Biofuels
A viable approach to carbon reduction?

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CRed is a catalyst to stimulate new thinking and action that might not otherwise happen.
CRed Renewable Transport fuels Activities
What are biofuels?

First generation primarily from food crops

Increasing interest in non-food sources - lignocellulose, algae
Bioethanol: fermentation of glucose in starch
Sugar cane in Brazil, Corn (maize) in USA,
Sugar Beet or Wheat in Europe

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

A dilute solution of alcohol is purified by energy intensive distillation.

Substitutes to 5% for gasoline in all cars or E85 in flex-fuel vehicles
Biodiesel: transesterified plant oils
Rape in Europe, Soya in Brazil and USA,
Palm oil in Asia, Jatropha in many hot countries

Substitutes to 5% in any diesel vehicle and up to 100% in many vehicles.

Oleic
Palmitic
Oleic
alpha-linoleic

A sample of biodiesel from UEA’s collection built up during work on the EU Civitas project

Loading B100 into a EuroIV Scania bus
Bimethane from anaerobic digestion

The product gas is roughly equal proportions of methane (CH$_4$) and carbon dioxide (CO$_2$) which can easily be separated by cooling prior to sequestration of the CO$_2$.

CH$_4$ for power

CO$_2$ to store?

Picture from “Methane to Markets”, Andrew Needham, Biogen
Unlike most renewable energies, liquid biofuels come with baggage.
There are exciting prospects but significant dangers and massive complexities. As with so much energy and climate change policy the focus is on supply not demand.

- Food
- Fuel
- Agriculture
- Forests
- Climate change
- Politics
- Accounting
Long-term targets inadequate: Need rapid reduction in demand very soon

“In the short term there’s no other game in town other than demand”: Kevin Anderson, Tyndall Centre

Fig. 3. Schematic representing the importance of cumulative emissions and messages for policy makers.
“By continuing to stress long-term carbon mitigation targets, the UK Government is relinquishing opportunities for meaningful and timely reductions in energy demand, and consequently is forgoing urgently needed reductions in CO2 emissions. … Consequently, if the UK is to demonstrate effective leadership on climate change and actively pursue a 450ppmv pathway, it is incumbent on the Government to redress the balance of its policy agenda in favour of an early transition to a lower energy-consuming society.”
Fossil fuel emissions are accelerating

Approx 300 GT C from fossil fuels and approx 150 GT C from land-use change since 1850

Annual increase:
2.7% over last 100 years
3.3% over last five years
Trajectory of Global Fossil Fuel Emissions

50-year constant growth rates to 2050

- B1 1.1%
- A1B 1.7%
- A2 1.8%
- A1FI 2.4%

Observed
- 2000-2006 3.3%

Actual emissions: CDIAC
Actual emissions: EIA
450ppm stabilisation
650ppm stabilisation
A1FI
A1B
A1T
A2
B1
B2

CO₂ Emissions (GtC y⁻¹)

Raupach et al. 2007, PNAS
Rate of increase of atmospheric CO$_2$ doubled since Mauna Loa measurements began.

Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration Seasonally Adjusted

Approximately 1ppm increase per year 1960s

Approximately 2ppm increase per year 2000 on

Data from Scripps CO$_2$ Program  Last updated March 2008
Large stores of carbon locked up in permafrost peatlands and biomass under increasing risk

Fig. 6.8.
C pools vulnerable to global warming and land-use change. They include: (i) frozen ground, (ii) tropical and high-latitude peatlands, and (iii) vegetation susceptible to land use and fire

“Saturation of the Terrestrial Carbon Sink”
Josep G. Canadell et al, 2007
Global warming impacts already apparent
Glaciers retreating around the world

Himalayan glaciers store about 12,000 cubic kilometers of freshwater in ~15,000 glaciers and are the lifeline for millions of people (IPCC, 2007)
"Glaciers in most parts of the world are rapidly melting and their loss will affect 2 to 3 billion people"

From:
“Retreating Glaciers”
Lonnie G Thompson,
Leverhulme Symposium, 2008
September 2007: dramatic impact of global warming; Arctic sea ice extent was a record low of 4.3m square kilometres.

Previous record low: 5.6m square kilometres, September 2005

2007 shows nearly a 25 per cent reduction in ice extent in just two years

The North-West passage was open for the first time in living memory

Source: US National Snow and Ice Data Center, Colorado Univ, [www.nsidc.org](http://www.nsidc.org), 1 October, 2007
Exceeding critical atmospheric CO2 levels may lead to irreversible and possibly rapid change back eventually to a ten degree warmer world.

"Target Atmospheric CO2: Where Should Humanity Aim?"
James Hansen et al, March, 2008
The Earth has been cooling for 50 million years

Tibetan plateau

Himalayas

from space; pictures courtesy of NASA
Are we close to the ghg levels where ice may eventually disappear?

Decreasing CO2 was the main cause of a cooling trend that began 50 million years ago, large scale glaciation occurring when CO2 fell to $425 \pm 75$ ppm, a level that will be exceeded within decades, barring prompt policy changes. If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO2 will need to be reduced from its current 385 ppm to at most 350 ppm.... An initial 350 ppm CO2 target may be achievable by phasing out coal use except where CO2 is captured and adopting agricultural and forestry practices that sequester carbon. If the present overshoot of this target CO2 is not brief, there is a possibility of seeding irreversible catastrophic effects.

“Target Atmospheric CO2: Where Should Humanity Aim?”
James Hansen et al, March, 2008
Liquid biofuels contrast to biomass

UEA’s biomass gasifier
UEA’s biomass gasifier under construction
Biomass gasifier - first in England

1.4MWe, 2MWh

• Reduces UEA carbon footprint by 35 per cent
• 1990 to 2006: 239 per cent increase in student numbers
• 10 per cent increase in CO₂ emissions
• 53 per cent reduction in CO₂ emissions per student
• Biomass gasifier will reduce absolute CO₂ by 2009 by approx 25 per cent from 1990
"Energy security and climate change are two of the most significant challenges confronting humanity. What we see, in response, is the familiar capture of policymaking by well-organised special interests. A superb example is the flood of subsidies for biofuels. These are farm programmes masquerading as answers to energy insecurity and climate change. Not surprisingly, they have the depressing characteristics of such programmes: high protection, open-ended support to producers, and indifference to economic rationality."

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*www.ft.com/wulfforum*
Politics 2: subsidies for fossil fuels are massive and distort behaviour

Stern, p422; The fossil fuel subsidy level may be underestimated

In “Lives per gallon”, Terry Tamminen, 2006, estimates annual US federal tax breaks and other direct subsidies for oil to be in the range $65billion to $113billion, close to $1 per gallon.
“Current subsidies to biofuels in the United States are large, between $5.5 and $7.3 billion per year.”

“Biofuels subsidies continue to grow rapidly in scope and scale, expected to soon reach $8-11 billion per year.”

“Under optimistic projections, it costs some $500 in federal and state subsidies to reduce one metric ton of CO2-equivalent through the production and use of corn-based ethanol.”

“Biofuels: At What Cost?”
Government Support for Ethanol and Biodiesel in the United States
Doug Koplow
Oct 06, www.globalsubsidies.org
Politics 4:
- and in Europe as well

The cost of obtaining a unit of CO2-equivalent reduction through subsidies to biofuels is very high, especially for biofuels produced from virgin materials. We calculate that subsidies per tonne of CO2-equivalent avoided are between € 575 and € 800 for ethanol made from sugarbeet, and around € 215 for biodiesel made from used cooking oil, and over € 600 for biodiesel made from rapeseed. Hence, even with best-case scenario assumptions for GHG reductions from biofuels, one could achieve far more reductions for the same amount of money by simply purchasing the reductions in the marketplace.
Politics 5: EU and UK mandates

Stem from the EU Biofuels Directive, 2003
Now part of EU and UK Renewable Energy Strategy

EU: 10 per cent of transport fuel consumption by 2020

UK Renewable Transport Fuel Obligation (RTFO) to be slowed to reach 5% in 2013-14 rather than in 2010-11.

A further £6 million to research being conducted by the Carbon Trust to accelerate the development of advanced sustainable biofuels technologies.

CONCERN WITH INDIRECT EFFECTS
The technical fix myth

• With biofuels (nuclear power...) we can fix our ghg problem and carry on behaving as before without major change.
• This model is wrong: a sustainable Earth is resource limited.
• Biofuels are not a technical fix and cannot create fuel security.
• They become valid only as one part of a comprehensive strategy to tackle transport emissions - including vehicles and travel patterns.
• Biofuels have been promoted without attention to the other essentials.
• In future we will need to obtain food, and fuel, and many other products from crops - this will be a massive challenge.
US bioethanol production has increased five fold since 2000 - could double again
Nearly one-third of corn crop

“Once all of the new construction currently underway is complete, the U.S. ethanol industry will be able to supply more than 13 billion gallons of ethanol, representing nearly 10% of the nation’s gasoline demand.”

Illinois is third largest producer
Ethanol accounts for nearly a third of US corn use - but still only five per cent of overall gasoline use.

But a major impact is to reduce soya planting and also to plough up virgin prairie for corn - direct and indirect land-use change.

Indirect effects: Nepstad and colleagues show the link between more US corn and Amazon deforestation

Figure 1. Economic teleconnections between US investments in corn-based ethanol production, Brazilian investments in sugar cane-based ethanol production and Amazon deforestation.

The chain is largely indirect through deforestation by cattle ranchers
Not just biofuels but animal feed especially

“Rising worldwide demands for biofuel and meat are creating powerful new incentives for agro-industrial expansion into Amazon forest regions.”

“The prospect of reducing global warming and keeping global average temperatures from rising no more than 2°C will be very difficult if emissions of carbon from tropical forests worldwide, and the Amazon in particular, are not curtailed sharply in the coming years.”

“Growing global demands for biofuel and animal ration provide new incentives to clear forest that are already colliding with a decade-long expansion of the Amazon cattle herd. Although some soya expansion takes place through the direct conversion of forest to soya, most of the expansion is onto areas that were previously cattle pasture, pushing up land prices in the process and capitalizing ranchers who can move on to acquire land holdings deeper into the Amazon forest region. This is particularly important given the prevalence of cattle ranching as a land use and as a driver of deforestation in the region.”

The Cerrado and other areas of Brazil are equally affected but less protected

“The Amazon and the Cerrado are particularly vulnerable. Interacting with climate change and land use, the upcoming stage of cellulosic energy could result in a collapse of the new frontier into vast degraded pasture.”

“There is now two or three times as much annual deforestation in the Cerrado as the Amazon.”

“There is no monitoring of deforestation outside the Amazon.”

Land use change and agriculture emissions are over two times transport emissions.
Indirect effects especially severe in wetland rainforest

“The draining of wetlands to produce any type of biofuel would produce a loss of stored carbon that would take hundreds of years to make up through the biofuels’ annual greenhouse gas savings.”
EU Biofuels Progress Report, January 2007

Good? OR BAD?
EU mandates can drive demand for palm oil for biofuels

Don’t put wildlife in your tank

Speak up before it’s too late

Visit www.rspb.org.uk/biofuelsaction to urge Transport Secretary Ruth Kelly to ditch this misguided policy.

Schematic of Neste proposed 800,000 tonne biofuel plant in Singapore - which will be the world’s largest
On current protocols, some companies are achieving reasonable GHG savings. But there is acknowledgement that we need to understand indirect effects.

Early experience – company performance

*Data for April to July 2008*
The “carbon debts” (in years) from land-use change caused by biofuels planting have recently been estimated.

But note

And also the impact on food prices - still higher than two years ago.
Population growth, poverty reduction, and the impacts of climate change will all increase pressure on food supplies.

“It is very hard to imagine how we can see a world growing enough crops to produce renewable energy and at the same time meet the enormous increase in the demand for food which is quite properly going to happen as we alleviate poverty.”

Professor John Beddington, UK Government Chief Scientific Advisor, March 6, 2008
“Global food production will need to double by the middle of the century just to meet demand. We have the knowledge and the technology to do this, as things stand, but the perfect storm of climate change, environmental degradation and water and oil scarcity, threatens our ability to succeed.”

Rt Hon Hilary Benn, Fabian Society Lecture, December 10, 2008
Peak oil already?
IEA World Outlook, November 2008

Flat oil demand requires four Saudi Arabias to be introduced
Impact on fuel prices, fertilizer prices...?
Coal to liquids if we don’t reduce demand...?
How will we cope with increasing global demand for transport fuels?

2005: 84 mbpd; 2050: 169 mbpd
Goldman Sachs Global Economic Paper, No 118, 2004

The increase will be driven by increasing prosperity in the developing world and by the production of ultra-cheap cars such as the $2500 Tata Nano.

The Tata Nano launched 10 January 2008.
Solution: Reduce demand before addressing supply

1. Reduce waste - cut demand
2. Use more efficient equipment
3. Switch to renewable energy

Change behaviour and innovate!
Demand reduction should be key

“The attempt to solve one problem--growing U.S. dependence on imported oil--is creating another far more serious problem. Fortunately this can be avoided. The 3 percent of U.S. automotive fuel supplies now coming from ethanol could be achieved, several times over and at a fraction of the cost, by raising automobile fuel-efficiency standards by 20 percent.”

EXPLODING U.S. GRAIN DEMAND FOR AUTOMOTIVE FUEL THREATENS WORLD FOOD SECURITY AND POLITICAL STABILITY
Lester Brown, November, 2006
http://www.earth-policy.org/Updates/2006/Update60.htm
Every day there are 10 million empty seats on UK roads

Radical initiatives can fill many of these

Getting average UK car occupancy back to the early 1960s level of 2 per car would save about 9 m tonnes CO2 - or about three times the saving (before land-use emissions factored in) that will come from the RTFO (Renewable Transport Fuels Obligation) for 5 per cent biofuels in 2010
More efficient equipment: innovate to create truly low CO2 emission vehicles

• The vehicle industry in Europe has repeatedly resisted reducing average fleet emissions to 120g CO₂/km.

• Even for 2012, the target has been relaxed because ‘biofuels’ and ‘soft measures’ can take up the slack.

• This is appalling and promotes additional ghg emissions in two unnecessary ways.

• The industry should aim for a maximum of 80g CO2/km (half today’s EU fleet average) by 2020 with further reduction thereafter.

Source: European Federation for Transport and Environment
The VW “One litre car”: 283mpg
30g CO$_2$/km

There’s a huge way to go in down-powering future cars to dramatically reduce CO$_2$ emissions
Biofuels from algae?

Phytoplankton:

1% of Earth’s photosynthetic biomass
but +/-45% of annual primary production
Micro-plants grow very quickly

Yields up to 100x conventional crops
Biofuel from Duckweed

**Input:** waste water (nutrients)

**Output:** protein

Duckweed biomass

**Output:** Bioalcohol from fermentation of cell wall sugars

**Output:** ‘Clean’ water

**Input:** CO₂

**Input:** Sunlight
One of the most exciting sources of renewable fuel is biowaste which can be converted to biogas through anaerobic digestion. Biogas contains about sixty percent biomethane which can be up-graded and tankered to a fuel depot or inserted into the natural gas grid.
Biomethane can save in favourable cases well over 100 per cent of fossil fuel CO₂ emissions.

Natural gas technology is in use today and can save over 20 per cent CO₂ emissions. CNG and ultimately biomethane is an ideal low emission fuel for long distance and urban fleets.

Probably 10 per cent of UK road transport fuel needs could be sourced by biomethane from waste - one-third of HGVs

A Hardstaff dual-fuel 44 tonne truck at UEA, April 2007

Natural gas technology can morph seamlessly to biogas when this becomes available: Hardstaff in UK about to run first vehicles on biogas
Malmo and other Swedish cities have success with gas-powered and now biogas-powered fleets
Solar collectors can harvest ten times more energy per unit area than plants. Solar concentrating power plants in hot, desert areas offer huge potential to provide renewable electricity for hybrid and electric vehicles.

Biofuels must only be made in innovative ways that do not conflict with food production and do not make greenhouse gas emissions worse. If vehicle emissions drop sharply then biofuels can play a valuable role in getting towards zero-carbon transport.
Support Trans-Mediterranean Renewable Energy Co-operation, TREC, a future source of renewable electricity

EUMENA is Europe, Middle East and North Africa


From: “Concentrating solar power for Europe, Middle East and North Africa - a roadmap to 2050”, Dr Franz Trieb, April 2007
Can HVDC of solar power from Africa provide renewable electricity for vehicle power? Perhaps with multinational vision and will

Areas of desert that could produce all the world’s and all the EU’s electricity

From: “Concentrating solar power for Europe, Middle East and North Africa – a roadmap to 2050”, Dr Franz Trieb, April 2007

“The sun-belt and the technology belt can become very powerful when they begin to understand themselves as a community: a community of energy, water and climate security; a community for their common future.”

H.R.H. Prince El Hassan Bin Talal of Jordan, Former President, The Club of Rome