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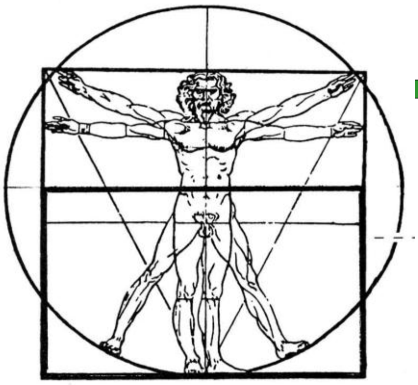

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GREEN PAPER PROPOSALS.

INTRODUCTION.

The following notes were originally a response to a request in The Independent newspaper to send in proposals for the Climate Change green paper. By and large we deal with considerations additional to those indicated in The Independent, whose judgement on climate change we generally uphold and respect. We are indebted to The Independent in galvanising us in this direction, the consequence of which is these proposals will now be submitted to government as part of the consultation on a Climate Change green paper.

Any proposals that are to be effective need to implement hard technological projects. That is why we mention some specific projects rather than a general legislative programme. There are many steps that can be taken to ameliorate climate change locally, and they can have a cumulative effect, but the steps which are presently envisaged are insufficient to prevent climate catastrophe and a much more urgent agenda is required, both nationally and internationally.

We list our proposals under the following topic headings:

- *Offshore Wind Farms and the Crown Estate Commissioners* (for background material see also appendix 1).
- *Stimulating Photovoltaic Industries* (likewise see also appendix 2).
- *Banning New Incinerator Construction, and the Alternatives* (see also appendices 5, 6, 7 and 8).
- *Research, Development and Manufacture – Algae CO_2 Bioreactors* (see also appendix 9).
- *Including Climate Change in the School Curriculum.*
- *Government Guidelines to Councils on Best Sustainability Practice.*

OFFSHORE WIND FARMS AND THE C.E.C.

Offshore wind farms are more efficient than land-based ones, energy efficiency being proportional to the cube of the wind velocity, which is generally higher offshore. It is also the case that large-scale wind turbines are more efficient than small-scale ones.

There have been many complaints from wind generation companies that the Crown Estate Commissioners (CEC) have and are stifling development of offshore wind farms in Britain. Britain, with the best characteristics for offshore wind generation in Europe is seriously lagging behind Denmark and Germany in the uptake of this technology.

Our proposals are to

1. Redirect revenues coming to the Treasury from the CEC so that money from selling offshore wind farm concessions is used to set up an offshore electricity grid, especially where that is most needed.
2. Change the obligation of the CEC away from maximising revenues from offshore wind farm auctions, in order to ensure that the greatest possible utilisation of offshore wind farms takes place.
3. Ensure that the CEC act efficiently and promptly in enabling the construction and operation of offshore wind farms.
4. Set targets for the construction of wind farms to match and eventually exceed those of other European states, in line with the higher wind energy density obtainable in Britain compared with other European countries.

STIMULATING PHOTOVOLTAIC INDUSTRIES.

There is a premium on renewable energy under the government’s ‘renewables obligation’. We believe that you can sell this power commercially at approximately £0.1 per kWh.

In Germany a particularly powerful subsidy is a government requirement that electric utilities be willing to buy electricity generated by small photovoltaic installations, such as those in homes and small businesses, at more than 27p per kWh.

We note that unlike wind turbine technology, photovoltaics is a rapidly developing technology that has not yet, but will, become a prudent method of energy generation.

In order to stimulate the British photovoltaic industry, we recommend a similar obligation on British electric utilities, at the very least of 20p per kWh.

BANNING NEW INCINERATOR CONSTRUCTION, AND THE ALTERNATIVES.

The government should ban the signing of new contracts for the construction of new incinerators as incompatible with Kyoto and other pollution requirements.

There are many low-pollution alternative methods to incineration of waste, including thermal depolymerisation bioreactors, and anaerobic digesters (see appendices 5, 6 and 7).

The government should develop an efficient national plan for locally processed (i.e. mainly British) recycling. If we can have a national electricity grid, we can have a national recycling grid (see appendix 8).

R&D AND MANUFACTURE OF ALGAE CO_2 BIOREACTORS.

The government should set up research and development into algae bioreactors and stimulate engineering implementations derived from these as a method of converting CO_2 to useful other products (see appendix 9).

INCLUDING CLIMATE CHANGE IN THE SCHOOL CURRICULUM.

The government should ensure information on climate change is included in the school curriculum.

For example, in comparison, we believe the Al Gore film ‘An Inconvenient Truth’ is being shown in schools in Sweden.

It is also possible for schools to implement many examples of sustainable solutions, some of which are later given in this article, in order to demonstrate to pupils some of the principles by which climate change can be tackled.

GOVERNMENT GUIDELINES TO COUNCILS ON BEST SUSTAINABILITY PRACTICE.

The government should issue guidelines of best practice in energy-conservation derived from optimum practice in Britain and elsewhere, for e.g.

1. *Electricity Generated with Powerful Wind Turbines.*
2. *Installation of Combined Heat and Power, (as in Woking).*
3. *Installation of Photovoltaics, (as in Woking).*

4. *Installation of Solar Heating Panels.*
5. *Installation of District Heating.*
6. *Installation of Heat Pumps in Council Flats* (see also appendix 4).
7. *Use of Bioreactors and Bio-digesters* (see also appendices 5, 6, and 7).
8. *Optimal Recycling* (see also appendix 8).
9. *Use of Biofuels.*
10. *Purchasing of Electric Vehicles for Council Business* (see also appendix 3).
11. *Minimising of Street Parking Charges for Electric, Honda Prius, Lexus or Similar Hybrid Vehicles, and Raising of Charges for SUVs.*
12. *Bicycle provision.*
13. *Sustainable Public Transport.*
14. *Structuring of Streetlight Contracts for Energy Efficiency Incentives.*
15. *Dimmable Control of Streetlights, (as in Oslo by the Echelon Company).*
16. *Implementation of LED (Light Emitting Diode) Traffic Lights.*
17. *Installation of Energy Efficient Light Bulbs in All Council Properties.*
18. *Model Energy Reviews of Public Buildings.*
19. *Model Council Energy Advice Units.*
20. *Installation of Swimming Pool Covers.*

APPENDICES.

1. WIND TURBINES.

The scale of the problem of climate change is so large, and the costs of solving it so immense, that it is essential that the most cost-effective means of tackling the problem are chosen. We sketch CO_2 saving and cost comparisons between *small-scale*, and inherently more efficient *large-scale* wind turbines, and note the difference between *onshore* and *offshore* sites.

Investing £2,000 in *commercial scale* wind turbine schemes will yield a greenhouse saving of approximately one tonne of CO_2 per year (I picked a recent commercial development in Perthshire for this calculation). The turbine will pay back the 'embodied' CO_2, emitted during manufacture and install, in approximately six months. Payback on investment is approximately two to three years.

In Brighton & Hove, where average wind speed is 5 metres per second, investing £10,000 in three *rooftop* wind turbines will also yield a greenhouse saving of approximately one tonne of CO_2 per year, and the turbines will pay back the embodied energy of manufacture and install in a minimum of three years. Payback on investment is more than 15 years (which I would anticipate is about the maximum life of most of these type of products). This is based on the 'Airdolphin Mark Zero', and uses manufacturer and reseller figures.

In London (wind speed 4 m/s), you would need to invest £20,000 (6 turbines), giving CO_2 payback in ~ 6 years, and payback on investment in over 30 years, certainly longer than the lifetime of the machine.

Given the massive potential in the UK for deployment of *large-scale* wind turbines, e.g. offshore, it seems crazy to invest in rooftop turbines, when you can get 5 times the benefit from investing in large-scale turbines. Not only this, but with large-scale turbines, you get all of your money back in three years, and you can then build another one!

The physics of wind turbines are such that large-scale just works better. Unfortunately, I think that the development of offshore wind is likely to be at best sluggish, unless the government invests the money to extend the electricity grid offshore, e.g. using long-distance DC loops, so that wind farm developers can come along and plug themselves into it, without having to build a more expensive network of *ad hoc* HV-AC farm-to-shore links. At the very least, the government could agree to foot part of the money for transmission, if the developer builds in room for expansion – in locations where this looks likely.

The UK is a very windy place (I believe we have more wind energy available than any other European country). With wind turbines, the machines are already close to their theoretical maximum efficiency, and the manufacturing process is unlikely to undergo any revolutionary changes. Pretty much all of the technologies involved – blades, bearings, generators – have direct equivalents in the motor, aviation and electrical industries, where R&D money has already been spent. In comparison, photovoltaics (see next section) is a dynamically changing technology where costs are reducing, but costs do not currently compare well with large-scale wind energy. I don't think small-scale wind will ever be as cost effective as large-scale.

According to the DTI's renewable energy atlas, the wind energy density is around 8 times higher 10 miles off the coast of Brighton. Power generation depends a lot on location, since wind energy varies with the cube of wind speed. The water 10 miles offshore from Brighton is less than 50 metres deep … or it is at the moment, at least!

2. PHOTOVOLTAICS (PVs).

There are various types of PV solar cells: for example crystalline silicon, and thin films consisting of amorphous silicon, copper indium diselenide, or cadmium telluride. There are other types.

In June 2006 Nanosolar started executing its $100 million plan to build a volume PV cell production factory with a total annual cell output, once fully built, of 430MW, or approximately 200 million cells per year. As well as Nanosolar, other US companies and Wurth Solar in Germany are developing CIGS (copper, indium, gallium, selenium) thin films. CIGS thin films convert 15% of incoming solar energy to outgoing electrical current. Costs are currently falling by about 4% a year.

Even if all the other companies manage to make solar cells a great deal cheaper, it will only be the beginning. Manufacturing the cells accounts for just half the roughly present $6 per watt it costs to get a solar cell up and running. The remaining cost is needed to put them into a protective, mountable module, tune their output from direct current to alternating current, and install them. This is why Nanosolar and almost all the other recent solar start-ups take a strong interest in new ways of mounting their cells – ways that take advantage of their light weight or flexibility. Chris Eberspacher, Nanosolar's vice-president of engineering hopes, for example, that such light-weight systems could be used on Nanosolar's own roof, which is too flimsy to take the load from a traditional array.

The ultimate aim is to integrate the cells straight into building materials of all sorts. New houses need roofs anyway. PV tiles could be wired into the house from the start. Heliovolt's printing process is meant to make integrating PVs as a cost-effective coating possible. And Konarka talks of adding its dye-based 'Power Plastic' to more or less anything from windows (it would just cream off a bit of the light) to wind sheeters.

None of these technologies, however cleverly mounted, will get the costs of generating electricity low enough for solar power to compete directly with coal, gas, wind or nuclear. But because solar panels are inherently easily decentralised, they do not have to compete with the cost of generating electricity; they just have to compete with the price consumers pay for it. This is four or five times more than the cost of

generation, because of the power companies' need to pay for transmission networks, build new plants and please shareholders.
So the industry's aim is to get significantly below 'grid parity'. This is the point at which the cost of borrowing the money to buy and install a solar-power system is more than covered by savings on your electricity bill. At the moment, grid parity is not quite within reach; in most places with a lot of solar cells there is or has been a great deal of government subsidy. In Germany, a particularly powerful subsidy is a government requirement that electric utilities be willing to buy electricity generated by small photovoltaic installations, such as those in homes and small businesses, at more than 50 cents a kWhr. It is a costly subsidy. In its favour is popularity with the electorate – and, of course, with Germany's producers of solar cells.
Reaching grid parity is not enough, but when a mixture of much cheaper cells and adaptable, easily installed modules brings down the total cost of installation by a factor of three, solar energy will start to look very prudent.
The "energy payback" gives how long a PV system operates to recover the energy – and associated generation of pollution and CO_2 – that went into the system in the first place. For thin films, it has been calculated, assuming 6% conversion efficiency in standard conditions and 1,700 kWh/m^2 per year of available sunlight energy, the payback period is about three years for current systems with frames, less for amorphous silicon. $CuInSe_2$ and CdTe modules are already being sold in the 9%-12% efficiency range, so the energy payback may be less than a year already. For CIGS modules the payback period will be a matter of months.

3. ELECTRICAL VEHICLES.

The UK has been chosen for a market trial of an electric car that has the performance to keep up with the rest of the traffic.
The Smart EV is an electric variant of the Smart ForTwo. Unveiled in London last July at the British International Motor Show, Daimler-Chrysler's Smart EV (electric vehicle) has a top speed of 70 mph and is said to offer better in-town performance than its petrol powered sister, achieving 0-30 mph in 6.5 seconds and going uphill at speeds that won't frustrate following vehicles. However, a range of 72 miles between charges limits its use.
Up to 200 of the two-seater cars will be leased to selected corporate customers from November this year. Jeremy Simpson, a consultant with Daimler-Chrysler UK, points out that the EV has energy costs equivalent to achieving 300 mpg on petrol, and is exempt from both vehicle excise duty and the London congestion charge, so it is possible to achieve a positive business case as well as presenting a 'green' corporate image. Users must agree to purchase electricity from renewable resources.
The EV features a highly integrated electric drivetrain developed in Britain by automotive technology business Zytek, which will also assemble the vehicle at its new production facility in Staffordshire.
Zytek group sales and marketing manager Steve Tremble says that

collaboration with Smart engineers helped Zytek interface with the vehicle architecture – producing a drivetrain that fits onto existing engine mountings, requiring only connections for HV, LV and cooling water. The complete package weighs 70 kg, including the motor, gearbox, inverter and control electronics.

Power is provided by a Zebra liquid sodium nickel chloride battery, mounted under the floor below the driver's seat. This keeps the car's centre of gravity low, making it easier to handle. Recharging is just a matter of plugging a connecting cable into a standard 13 A socket, and the electronics ensure that partial charging will not damage the battery.

The drivetrain can achieve an output of 55 kW in other applications, but for the EV it is currently limited to 30 kW by the battery capability. Zytek has also developed a 70 kW drivetrain for trucks.

Although Smart GmbH has partnered with Zytek for a number of years, it was Daimler-Chrysler UK that was the catalyst for this first market trial. Simpson explains: "We have the highest fuel price in the EU, and we have congestion charging and air quality targets beginning to appear in planning consents. Also, Zytek is here, and we have already sold 40,000 Smart cars in the UK, so the product is trusted".

Who wants it? The market trial has attracted a number of corporate partners with a variety of needs. (1) London estate agency Knight Frank is leasing 10 of the vehicles for its staff to use when taking clients to view properties. (2) Lloyds Pharmacy head office staff will be able to use the cars for journeys in Coventry, including travel to the airport. (3) Traditional sash window specialist Refurb-a-Sash is replacing its existing Smarts with EVs as part of its overall environmental policy. (4) CityCarClub plans to place Smart EVs in prestige residential developments in central London. (5) Smarts Brentford workshop is replacing three of its petrol powered courtesy cars with the electric vehicles, and will ask their customer's opinions about them.

4. HEAT PUMPS.

Refrigerators, air conditioners and some heating systems are all common applications of heat pumps. The principles by which heat pumps operate are as follows.

Imagine the heat in a given space – say the volume of a football – has 100 units of heat. The air in the football is then compressed to the size of a ping-pong ball. It still contains 100 units of heat, but the heat is much more concentrated and thus the average heat per unit of volume is much higher. In other words, the temperature of the air in the ball will have increased. Now the walls of the ping-pong ball will become hotter, and therefore heat will start to flow out of it faster than before. To transfer this heat somewhere else, we can move the ping-pong ball to a cooling area, and the ball will gradually adjust its temperature to match it. By the time the temperature has equalised, it may have transferred 50 units of heat to the cooling area. After the ball has cooled a bit, move it back to the source area and allow it to expand. Since it has lost a lot of heat, once it expands the temperature will be lower than it was at the start of the

whole process. The ball will now be cooler and can absorb energy to cool the surrounding input area.
Heat pump efficiency is measured by the *coefficient of performance* (COP), which is used to describe the ratio of heat output to electrical energy input. When used for heating on a mild day, a typical heat pump has a COP of three to four, whereas a typical resistive electric heater has a COP of one. That is, one joule of electrical energy will cause a conventional heater to give off one joule of warmth, while under ideal conditions one joule of electrical energy can cause a heat pump to move more than one joule of heat from a cooler place to a warmer place. Heat pumps are typically somewhat more efficient for heating than for cooling. Commercial heat pump technologies are currently in a stage of rapid improvement: the COP for commercially available heat pumps has risen in the last five years from 3 to 4 and even (in a few cases) 5. As a result heat pumps are becoming popular choices for home heating. Two common types of heat pumps are air-source and ground-source heat pumps depending on whether heat is transferred from the air or from the ground. Ground-source heat pumps have a higher COP than air-sourced heat pumps. The penalty for this improvement in performance is that ground-source heat pumps are significantly more expensive to install than air-source heat pumps.

5. BIO-DIGESTERS.

Greenfinch were awarded a DTI grant in 1998 to design, build and operate a demonstration digester to recycle kitchen waste from 1200 households in the Ludlow area of South Shropshire, which was successfully completed in 2001.
South Shropshire District Council funded the collection, which was carried out using a 7.5 tonne vehicle.
Participating households were issued with a 15 litre bucket and lid, and plastic bin liners. Kitchen waste was left on the kerbside for collection once per week.
A number of important conclusions were made from the project. The biogas plant was able to mechanically handle the kitchen waste and the process worked well biologically. The average amount of kitchen waste collected was 4.2 kg per household per week, and 80% of the volatile matter was transformed to biogas. The digestate production was ideal for re-use as a liquid fertiliser.
In a later (to March 2003) project in partnership with Southampton University, Greenfinch used the kitchen waste to investigate pathogen destruction in a mesophilic (37 ºC) and a thermophilic (56 ºC) digester. With the additional process stage of pasteurisation at 70 ºC for one hour, salmonella, e.coli and f.streptococci were eradicated, meeting the standards in the EU Animal By-Products Regulation.
Since January 2006, in partnership with South Shropshire District Council, and using Defra funding, a Greenfinch biogas plant is redirecting 5,000 tonnes per year of source-separated kitchen and garden waste from landfill.

6. THERMAL DEPOLYMERIZATION.

Thermal depolymerization (**TDP**) is a process for the reduction of complex organic materials (usually waste products of various sorts, often known as biomass) into light crude oil. It mimics the natural geological processes thought to be involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen, and carbon decompose into short-chain petroleum hydrocarbons with a maximum length of around 18 carbons.

Thermal depolymerization is sometimes mistaken for similar processes:

- Thermochemical conversion (TCC*)* is limited to the changing of manure crude oil.
- Thermal conversion process (TCP*)* is limited to the changing of manure and vegetable waste to crude oil.

Thermal depolymerization can change many carbon-based materials into crude oil and methane, and is not limited to manure or vegetable waste.

History

Thermal depolymerization is similar to the geological processes that produced the fossil fuels used today, except that the technological process occurs in a timeframe measured in hours. Until recently, the human-designed processes were not efficient enough to serve as a practical source of fuel—more energy was required than was produced.

A new approach that exceeded break-even was developed by microbiologist Paul Baskis in the 1980s and refined over the next 15 years. The technology was finally developed for commercial use in 1996 by the American Company Changing World Technologies. Brian Appel (CEO of Changing World Technologies) took the technology in 2001 and expanded and changed it into TCP and has applied for a patent. A Thermal Depolymerization demonstration plant was completed in 1999 in Philadelphia by Thermal Depolymerization, LLC, and the first full-scale commercial plant was constructed in Carthage, Missouri, where it is expected to process about 200 tons of turkey waste into 500 barrels (21,000 US gallons or 80 m^3) of oil per day.

Theory and process

Previous methods to create hydrocarbons from depolymerization expend a lot of energy to remove water from the materials. This hydrous pyrolysis method instead uses water to improve the heating process and contribute hydrogen from water to the reactions.

The feedstock material is first ground into small chunks, and mixed with water if it is especially dry. It is then fed into a reaction chamber where it is heated to around 250 °C and subjected to 600 lbf/in² (4 MPascals) for approximately 15 minutes, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals, which are separated out. The hydrocarbons are sent to a second-stage reactor where they are heated to 500 °C, further breaking down the longer chains, and the resulting mix of hydrocarbons is then distilled in a manner similar to conventional oil refining.

Working with turkey offal as the feedstock, the process proved to have yield efficiencies of approximately 85%; in other words, the energy required to process materials could be supplied by using 15% of the petroleum output. Alternatively, one could consider the energy efficiency of the process to be 560% (85 units of energy produced for 15 units of energy consumed). The company claims that 15 to 20% of feedstock energy is used to provide energy for the plant. The remaining energy is available in the converted product. Higher efficiencies may be possible with drier and more carbon-rich feed-stocks, such as waste plastic.

By comparison, the current processes used to produce ethanol and biodiesel from agricultural sources have energy efficiencies in the 320% range when the energy used to produce the feedstocks is considered (in this case, usually sugar cane, corn, soybeans and the like).

The process breaks down almost all materials that are fed into it. TDP even efficiently breaks down many types of hazardous materials

Feed Stocks and outputs with thermal depolymerization.

Feedstock	Output		Feedstock	Output	
Plastic bottles	Oil	70 %	Turkey offal	Oil	39 %
	Gas	16 %		Gas	6 %
	Carbon solids	6 %		Carbon solids	5 %
	Water	8 %		Water	50 %
Sewage sludge	Oil	26 %	Medical waste	Oil	65 %
	Gas	9 %		Gas	10 %
	Carbon solids	8 %		Carbon solids	5 %
	Water	57 %		Water	20 %

Reactor products

The yield from one ton of turkey waste is 600 pounds petroleum, 100 pounds butane/methane, and 60 pounds minerals. In addition, the water is recycled back into the system for reuse.

The fixed carbon solids produced by the TDP process have multiple uses as a filter, a fuel source and a fertilizer. It can be used as activated carbon in wastewater treatment, as a fertilizer, or as a high thermal value fuel similar to coal.

Limitations

The process only breaks long molecules into shorter ones. Longer molecules are not created, so short molecules such as carbon dioxide or methane can not be converted to oil through this process. The process can break down organic poisons, due to breaking chemical bonds and destroying the molecular shape needed for the poison's activity. It is highly effective at killing pathogens, specifically including prions. It can also safely remove heavy metals from the samples by converting them from their ionized or organometallic forms to their stable oxides which can be safely separated from the other products. Many agricultural and animal wastes could be processed, but many of these are already used as fertilizer, animal feed, and in some cases as feedstock for papermills or as boiler fuel.

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Experimental Bioreactor.

NB: The technologies outlined in this paper are detailed in terms of their maximum technical capacities. Thus, a bioreactor able to process highly hazardous waste, such as medical, pharmaceutical and agricultural/food wastes, in the examples given, has inherent capacity to handle conventional urban wastes and materials. The use of these technologies in Brighton & Hove would be entirely safe and secure, unlike the operation of a large industrial incinerator.

7. PRESS ARTICLE - IS THIS THE ULTIMATE RECYCLER?

An experimental recycling plant in Philadelphia is turning waste from a nearby turkey factory into gas and oil. It could, in theory, convert any old kind of rubbish into fuel. Jerome Burne reports

Thursday May 22, 2003
The Guardian

How about this for a ridiculous modern myth. There is a machine somewhere in America that can take virtually any sort of waste - offal from an abattoir, old tyres, junked computers - and turn it into high quality oil, plus pure minerals and clean water, all in a few hours. It is an invention that could change the world. Not only might it end the west's, and in particular America's, dependence on imported oil, but it has also the potential simultaneously to solve the increasingly pressing problem of waste disposal.
A fantasy along with the everlasting light bulb, the car that runs on water and the perpetual motion machine, right? Well, no.
An experimental unit that uses a technique known as the "thermal depolymerisation process" (TDP) that can recycle seven tonnes of waste a

day into gas and oil has been running for three years in Philadelphia. A scaled up version is due to open in Carthage, Missouri next month. It is designed to transform 200 tonnes of guts, beaks, blood and bones a day from a nearby turkey processing plant into 10 tonnes of gas and 600 barrels of oil.

This is not being funded by some eccentric billionaire. The impressive results from the Philadelphia plant convinced the US environmental protection agency to put up $14.5m (£9m) to fund four more plants, while private investors are backing the Missouri plant to the tune of $40m (£25m). The company, Changing World Technologies, has also acquired such powerful friends as James Woolsey, former CIA director, and Alf Andreassen, former science adviser to George Bush. It's worth mentioning such well-connected backers because, says chief executive officer Brian Appel: "When people first hear about us they always say they don't believe it."

Trials at the Philadelphia pilot project have given the engineers a good idea of what different feed-stocks would produce. For instance, a 175lb (79kg) man could, theoretically, yield 38lb of oil, 7lb of gas, 7lb of minerals and carbon and 123lb of sterilised water. More practically, 100lb (45kg) of sewage becomes 26lb (11kg) of oil, 9lb of gas, 8lb of minerals and carbon and 57lb of water. Medical waste, generally regard as tricky to dispose of, is particularly valuable - its equivalent yields are 65, 10, 5 and 20.

Philadelphia council is planning to give this value-added treatment to its sewage and there are also plans to handle chicken offal and manure in Alabama and pork and cheese waste in Italy.

The company envisions a large chunk of the world's agricultural, industrial and municipal waste going through TDP recycling plants all over the globe. "You are not only cleaning up waste: you are talking about the distributed generation of oil all over the world" says Michael Roberts, an engineer with the Gas Technology Institute. Changing World say that converting all of the US agricultural waste into oil and gas would yield the energy equivalent of 4bn barrels of oil, roughly equal to the volume of US oil imports in 2001. So oil tankers might soon go the way of tea clippers.

Transforming waste into energy is an old vision and there have been many attempts at it but only a few minor successes, such as the production of ethanol from cornstarch. All suffer from two big flaws. They can only handle a few different types of "feedstock" and they usually generate only a little more energy than they use. "The only thing this process can't handle is nuclear waste," says Appel. "If it contains carbon we can do it."

TDP is said to be 85% efficient - that is, only 15% of the energy it produces goes to fuelling the process. The initial estimate of the cost of the oil from the Missouri plant is $15 (£9) a barrel. The "lifting" price - how much it costs to get oil out of the ground - is very cheap in the Persian Gulf, around a dollar a barrel, while from Gulf of Mexico, North Sea or Alaska the "lifting" price is $8-12. So a price of $15 a barrel for this technology is high but Appel predicts his prices will come down to $10 in a few years, making them comparable with a medium-size oil exploration and production company. "The oil that comes out is very light," says Appel. "It is essentially the same mix as half fuel oil, half gasoline."

Environmental legislation seems to be running in TDP's favour. Last month, tougher emissions standards were set for diesel in the US, prompting a switch to the type of low-sulphur fuel that Changing World produces. The US is expected to ban recycling of abattoir waste into animal feed soon. That could well launch TDP big-time.

Making the switch is going to take a long time, but experts reckon it can make the oil industry cleaner and more profitable. The process can handle heavy crude, shale and tar sands - generally considered not to be cost-effective - as well as heavy solid waste left over from normal refining. A modified version could also be used to pre-treat coal, extracting a range of minerals and leaving the residue to burn hotter and more cleanly.

Although trial results have been impressive, the technology has to prove itself at the new Missouri plant. There are a few sceptical voices. "Once they are producing something as valuable as they say they are," says Professor Robert Brown of the Center for Sustainable Environmental Technologies at Iowa State University, "people aren't going to give dead chickens to them any more."

Where there's muck there's gas...how the recycler works

Turning organic waste into oil is a trick the earth perfected long ago. Applying pressure and heat to the decaying remains of plants and animals transforms their long chains of hydrogen, oxygen and carbon into the short-chain hydrocarbons that make up oil. But while the earth takes millions of years, TDP takes a few hours.

The principles remain the same, however, and no fancy new technologies are involved. In fact most of the pressure tanks and reactor vessels the system uses are available off the shelf. What allows TDP to succeed where others fail is the way it handles the volumes of water found in most organic waste.

Feedstock is first ground into slurry and heated under pressure, which breaks down some of the long carbon chains. Then it flows into a "flash vessel" where a dramatic drop in pressure removes much of the water far more efficiently than boiling it off. Minerals settle out at this stage and the remaining organic soup is then heated in "coke ovens" to break any remaining chains before the end products - oil, gas, water and carbon - are drawn off from a distillation column. The "coke oven" heats the organic soup to about 900F (480C) turning it into a vapour. What happens next is just the same as what goes on in an oil refinery, or indeed in a whiskey still. The vapour flows into tall containers, known as distillation columns, where the various molecules separate out - the lightest molecules rising to the top and the heaviest sinking to the bottom. So the gas is drawn off from the top, the oils are removed from the middle and the powdered carbon is taken out from the bottom.

The gas, expensive to transport, is used to power the process, while the oil, minerals and carbon are sold off. The calcium and magnesium produced from the turkey waste, for instance, make a perfect fertilizer.

8. PRESS ARTICLE – PROOF WE’RE RUBBISH AT

RECYCLING. By Georgina Littlejohn and Jonathan Prynn.

The article points out that London batteries go to France, plastic bottles to Germany, mixed papers to India and Vietnam, plastic bottles to China, and newspapers to Malaysia and Indonesia.
Every tonne of recycled material shipped to China generates 400 kg of carbon dioxide, the same as produced by a car driven from John O'Groats to Lands End.
A heavily-laden truck going from London to Llanelli and back will emit 1,000 kg of carbon dioxide, the same as a car going from London to Moscow.

Tuesday October 17, 2006
London Lite

How Your Green Household Waste is sent 5,000 Miles for Processing.

You may think that you are helping to save the environment by filling up the recycling bin.
But the chances are that the household waste will be sent half-way around the world – generating more of the harmful emissions we are encouraged to reduce.
Recyclables collected by at least 15 London boroughs end up abroad, in most cases in the Far East, where there is huge demand for 'green' waste.
The reason is a shortage of processing plants and limited demand in the UK for the materials. In total about 57 per cent of recycled plastic, 41 per cent of paper, 25 per cent of aluminium and 19 per cent of glass is sent abroad.
Haringey, for example, ships its cardboard and plastic bottles more than 5,000 miles for processing in China. Papers collected in the borough travel to mills in France, Malaysia and Indonesia.
Ealing council sends its recyclable household batteries to France.
Newsprint from Tower Hamlets goes to the Far East while Enfield and Westminster sends it to Belgium. Westminster sends the rest of its paper material to China, Indonesia, Vietnam and India and its plastics to Germany and China.
Although some say any recycling is better than incinerating waste or putting it in landfill, Jenny Jones, Green Party member of the London Assembly, said sending materials overseas defeated the purpose of recycling.
She said: "Recycling is all about not using the Earth's resources but you're nullifying those intentions by transporting materials overseas.
When boroughs start shipping things to China, they have to ask 'Why?' and get their act together. All recycling should be done as local as possible and if it needs new plants, then so be it".
Many other councils send their recyclable material to other parts of Britain. Glass collected in Bexley and Harrow is sent to Yorkshire. In Barnet, where recycling is compulsory, aerosols, aluminium cans and foil travel to Llanelli, Wales.
Brent's recycled aluminium cans and foil go to processors in

Birmingham, while textiles and shoes are sent to Northamptonshire. However, Hillingdon recycles all materials at Colnbrook while Hackney and Islington use the North London Waste Authority. A spokesman said Mayor Ken Livingstone was trying to set up a London-wide waste authority to encourage a reprocessing market in the capital.

9. ALGAE BIOREACTORS

From smokestack to gas tank

New Scientist 7th October 2006
by Phil McKenna, Boston

Power plants emit carbon dioxide, algae make sugar and oil out of it. It's time to put the two together.

"If you're working at a power plant, you just saw your carbon dioxide turned into something you can drive home with". So says Isaac Berzin of GreenFuel Technologies in Cambridge, Massachusetts, which is developing a way of producing biofuel from the noxious emissions of power plants.

Two of the world's greatest energy users are electricity generation and transport. Both are responsible for huge quantities of greenhouse gas emissions, as most power plants and vehicles still rely on fossil fuels. Now GreenFuel and others are hoping to marry the two together with an emerging technology that uses a by-product of one to supply to the other. Doing so could dramatically reduce their overall carbon dioxide emissions.

At the heart of the technology is a plastic cylinder full of algae, which lierally sucks the CO_2 out of a power plant's exhaust. The algae can in turn be converted into biofuel, creating a cycle that takes the carbon from the smokestack to the gas tank before it enters the atmosphere.

If successful, the technology could capture all of a power plant's CO_2 emissions. "Right now, when you say CO_2, people want to hide under the table. Carbon dioxide is not something you want to pump underground, it's something you want to reuse", says Berzin.

To produce fuel from CO_2, the flue gases are fed into a series of transparent "bioreactors", which are two metres high and filled with green microalgae suspended in nutrient-rich water. The algae use the CO_2, along with sunlight and water, to produce sugars by photosynthesis, which are then metabolised into fatty oils and protein. As the algae grow and multiply, portions of the soup are continually withdrawn from each reactor and dried into cakes of concentrated algae. These are repeatedly washed with solvents to extract the oil.

The algal oil can then be converted to biodiesel through a routine process called transesterification, in which it is processed using ethanol and a catylist. Enzymes are then used to convert starches from the remaining biomass into sugars, which are fermented by yeasts to produce ethanol.

GreenFuel is testing a pilot facility at the Redhawk power station in the

Arizona desert. The size of a couple of trailers, it treats only a tiny fraction of the plant's exhaust, but it works, and has so far produced several gallons of algal oil, which the company is planning to convert into biodiesel this week. A second, larger prototype of around 1300 square metres is now under construction.

The new facility will also capture the heat produced by the plant and use it to help dry the algae before the oil is extracted and converted to biodiesel. This excess heat could also make it easier to recover the solvent from the oil after extraction. "The main energy requirement is recovering the sovent from the oil once it is extracted", says Berzin. "Seventy per cent of a coal-burning plant's energy is lost as heat. That's a lot of waste heat to use".

GreenFuel has so far received more than $18 million in venture capital funding, and hopes to install a full-scale algal farm at least one kilometer square near the Redhawk plant by 2009. Berzin calculates that if the farm has enough algae to absorb all the CO_2 produced by the 1000-megawatt plant, GreenFuel could ultimately produce more than 150 million litres of biodiesel and 190 million litres of ethanol a year. To do this, it would need a farm of between 8 and 16 square kilometers.

The idea of producing biofuel from algae is not new. The US Department of Energy began investigating algae in the 1970s during the global oil shortage. Researchers scoured the US, collecting more than 3000 different strains of "extremophile" algae that could withstand the high temperatures, salinity and pH required to absorb the exhaust from power plants.

The Aquatic Species Program, as it was known, grew algae in open pond test sites in Hawaii, California and New Mexico, but was mothballed in 1996 when lower crude oil prices made it difficult for alternative fuels to compete. "It's an entirely different world now", says John Sheehan, an analyst with the National Renewable Energy Laboratory in Golden, Colorado, who worked on the project. "I've had a call or email a week enquiring about it".

Although ahead of the competition in terms of developing prototype bioreactors, GreenFuel is not the first to use algae to produce samples of biofuel from power plant exhaust. In March Laurenz Thomsen and his team at the Greenhouse Gas Mitigation Project at the International University Bremen in Germany used microalgae to produce 10 milliltres of biodiesel. Thomsen is now working with GreenFuel to develop algae farms at CO_2-belching coal-fired plants in eastern Europe.

"Using technology based on GreenFuel, we can mitigate 50,000 tonnes of CO_2 per square kilometer per year", he says. Building a one-square-kilometer facility would cost approximately $20 million, he estimates, but the payoffs would be equally large. "I think we are close to the point where we can gain $5 to $10 million a year by selling the fuel".

Another company building a pilot algae reactor is New York-based Greenshift. The company plans to begin testing its reactor at a bioethanol plant in Iowa in early 2007, where waste CO_2 is emitted when corn is converted into ethanol. "Roughly one-third of the corn that goes into a facility comes out as ethanol", says Kevin Kreisler of Greenshift. "With algae and other technologies we can increase that to two-thirds". Like

GreenFuel, the company eventually plans to use the technology at power plants.
Instead of exposing the algae directly to sunlight, Greenshift uses an array of mirrored troughs and fibre optics to carry sunlight to the plants. Algae don't need strong sunlight for photosynthesis, so the bioreactors could feasibly be housed in buildings or underground. "It's all about efficiency", says Kreisler. "By diffusing the light we can take one square metre of sunlight and spread it out over 10 square metres of growth plates, thus reducing the amount of land we need by a factor of 10".
Indeed, one key advantage of algae farms over other sources of biofuel such as corn and soybeans is that they need much less space (*New Scientist*, 23rd September 2006, p 36). In Germany, where rapeseed is the primary crop used for biodiesel, it would take up to 33 times as much land as is needed by the algae bioreactors to produce the same amount of fuel, Thomsen says. What's more, unlike other biofuel crops, algae do not require precious commodities like fresh water or fertile land. That makes the technology suitable for use in the deserts of the American south-west and China. "If you really want to make an impact on CO_2, you have to look at the US and China", Berzin says.
If the technology is to be successful, though, the energy industry will need to be convinced. Barry Worthington of the US Energy Association in Washington DC, which represents the electricity generators, says the economics of algal biofuel still have to be borne out. But he is optimistic about its potential. All the conventional ways of reducing CO_2 emissions are considered a cost, he says. "This changes the dynamics dramatically".

A Taste for Sewage

Carbon dioxide is not the only waste substance algae can convert into biofuel. Algae also like to munch on the organic matter in human waste, producing a carbon-rich oil.
Aquaflow Bionomic of Marlborough, New Zealand, is extracting oil from the algae that grow naturally in wastewater treatment facilities. In May the company produced its first 300-millilitre test batch of biodiesel, and hopes to have enough to fuel a vehicle test-drive this year.
"There is a certain elegance to unlocking the waste flow and turning it into a significant asset", says Nick Gerritsen of Aquaflow. "If you leave a bucket outside your back door anywhere in the world, it will turn green with algae. We are basically leveraging existing assets, because sewage ponds exist all over".