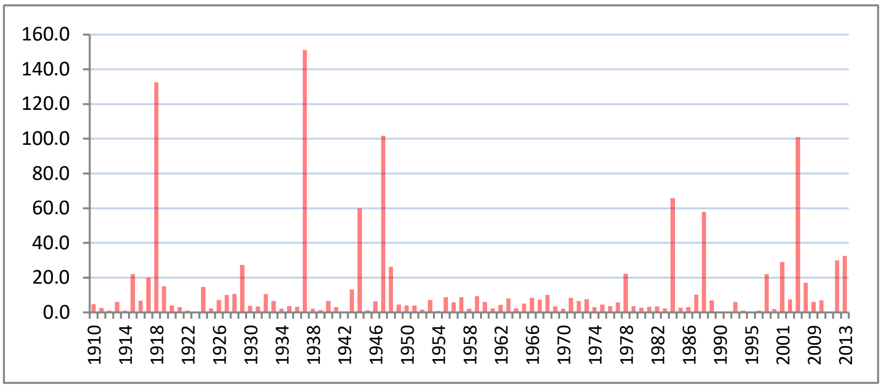
4 Potential for improved safety by using high flashpoint fuels

Vegetable oil flashpoints range from 150°C (Babassu oil) to 400°C (Cottonseed oil). These are higher than any other kind of fuel for example biodiesel 130°C, diesel 62°C, ethanol 16.5°C, methanol 11°C, dimethyl ether -41°C, petrol -43°C, diethyl ether -45°C, LPG -104°C, CNG/LNG -188°C and hydrogen -253°C. All current fuels are more dangerous than any of the vegetable oils. Diluting vegetable oil with diesel fuel reduces the flashpoint for example to between 110 and 120°C for a 50/50 blend [16]. The impetus in terms of safety should therefore be to use pure, undiluted plant oil.

An attempt is made to establish the reduction in loss of life which might occur if all fuels were vegetable oil by assessing the number of deaths caused by events involving current fuels and fuel-like substances. Two sources of data are used namely road accidents involving fire [17-21] and 616 non-natural accidental explosions which occurred in the period 1910-2013 (Figure 11) [19, 22-33]. The full explosion list is available on request.

Analysis of these events shows that over time, explosions keep happening with high and low loss events occurring in a cyclic manner. Generally, the greater the confinement the greater is the extent of harm caused, with the exception that some of the most devastating explosions occur in the open air as so-called unconfined vapour cloud explosions (UVCEs). With munitions designed to be harmful, the confinement is of the explosive material in its casing. With mines, tunnels and any form of building, the confinement is by the enclosing structure.

Figure 7 : Deaths per explosion for 616 events 1910-2013, which caused 11,466 deaths



In the open air, the change from deflagration (burning) of a cloud of vapour to deto-nation (explosion) depends upon the extent to which obstacles are encountered as the flame-front progresses. The change from deflagration to detonation occurs when the flame velocity reaches and then exceeds the speed of sound [34-37].

Natural gas caused most of the explosions followed by petrol, propane, butane, solvents, dust, LPG, kerosene, ethylene, acetylene, hydrocarbons and crude oil. Natural gas also caused the most deaths followed by agricultural chemicals, LPG, petrol, propane, dust, solvents, LNG, propylene and diethyl ether. The greatest number of deaths per event was caused by diethyl ether, followed by agricultural chemicals, LNG, propylene and LPG. Although factories have the most events and caused the most deaths, the worst events in terms of deaths per explosion are those involving pipelines, roads, and large scale occupied premises. To prevent this, it is reasonable to suggest that reticulation of gases by pipeline and gas supply to multiple occupancy premises should be reconsidered. The US has the highest number of events and of deaths. This does not suggest that this country is less responsible rather, it shows that its data is more readily available internationally. In contrast, the only event listed for North Korea is one which remained unreported for a considerable period and where help from other countries was initially declined. The event however appears to have been so large that the country acceded to allowing access to the International Red Cross. It was not until much later that North Korea published details of what had happened. Deaths per explosion were highest for the former USSR followed by Congo, North Korea, Mexico, Germany, Bangladesh, Ukraine, Venezuela, Spain, Kenya, Iran, Singapore, Turkey, Nigeria, Thailand, China and South Korea. Twenty four other countries registered 50 or less deaths/explosion.

The total number of deaths caused by the 616 events was 11,466 (111.3/year). This compares with the International Labour Organisation (ILO) figure of 22,898 deaths in 25 years from 1969 to 1993 (915.9/year) caused by all non-natural causes including warfare and malicious acts [30]. Clearly the latter figure should not be used in the present context. However if the ILO analysis is correct, the higher figure provides a glimpse into the totality of deaths which might be caused per year from all fire-related events involving fuels. Neither of these figures will allow for non-reporting and the reluctance of many countries to publish at all. Openly reporting, analysing and learning from accidents when they happen is the best way to ensure that they do not recur or at least, to minimise that occurrence. Charts showing explosions, deaths and deaths/explosion over the whole period, analysed by country, by substance involved and by premises involved are available on request.

Current world population is 7.6 billion people [38]. Using the UK and US derived figures of 0.71 and 0.94 road accident fire-caused deaths per million population and assuming that the rest of the world is the same as the UK and the US yields a potential loss-of-life in the range 5396 to 7144 persons/year. If all fuel was replaced with vegetable oil, the potential for loss-of-life saving is all of these plus 111.3 persons/year from explosions established above. This is a loss-of-life saving in the range 5507 to 7255 persons/year. The reality presently because biofuel as a whole is such a small portion of total energy, is that the non-volatile fuel use advantage will be diminished to an estimated 0.5% x 5507 to 7255 = 27.5 to 36.3 persons/year. This assumes that all biofuel is straight vegetable oil whereas most in fact is biodiesel and blends of biodiesel with conventional fuels.

5 Availability and status of non-food oil-producing species

Vegetable oil fuel is presently being sourced entirely from food oils, principally low-acid rapeseed (Canola) oil. Unless this changes, it will ultimately lead to mass starvation. This is neither desirable nor necessary. A listing of 204 non-food oil-producing species and 73 species cultivated principally for food production has been compiled and is available upon request. The distinction between these two sub-sets is not rigid as all species have some use and often that includes use as food or food supplementation. Of the non-food species 18 are salt tolerant and 34 are capable of growing in arid areas (Tables 6, 7). Of the total of 277 species 175 are trees, bushes or large shrubs and 102 are ground crops. The latter are easier and therefore cheaper to harvest but tree crops once established produce for many years without the need to re-sow. Ground crops are mostly grown as annual plants. Thirty of the non-food species have an average crop seed yield of 0.95 t/ha/yr and 27 food-related species yield an average of 1.38 t/ha/yr. These are sufficiently similar to suggest that with cultivation, there is oil available for fuel use without using food oils. Highest crop seed yielding non-food species are Torchwood (*Canarium indicum*, 4-7 t/ha/yr) [39] and Pongam, Karanji, Honge or Indian Beech tree (*Milletia pinnata*, 3-5 t/ha/yr) [40]. Highest crop seed yielding food-related species are the Oil Palm tree (*Elaeis guineensis*, 5.95 t/ha/yr) and Coconut Palm tree (*Cocos nucifera*, 2.67 t/ha/yr).

Table 6 : Some salt tolerant species

	Common name	ICN name
1	Arak or Toothbrush tree	*Salvadora persica*
2	Beaded Samphire	*Sarcocornia quinqeflora*
3	Cabbage Palm	*Sabal palmetto*
4	Glasswort	*Salicornia persica*
5	Long-spiked Glasswort	*Salicornia dolichostachya*
6	Marsh Samphire	*Salicornia bigelovii*
7	Perennial Saltwort	*Sarcocornia fructicosa*
8	Pinot peanut	*Arachis pintoi*
9	Saltmarsh Mallow	*Kosteletzkya virginica*
10	Sand Rocket	Diplotaxis tenuifolia
11	Scurvy Grass	*Cochlearia officinalis*
12	Sea Asparagus	*Salicornia brachiata*
13	Sea Buckthorn (Common)	*Hippophae rhamnoides*
14	Sea Mango tree	*Cerbera manghas*
15	Sea or Bengal Almond	*Terminalia catappa*
16	Sea Radish	*Raphanus raphanistrum*
17	Sea Rocket (American)	*Cakile edentula*
18	Sea Rocket (European)	*Cakile maritima*

Of the thirty non-food species, the average seed oil content is 34.8% and for three food-related species, the average is 47.7%. Highest non-food seed oil content species are Kukui Nut tree (*Aleurites montana*), 59% [41], Bagilumbang tree (*Aleurites trisperma*), 55% [42], Hunters Nuts tree (*Omphalea megacarpa*), 57%, Torchwood (*Canarium indicum*), 50.9% and Mahwa tree (*Madhuca indica*), 50%. The highest food-related species seed oil content is Oil Palm (*Elaeis guineensis*/*E. oleifera*), 49%. These figures also indicate the potential viability of using non-food species for fuel.

It is the combination of salt tolerance and drought resistance of some of the plants which leads them to be particularly promising for fuel production in desert/semi-desert areas and also in arid and semi-arid coastal margins.

Plants of the *Salicornia* genus are being heavily researched and several trials are underway. Some examples where cultivation of biocrops has been performed or planned are *Salicornia* spp and Salltmarsh Mallow (*Kosteletzkya virginica*) in Bahia Kino, Sonora, where planned production is 2600 t/yr for biodiesel and 52,500 t/yr for solid biofuel from 480 ha. Genetic research is also underway here to improve cetane number, oxidative stability, cold-flow properties, lubricity and productivity. An integrated seawater village is planned combining living, recreation, tourism and farming of shrimps, seaweed, bivalves, fish, *Salicornia*, mangroves, microalgae, *Artemia* and salt [43-45].

Some other cultivation activities are *Salicornia* – 4500 acres in Eritrea, also in Ras al-Zawr Saudi Arabia, Kahuku Hawaii, San Francisco Bay California and Yuma, USA; other large areas of natural growth in protected wilderness areas are being partially exploited eg Dawlish Warren & Hayle UK, Texel Holland, Wilhelmshaven Germany and Alicante Spain. *Jatropha* – 80,000 acres in India, 75,000 acres in Brazil, also in Costa Rica, Dakatcha Woodland Kenya, Tamil Nadu, Ghana and Uganda. Other species being experimentally grown are 250 acres of algae in Karratha Australia microalgae in India, *Dunaliella* microalgae in Israel, *Miscanthus* in Iowa USA; Sweet Sorghum in Brazil; Switchgrass in Loudon County USA, *Camelina* in USA, Sask Mustard in Canada and Giant Reed in USA.

Table 7 : Some arid area growing species

	Common name	ICN name
1	Arak tree	*Salvadora persica*
2	Argan tree	*Argania spinosa*
3	Beaded Samphire	Sarcocornia quinqueflora
4	Ben tree	*Moringa peregrina*
5	Bladderpod	*Physaria fendlerii*
6	Blue Flax	*Linum lewisii*
7	Brahea Palm	*Brahea salvadorensis*
8	Buffalo Gourd	*Cucurbita foetidissima*
9	Artichoke Thistle	*Cynara cardunculus*
10	Crown flower	*Calotropis gigantea*
11	Desert False Indigo	*Amorpha fruiticosa*
12	Desert Sunflower	*Helianthus anomalus*
13	Egusi	*Cucumeropsis mannii*
14	Firestick/Pencil tree	*Euphorbia tiraculli*
15	Ghaf tree	*Prosopis spicigera*
16	Glasswort	*Salicornia persica*
17	Horseradish tree	*Moringa oleifera*
18	Jojoba	*Simmondsia chinensis*
19	Karir tree	*Capparis decidua*
20	Marsh Samphire	*Salicornia bigelovii*
21	Milkweed	*Asclepias syriaca*
22	Mongongo Nut tree	*Schinziophyton rautanenii*
23	Mustard Greens	*Brassica juncea*
24	Palestine Pistachio	*Pistacia palaestina*
25	Patawa tree	*Jessenia bataua*
26	Pinot Peanut	*Arachis pintoi*
27	Quechua or Goosefoot	*Chenopodium quinoa*
28	Royle tree	*Prinsepia utilis*
29	Sea Buckthorn tree	*Hippophae rhamnoides*
30	Sea Radish	*Raphanus raphanistrum*
31	Sea Rocket, American	*Cakile edentula*
32	Sea Rocket , European	*Cakile maritima*
33	Sesame	*Sesamum indicum*
34	Sprengel Seed	*Euphorbia lagascae*

6 Land available for renewable energy production

A major concern associated with the production of biofuels is the current reliance on rapeseed, sunflower, cottonseed and palm oils. There is competition between food and fuel uses of these edible oils, posing somewhat of a moral dilemma. The issue is being debated in scientific journals as well as in the popular press but there are few actual scientific studies that help to clarify this [46]. Because food crops have been cultivated for many years, it may actually be wiser to use these for fuel by producing more of them, rather than by opting to use new, less understood non-food species. That is, apart from their need for arable land.

The global land surface of 256 countries is 14,900 Mha [47-49]. Human related land-use is between 7700 and 9900 Mha. 5000 to 7200 Mha is unused wilderness of which 3200 Mha are declared protected areas and are unavailable leaving 1800 to 4000 Mha of wilderness available. Currently unused, potentially productive land which may be considered to be available for the cultivation of sustainable energy crops is 400 Mha [46]. In energy terms, the current world requirement is 550 EJ/yr. If biomass was to completely replace current fossil-derived fuels, estimates between 4400 and 14,100 Mha would be required and this is clearly not possible [46]. Many of the arid area growing species are declared weeds in certain countries and others which have not yet been cultivated may become invasive and prove difficult to eradicate. Cultivating previously non-cultivated lands also results in loss of soil black-carbon taking many years to recover. An example of this is the draining of peat bogs to create farmland [50]. Notwithstanding these difficulties, potential for energy production by new sources has been assessed by various workers (Hoogewijk, Smeets, Doornbosch, Faaij) [46]. Collectively, their predictions range from 30 to 1400 EJ/yr with an average of approximately 400 EJ/yr. In the next 21 years to 2035, world energy use is predicted to increase by 20% from 550 to more than 600 EJ/yr according to the World Nuclear Association [47]. The latter organisation advocates the use of nuclear power both because it is an extremely dense form of energy and because it saves other natural resources. WNA also describes nuclear energy as 'clean' - correct in CO_2 emission terms but the author suggests, not in any other sense. *'If the Romans had had nuclear power, we would still be dealing with their waste' [51].* The author considers the use of nuclear power to be inappropriate until a safe process is found which also does not produce radioactive waste.

By taking the average future energy value of 400 EJ/yr postulated above, it is possible for the world to create sufficient energy to last until 2035. WBGU [46] states that 34% of world land area is used for agriculture (5000 Mha). Of this 1500 Mha is arable, 2500-3500 Mha is pasture, 20 Mha are used for growing fuel, and cities occupy 200-300 Mha, usually on low-lying prime agricultural land (Faaij, Salvatore) [46]. 80% of farmland is used for rearing cattle which provide only 17% of world food needs (Steinfeld) [46]. In the 40 years from 1963 to 2003, farmland has increased by 460 Mha.

If we ignore the politics and complexity of energy distribution, use of a 600 km x 600 km area of the Sahara Desert (40 Mha) could create current world energy needs using photovoltaic solar power generation [46]. A similar area would be required using solar thermal energy production [52]. This in area terms alone appears possible. A 20-member 2009 German-led international consortium planned the *Desertec industrial initiative* formed in Germany as Dii GmbH, to develop concentrated solar power (CSP) in the Sahara Desert. This was to be a combination of mirror arrays, heat-transfer fluid filled receivers and steam-turbine power generation using natural gas at night [53]. The plan was to distribute power to Middle East and North African (MENA) countries as well as Europe and Iceland using high voltage direct current transmission. It is understood that the Moroccan first stage was started. The consortium claimed that 0.3% of the Sahara Desert (2.8 Mha) would be sufficient to power Europe. The project was abandoned in 2013 however, as being too expensive (€400 billion) with its aim of producing 100GW by 2050, and as being 'utopian'. Hence political and energy transmission and storage realities are likely to mean that solar power is not the complete answer. Rather, where arid land or land-sea margins can be used to grow oil-producing species, this should be encouraged provided that adequate steps are taken to prevent social upheaval, escalating commodity prices and reduced biodiversity. Equally where countries have a high incidence of solar radiation (eg Australia), use of solar power should be encouraged. A reportedly more efficient way of producing biofuel is by the use of algae for example in Brazil where 5000L/yr can be manufactured from a reactor containing 3.5km of tubes occupying 10 m^2 of land [54]. Similarly the race is on to find decomposer fungal enzymes which can help to produce second generation biofuels more efficiently [55] and to produce biofuel from seaweeds.

7 Social and environmental considerations

Countries which have a mandate to produce biofuel to offset the rising cost and reducing availability of fossil fuels following the 1992 EU-US Blair House Agreement [56] and limited ability or desire to use their own lands for fuel production, are buying land in other countries on a large scale. This 'land grabbing' is unregulated and less than transparent. The International Land Coalition (ILC) is drawing attention to this phenomenon. ILC's vision is that *'secure and equitable access to and control over land reduces poverty and contributes to identity, dignity and inclusion'* [57]. Europe is described as the central driver of this land acquisition because it imports much of the raw materials it uses. In addition some 27 countries as well as the EU, Brazil and the US have biofuel mandates. Eleven countries mainly in East Africa and Southeast Asia account for 70% of the 'grabbed' land according to ILC. From 1006 transactions in the period 2000 to 2012, ILC shows that 70.2 Mha of land were acquired as claimed, equal to nearly half of the size of Western Europe. China announced plans in 2010, to set up ethanol projects in a range of African countries. Malaysia's *Sime Darby* and Finland's Singapore-based *Nesté Oil* are claimed to be exploiting palm oil to meet European needs according to Grain [58]. Sime Darby has developed 500,000 ha in Malaysia for palm oil production and plans a further 220,000 ha in Liberia. In the first 10,000 ha stage of this development 15,000 people were displaced [58]. In Gabon, Singapore-based *'Olam'* plans to clear 50,000 ha for a palm oil plantation within a 300,000 ha concession area provided by the Gabon government. In areas like this as well as deforestation and displacing of people, available water is being consumed by the plantations and wildlife species such as gorillas and orangutans are under threat. Some other examples of countries where peoples are being displaced are Kenya, Sierra Leone, Guinea, Brazil, West Papua and Colombia.

Large-scale cultivation of species which have been used for thousands of years by local populations can adversely affect them in other ways as well as displacement. Their normal sources of herbs, food and medicine can become unaffordable resulting for example in a drop in per capita caloric intake. To ensure minimisation of these adverse social impacts WBGU [46] has proposed a series of *'guard rails'* for example recommending that *'the amount of land available must be sufficient to ensure a daily intake of all people, of 2700 kcal'*. Given that over 900 million people are presently 'food insecure' this means that all available farmland must be used primarily to produce food. *'There are alternative sources of energy but there are no alternatives for food'* [46]. A second guard rail is proposed to ensure that *'all humans receive between 700 and 1000 kWh annually to meet their basic energy needs'*. A third guard rail proposal addresses health and its continued good state as being '*a fundamental human right'*. Without enough food in the world presently it is difficult to see how we can also provide fuel, even with our ability to continually improve production efficiencies.

8 Population

Human population has been growing exponentially over nearly all of recorded time. This cannot continue even if crop yields were also to grow exponentially. Therefore the solution to the current food plight, overcrowding, competition for resources, the fuel dilemma, impacts on climate, impacts on biodiversity and species extinctions, is for our population to stabilise. Not only must this happen, but it must also stabilise at a level which is sustainable. The difficulty in controlling world population is the fact that we live in many autonomous regimes. WBGU in its *'Summary for policy makers'*, advocates the setting up of a *'Global commission for sustainable land use'*. Clearly a wise initiative but one which the author considers should be preceded by the setting up of a *'Global commission for a sustainable population'*. No country will be inclined to stabilise or reduce its population in isolation, given fears that other countries would take advantage. The effort must be universal.

Sustainable Population Australia Inc stated in its February 2014 newsletter "*Most problems in the world today, such as climate change, stem from one immense problem which seems to be the 'elephant in the room' that no-one wants to talk about. This problem is our ever expanding population"* [59]. Current world population occupying 244 countries is 7.13 billion people [60, 61]. Human beings were described recently by the famous environmentalist Dr David Suzuki as a *'cancer on the planet'* [62] and similarly by Paul Ehrlich in the 1970s in his book *'The Population Bomb'* [63]. Sir David Attenborough said *'I've never seen a problem that wouldn't be easier to solve with fewer people'* [64]. The population is predicted to increase by 22% from 1999 to 2030 (UN Food and Agriculture Organisation) [46]. 923 million people are presently 'food insecure' [46, 65] and China with 1300 million people will more than double its energy use by 2030. The rate of world population growth and the extent to which it is accelerating is indicated by the time taken to double the population. The doubling time in 1715 from 0.38 to 0.75 billion was 544 years, in 1804 it was 304 years, in 1881 166 years, in 1927 123 years, in 1960 79 years, in 1974 47 years and in 1999 the population doubling time from 3 to 6 billion was 39 years [66].

9 The post fossil fuel dilemma

This work makes clear that vegetable oil fuel, the full range of biofuels and even the whole spectrum of safe renewable forms of energy post fossil fuel, cannot cater for current energy needs and therefore certainly not for any increasing demand as our population continues to rise. Any entity which has fixed inputs cannot increase its outputs indefinitely - *'Only mad men and economists believe that infinite growth is possible in a finite world'* [67]. The only realistic way that indefinite economic growth can be contemplated is by circumventing the *'finite world constraint'* by developing communities and seeking resources outside of our present planet. For example, first by forming permanent self-sufficient orbiting communities and later by using resources sourced outside of the limited Earth. Ultimately such activity would lead to the colonising of other worlds. This however, at least at the present and impending early stage, involves enormous energy resources and considerable danger, and is therefore unlikely to happen in the foreseeable future. Unless we appreciate the need to de-grow and to de-populate therefore, it is likely that we will become extinct before we are able to get out into space in any significant way. Although not the only form of existential demise we may face, Bostrom explains that the dominant existential risk is that the human race *'goes extinct before reaching technological and moral maturity'* [68].

Before fossil fuels

Before the fossil-fuel driven revolution, China and India were the largest economies in the world generating one third of world income [69]. Until the 18^{th} century energy was based on human and animal muscle power (80-85%), wind, water and the burning of charcoal and wood. Such energy was generated and used locally with little surplus that could be used elsewhere [70, 71]. The Chinese use of hydraulic power over many centuries required enormous labour made possible by its despotic system of control.

That these great communities had declined relative to the western world does not suggest that the west is cleverer but rather is considered a direct result of the discovery and use of fossil fuels – coal, oil and gas to underpin the industrial revolution and the associated increase in mobility. It is the view of Urry [70] that the fossil-fuel resource, once discovered, should have been used with care and with rationing and that long before now, we should have scaled-down and ceased its use.

Ecological sustainability and economic degrowth

Although there are indications of collapse in our economy such as the current fuel crisis and exponentially growing population, complete economic collapse has to-date been averted by technological advances and by exploitation of the environment. It is likely that this cannot continue. Instead of using our advanced technology in this way, with careful application and sufficient wisdom, we can use it to achieve equality and sustainability for all people, reversal of the greenhouse effect and the halting of extinction of other species. To achieve this, the mantra of *'economic growth'* needs to desist in favour of, for example, *'ecological sustainability'* in conjunction with selective *'economic degrowth'*.

Jevons' Paradox

'Energy is not just another commodity, it is the prerequisite of all commodities' [70]. Our use of fossil fuels commenced some three centuries ago, blossoming in the west in 1776 when Matthew Boulton opened the world's first 'manufactory' based on the use of James Watt's steam engine - *'I sell here sir, what all the world desires to have – power.'* [72]. Its use has permitted massive acceleration in all aspects of society including population, mobility and technology – the growth economy. But rather than acknowledging that growth cannot continue indefinitely, we rely on the assumption that technological improvements such as in food production and transportation efficiency, will continue to allow growth as they have done in the past. The fallacy of this, however, is that where an improvement in efficiency allows constant output with less input, our collective realisation of this increases demand, quickly eclipsing any gain in efficiency. This is known as Jevons' Paradox [73].

Continuing our current level of energy use unabated

We too are insufficiently aware of the downsides of technological innovation. We all know about the mass extinctions of species which are occurring and the threat of climate change. Many developed countries are doing something about their own population, about preventing yet more extinctions and about alleviating climate change. Few of us are sufficiently aware of the threats to our very existence which unabated technological innovation may pose. Many who advocate replacing fossil fuels with a range of non-fossil alternatives do not appreciate the potential harms to society in so doing. Rather, they act as though maintaining our current, artificially high, unsustainable rate of energy use may continue unabated.

The view of philosophers, sociologists and of many economists

Philosophers, sociologists and economists have been drawing our attention to the risks to human society associated with continued economic growth for centuries. Early examples are Aristotle [74], Adam Smith [75], Karl Marx [76], Thomas Malthus [77], Gilles Deleuze [78] and John Maynard Keynes [79] and more recent workers such as Nikolai Georgescu-Roegen [67, 80], Serge Latouche [81], Herman Daly [82], John Urry [70], Jan Van Bavel [83], Frederik Blauwhof [84], Minqi Li [85], Christian Kerschner [86], Kenneth Boulding [87], Charles Eisenstein [88] and Nick Bostrom [68]. Pre-biblical and biblical society abhorred any practice which did not produce required goods and services particularly, activities such as money-making, speculation, investment and marketing. Since the 1930s, many in modern society have advocated against the growth economy and in favour of various forms of economic degrowth. Few, however, particularly those who are in positions of influence, take these views seriously.

Chrematistics, oikonomia and existential risk

Chrematistics is the polite name used for our current growth-driven form of economics. It is perhaps better described as the cancerous money economy [89-92]. The old style of living first described by Aristotle as Oikonomia involved local production of goods and services for the benefit of the community without accumulation or individual wealth as objectives. When excess was produced it was distributed wisely or held for less fortuitous times again, for use within the immediate community. All forms of work were enacted for the public good not for private wealth. Philosopher Nick Bostrom uses the term *'existential risk'* to describe current threats to our very existence. Events that threaten us are both external and internal. An external example is asteroid impact. Bostrom claims, however, that the biggest existential risks are anthropogenic and largely related to potential future technologies. He says that a moral case can be made that existential risk reduction is strictly more important than any other global public good. Doing so will lead us into an indefinitely long and satisfying future. First however, we need to develop collective wisdom, technological foresight and the ability to mobilise a strong global response when threats are perceived [68]. Degrowth is already underway in the developed world consequent upon the internet. Other individual actions are happening such as the Tiny House Movement, Voluntary Simplicity Movement, Transition Towns movement, Creative Commons, Cohousing and free and open exchange of information in the form of Peer-to-Peer (P2P) practices. Further, advocates of degrowth suggest that developing countries should be allowed to continue growing. Unfair as it may seem, even this could lead to catastrophe. Regardless of how we achieve it, degrowth needs to be an action voluntarily entered into rather than being imposed upon us – a consequence of collective realisation [62, 93].

Complete social re-organisation

John Urry cites Karl Marx, David Nye [94], Mimi Sheller [95] and Frank Geels [96] in suggesting that any change in energy source will require a complete social re-organisation and is most unlikely to happen quickly, if at all. He suggests that there is a 40-year lag between starting to make such a change and actually achieving it. He suggests that Adam Smith, James Boswell, James Watt and Matthew Boulton would indeed be amazed how the fossil fuel societies that they saw the birth of in the late 18th century have turned out now to have such systemic dysfunctional consequences. Energy indeed is the root of very many problems' [70]. It may be a start that Herman E Daly a former economic advisor to the World Bank has advised the bank that a growth economy is actually the root of many of the problems we face today [97]. The author believes that given the track record of the World Bank, a new and separate world organisation is needed if we are indeed to move towards so-called 'economic sustainability' and a sustainable population. Samuel Alexander of the University of Melbourne puts it more succinctly. *'Given the magnitude and multifaceted nature of the global predicament, any response to it that merely tinkers with growth capitalism will be grossly insufficient. An adequate politico economic response must reflect the gravity of the problems and degrowth is the most coherent framework within which to formulate a response. Nevertheless it is worth acknowledging that however necessary it is for there to be committed politico economic response, it is highly unlikely to ever eventuate in the absence of a cultural revolution in attitudes toward Western style consumerism. That is to say, the voluntary emergence of degrowth in a consumerist culture is essentially a contradiction in terms, such that if a politics of degrowth is ever to emerge it will almost certainly have to be driven from the grassroots up by a culture that embraces some notion of 'sufficiency in consumption'* [98].

10 Conclusions

1. The developed world has some interest in biofuels particularly in Germany where a rapeseed oil fuel standard and many service outlets are available. Sixty two countries have set objectives to use a certain percentage of sustainable fuel by defined future dates. This however appears to be causing a problem rather than solving one (as is purported to be the justification), through the impacts on people and other species occupying lands in developing countries displaced by the need for growing developed-world fuel crops.

2. Developed countries are likely to be influenced in their relative lack of enthusiasm for biofuels, by ample availability of fossil fuels. In Australia, which has a wealth of conventional fuels available, development is of progressively more volatile fuels some of which are not sustainable for example mineral LPG, CNG, NG, LNG, CTL and GTL. Progressively more complex fuel-production methods are being used as 'easy' resources dry up, such as oil from shale, underground coal gasification (UCG) and coal-seam gasification (CSG). They are being exploited without sufficient regard to the additional cost and risk.

3. Relatively fuel-starved developing countries are enthusiastically researching into the use of vegetable oil. This enthusiasm is not limited to any one particular use or fuel type but encompasses numerous vegetable oil species both as neat oils and in blends for use in vehicles, in agriculture and in stationary engines such as for power generation.

4. Exhaust emissions vary when vegetable oil is used, both alone and in blends. However considerably more workers claim decreases rather than increases in emissions (91 vs 54). Engine performance parameters are either equal to or improved over diesel fuel at least in the short term. Long term, many workers have the view that difficulties associated with the higher viscosity of vegetable oils, greater difficulty in producing conventional fuel spray patterns, acidity and polymerisation, have yet to be overcome. This situation will improve only when large-scale on-road trials are conducted using engines specifically designed for vegetable oil. Work done by Kleinova in the Slovak Republic however, monitored 171 dual-fuel adapted conventional trucks over two years travelling a collective distance of 2.9 million km and found them to be without problems running on 100% vegetable oil. Nevertheless an engine known as the Elsbett Motor was developed in Germany in 1977 and produced for a number of years until interest in vegetable oil fuel waned. It could easily be reinstated as demand for sustainable fuel rises.

5. The increased safety associated with the use of non-volatile, non-flammable fuels such as straight vegetable oil has been highlighted. Here, the findings of an appraisal of 616 explosions involving fuel and fuel-like substances over a 103-year period together with US and UK annual vehicle-fire accident statistics are combined to postulate the potential life-saving if all fuels were non-volatile. Without suggesting that these are the ultimate figures given the limitations of the data obtained, between 5500 and 7200 lives per year would be saved if non-volatile fuels were to replace all other fuel types.

6. There are numerous non-food vegetable oil species available for consideration some of which are already being grown in trial plantations. Of the 277 species addressed, 25 have been researched in test engines and found to be viable. Australia is an ideal candidate for trial growth given its large diversity of climate zones and the fact that many of the non-food species are either indigenous to the country or capable of being grown. For Australia to do this it might need to moderate its current attitude towards so-called 'weed' species for example Artichoke Thistle, Sea Radish, Indian Beech tree, Horseradish tree and Lincoln weed. The author considers that the greatest potential is for salt-tolerant land-sea margin growing species such as Sea Asparagus, Common Sea Buckthorn, Sea Mango, Sea Almond, Sea Radish and Sea Rocket.

7. There is only enough land available to meet some 16% of the current demand if all energy is to be produced in the form of biofuels. The practice of 'land grabbing' in developing countries by developed nations lacking sufficient of their own agricultural land has been highlighted. It is clear that presence of people and wildlife 'in the way' of these biofuel needs, take second place. This practice requires regulation.

8. The continuing exponentially rising world population and associated inequalities of consumption between developed and developing countries have led to fundamental difficulties such as inequitable availability of food, energy and sanitation. All of the world's human-caused difficulties would be overcome if we controlled our population to a sustainable level and abandoned the current economic mantra of 'indefinite growth' in favour of some form of 'economic degrowth'. It is unlikely that such a change will succeed by dictate. Rather, there needs to come into being a 'collective realisation' and resulting 'collective conscience' to cause change. Many fear that given human nature this is most unlikely to happen. Others argue that, as we ourselves are a part of nature, our survival instinct and associated greed are themselves natural. The difference between humans and other species perhaps, is that we realise that change is needed and we have the ability to make it happen. This in the author's view is our collective moral obligation.

11 Recommendations

Diversion of future sustainable energy efforts in Australia towards development of safer fuels in particular, of vegetable oils in lieu of the inherently more dangerous fuels currently being developed.

Phasing-out non-sustainable fuels in Australia such as liquefied petroleum gas (LPG), compressed natural gas (CNG), liquefied natural gas (LNG), gas-to-liquids (GTL, eg methane-to-methanol) and hydrogen.

Progressively phasing-out all forms of non-sustainable fossil fuels in Australia such as black-coal, brown coal, mineral oil, shale-oil, fracked oil & gas and natural gas ahead of their complete depletion or of their becoming prohibitively expensive.

Initiation of large-scale on-road trials of a wide range of non-food vegetable oils in Australia used both in straight form (SVO) and as blends, in conventional compression-ignition engines

That Australia designs compression ignition engines specifically for vegetable oil use based on Rudolf Diesel's original design and Ludwig Elsbett's more recent engine (Motor).

Large-scale experimental cropping of non-food, arid-area-growing, halophyte species in this primary saline continent major parts of which are also secondary salt-affected consequent upon inappropriate agricultural activity. This should include careful exploitation of the 18% of the country which is desert by using low-level irrigation with both seawater and borewater.

That actual and serious consideration be given to controlling further population growth and economic growth in order to permit our survival and that of all plant and animal species which are not already extinct.

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