ISIS

# Which Energy?

2006 energy report from the Institute of Science in Society

ISIS

# Which Energy?

## 2006 Institute of Science in Society Energy Report

**Mae-Wan Ho**
**Peter Bunyard, Peter Saunders, Elizabeth Bravo, Rhea Gala**

Sponsored by:
**Third World Network, Penang, Malaysia**
**Fondation pour une Terre Humaine, Switzerland**
**Institute of Sustainable Development, Addis Ababa, Ethiopia**
**Ecological Society of the Philippines, Manila, Philippines**
**Yoko Civilisation Research Institute, Tokyo, Japan**
**Edward Goldsmith, Founding Editor of *The Ecologist*, UK**
**Weston A. Price Foundation, Washington DC, USA**
**Globally Sustainable, Somerset, UK**
**Oilwatch, Quito, Ecuador**
**Kasisi Agricultural Training Centre, Lusaka, Zambia**
**Kindersley Centre, Sheepdrove Organic Farm, Berkshire, UK**
**Dr. Caroline Lucas, Member of European Parliament, Brussels**
**Alan Simpson, Member of Parliament, Nottingham, UK**
**Rt Hon Michael Meacher, Member of Parliament, Oldham & Royton, UK**
**Margaret Stronach, Wokingham, UK**
**HOPE, Health Our Planet Earth, France**
**The Dharmic Trust, New Plymouth, New Zealand**
**Jeanette Wilson Limited, New Plymouth, New Zealand**
**Ian Panton, Caerfai Bay, St Davids, Pembrokeshire, Wales**
**Life Force Summit, www.life-force-summit, California, USA**
**Dr Morag Parnell, West Lothian, Scotland**
**Josephine Sikabonyi, Chemist, Kent, UK**
**Dr Siewpeng Lee, Organic-ally, Middlesex, UK**
**Alara Whole Foods, Ltd., London, UK**
**Nature and Society Forum, Australia**
**Riverford Organic Vegetables, Devon, UK**

## Contents

# Foreword

"One of the big changes this winter is that a large area of the Barents Sea has remained ice-free for the first time. This is part of Europe's 'back yard'." Professor Peter Wadhams of Cambridge University, the first Briton to monitor Arctic sea ice from nuclear submarines, was quoted in the 14 March 2006 issue of UK newspaper The Independent,

"Climate models did predict a retreat of sea ice in the Barents Sea but not for a few decades yet, so it is a sign that the changes that were predicted are indeed happening, but much faster than predicted."

Meanwhile, huge chunks of Greenland's glaciers are breaking up, raising fears that the melt waters will lead to drastic slowing, or even reversing of the Gulf Stream that keeps Western Europe in a temperate state.

Global warming is no longer fiction or prediction. It is happening and at a pace faster than expected.

For the peoples of the South, the ecological and human devastation that will accompany climate change is simply unthinkable.

At the heart of the crisis is the unfettered use of fossil fuels that has been powering unsustainable economic growth. Yet politicians and technocrats are unwilling, and at times, seem unable to take bold steps to deal with the climate change crisis, or the energy crisis, which is the other side of the same coin. In that vacuum and paralysis largely sustained by major corporate-interests, false and dangerous solutions, such as nuclear energy, are aggressively promoted. The growing enthusiasm for biofuels, similarly, is obscuring fundamental socio-economic, technical, and environmental problems that are urgently in need of public scrutiny and debate.

In asking "*Which Energy?*" the Institute of Science in Society is challenging us to think radically and holistically. The UK Government's Energy Review and ISIS' critique and recommendations have invaluable lessons for all countries and societies. The forward-looking solutions to the energy crisis presented in this ISIS Report offer hope for citizens and options for governments.

**Chee Yoke Ling**
Third World Network

# Preface

We started this energy review in the summer of 2005, when accelerating global warming and soaring energy prices finally struck home to most of the world's political leaders that business as usual is no longer an option. The challenge to find the right survival strategies has never been greater; and we have to find them now. Time and energy resources are both running out. Squander them on the wrong technologies and the consequences will be catastrophic. Choose the right options and we can mitigate global warming and thrive in a greener, cleaner post fossil fuel planet.

Choosing the right options requires a critical understanding of the science and technologies involved. We need to know how our energy options affect the health of the planet and the human species, and impact on other life necessities, above all, food security. We need to know how the way we produce and distribute food affects energy use and energy security. We also need to take account of the social, ethical, economic and political consequences of our choices. And finally, we need to question some of the most deeply held assumptions of the dominant model of unlimited unsustainable growth based on competition and market forces. Our Energy Report does all of that.

We concentrate on the energy options that are most immediately available, the most promising and the most contentious. We address many of the key issues tackled by the world's governments in response to climate change and the impending energy crisis, and others they have yet to do. No country can act in isolation. The most important lesson of global warming is that the ecological impacts of our energy consumption in all forms cannot be outsourced with impunity, and the best way to protect our own ecosystem may be to protect the integrity of far-flung forests on the other side of the globe and enable people living there and elsewhere to claim an equitable share of the resources.

Please make this Report widely available to policy-makers and the public across the world to help people everywhere make the transition to a greener, cleaner, healthier, wealthier and more fulfilling life without fossil fuels.

**Mae-Wan Ho**
14 March 2006

# Executive Summary

## I. Introduction

The UK government's response to climate change and the impending energy crisis, as presented in its 2003 Energy White Paper, has not yielded concrete results despite many good intentions. We believe that is because the government's trade- and market-dominated approach has prevented it from investing sufficiently in the appropriate technologies and adopting policies that promote self-sufficiency over trade.

The Energy Review released for public consultation in January 2006 is widely seen as a statement of the UK government's intention to commission new nuclear plants, an option explicitly *not* included in the 2003 Energy White Paper.

Our recommendations - based on the options considered in this Energy Report - are as follows.

1. Nuclear energy should be ruled out on grounds of safety, world security, and economics; also because it is a finite, non-renewable resource, and it gives energy returns and savings on carbon emissions no better than gas-fired heat and power co-generation.

2. Energy self-sufficiency is the best guarantee of energy security. This can be achieved by a diversity of sustainable, renewable energies at medium-, small- and micro-generation scales, according to resources locally available, so that energy is used at the point of generation, saving up to 69 percent of the energy lost through long distance transport of electricity from big centralised power plants and the associated carbon emissions.

3. The electricity grid should be restructured for all levels of embedded local generation that would enable neighbouring communities to supply electricity to one another in times of need (through electronic switching devices), thereby maximising stability of electricity supply throughout the grid. This distributed network is also the best protection against blackouts and terrorist attacks.

4. Food self-sufficiency should be considered an integral part of energy self-sufficiency, as it reduces food miles and ecological footprints, saving on both energy and carbon emissions. Food produced locally and consumed fresh enhances its quality and nutritional value, and improves the health of the nation.

5. Organic, low input sustainable farming should be encouraged as an effective way to reduce fossil-fuel intensive fertiliser and pesticide inputs and carbon emissions.

6. The renewable options adopted must be sustainable. In the present context, we define sustainable as being safe for health and biodiversity, affordable, ethical, energy efficient, as near as possible to 'zero-emission' and 'zero-waste'; and above all, does not compromise the world's food security.

7. Two energy-from-waste technologies ideally satisfy the criteria for renewables that are sustainable: producing biogas from organic wastes (agricultural, municipal and industrial), and using green algae for capturing carbon dioxide from the exhaust of power plants coupled with biodiesel production.

8. Solar energy is getting better and more affordable all the time, and will be an important small- to micro-generation technology especially suited for Third World countries lacking energy infrastructure.

9. The production of biodiesel from waste cooking oils and other industrial food wastes, and diesel from waste plastics that cannot be easily recycled into plastics should all be considered.

10. We do not support energy crops for biofuels, especially not in poor Third World countries, unless they can be shown to truly satisfy our criteria of sustainability. Biofuels from most existing energy crops give poor to negative energy returns and small savings, if any, on carbon emissions. They are damaging to the environment and will accelerate global warming if primary and secondary forests are converted to energy crop plantations, as they are likely to be in Latin America. Most of all, they compromise food security in competing for land with food crops, and can push up the price of food.

11. We do not recommend investing in physical and chemical carbon capture and storage technologies.

12. We do not support energy intensive extractive technologies as they merely extend our dependence on fossil fuels and divert scarce resources away from developing sustainable renewable energy sources.

13. An integrated food and energy self-sufficient farming system should be widely implemented in developing as well as developed countries, as a cost effective and sustainable solution to global warming and the energy crisis.

14. Subsidies and tax incentives should be used to support the appropriate options, and over a long time scale.

15. Carbon credits should be extended to include small and medium enterprises engaged in carbon savings, such as the production of biogas from organic wastes on farms.

16. Special subsidies and grants for research and development should be earmarked for small to medium enterprises, non-government organisations and individuals, because these are responsible for most of the innovations in renewable energies.

17. Legislation to promote savings on energy and carbon emissions should be put in place and enforced through inspection of buildings, for example.

18. There is an urgent need to remove bureaucratic hurdles from individuals, small to medium enterprises, and non-government organisations setting up innovative, energy and carbon emissions savings projects.

## II. Nuclear

Conventional nuclear energy is known from past experience in the UK to be highly uneconomical, while the disposal of enormous amounts of hazardous radioactive wastes remain an intractable problem to this day. What is less well known is that the energy returns of conventional nuclear power plants are not better than those of a gas-fired plant if low-grade uranium ore has to be mined and processed. Furthermore, a natural gas-fired heat and electricity co-generation power station is comparable to a nuclear power/natural gas plant in both energy yield and carbon emissions savings, but is much cheaper to construct, and supplies heat and electricity more cheaply to the consumer. A biogas-powered co-generation plant is even better, and saves seven times the carbon emissions of a nuclear power/natural gas plant.

The new generation pebble bed nuclear reactor is said to be economical and safe, but the economy is contingent upon the assumption that it does not require the safety measures used in other types of reactor, and large doubts remain over that.

1. Nuclear energy is extremely uneconomical, as the past performance of the nuclear industry in Britain has shown. The other major problem is safety. Once set up, a nuclear power nation must be maintained and monitored continuously to high standards. Reprocessing spent fuel is no easier. In June 2005, a leak of highly radioactive waste was discovered in the reprocessing plant at Sellafield containing enough uranium and plutonium to make several atomic weapons; and had gone unnoticed for more than eight months. Reprocessing spent fuel also leads to an exponential increase in the volume of hazardous radioactive wastes, and provides ideal opportunities for the proliferation of nuclear weapons.

2. The potential of nuclear power is limited by the amount of sufficiently high-grade uranium ore available. At today's rate,

economically recoverable reserves of uranium, about 10 million tonnes, would last less than 100 years.

3. Uranium extraction is an energy intensive and hazardous process. It has resulted in more than 6 billion tonnes of radioactive tailings of potent carcinogens. Once in the reactor the uranium generates a million times more radioactivity, about a thousandth of which still remains after 100 years.

4. To date, nuclear power has been built and subsidised through the use of fossil fuels, which have provided the energy for mining, extraction, enrichment and construction. A life-cycle comparison between the carbon dioxide emissions resulting from a nuclear plant and an equivalently sized gas-burning plant indicates that with the poorer uranium ores, below 0.002 per cent, the gas-fired plant comes out better, with lower overall carbon dioxide emissions. Life-cycle analysis done by the Öko-Institute of Germany estimates a carbon dioxide cost of 35 g/kWh. A natural gas co-generation system is even with the nuclear power/natural gas combination in terms of emissions, while being far cheaper to the consumer simply because of the three-fold better efficiency in delivering end-use energy. A co-generation system based on biogas emits seven times less greenhouse gases in providing end-use energy compared to a nuclear power/natural gas combination.

5. Proponents claim that a new generation nuclear reactor, the pebble bed modular reaction (PBMR) will produce electricity both economically and safely, but this is on the basis of a new and largely untested technology. Furthermore, much of the expected savings arise because the designers are so confident of the safety of the reactor that they plan to build plants without containment buildings and close to populated areas where the power is required, and to operate them with much lower staffing levels than other types of reactor. However, large questions hang over safety, while the intractable problems of nuclear wastes remains, and it is still at best a temporary solution to the energy problem. It also greatly increases the risks of nuclear proliferation by its very nature.

### III. Biofuels

Biofuels based on energy crops and crop residues compete with land that grows food, and are unsustainable and damaging to health and the environment especially in the long term. Energy crops are being outsourced to poor Third World countries, which will put pressure on agricultural land. This will threaten food security, exacerbate hunger, destroy biodiversity, and has the potential to cause massive deforestation that accelerates climate change.

1. Bioethanol and biodiesel from energy crops in Europe and the United States compete for land that grows food, and when subject to realistic life-cycle analysis, are shown to return less energy than the fossil fuel energy squandered in producing them. They deplete the soil, necessitating fossil-fuel intensive fertilisers and pesticides that pollute the environment, and are also disastrous for the economy both because they entail agricultural and other subsidies, and push up the price of food and feed where food crops such as corn is involved.

2. Major technical and economic hurdles remain in getting ethanol from plant wastes, the most serious being that the fermenting bacteria will not grow beyond a dilute concentration of ethanol. This makes it more costly in terms of water and much more so in terms of energy used for distillation. Genetically engineered ethanol-producing bacteria could devastate agricultural crops if released into the environment; some years ago, a genetically engineered bacterium *Klebsiella planticola* that produced ethanol from wood debris was found to kill *all* the wheat plants in every microcosm tested. Burning ethanol also produces carcinogens and increases ozone levels in the atmosphere.

3. The predicted boom in biodiesel has yet to take off in Europe as the major feedstock oilseed rape is an expensive crop to grow, and there are increasing doubts over its long term sustainability. Growing biodiesel or ethanol-producing energy crops in Europe will involve planting on set-aside land for conserving natural biodiversity, and compete with land used in growing food. Investors are looking to grow alternative energy crops abroad.

4. Brazil is set to greatly increase its export of ethanol from sugarcane while biodiesel from genetically modified soya is entering the market. Bioenergy crop plantations and the infrastructure needed for massive export of biofuels will place additional pressures on its dwindling forests.

5. Poor developing nations are in danger of being forced to feed the voracious appetites of rich countries for biofuels instead of their own hungry masses, and suffer the devastation of their natural forests and biodiversity.

### IV. Wind

The criticisms of wind farms range from "unsightliness and a blot on the landscape", to noisiness and perhaps the most damning of all, to its ineffectiveness and inefficiency, particularly the intermittent and unpredictable nature of the wind. Its efficiency in supplying electricity is about the same as a nuclear power plant. As far as its intermittency is concerned, this can be addressed by embedded local generation. Locating wind farms offshore would cancel out most of the other criticisms. With improvements in aesthetic design and considerably scaled down, wind turbines could have a role in small- to micro-generation on land.

1. More than ten years' experience of wind farms in Cornwall has shown that wind generation and demand generally go together, so its intermittency is less of a problem than its critics make it out to be.

2. Embedded local generation improves the quality of supply, evening out fluctuations characteristic of electricity supplied by distant power plants. The central grid should act as a back-up system for local generation.

3. A black box between the end-use consumer and the supply can take any excess power, over and above that used for lights and appliances and dump it in a buffer heating circuit. It can also warn the household that it is approaching the limits when demand for quality electricity is near to exceeding supply, and encourage households to use electricity responsibly.

4. To supply 20 percent of UK's electricity would require just over 1 per cent of the total UK land area.

### V. Solar

Solar cells even at a low 10 percent energy conversion efficiency could satisfy the world's energy needs with just over 0.1 percent of the earth’s surface. Solar power is poised to enter the mainstream market. Worldwide, photovoltaic installations jumped by 61.5 percent to 927 MW in 2004, up from 574 MW installed in 2003. A big advantage of solar power is that it has minimum impacts on the environment, which are mostly associated with the manufacturing processes, and do not require major changes in land use. Solar panels can be conveniently integrated into existing building structures and rooftops, and are ideal for micro-generation. There are two trends in solar cell development: bringing down manufacturing costs and boosting energy conversion efficiency, both of which are making solar energy much more affordable.

1. Over the past decade, "second generation" thin-film technologies have been developed that do not require costly crystalline silicon wafers and can be manufactured much more cheaply. These include devices based on a range of new inorganic semi-conducting materials, as well as multi-junction amorphous (non-crystalline) silicon. Thin-film cells are fabricated using techniques such as sputtering, physical vapour deposition and plasma-enhanced chemical vapour deposition.

2. Multi-junction cells based on amorphous silicon have been the most successful second-generation technology to-date, capturing 5-6 percent of the market not dominated by crystalline silicon. Amorphous silicon can be made from waste silicon from the computer chips industry.

3. Organic photovoltaics are made from organic materials, which are diverse and versatile, offering endless possibilities for improving a wide range of properties. Organic molecules are cheap to make,

they can have very high light absorbing capacity so that films as thin as several hundred nanometres would be sufficient for the purpose. Organic materials are compatible with plastic and other flexible substrates; and devices can therefore be fabricated with low-cost, high throughput printing techniques that consume less energy and require less capital investment than silicon-based devices and other thin-film technologies. One estimate put the reduction in cost by a factor of 10 or 20. These affordable new generations of solar devices will be a boon for the energy needs of poor countries that do not have power grids or other infrastructure support

4. Dye sensitised solar cells (DSSCs) are among the third generation devices nearest to the market, or already in the market. These are not purely organic solar cells, but are made of a hybrid of organic and inorganic semi-conducting materials. Some of these have reached energy conversion efficiencies of about 11 percent.

5. A study published in 2000 indicated that the N3 ruthenium dye used in the DSSCs is not mutagenic, but its other potential toxicities have not been investigated. Although conventional $TiO_2$ may be relatively harmless, many ultrafine nanoparticles (less than 1 micron), such as those used in DSSCs, *are* pathogenic, and chronic exposure to the nanoparticles may result in fibrosis and airflow obstruction in the respiratory tract. It is important for proponents and developers of these very promising solar cells and applications to ensure that researchers and workers as well as the public are protected from the hazardous materials, that appropriate containment and recycling of wastes take place to prevent environmental pollution, and that research on safety and safe use goes hand in hand with development and commercial exploitation. In addition, effort should be devoted to finding safer alternatives for toxic materials.

6. Quantum dots are offering the possibilities for improving the efficiency of solar cells in at least two respects, by extending the band gap of solar cells for harvesting more of the light in the solar spectrum, and by generating more charges from a single photon. Solar cells based on quantum dots could theoretically convert more than 65 percent of the sun's energy into electricity, approximately doubling the efficiency of solar cells.

## VI. Wastes

Wastes may be the most important source of sustainable renewable energy in a post fossil fuel economy. Treating wastes to recover energy prevents them from polluting the environment, and harvesting energy from organic wastes saves carbon emissions twice over, by preventing carbon emissions that would otherwise have gone into the atmosphere, and by substituting for fossil fuels.

Biogas is efficiently generated by anaerobic digestion of organic wastes, and can be used for combined heat and power generation in buildings and as fuel for mobile vehicles when carbon dioxide and hydrogen sulphide are removed from the methane. Fuel-efficient super-clean cars that run on biogas methane are already on the roads in Sweden, Switzerland and Germany, which have no fuel duty on renewable natural gas. Sweden is the world leader in gas-powered vehicles, and has around 4 500 natural gas vehicles, 40 percent run on biogas produced in community biogas plants.

Hydrogen can be readily produced from organic wastes, but compact hydrogen storage remains a major obstacle for using it as fuel in small vehicles.

A new fully contained, low temperature thermal conversion process shows considerable promise in recovering biodiesel from food-processing and slaughterhouse wastes and also in making diesel from waste plastics. Recycling plastics save substantially on energy and carbon emissions, but the best way to save on both is to use less. Diesel produced from plastic wastes that are difficult to recycle into plastics is not renewable, but it prevents toxic pollutants from landfills and incinerators and generates extra non-renewable fuels.

Green algae can potentially combine low-cost and energy efficient capture of carbon dioxide from power plant exhausts with sustainable biodiesel production.

1. Common bacteria, naturally found in organic wastes when confined in anaerobic digesters, ferment the wastes to produce 'biogas' as by-product, which typically consists of about 60 percent or more of methane ($CH_4$) and a small amount of hydrogen ($H_2$), both of which can be burnt as smokeless fuel.

2. Hydrogen can be produced by anaerobic digestion in a two-stage process, with the first stage optimised to produce hydrogen, followed by methane in the second stage. The key appears to be a slightly acidic pH of 5.5 in the hydrogen reactor, instead of pH 7 in the methane reactor, with both reactors run at 35 C. In the pilot lab experiment, the two stages together removed 68 percent of chemical oxygen demand in the waste.

3. A bioelectrochemically-assisted reactor at bench-top scale was able to produce hydrogen from any biodegradable organic matter. A combined fermentation and bioelectrochemically assisted anaerobic microbial fuel cell has the potential to produce as much as 8 to 9 molecules of hydrogen starting from a molecule of glucose (the theoretical maximum is 12).

4. A conservative estimate suggests that if all the wastewater sites in large urban areas of Ontario, Canada, were to use anaerobic digesters and simply recover the methane to generate electricity, this would produce 1.51 GWh/day and save 432 tonnes of $CO_2$.

5. Methane mitigation will slow global warming and benefit public health by reducing the growing global background concentration of ozone. Ozone damages agriculture and ecosystems, and is associated with premature deaths in humans. It is estimated that reducing methane emissions 20 percent beginning 2010 will decrease ozone levels in the atmosphere sufficiently to prevent 370 000 premature death by 2030.

6. The United Nations Development Programme (UNDP) 1997 Report, *Energy After Rio: Prospects and Challenges* identified community biogas plants as one of the most useful decentralized sources of energy supply.

7. The many benefits of biogas in the Third World are now generally recognized. It has resulted in a smoke- and ash-free kitchen, so women and their children are no longer prone to respiratory infections. Women are spared the burden of gathering firewood, a load of 60-80 lb per week, which can take up to one day a week. That, and the practice of containing livestock for manure collection, which might otherwise graze in the forest, both contribute to protecting the remaining forests and allowing the forests to regenerate. The sludge remaining after anaerobic digestion is richer in valuable nutrients than the animal manure, providing vegetables, fruits and cereals with a top quality fertiliser that guarantees better crops.

8. Nepal has overtaken China and India in the number of biogas plants per capita. Each of its 125 000 functioning digesters prevents five tonnes of carbon dioxide equivalents from being pumped into the atmosphere every year. This 'saved' greenhouse gas is worth US$5 million. This money can be invested back into clean energy that would make Nepal eligible to trade even more carbon offset to rich polluters.

9. Producing carrier bags from recycled rather than virgin polythene reduces energy consumption by two-thirds, produces only a third of the sulphur dioxide and half of the nitrous oxide; it reduces water use by nearly 90 percent, and carbon dioxide emission two and a half times. For every tonne of recycled polythene produced, 1.8 tonnes of oil are saved.

10. Although all types of plastics could be recycled, only 7 percent actually were in 2001. The rest were buried in landfills (80 percent) or incinerated (8 percent). Recycling is done mechanically or chemically. In mechanical recycling, the waste plastics are sorted, then melted, shredded or turned into granules and moulded into new shapes. In chemical recycling, the plastic polymers are broken down into their constituent monomers by heat treatment (thermal depolymerization), which can then be used again in refineries or petrochemical and chemical production.

11. PVC, polyvinyl chloride, is the second most commonly used plastic in the world, and causes the most problems for health and the environment. It is the largest source of dioxin when burnt in

incinerators and in accidental fires in buildings. Dioxin is also created during the manufacture process, and toxic chemical additives are incorporated in PVC products. PVC is difficult to recycle and contaminates other plastics.

12. A relatively new low temperature thermal conversion process (TCP) - which can be carried out in adapted oil refineries - offers a completely contained and highly efficient way of turning food-wastes into biodiesel. One claimed advantage of TCP in treating food-processing and slaughterhouse wastes is that it breaks down the prion proteins associated with mad cow disease, which survive normal boiling or autoclaving. However, no evidence was presented for this claim.

13. TCP looks promising also for recycling mixed plastics wastes chemically that cannot easily be recycled back into plastics.

14. Green algae could offer a cost-effective and environmentally benign way to capture carbon dioxide on-site with no need for transport or storage, and at the same time, provides renewable biodiesel fuel much more effectively and sustainably than energy crops. The algae proliferate in the exhaust from power plants, removing up to 40 percent of the carbon dioxide for photosynthesis, and also 86 percent of the nitrous oxide. Algae are prolific and can produce 15 000 gallons of biodiesel per acre, compared to just 60 gallons from soybean.

15. Fuel-efficient super-clean cars are now available, which run on biogas methane. Compared with petrol or diesel, renewable methane (from biogas) considerably reduces exhaust noise levels, lowers emissions of nitrogen oxides, and has almost zero emissions of particles or dust. Sweden, Switzerland and Germany have no fuel duty on renewable natural gas, and Sweden is world leader in gas-powered vehicles. There are around 4 500 natural gas vehicles in Sweden, 40 percent run on biogas. The Swedish Association of Green Motorists has ranked biogas methane driven cars the best environmental car for 2005.

## VII. Food & Energy

Food provides the energy people need to survive and do work. The globalisation of the food industry and concentration of the food supply chains are the major causes of increase in food transport across the globe, wasting a lot of energy and spewing extra tonnes of carbon dioxide into the atmosphere. It is estimated that the direct social, environmental, and economic costs of food transport within the UK amount to over £9 billion each year, which is 34 percent of the market value of UK's agriculture and food and drink manufacturing industry. Policies are needed to minimize food import/export, to promote instead, national/regional food self-sufficiency.

Food production itself is in crisis from rising energy costs, the severe depletion of water, the loss of agricultural land from decades of unsustainable farming practices, and global warming. An integrated approach to food and energy would do much to increase both energy and food security, save on carbon emissions and mitigate global warming, and contribute greatly to improving the health of the nation.

1. A report commissioned by UK's Department of the Environment, Food and Rural Affairs identified globalisation of the food industry and concentration of the food production base and food supply chains as the major causes of increase in food transport.

2. The direct social, environmental and economic costs of food transport within the UK have been estimated at over £9 billion per year, and are dominated by congestion, estimated at £5 billion, with accidents accounting for £2 billion per year, and greenhouse gas emissions, air pollution, noise and infrastructure a further £2 billion.

3. The United Nations Environment Programme estimates that the food sector consumes about 10-15 percent of total energy in industrialised countries, though only 2-5 percent are on the farm, due to fertilisers, pesticides and machinery. Estimates for the US and Canadian food sector put the figure at 17 percent and 11.2 percent respectively, which include total energy consumed on the farm, processing, transport, packaging, and storing farm products, as well as energy used by households to purchase, store and prepare food. The figures do not include energy costs in food-processing machinery and buildings, waste collection and waste treatment, or roads for transport; nor do they include energy consumed in importing/exporting food.

4. The depletion of water is perhaps the most serious threat to food production, as industrial agriculture is extremely thirsty. It takes 1 000 tonnes of water to produce one tonne of grain; aquifers are pumped dry in the world's major breadbaskets in the United States, China and India.

5. Not only water is depleted but also soil and soil nutrients and fertility, so productivity has been falling. Grain yields fell for four successive years from 2000 to 2003, and the world reserves are still at the lowest levels in 30 odd years.

6. Unsustainable practices over the past decades have resulted in massive losses of croplands from salination and soil erosion, totalling 20 million ha a year, or 1.3 percent of the world's croplands. Replacing lost croplands accounts for 60 percent of deforestation, greatly accelerating climate change. That is why catastrophes such as hurricane Katrina, flood, drought and extreme weather are increasingly frequent, impacting further on food production.

7. Global warming itself threatens food production through the increase in temperature alone. Yields fall by 10 percent for every deg C rise in night temperature; and the latest predicted rise in average global temperature is 1.9 to 11.5 C within this century when carbon dioxide in the atmosphere reaches 560 ppm (parts per million), double the pre-industrial level.

8. There is an urgent need to reduce greenhouse gas emissions to mitigate climate change, and a lot can be done through our food system. An estimate of the French food sector put its carbon emissions at more than 30 percent national total; not including import/export, household use and storage, food processing, and imported fertilisers.

9. Policies are needed to minimize food import/export, to promote instead, national/regional food-sufficiency, and to reverse the concentration of food supply chains in favour of local shops and cooperatives run directly by farmers and consumers. In addition, there should be government subsidies and incentives for reducing carbon dioxide emissions on farms, and for farms and local communities to become energy self-sufficient in low or zero-emission renewables.

10. What we need above all is a new model of balanced growth based on reciprocity and symbiotic relationships to replace the dominant model of unlimited growth based on rampant competition and the survival of the fittest.

11. The new model is exemplified by abundantly productive farming systems with 'zero-input' and 'zero-emission' that have now been implemented in many Third World countries, which combine integrated farming (crops, livestock and fishponds) with anaerobic digestion of livestock wastes to provide biogas energy and rich fertilisers.

12. Big farms, meat and fish-packing plants, distilleries, and various agro-industries in the Third World that have adopted anaerobic digestion to recover biogas from organic wastes are now self-sufficient in energy, besides having big volumes of nutrient-rich effluent for feeding fishponds, and 'fertigating' (fertilizing and irrigating) many kinds of crops.

13. ISIS is proposing to set up a 'zero emission' Dream Farm II for demonstration, education and research purposes; combining the best and most appropriate technologies to showcase the new paradigm and at the same time, to serve as an incubator and resource centre for new knowledge and technologies that really serve people and planet.

14. A network of such farms - without the research education components in Dream Farm II proper - dotted around the countryside would supply cities with fresh nutritious food, cutting down immeasurably on food miles and ecological footprint. It would also supply local farmers' markets, revitalise town centres, provide employment and rebuild the rural economy.

# Acknowlegments & credits

We thank Eva Novotny, Chee Yoke Ling, Alan Simpson MP, Caroline Lucas MEP, Michael Meacher MP, Zac Goldsmith, Dave Gledhill, Alick Bartholomew, Kenneth Spelman, Chris Maltin, Peter Rae, Antonio Claparols and Peter Read for comments to drafts of this manuscript in part or in whole. We are also grateful to many of the scientists whose work we have cited in this Report, and whom we have consulted for points of accuracy or for review. Most of the chapters have been updated and modified from previous articles circulated on ISIS' extended e-mal list and printed in our quarterly magazine, *Science in Society*. A large proportion of the articles have been republished on many websites and magazines. As a result, many subscribers and readers have given us valuable feedback that has substantially improved individual chapters.

Mae-Wan Ho and Peter Saunders have co-edited this Report, Julian Haffegee is responsible for design and layout, and Sam Burcher and Andy Watton for other support. Joe Cummins kept the editors up-to-date on the scientific literature.

**About the Institute of Science in Society (ISIS)**

The Institute of Science in Society was co-founded in 1999 by scientists Dr. Mae-Wan Ho and Prof. Peter Saunders to provide critical yet accessible information to the public and policy makers. Its aims are to reclaim science for the public good; to promote a contemporary, holistic science of the organism and sustainable systems; and influence social and policy changes towards a sustainable, equitable world. ISIS is a partner organisation of the Third World Network based in Penang, Malaysia, and also works informally with many scientists who are members of ISIS or of the Independent Science Panel that ISIS has initiated (see below). ISIS works through lively reports posted on a popular website www.i-sis.org.uk and circulated to an e-mail list that includes all sectors of civil society worldwide, from small farmers in India to policy-makers in the United Nations. We publish an attractively illustrated quarterly magazine *Science in Society* and produce topical in-depth reports and books, such as *Which Energy?* (2006), *Unravelling AIDS* (2005) and *The Case for a GM-Free Sustainable World* (2003, 2004), and *Living with the Fluid Genome* (2003).

ISIS also initiates major campaigns from time to time, including:

**World Scientists Open Letter**, February 1999, calling for a moratorium on genetically modified (GM) organisms, ban on patents on life, and support for sustainable agriculture; now signed by 828 scientists from 84 countries http://www.i-sis.org.uk/list.php

**Independent Science Panel** (ISP) (http://www.indsp.org), May 2003, consisting of dozens of scientists from many disciplines. Its highly influential report (The Case for a GM-Free Sustainable World) calling for a ban on GM crops and a comprehensive shift to sustainable agriculture was presented in the UK Parliament and European Parliament, circulated worldwide, and translated into 5 or more languages.

**Sustainable World Global Initiative**, launched on the web April 2005, http://www.i-sis.org.uk/SustainableWorldInitiativeF.php. First international conference, held 14/15 July 2005 in UK Parliament, followed by a weekend workshop 21 January 2006, out of which came a proposal for an innovative food and energy self-sufficient farm for demonstration/education/research purposes. We shall produce a definitive report on sustainable food systems under a new economic model, together with the socio-economic, political and structural changes needed for implementation.