GREEN ENERGIES

100% RENEWABLES BY 2050

MAE-WAN HO
BRETT CHERRY, SAM BURCHER & PETER SAUNDERS

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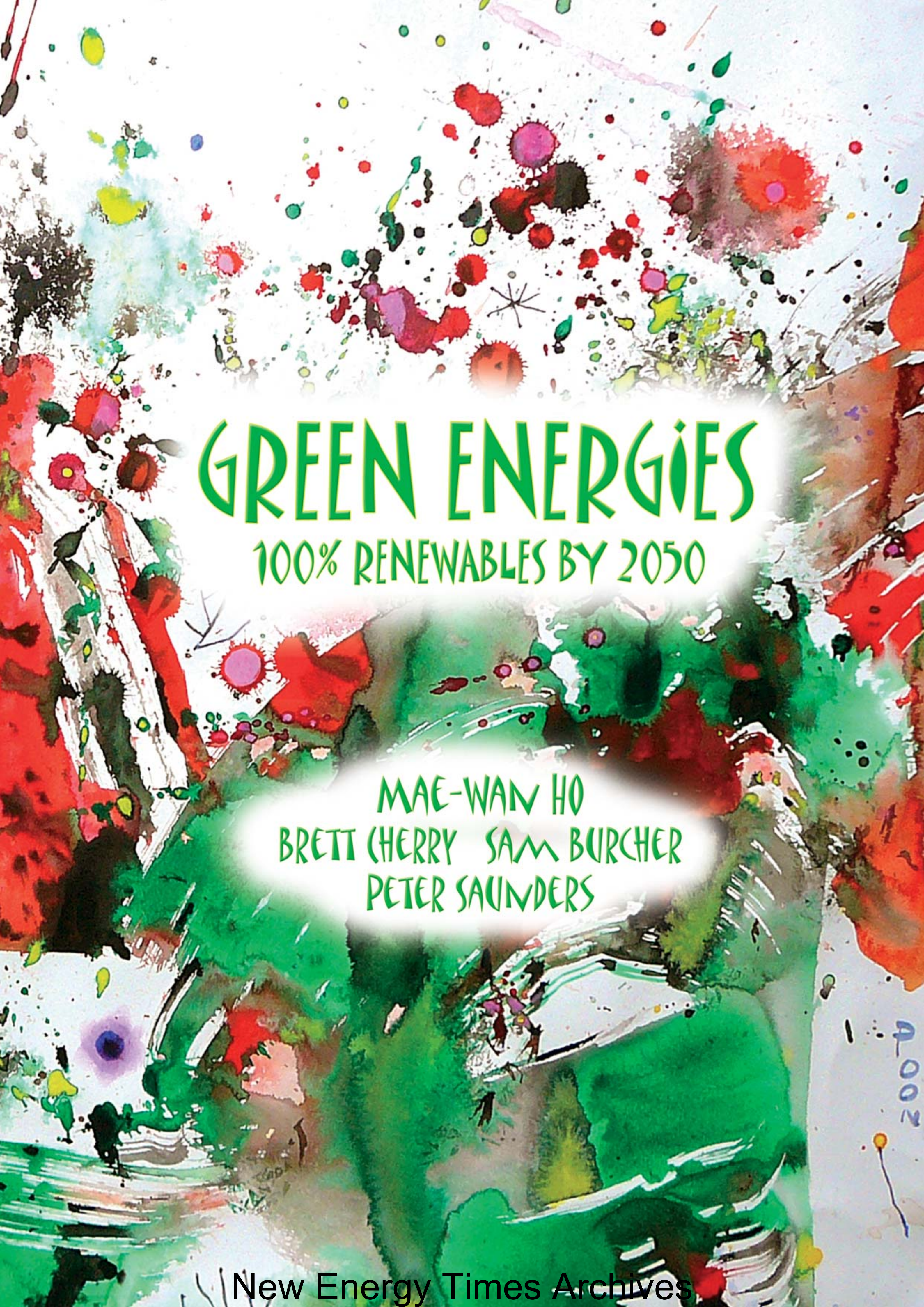
Institute of Science in Society
Third World Network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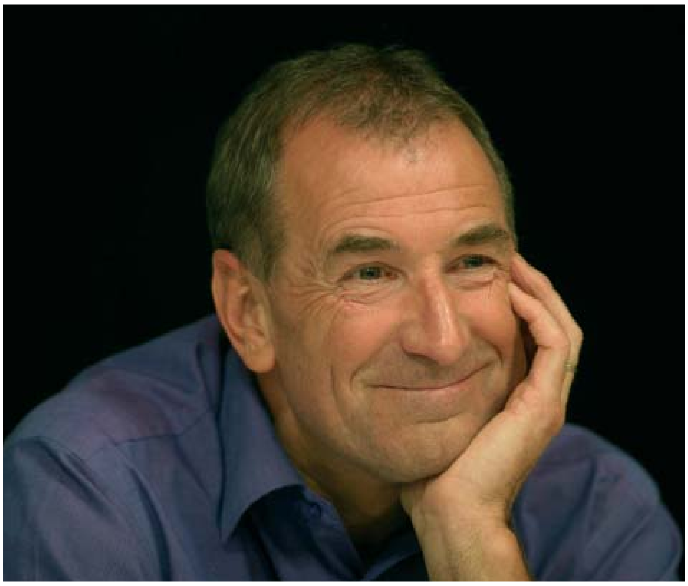
FOREWORD BY ALAN SIMPSON MP

Alan Simpson MP
UK Government Special Advisor on
Renewable Energy and Feed-in Tariffs



Let no one be in any doubt about the importance of this report. Take it seriously and this could be the 'get out of jail' card that Britain, and many other countries, will need to play in avoiding the drift into climate chaos.

The time for transformation is astonishingly short. There is no point in having 2050 targets without a programme that races into this transformation now. Rajendra Pachauri, the head of the International Panel on Climate Change, gives us three years in which to make dramatic switches in the whole way in which we think about energy systems.

Global leaders gathering in Copenhagen will haggle about a 2050 plan that can keep atmospheric carbon dioxide levels within a maximum of 450ppm. They hope it is not a bridge too far for the world's politicians. The difference between the politics and the science is that the real survival threshold is around 350ppm. We are already beyond this level. Tomorrow's agenda is not about the slowing down of carbon emissions, it is about how we row back form where we are now.

Many of the renewable energy choices set out in this report are already with us. Some require little more than a hop, skip and a jump to reach them. The trouble is that this leap has to be in a different direction from where we are currently heading. It involves some fundamental breaks from 'big energy', big pollution and the waste making society. Treading more lightly on the planet involves a shift into holistic economics which puts back as much - if not more - than we take out.

The report is a road map for survival. It sets out the science, the technology and the choices for a different future. All it requires is the political will… and that's where we're stuck. It invites changes that are as much about power as energy. Most of the choices touched on in the report work best where there is local and public ownership to ensure that the energy system supports sustainable communities rather than global shareholders.

It is not just about empowering the scientists to spell out what can be done. It is about empowering the public to become the drivers of change we can all live with. If we have the sense to act on this report may be we will.

FOREWORD BY CHEE YOKE LING

Chee Yoke Ling
Director
Third World Network

This report is an explosion of hope in a world caught in the morass of false and exorbitant solutions to the energy and climate crisis promoted by corporate interests.

The latest science alerts us that 350 ppm atmospheric CO_2 is the maximum limit that we must target in order to avoid “irreversible catastrophic effects”. Developing countries with 80 percent of the world population - the vast majority struggling to rise above poverty - are already hard hit by more frequent and intense climate disasters, and any false solution foisted upon them will certainly stress them beyond the breaking point.

Fortunately, tremendous human capacity and technologies for real solutions to the crisis already exist, with more innovation emerging and further possibilities on the horizon, as *Green Energies* so clearly documents.

The challenge before us is to rapidly adopt renewable energies solutions across communities and nations. *Green Energies* is extremely timely as governments gather in Copenhagen in December 2009 to renew their commitment to fully and effectively implement the United Nations Framework Convention on Climate Change (UNFCCC) forged in 1992. It is our only legally binding global treaty on climate change, and nations small and large stated in the Preamble that they are “*Determined* to protect the climate system for present and future generations.”

Equity is a pillar of the necessary transformation towards climate stabilization and sustainable development is enshrined in the UNFCCC. It was agreed that “the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs.”

Thus it was acknowledged that “the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities”.

Green Energies clearly states: “For the human species, it is the capacity to use natural resources responsibly and *equitably*, to meet the needs of *all* in the present without compromising the ability of future generations to meet their own needs.”

It challenges governments to take a bold step in setting a national target for 100 percent green, renewable energy sources by 2050 that the report shows is possible with the right policies and global cooperation in place. The report is inspiring and realistic. We *can* do it, and cannot *not* do it. Climate and our survival are non-negotiable.

PREFACE

350 PPM THE NEW TARGET

Global warming is happening much faster than the IPPC (Intergovernment Panel on Climate Change) predicted in its latest 2007 report. For one thing, Its climate models failed to account for the rapid summer melting of the polar ice caps that's been making headlines several years in a row.

The IPCC helped set the 450 ppm maximum of atmospheric CO_2 that is supposed to limit the global temperature rise to below 2 ˚C, and prevent "dangerous anthropogenic interference with the climate system."

But top climate scientists Jim Hansen and colleagues, using more realistic climate models and key data from the remote history of the earth, showed that 450 ppm is beyond the danger zone, and we must even reduce atmospheric CO_2 down from its 385 ppm to 350 ppm, or else face "irreversible catastrophic effects" [1]. The head of IPCC Rajendra Pachauri now agrees [2].

The good news is that we can still do it. It is not too late. All it takes is to stop burning fossil fuels to bring atmospheric CO_2 back down to 350 ppm within the next decades. But we must act now, because 385 ppm is already within the danger zone, and we cannot afford to let it remain there for too long, or we push the planet past the point of no return.

That is why we need to commit ourselves to truly green energies as a matter of urgency

WHAT'S TRULY GREEN?

'Green' is environmentally friendly, healthy, safe, non-polluting, renewable, and sustainable.

Renewable energy, as defined by British Petroleum (BP) [3], is derived from natural processes that do not involve the consumption of exhaustible resources such as fossil fuels and uranium. But it could include industrial scale biomass, biofuels, or hydroelectric from large dams, none of which is sustainable.

'Sustainable' is the key to being truly green. But the word 'sustainable' has been hi-jacked so often to mean just the opposite that it needs to be redefined.

To be sustainable is to endure like a natural biodiverse ecosystem for hundreds if not thousands of years, thanks to a circular economy of cooperation and reciprocity that regenerates and renews the whole [3]. For the human species, it is the capacity to use natural resources responsibly and *equitably*, to meet the needs of *all* in the present without compromising the ability of future generations to meet their own needs. We have updated the usual Bruntland definition of sustainability [4] to incorporate the overriding lesson from nature that cooperation and reciprocity between the biodiverse inhabitants of the ecosystem are necessary for the survival of the whole; and this applies all the more so to ecosystem Earth.

Unfortunately, our policy-makers are by and large still engaged in confrontational politics, being misled by the Darwinian myth of competition and the survival of the fittest that will surely take us beyond the point of no return. History has taught us why civilisations collapse in the past when faced with ecological crises [5], simply through the failure to take the political decisions necessary for survival. Are we going to repeat history in the present global ecological crisis that has the survival of the entire human species at stake? Or will our political leaders in the United Nations Framework Convention on Climate Change learn to cooperate and adopt the most appropriate green energy policies for us to meet the 350 ppm target?

As Germany has demonstrated so well within the past decade, the appropriate policies can trigger a dramatic growth in new renewable energies, with industry offering a variety of distributed, decentralised options that also give people autonomy and independence from big centralised power stations. The global shift to renewable energies is happening, and many politicians and energy experts see no difficulty in producing a 100 percent of our energy from renewable sources by 2050, which is what Germany intends to achieve [6], as the world's first major renewable economy.

Green Energies is a follow up on *Which Energy?*, the first in the series of ISIS' Sustainable World Initiative reports, and an elaboration of the theme of local food and energy systems presented in *Food Futures Now, Organic, Sustainable, Fossil Fuel Free*, the second report in the series.

Green Energies provides policy-makers and the public with the evidence for making the right decisions that will enable us to meet the 350 ppm target and 100 percent renewable energies by 2050. Time is running out, as are remaining resources. That's why it is important at the outset to recognize and reject options that are neither renewable nor sustainable *are* dangerous, notably nuclear, carbon capture and storage, and biochar. Our capacity for truly sustainable and renewable energies is growing every day. It is neither necessary nor acceptable to export the burden of cutting carbon emissions to poor developing countries via carbon trading schemes. The developed nations must take responsibility for reducing their own emissions at home, while providing genuine financial and technological assistance to poor nations that have to cope with the worst effects of climate change.

Renewable energy is inexhaustible energy. Wind energy alone can supply 40 times the world's electricity use or its total energy consumption five times over. An enormous potential also exists for solar energy, and electricity from locally installed solar panels is already as cheap as electricity from the grid. People everywhere are innovating and switching to renewables to save on fuel bills and saving communities as they are saving the planet. In 2008, for the first time, more renewable energies capacity has been added than conventional energies and the trend continues. Local small scale and micro-generation are booming in the developed countries wherever feed-in tariffs have been introduced, giving people independence and autonomy, plus the flexibilities for upgrading as technologies improve.

At the same time, appropriate science at the frontiers has opened up new possibilities for recycling waste heat as electricity, harvesting and storing sunlight by artificial photosynthesis, and solving our nuclear waste problem by low temperature transmutation after we give up nuclear energy for good. These are exciting times. All we need to save the planet is for our leaders follow the way of nature and the will and wisdom of the people.

Mae-Wan Ho and **Peter Saunders**

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AUTHORSHIP & ACKNOWLEDGMENT

Brett Cherry wrote Chapters 15, 16 and 17, and contributed to Chapters 1 and 13. Sam Burcher wrote Chapters 19, 20 and 23, and contributed to Chapter 22. Prof. Peter Saunders wrote most of Chapter 1, co-wrote Chapter 2 with Dr. Mae-Wan Ho, and co-edited the volume. Chapters 34 and 35 are assembled from previous articles written by Lewis Larsen of Larttice Energy LLC and edited by Dr. Mae-Wan Ho. Prof. Joe Cummins wrote Chapter 24 and co-wrote Chapter 26 with Dr. Mae-Wan Ho. Peter Bunyard wrote Chapter 25. Prof. Li Kangmin co-wrote Chapter 21 with Dr. Mae-Wan Ho. The rest were written by Dr. Mae-Wan Ho, who also edited the volume with Prof. Peter Saunders.

Andy Watton was responsible for design and production, Sam Burcher for publication, print and distribution, liaising with sponsors, and organizing the launch conference, and Julian Haffegee and Brett Cherry for other support.

Most of the artwork in this volume has been generously donated by a member of ISIS' Board of Trustees, Canadian artist Li Poon, much acclaimed for his unique style and "shamanistic" qualities. His most recent paintings can be seen at http://lipoon.wordpress.com.

All except Chapters 1, 2, 11, 13, 17, 18, 20 and 23 (which are new) are based on articles that have appeared in past issues of *Science in Society* and updated, and revised to varying degrees, having benefited from feedback from our readers.

We thank the numerous scientists who check the accuracy of our description of their work in different chapters and gave us useful comments and suggestions. The deficiencies that remain are entirely our own.

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GREEN ENERGY OPTIONS FOR ALL

The world is shifting to renewable energy in the wake of peak oil and accelerating global warming. In contrast to the exhausting supplies of fossil and nuclear fuels, renewable energy is inexhaustible.

But being renewable is not enough. It must also be environmentally friendly, healthy, safe, non-polluting and sustainable. 'Green' energy encapsulates all of these qualities, of which the most important perhaps is 'sustainable'. 'Sustainable' needs to be redefined at the outset to counter its widespread misuse to mean just the opposite.

To be sustainable is to endure like a natural biodiverse ecosystem for hundreds and thousands of years through a circular economy of cooperation and reciprocity that regenerates and renews the whole. For the human species, it is the capacity to use natural resources responsibly and *equitably*, to meet the needs of *all* in the present without compromising the ability of future generations to meet their own needs. The overriding lesson from nature is that cooperation and reciprocity between the biodiverse inhabitants of the ecosystem are necessary for the survival of the whole; and this applies all the more so to ecosystem Earth.

This report shows that a wide variety of truly green and affordable energy options already exist for all nations to become energy self-sufficient and 100 percent renewable within decades. Policies and legislations that promote innovations and internal market, and decentralised, distributed small to micro-generation are the key.

100 PERCENT RENEWABLE BY 2050 TRANSITION TO LOW CARBON AN OPPORTUNITY

Transition to a low carbon or zero carbon economy is a matter of urgency especially for the developed nations that are also the major emitters of greenhouse gases.

It is generally assumed that transition to low carbon is an economic hardship that should be avoided as far as possible. But as Germany has clearly demonstrated, it can be an unprecedented opportunity for innovations, for creating new jobs and new markets, and delivering health and wealth to the nation.

Germany has stolen a march on the rest of the world in research and development of renewable energies since the last oil crisis of 1974. Within the past two decades, the government has provided subsidies and important legislations to create an internal market, the most important of which is the Feed-in Law, first introduced in 1991, and in a modified form in 2000, which obliges national utilities to buy electricity generated from renewable sources at above-market rates set by the government.

As a result, Germany now generates 7.3 percent of its primary energy from renewable sources: 29 GW of wind energy, 13.5 GW in photovoltaic (PV), 7.3 GW in solar thermal, the rest in hydroelectric, geothermal and biomass, as appropriate to resources available in the country. The government is committed to increasing the proportion of renewable energy to 50 percent by 2050, but its renewable industry claims it can do three times as well to reach 100 percent renewable by that date.

There is no provision for nuclear energy in Germany's low/zero carbon future; it is to be phased out completely by 2022. Carbon capture and storage does not figure up to 2020, as even its supporters do not expect it to be commercially available by then.

Germany is also to reduce greenhouse gas (GHG) emissions by 40 percent from their 1990 levels by 2020. And it is not counting on carbon trading to export its GHG emissions to developing countries and increase their burden.

In contrast, the UK Government's Low Carbon Transition Plan is a lackluster, business-as-usual paper exercise, consistent with its failure to stimulate and support renewable energy options over the years. The UK's renewable energy contribution is currently about 1.8 percent, third from bottom in the European Union league table, ahead of Malta and Luxembourg. The government has also opted to depend on a nuclear industry that has already become a financial and safety nightmare, and on carbon capture and storage, an untried technology that will entrench the nation in fossil fuels. Worse yet, it will rely on carbon trading to export GHG emissions to developing countries.

THE NUCLEAR BLACK HOLE

The much touted "nuclear renaissance" promoted by Ppresident George W Bush and other governments is unravelling. Across the USA, the nuclear power industry has so far failed in its efforts to overturn any state ban on building more reactors. The Obama administration put a freeze on Yucca Mountain as a long-term nuclear waste deposit in February 2009 amid new evidence of runaway construction costs.

The nuclear industry is notorious for cost overruns during construction of power plants. But that is nothing compared to the downstream costs of decommissioning, waste management and disposal. It is considered a bad investment for private industry. Consequently, the UK taxpayer has had to take over all liabilities and costs of running the dirtiest, loss-making parts of the industry at Sellafield, now £3 billion a year and rising. Meanwhile the cost of clean-up and decommissioning has ballooned to over £73 billion. Sellafield has become the world's nuclear waste dump with no end in sight, its reprocessing plants are not functioning and there is as yet no designated final waste repository as more spent nuclear wastes pile up.

As one commentator remarked of the US industry: "Rarely has so much money, scientific know-how and raw state power been marshalled to achieve so little." Several hundred billion dollars of investment resulted in 104 operating plants, about a quarter of the global total that produces just 19 percent of electricity in the country. The cost of nuclear waste disposal was last estimated at US$96.2 billion.

The US taxpayer too, was left with enormous burdens in "stranded costs", while the nuclear industry in both countries continue to milk the old reactors for sheer profit, well past their decommissioning dates, and often their safety limits.

Adding to the hundreds of billions already squandered are an estimated US$1 trillion in research and development that governments around the world have spent on 'safer', 'cleaner' reactors that have proven fruitless so far.

Safety is a major issue. It turns out that none of the existing reactors or even 'generation 3' reactors under construction are proof against malfunction or sabotage. In addition, a main source of hazard is the spent fuel sitting in overcrowded cooling ponds on site that can easily catch fire and cause explosions.

The fallout from Chernobyl was 30 to 40 times that released by the atom bombs of Hiroshima and Nagasaki in Japan during World War II. A 2005 report estimated it was responsible for 56 direct deaths, and an estimated 4 000 extra cancer cases among the approximately 600 000 most highly exposed, and 5 000 among the 6 million living nearby.

There is also strong new evidence from Germany linking childhood leukemia to proximity to nuclear power stations, which gives a hint of the health burden of accumulating toxic and radioactive wastes to present and future generations.

Globally, nuclear power contributed to14.8 percent of electricity and a mere 2.1 percent of energy consumed in 2006, and falling since; in the meantime, the world's new renewable energy contribution has risen from 0.4 to 6.2 percent. To put nuclear power in perspective, Germany in a single year of 2007 increased its renewable energy output by 15 TWh, the equivalent of two nuclear reactors.

High grade uranium ore is fast depleting, and mining and extracting uranium is energy intensive as well as environmentally destructive. Lifecycle assessments show that when uranium ore grade falls below 0.02 percent in the next 50 or 60 years, it would consume more energy to build uranium fuel reactors than the energy they could ever produce.

It is obvious that we must abandon the nuclear option as quickly as possible and concentrate on installing renewable energy generators. It takes only a few days to install wind turbines or solar generators, while a nuclear power plant takes an average of 10 years or more.

Meanwhile, as part of global nuclear disarmament, high weapons grade uranium could be burnt up in the remaining nuclear reactors. At the same time, serious investments should be made into condensed matter nuclear science that could transmute toxic and radioactive nuclear wastes into safer elements while generating more energy (see later).

BEWARE THE BIOCHAR INITIATIVE

We warned against biofuels from 'bioenergy' crops and plantations in our 2006 *Which Energy?* report and predicted the increased deforestation, land grab and food price hikes that have come to pass. Calls for moratorium on biofuel plantations have now come from Africa, the United Nations, the US, and the UK government's Environment Audit Committee.

The International Biochar Initiative (IBI) is similar in that it proposes is to grow crops and trees on hundreds of millions of hectares of illusory 'spare land' in Africa, South America South Asia, and other developing countries. But instead of making biofuels from the harvested biomass, it will be turned into biochar (charcoal) to be buried in the soil, where it will remain stable for thousands of years and increase crop yields. Biochar is therefore promoted as a "carbon negative" initiative that could save the climate – by sequestering stable carbon in the soil - and boost food production. The industrial 'pyrolysis' process that produces biochar could also recover some low grade fuels as by-products.

IBI is strongly criticised as a "new threat to people, land and ecosystem" in a declaration signed by more than 155 non-profit organisations worldwide.

The IBI was inspired by the discovery of 'terra preta' (black earth) in the Amazonian basin at sites of pre-Columbian settlements (between 450BC and 950 AD), made by adding charcoal, bone, and manure to the soil over many, many years. According to local farmers in the Amazon, productivity on the terra preta is much higher than surrounding soils.

But biochar produced today is not terra preta, as research findings have indicated. Furthermore, buried biochar is not stable, and could also increase the breakdown of humus in the soil. At the same time, its ability to improve crop yields appears sporadic, short-lived, and dependent on local conditions.

Most of all, saving the climate is not just about curbing the rise of CO_2 in the atmosphere that can be achieved by burying stable carbon in the soil (or CO_2 in the ground in case of carbon capture and storage), it is also about keeping oxygen (O_2) levels up. Keeping O_2 levels up is what only green plants on land and phytoplankton at sea can do, by splitting water to regenerate O_2 while fixing CO_2 to feed the rest of the biosphere. Climate scientists have only discovered within the past decade that O_2 is depleting faster than the rise in CO_2 both on land and in the sea. The acceleration of deforestation spurred by the biofuels boom since 2003 appears to coincide with a substantial steepening of the O_2 decline. In addition, biochar itself is an oxygen sink in the course of degrading in the soil; adding to the depletion of oxygen that cannot be regenerated because trees have been turned into biochar for burial. If biochar is promoted under the Clean Development Mechanism, it will almost certainly further accelerate deforestation and destruction of other natural ecosystems (identified as 'spare land') for planting biochar feedstock. All that will swing the oxygen downtrend that much closer towards mass extinction. And humans may be among the first to go, given our high oxygen requirements.

CARBON CAPTURE & STORAGE

Carbon capture and storage (CCS) is intended to reduce the impact of burning fossil fuels by capturing CO_2 from power stations and storing it underground in depleted oil and gas reservoirs, disused mines or deep saline aquifers. CCS has wide support among governments as the world oil supply is failing to meet demand and many countries still have large coal reserves.

CCS is an unproven technology. Its earliest commercial deployment is not expected before 2030, which would make it too late to be of use. The International Energy Agency estimates that for CCS to deliver any meaningful climate mitigating effect by 2050, 6 000 projects each injecting a million tonnes of CO_2 per year into the ground would be required.

CCS uses up between 10 and 40 percent of the energy produced in the power station, thereby erasing the efficiency gains of the last 50 years and increasing fuel consumption by one third. Power stations with CCS also require 90 percent more fresh water than those without. CCS is expensive and could double the plant costs and increase the price of electricity by 21 to 91 percent. A recent study commissioned by the German federal government confirmed that compared with renewable energy options such as wind and solar, CCS will increase CO_2 emissions 10 to 40 fold and raise the cost of electricity by 100 percent

The efficacy and safety of CO_2 storage is very much in doubt. A 2006 US Geological Survey pilot field experiment in a saline sedimentary rock formation in Frio, Texas, found that the buried CO_2 dissolved large amounts of the minerals in the rocks responsible for keeping the gas contained, thereby releasing CO_2 into the air. To be viable, the CO_2 captured and stored must leak at a globally averaged rate of not more than one percent per year over a timescale of centuries; otherwise, the emitted flux will be greater than or equal to that intended to be mitigated initially.

WORLD SHIFTING TO RENEWABLES

In 2008, for the first time, more renewable energy than conventional power capacity was added in both the European Union and United States, and the trend is continuing. Global power capacity from new renewable energies (excluding large hydro) reached at least 280 GW in 2008, a 16 percent rise from the 240 GW in 2007. New renewable energies now account for 6.2 percent of the global formal power sector capacity. This does not include, for example, the rapidly growing household generation of biogas in China, estimated to have reached 9 GW at the end of 2008, and is in addition to the traditional renewable of large hydroelectric that accounts for 6 percent, and fuel wood and other biomass in poor households, estimated at 12 percent.

Solar tops the new renewable energies. Solar heating capacity increased by 15 percent to 147 GW. Solar hot water in Germany set record growth in 2008, with over 200 000 systems installed, taking its total capacity to 7.3 GW. Grid-connected solar photovoltaic power continued to be the fastest growing power generation technology, with a 70 percent increase globally to reach 13.4 GW.

Global wind power capacity grew by 28 GW in 2008 to 122 GW. This was the fifth consecutive year of accelerating growth at just over 28 percent per annum. The US led the growth with 8.4 GW, a 49.5 percent increase on 2007; while China came second with the fastest growth rate and the second highest capacity increment at 6.2 GW.

At least 73 countries had renewable energy policy targets by the end of 2008, and several more were added to the list in 2009.

Feed-in tariffs were adopted in at least five countries for the first time in 2008 and early 2009: Kenya, the Philippines, Poland, South Africa and Ukraine.

Many politicians and renewable energy experts in Europe see a realistic option of 100 percent renewable energy supply in a commercial market free of any subsidy by 2050. The key is decentralised, distributed generation that provides energy autonomy at the point of use, a model that has proven so successful in Germany.

WHY & WHICH RENEWABLES?

The electricity industry contributes 37 percent of the world's carbon emissions, predominantly from burning fossil fuels. Renewable energies such as solar and wind do not emit CO_2 while generating electricity, and have the further advantage of improving the efficiency of energy use considerably.

Big power plants are located far away from most users, so the electricity generated has to be transported long distances over power lines where more than 7 percent may be lost before it is used. In addition, some 60-70 percent of the energy is lost as 'waste' heat. In contrast, solar panels and wind turbines are readily installed on or near homes and farms and the electricity generated as well as the heat can be consumed directly without much loss. Furthermore, because the capital costs of installation are much lower, they can be easily be upgraded to take advantage of technological improvements.

A 'cradle-to-grave' life-cycle assessment (LCA) gives a clearer idea as to how much better off we are with renewable electricity generation, and how different renewable options compare with one another. LCA includes upstream processes such as mining, refining, transport and plant construction, the production of the device or equipment, the generation and distribution of electricity, and downstream processes such as decommissioning and disposal of wastes.

Convenient measures are energy payback ratio, *EPR*, the energy produced during the operational lifetime *versus* total energy spent in LCA, and the amount of CO_2 produced per unit of energy in g CO_2/kWh.

Currently, small hydroelectric power tops the list with EPR 30-267 and 4-18 g CO_2/kWh; wind comes next at EPR 18 and 16.4 g CO_2/kWh offshore, and EPR 34 and 9.7 g CO_2/kWh onshore. Photovoltaics (PVs) come third at EPR 6-9-and 44-217 g CO_2/kWh. These performance parameters are clearly far superior to conventional oil or coal-fired plants.

Interestingly, modern combined cycle fossil fuel plants already perform as well or better than a conventional boiler plant fitted with carbon capture and storage.

PVs are improving rapidly; a 2008 study on 11 types of PV panels gave greenhouse gas emissions of 26 to 55 g CO_2/kWh, with CdTe (cadmium telluride) thin film PV modules clearly ahead with the lowest emissions of GHG as well as nitrogen oxides and sulphur oxides. But concerns remain over the high toxicity of components such as Cd, particularly if large numbers of such panels are to be fitted in earthquake zones. Efforts should be made to substitute safer alternatives in the fabrication of PVs as these are becoming common household fixtures.

SOLAR POWER TO THE PEOPLE

It is estimated that with a modest 10 percent efficiency at capturing solar energy, less than 0.1 percent of the earth's surface covered with solar panels would satisfy all the world's energy needs. Rapid technological improvements and savings from distributed local small scale and micro-generation could easily reduce the required area by an order of magnitude.

By far the greater capacity of solar power is in solar thermal that harnesses solar energy for heating, cooling, or producing electricity. However, solar photovoltaic (PV) - capturing sunlight to generate electricity directly - has undergone exponential growth since 2002, and is now the faster growing solar sector

Ease of manufacture and installation, modular design that could make use of any exposed surface such as roofs and walls, maximum flexibility, and minimum intrusion and maintenance, all contribute to the success of solar power. Solar power has topped the world's renewable energies capacity at least two years running and is set to grow further as China and India have entered the market and are offering strong competition to Germany, and stimulating further innovation.

Solar PV especially is improving by leaps and bounds. Thin film technologies have brought down the price of PV panels and solar electricity is competitive with electricity from the grid in the highest-priced markets in the developed world. Although less efficient, thin film PVs more than compensate for that in being much cheaper and easier to manufacture.

'Third generation PVs are boosting efficiency while maintaining the cheaper manufacturing techniques of thin films. One example is quantum dots, nanometre size particles that improve efficiency by extending the band gap of solar cells for harvesting more of the solar spectrum and by generating more charges (and hence more electricity) from absorption of a single photon. Using quantum dots mixed with semi-conductor printed onto a highly conductive metal foil, one company has achieved a module efficiency of about 12 percent at a cost of US$0.3/watt. The company plans to sell these modules at US$1.0/W which makes them currently the cheapest solar panels on the market.

Another strategy to increase efficiency is to use light tracking lenses and non-imaging optics to concentrate sunlight onto solar cells, thereby decreasing the size of solar cells required. A record efficiency close to 40 percent has been reached in the laboratory. New light concentrator based on light absorbing organic dyes could cut costs down substantially.

A third strategy is to use transparent thin films that are also conductors of electric charge, allowing light to pass through to the light absorbing material beneath and serving as an electrical contact to transport charge carriers away from the light absorbing material, thereby increasing the efficiency.

Other current approaches include quantum wells, which trap electrons and holes (separated charges) in two dimensions, preventing them from recombining, and effectively increasing the gain and efficiency of solar cells. Organic solar cells using organic polymers mixed with fullerenes (carbon nanostructures) have achieved a solar cell efficiency of 6.5 percent. Their main advantage is being flexible and light weight, and can be made transparent to be used on windows for urban buildings, for example. Successive layers absorbing in different parts of the spectrum could be placed one on top of the other by a printing process, and further improvements in efficiency are on the cards, though major obstacles remain in the longevity of these solar cells.

WIND ELECTRIFIES THE WORLD 40 TIMES

A study based on state-of-the-art data combined from multiple sources and computer simulation shows that wind turbines on land restricted to ice-free, non-forested, non-urban areas operating at as little as 20 percent of their rated capacity could provide more than 40 times the world's current electricity consumption, or over five times its total energy needs.

Wind power is on a steep ascent. It accounted for 42 percent of all new electrical capacity added to the US in 2008. The Global Wind Energy Council projected a 17-fold increase in wind-powered electricity globally by 2030.

The ten biggest CO_2 emitting countries in the world – US, China, Russia, Japan, India, Germany, Canada, UK, South Korea and Italy – all have far more than enough potential from wind to power their electricity needs: 18 times for China (89 percent from land), 23 times for the US (84 percent from land) and 30 times for the UK (41.5 percent from land).

Wind power is coming to Africa. Plans are afoot to build Africa's largest wind farm in the desert land around Lake Turkana in Kenya, 70 percent of the funds, €300 million coming from the African Development Bank. The Lake Turkana Wind Project consists of 365 wind turbines each 30-40 m high with a capacity of 850 KW. When complete, it will add about 25 percent to Kenya's existing electricity capacity. The Tigray region of neighbouring Ethiopia recently commissioned a £190 million wind farm, representing 15 percent of Ethiopia's current electrical capacity. In Tanzania, 100 MW power will be produced from two projects in the Central Singida region, which accounts for more than 10 percent of the current supply. Two further wind projects are underway in Kenya. One is in the popular tourist town Naivasha and one is in the Ngong Hills near Nairobi where Danish wind company Vestas have already installed six 50-metre V52 turbines contributing 5.1 MW to the national grid.

Earlier in 2009, South African became the first African country to announce a feed in tariff for wind power

However, more than 20 percent of Africans do not have access to electricity, and extending the grid does not help the poorest. What they need is local power.

Local micro-generation of wind power is eminently feasible. In the UK, micro wind electricity generation is increasingly popular for households and commercial buildings. UK's Department for Business Enterprise and Regulatory Reform (BERR) runs a Low Carbon Buildings Programme that provides grants for micro-generation technologies including wind turbines and solar power for householders and public building.

The current cost of micro wind generation is still rather high, but it could come down considerably. William Kamkwamba from a remote village in Malawi built his first wind turbine from scrap when he was 14 years old, and Max Robson in the UK has been inspired to produce an Envirocycle Scrap Wind Turbine prototype at £20 budget that he claims cost £2 000 on the market. Such low cost micro-generation options are particularly appropriate for developing countries.

A new low cost wind turbine has been invented using an induction motor as a generator. The high costs of wind turbines are due to custom-built generators, invertors, storage batteries and complex circuitry in order to fit in with the 60 cycles alternating current (AC) of the domestic electricity supply. The electricity generated by using an AC inductor motor is not at constant voltage or frequency, but hot water tanks heater elements don't mind variable voltages or frequencies; so the electricity generated by the wind-turbine is simply used to heat water. In addition, a patented electronic control acting like a gearbox ensures that the turbine aerofoils operate at peak performance at all time, so that all the power is harvested and channelled to the load, a heat exchanger tank, which heats the domestichot-water tank and also feeds surplus heat into the domestic central heating.

BIOGAS ECONOMY ARRIVING

Biogas is a combustible mixture of gases produced in anaerobic digestion by micro-organisms of livestock manure and other biological wastes. The major constituents of biogas are methane (CH_4, 60 percent or more by volume) and carbon dioxide (CO_2, about 35 percent), with small amounts of water vapour, hydrogen sulphide (H_2S), carbon monoxide (CO), and nitrogen (N_2). . Biogas is used as fuel, like natural gas, for combined heat and power generation, while the digested mixture of liquids and solids is mainly used as organic fertiliser for crops. When upgraded and purified, biogas methane can be used as fuel for cars and farm machinery, producing much less particulates and other toxic substances in its exhaust than fossil fuels. Another major advantage of anaerobic digestion is that it prevents at least 90 percent of the environmental pollution from agricultural and industrial wastes.

We have been promoting anaerobic digestion since 2005 for recycling wastes into resources in an integrated food and energy 'Dream Farm 2' that, if universally adopted could cut more than 50 percent in energy consumption and GHG emissions.

We are gratified that anaerobic digestion has grown substantially since. In China, the original home of anaerobic digestion, the number of biogas digesters increased from 17 million in 2005 to 26 million in 2007, and an estimated 31 million at the end of 2008, equivalent to 9 GW of renewable energy, mostly in small rural households.

Biogas is booming in Germany and has become Europe's fastest growing renewable energy sector. Unfortunately, biogas production in Germany has relied to a large extent on energy crops such as maize. Big companies are involved in building gigantic biogas digesters and developing biogas refineries that clean the resulting biogas to produce pure methane to be fed into the natural gas grid.

Sweden pioneered the use of biogas methane as vehicle fuel in the 1990s with strong government support. By 2006, 54 percent of the gas delivered to vehicles was biogas methane. By June 2007, there were 12 000 vehicles driving on biogas methane and 500 filling stations and 70 000 vehicles are expected by 2010. In June 2009, a new plant was announced in Stockholm that will supply the capital with bio-methane both as vehicle fuel for buses and cars and for the new city gas grid. It will be the largest bio-methane plant in Sweden, producing 10.5 million m^3 bio-methane a year, doubling the production capacity in Stockholm, and constituting 31 percent of the Swedish market in 2008.

A conservative estimate for the USA indicates that biogas from livestock manure could generate between 68 and 108.8 TWh of electricity a year, or 1.8 to 2.9 percent of the country's electricity, at a saving of between 47.2 and 150.4 Mt of CO_2, about 1.9 to 6 percent of the country's GHG emissions.

There is, however, a danger that the biogas economy will be hijacked by big companies for centralised power generation from bio-energy crops, which may jeopardise our food security and prevent its full energy and carbon mitigating potentials and other benefits of distributed decentralised small scale generation from being realised.

A COMMUNITY PROJECT

A project based on a community cooker that burns rubbish is potentially capable of transforming the slums of Kibera, Kenya. The special cooker is the technical innovation of local, self-taught furnace-builder Francis Gwehonah, and is at the heart of a an award-winning project designed by Nairobi-born architect Jim Archer and implemented with the help of his Kenyan fellow Director Mumo Musuva and their Planning Systems Services team.

The cooker boils water, cooks vegetables, stews beef, bakes cakes, fries food, and has two ovens each large enough to grill a whole goat. The slum dwellers have solved several practical problems themselves. Volunteers from various local youth groups collect, sort and store the garbage in metal racks next to the cooker where it can dry. Materials that cannot be burnt such as rubber and glass are put to one side. Biodegradable scraps that fall through become compost manure. The useful solid waste material like paper and plastic - bags, drinks bottles and packaging - as well as food scraps from banana, cassava, maize cob and sugarcane, peel, sawdust and even the discarded carrier bags of human and animal excrement colloquially known as 'flying toilets' are forked up to the top level of the racks ready for incineration. All these items would normally be left to rot in the street, thrown into water courses, or dumped in local rivers.

The volunteers also suggested how they could be rewarded: they do the sorting for the public from say 6 am until midnight. But from midnight until 6am they work the cooker for themselves, making bread and buns and hot water that they sell during the day.

It costs 5 Kenya shillings or US$0.06 to make a family meal, much cheaper than the kerosene that would otherwise be needed. The cooker also heats water for communal washing. On average 50 people a day take hot water into the 'bafu' (bathroom) closet for washing, and as many as 200 people could wash from the rain water stored in the tanks.

Since the Laini Saba community cooker became operational in 2007, Jim Archer has drawn up plans to increase the number of cookers to one per every 50-70 households. He is planning to recycle waste water from bafu closets to flush through the open pit latrines that often block and overflow, which are to be redesigned as "aqua privies". The runoff from the "aqua privies" can then be bio-digested, and the resulting matter and moisture gravity-fed to support the growth of vegetables, fruit trees and shrubs to create green spaces within the slum. This project has attracted wide interest from UN agencies, non-government organisations, as well as private companies

But before that, the temperature of the cooker's firebox must be increased from its current 600 ˚C to 800 ˚C, which is the World Health Organization's minimum temperature requirement for incinerators in the developing world. Jim is confident this can be done easily.

Some 91 250 tonnes of charcoal biomass is used for energy every year in Kenya, Contributing to this are several 'temporary' displaced persons camps, which permanently shelter well over 110 000 people each. Women and children in these camps travel further and further every day to find wood and fuel for cooking, denuding the countryside for miles around and creating health problems for themselves from the smoke of firewood. Recent research findings show that black carbon (BC), the black soot resulting from the incomplete combustion of burning fossil fuels and biomass contributes to warming the planet 55 percent as much as CO_2, and that reducing black carbon emissions may be the quickest, cheapest way to save the climate. Community cookers will contribute a great deal to that.

AIR CONDITIONING & ENERGY FROM DEEP WATER

Deep lake and ocean water and even ground water is being exploited for cooling buildings, providing drinking water, and generating electricity.

The cities of Toronto and Stockholm, and the Cornell University campus have been using cold deep water to cool large buildings and making big savings in energy and carbon emissions and cutting other pollution from energy generating plants.

Toronto, for example, draws cold water from the depths of Lake Ontario to Toronto Island where the water is filtered and treated with chlorine as it is delivered to taps in homes and businesses. After treatment, part of the very cold water flows to a city plant, and via heat exchanger, cools a closed water loop that circulates to the distribution network where more heat exchangers cool the water circulating through the air conditioning systems in the office towers. A total of 46 buildings signed up to the system, saving 85 GWh and reducing 79 000 tonnes CO_2 emission annually.

Honolulu has been investigating the possibility of converting the energy of sun-warmed surface water to electricity (ocean thermal energy conversion, or OTEC). OETC systems include the closed-cycle system that uses a working fluid, such as ammonia, pumped around a closed loop with three components: a pump, turbine and heat exchanger (evaporator and condenser). The warm seawater passes through the evaporator and converts the ammonia liquid into high-pressure ammonia vapour. The high-pressure vapour is then fed into an expander where it drives a turbine connected to a generator. Low-pressure ammonia vapour leaving the turbine is passed through a condenser, where the cold seawater cools the ammonia, returning the ammonia back into a liquid.. The open-cycle system uses the warm seawater as the working fluid. The warm seawater passing through the evaporator is converted to steam, which drives the turbine/generator. After leaving the turbine, the steam is cooled by the cold seawater to form desalinated water. The desalinated water is fit for domestic and commercial use.

The hybrid system uses parts of both open-cycle and closed-cycle systems to produce electricity and desalinated water. In this arrangement, electricity is generated in the closed-cycle system, and the warm and cold seawater discharges are passed through the flash evaporator and condenser of the open-cycle system (i.e., the original open-cycle system with the turbine/generator removed) to produce fresh water. The first OTEC was deployed in Hawaii in 1979.

Japan began pumping up deep ocean water in 1979 to support fisheries that had been depleted by over-grazing of seaweed beds that support fish and marine mammals.

Pumping deep ocean water to air condition cities, produce energy and fresh water, and to fertilize the productive surface waters, appears a promising approach to mitigating global warming by reducing the consumption of polluting oil and coal and the impact of overgrazing on marine food production.

But is large-scale pumping of deep ocean water sustainable? The deep ocean is ventilated through a giant thermohaline circulatory system that moves deep waters from north to south as salt-laden cooled water sinks into the depths in the North Atlantic and energizes a global conveyor belt that sends nutrient laden deep waters naturally to the surface in the North Pacific, north Indian Ocean, and south-east Pacific. This circulatory system is already being seriously disturbed by global warming.

There is a potential threat to deep sea communities as food particles and organisms are sucked up with the cold water and hence removed from the deep water environment. Furthermore, the construction and maintenance of the pump and pipe system could damage the deep sea habitat and its wild life. These applications, if practised on a large scale could contribute to warming the oceans, thereby decreasing their net primary production and impacting on all marine life.

Many big projects have remained on the drawing board also because the technology is expensive. Nevertheless, small scale air conditioning projects are definitely sustainable, and there are increasing examples, including the use of ground water to cool the tunnels of the London underground in the UK, and deep-mine flood water for air-conditioning in Springfield, Nova Scotia in Canada, and Park Hill Missouri in the US.

REEF NOT BARRAGE TO TAP THE TIDES

The Severn estuary has the third highest tidal range in the world, and a barrage across the estuary to trap the high tide could contribute 0.6 percent of UK's primary energy use and 2 percent of its electricity. The barrage, estimated to cost of £15 billion many decades back, had triggered widespread environmental concerns as it would lead to the loss of hundreds of square kilometres of mudflats and salt marsh, home to waders and other coastal birds and a host of migratory species. The powerful surge of water over the turbines when the barrage gates open will profoundly disturb estuarine life, including fisheries and salmon runs.

A possible solution proposed by Cornish hydraulics engineer Rupert Armstrong Evans is to build a reef instead of a barrage that would generate as much electricity and far more steadily than the big barrage. This would consist of a semi-floating set of box structures housing the turbines and stretching across the estuary riding over a fixed base on the estuary floor. By using a moveable 'crest gate' to track the tide level and therefore to maintain a small head difference, irrespective of the stage of the tide, the turbines would operate for long periods, at least double the generation period of the proposed big barrage.

The reef would minimise environmental effects, save on construction and costs and still allow big ships to pass. The UK government announced in 2008 it believes the Severn tidal reef to have merit and would consider it. In July 2009, however, a row broke out as Evans' idea, entered in a Department of Energy and Climate Change competition, was rejected in favour of a similar design put forward by another engineering firm.

SALINE AGRICULTURE TO FEED & FUEL THE WORLD

Shortage of fresh water is a greater threat to world food supply than shortage of fossil fuels, and cultivating salt-tolerant crops could solve both problems.

Fresh water constitutes about 1 percent of water on earth, while another 1 percent is brackish and 98 percent is sea water. Half the global supply of fresh water is now used, and good fresh water is increasingly scarce and expensive. The problem is compounded by salinization from chronic irrigation, making land unsuitable for cultivation, and sea level rise flooding coastal regions that contain a large proportion of agricultural land.

The solution is to cultivate salt-tolerant plants (halophytes) in coastal areas, marshes, inland lakes, desert regions with subterranean brackish aquifers, and directly in oceans or seas. Cultivating halophytes would not compete for land that should be cultivating food, and could provide more food and feed, as well as protection against shoreline erosion and feeding areas for birds, fish and animals. Some halophytes may even reclaim the land for freshwater plants by leaching salt through enhanced percolation, and by storing salt in their leaves that are harvested and removed from the fields.

There are some 10 000 halophytic species of which 250 are potential staple crops. Various livestock can thrive on halophytes or a combination of halophytes and conventional feed. Some are oil-producing plants suitable for edible oils or biodiesel. Micro-algae, in particular are prolific growers. Currently, an Israeli company maintains a 1 000 m^2 site that can produce approximately 23 g dry mass /m^2/day. This translates to more than 5 600 gallons/ha/year of algal oil, compared to palm oil yield at 1 187 gal/ha/y, Brazil ethanol at 1 604 gal/ha/y, and soy oil at 150 gal/ha/y. The theoretical upper limit of micro-algae yield is 100 g dry mass/m^2/day. An area the size of the Sahara desert (13.6 percent of the world's arid and semi-arid area) would be sufficient to produce 16 times the energy used by the world in a year.

HARVESTING SUNLIGHT WITH ARTIFICIAL PHOTOSYNTHESIS

Although we are quite successful in harvesting solar energy with thermal and PV technologies, storing it is a problem. The sun shines intermittently, and then only during the day. So it is necessary to have efficient and cost-effective storage capacity, if solar is to become a primary energy source for society. Nature has solved that problem admirably with photosynthesis. The problem with photosynthesis is that it has not evolved to maximise efficiency in harvesting solar energy because solar energy is rarely limiting; there's usually too much of it and plants have evolved many mechanisms to protect themselves from oxidative damages that strong sunlight can inflict.

There is much scope for artificial photosynthesis to do better in harvesting and storing solar energy. One main approach is photo-electrochemical splitting of water into its elements in an photo-electrochemical cell. This consists of two half-reactions, one reducing water to produce hydrogen, the other oxidizing water to produce oxygen, each of which requires its own catalyst and optimum conditions. Hydrogen can be stored and used as fuel in a fuel cell, which does the reverse of the photo-electrochemical cell: hydrogen is recombined with oxygen to generate electricity.

Much current effort is devoted to finding better catalysts for each of the half reactions in splitting water, but there is also a problem in fitting the two half reactions together.

An efficient and robust catalyst for oxidizing water has been found recently in nano-sized crystal clusters of cobalt oxide, which improves the catalytic activity 1 550 times. Cobalt is also a much more abundant element than the iridium it displaces. The researchers were taking inspiration from nature, which always uses the most abundant materials that can do the job.

Another team of researchers departed from artificial photosynthesis substantially in using a single metallo-organic compound to catalyze the two reactions sequentially and in a cycle that regenerates the catalyst. In the process, they also discovered reactions new to chemistry.

HARVESTING WASTE HEAT

Harvesting heat is particularly fascinating because heat is normally the end of the line as far as energy transformation is concerned. Turning it back into useful energy effectively recycles the waste energy thereby increasing overall energy efficiency. This is another instance of the circular economy of living systems and sustainable systems.

Thermoelectric (TE) devices depend on the thermoelectric effect, the inter-conversion of temperature differences and electricity. A thermoelectric generator creates an electrical voltage when there is a temperature difference on each side. Conversely, when a voltage is applied, it creates a temperature difference. Hence the effect can be used to generate electricity, or as a heat pump to heat or cool objects and spaces. It depends on special TE solid state semiconducting materials.

Miniature TE devices are now in mass production for cooling, heating, and temperature control applications in laser diodes, Polymerase Chain Reaction systems, and portable beverage and picnic coolers. Personal temperature-control systems that provide cooling and heating for the office have come onto the market, as have TE-based cooling systems for computer boards. One main application is power for remote data communication systems for oil and gas pipelines, polar weather station power generators, and cathodic protection for oil drilling platforms. TE generators are chosen for these applications because of their proven reliability (often maintenance-free for 20 years), durability under extreme conditions, and very little if any degradation in performance over their operating life time.

TE generators are being used to harvest waste heat from automobile engine exhaust to boost fuel economy. Further down the line they could provide heating and cooling for vehicles, buses, aircraft, trains, and homes, replacing the refrigerant R-134a that has a greenhouse warming potential 1 430 times that of CO_2. R-134a will be banned in new European cars by 2011; and the US DoE has announced a US$13 million cost-shared programme to develop TE technology for cooling.

CONDENSED MATTER NUCLEAR REACTIONS TRANSMUTATION OF TOXIC NUCLEAR WASTES?

Nuclear fusion is a process whereby the nuclei of light chemical elements fuse together to form heavier ones. As conventionally understood, nuclear fusion only takes place in our sun and other stars, producing all the chemical elements starting from the lightest, hydrogen. A lot of energy is needed to force even t he lightest nuclei to fuse. That is because all nuclei have protons that are positively charged, and as like charges repel, nuclei strongly resist being too close together. However, should they get beyond this 'Coulomb barrier' a strong nuclear attractive force takes over and cause the nuclei to fuse. This is achieved by accelerating the nuclei to very high speeds by heating to 'thermonuclear' temperatures in excess of 10^6 °K. Only then would the nuclei get close enough by random collision to fuse together. Once the fusion starts, it generates so much excess heat that it becomes a sustained chain reaction. The hydrogen bomb is an uncontrolled fusion chain reaction.

In 1989, Martin Fleishmann and Stanley Pons claimed that atomic nuclei could be made to fuse at ordinary temperatures with the release of considerable 'excess energy'. They were greeted with derision and disbelief; and 'cold fusion' continued to have a bad press for over a decade.

But a small international coterie of scientists became impressed, especially when Fleishmann and Pons published more substantial results in 1990, documenting the accuracy of their measurements and answering many of the criticisms made against their preliminary findings published the year before. These cold fusion enthusiasts managed to keep the research alive. And at the beginning of 2007, the Royal Society of Chemistry sponsored a symposium. This resulted in a thorough investigation and a write-up by ISIS, which helped bring the subject to the attention of the intelligent public and policy-makers.

Fleishmann and Pons' findings were repeated by many groups, and in many different forms. The key to 'cold fusion' is that it happens in the solid state, or condensed matter state, in which nuclear fusions, plus a whole range of other nuclear reactions can take place much more readily. The cold fusion scientists have pioneered a new discipline of "condensed matter nuclear science", the reactions are often referred to "low energy nuclear reactions" (LENRs).

Fleishmann and Pons packed deuterium (D, or $^2H_1$, a heavy isotope of hydrogen with twice the atomic mass) into a palladium lattice by electrolysis of heavy water. Palladium has a high affinity for hydrogen, and the palladium electrode absorbed a lot of deuterium. Consequently, the deuterium nuclei (each consisting of a proton and a neutron) are packed in close proximity in the palladium metal lattice, with the help of shielding electron (negative) charges that are also delocalised over the condensed matter. In this configuration, the nuclei can either fuse directly to produce helium-4, $^4He_2$, or else the proton in the nucleus could capture an electron resulting in two neutrons. These neutrons are special, as they are very slow (ultra-low momentum neutrons) and can easily be captured by other nuclei that undergo beta-decay (ejection of an electron) to give a range of transmutation products.

Electron-capture by proton could also take place in hydrogen nuclei (which have only one proton and no neutron), and that explains why transmutations have been detected in electrolysis of ordinary light water.

The minimum requirement for transmutation is a metal hydride film or membrane loaded up with hydrogen or deuterium to a high level, and kept in constant flux, Electrode materials ranged from carbon, nickel, to uranium. The metal hydride can be loaded by electrolysis of water or heavy water using a thin film of the metal as cathode; or else deuterium gas can be made to diffuse through the metal membrane by injecting the gas on one side and evacuating from the other side. A wide variety of experimental conditions have been used to trigger or speed up the reactions, including surface plasma electrolysis, plasma discharge, laser initiation and external electric or magnetic fields. A typical experiment is run continuously for 260 hours, resulting in a wide variety of elements.

George Miley's team at the University of Illinois Urbana-Champaign in the United States is one of the main groups involved in transmutation. The most commonly reported elements are calcium, copper, zinc and iron, found in more than 20 different experiments. Forty percent of the least frequently observed elements were rare earths from the lanthanide group: lutetium, terbium praseodymium, europium, samarium, gadolinium, dysprosium, holmium, neodymium and ytterbium.

There were other effects associated with nuclear transmutation. These include energetic charged particles, protons (~1.6 MeV) and alpha (~16 MeV) emissions, and low level soft X-ray emissions. Excess heat was also produced simultaneously.

The transmutation of elements is the old alchemist dream come true. The transmutation products fall into five peaks of atomic mass. The maxima and minima in abundances resemble those predicted if ultra-low momentum neutron capture followed by beta-decay were involved in the transmutations in accordance with the theory of Alan Widom at Northeastern University Boston, and Lewis Larsen of Lattice Energy in the United States.

These findings not only challenge the story of how the chemical elements were created, they have the potential for a new source of much safer, cleaner nuclear energy. It could "revolutionize" the energy industry, according to Larsen, in providing highly concentrated energy sources that could, for example, allow a car or an airplane to travel around the world without refuel.

Perhaps more importantly, there is a potential for making safe the accumulated nuclear wastes from conventional nuclear reactors. Spent fuel rod assemblies could be processed on site and injected into co-located LENR transmutation reactors that would 'burn' the hot radioactive wastes down to stable isotopes using large fluxes of ULM neutrons that are easily captured by the radioactive isotopes. This process will also provide an enormous source of concentrated energy for enriching the future zero-carbon world.

RECOMMENDATIONS

1. An explicit national target should be set for 100 per cent green, renewable energy sources by 2050
2. Nuclear power, carbon capture and storage, and large scale biofuel or biochar plantations should be excluded
3. There should be no carbon trading to offset greenhouse gas emissions in developing countries
4. The developed nations must take responsibility for reducing their own emissions at home, while providing genuine financial and technological assistance to developing nations that have to cope with the worst effects of climate change
5. Public investment should be targeted at education, research and development of the appropriate green energy technologies present and future, including those mentioned in this report
6. Grants and subsidies should be targeted to encourage decentralised distributed small scale to micro-generation of green renewable energies, and to promote green initiatives from local communities
7. Feed-in tariffs should be introduced for all new renewable energies
8. Existing nuclear power stations should be decommissioned at the end of their designated life times. Uranium mining should cease and clean-up should begin. At the same time, weapons grade uranium should be consumed in existing reactors in accordance with nuclear disarmament
9. Major public investment should be directed towards making safe toxic and radioactive nuclear wastes by low energy nuclear transmutation

Contents

NEW FRONTIERS

TRANSITION TO LOW CARBON ECONOMY

1

UK'S LACKLUSTER LOW CARBON TRANSITION PLAN

Belated, good in parts, but not green and definitely lacking in vision

Vista 2 by Mae-Wan Ho

THE BELATED

The world is shifting to renewable energies in the wake of peak oil and accelerating global warming. In contrast to exhausting supplies of fossil and nuclear fuels, renewable energy is inexhaustible energy. In 2008, more capacity in renewable energies has been added than conventional, and the trend is continuing, with many politicians and experts considering 100 percent renewable by 2050 a distinct possibility (see Chapter 11). The German government, for one, appears to have made 50 to 100 percent renewable energy by 2050 its target (see Chapter 2).

The UK has lagged far behind. It is trailing the EU league for renewables, being third from bottom, ahead of only Luxembourg and Malta [1]. The UK generated 1 percent of its energy from renewables in 1995; that increased to 1.3 percent ten years later in 2005, and is currently about 1.8 percent.

The UK government's White Paper [2] is a belated attempt to salvage the situation by taking on board the message of the Stern Report [3, 4] including the positive finding that mitigating climate change is not only possible but affordable.

THE GOOD

The short term aim is that by 2020 the UK's emissions should be reduced by 18 percent from the 2008 level, a larger reduction if the Copenhagen summit agrees appropriate international targets. By 2050, emissions are to be cut by 80 per cent from 1990 levels, a target recommended by the Independent Committee on Climate Change as the UK's contribution to halving global emissions by 2050.

A separate report, *The UK Renewable Energy Strategy 2009* [5] from the Department of Energy and Climate Change sets out a path to a "legally binding target" of 15 percent of UK's energy from renewables by 2020, reducing emissions by 750 Mt CO_2 by 2030, and decreasing UK's overall fossil fuel demand by around 10 percent and gas imports by 20-30 percent. A £100 billion new investment will create 500 000 jobs in the renewable energy sector..

The White Paper [2] contains a great deal of detail on how the targets are to be achieved. There is a long list of measures (see Box 1.1) for producing low carbon energy and for reducing energy consumption, and a long appendix giving the savings that each is supposed to contribute. There is to be an EU-wide carbon trading scheme with a total that reduces year by year. There is to be support for energy conservation, for the development of renewable energy sources, for measures to reduce emissions from farms, for the creation of more woodland to remove CO_2 from the atmosphere, and more. That's the good news.

THE BAD

The bad news is that there will be great reliance on carbon capture and storage and on nuclear power; both not renewable, not sustainable and not green (see Chapters 3-7, 9, 10). The Government will seek an agreement on including international air and sea transport into the national emission totals, but there is nothing about taxing aviation fuel, or plans to reduce air travel.

The basic principle underlying the White Paper is "Business as usual, only smarter". We will unplug our old fossil fuel and nuclear power stations from the grid and plug in new, hopefully better ones. We will continue to rely heavily on private transport, though with cars that emit less CO_2 per mile. There will be at least as much air travel in 2050 as today, though in more efficient aircraft. And so on.

Life was very different 50 years ago and it will be very different 50 years from now. It will have to be, if our descendents are to live well and yet produce only a tiny fraction of the greenhouse gases that we do. In a White Paper that claims to look 50 years ahead, there is remarkably little in the way of forward planning to avoid committing our successors to a life style that's essentially the same as ours. Many crucial things like the design of our cities and major infrastructure such as railways take a very long time to change, and if they are to be ready for 2050 the planning has to start now.

Box 1.1
KEY PROPOSALS
All major Government departments have been allocated their own carbon budget and must produce their own plan

- About 30 percent of electricity to come from renewables by 2020
- Up to four demonstration coal burning power plants with carbon capture and storage
- Facilitate the building of new nuclear power stations
- About £3.2 billion to help households become more energy efficient; smart meters in every home.
- People and businesses to be paid for generating electricity from low carbon sources
- Assistance to low income groups
- Support development of green industry including up to £120 million investment in offshore wind and £60 million for marine energy
- A 40 percent cut in average CO_2 emissions from new cars in EU. Support for new electric cars.
- A framework for tackling emissions from farming
- A "smart grid"

About 70 percent of UK emissions come from industrial sectors that are within the EU Emissions Trading Scheme (ETS) and the Government does not propose to limit the number of credits that can be bought to meet the reduction target for this sector

THE WORSE: EMISSION CREDITS

Within the EU, a carbon trading scheme allows some flexibility while the total emissions are being reduced (see Box 1.2). The White Paper, however, anticipates that rather than driving through all the emissions cuts to which it has committed itself, the UK will purchase credits "that will deliver emissions

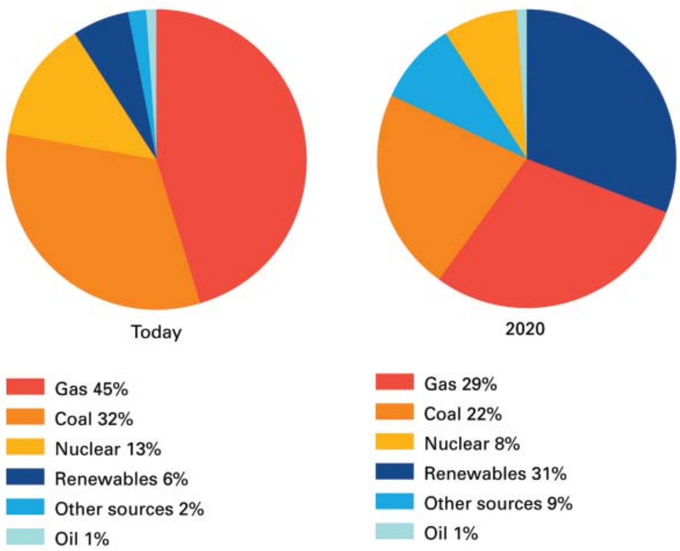

Figure 1.1 UK's planned transition to low carbon electricity generation

Box 1.2
WHAT IS CARBON TRADING?
The principle of carbon trading is that a central body, such as a government or an international organisation, sets a limit, or 'cap', on the total amount of greenhouse gases (GHGs) that can be emitted. Companies buy or are given credits that allow them to emit given amounts of GHGs. If they want to emit more GHGs than they have credits for, they can buy them from companies that intend to emit less than their allowances.

The EU Emissions Trading Scheme (EU ETS) is the largest system of this kind but it will still cover only 45 percent of the EU's emissions. There are a number of criticisms of the EU ETS.

- Countries can offset their carbon emissions by purchasing other countries' unused carbon allowances, resulting in little if any real reduction in total carbon emissions; when offset is done in developing countries as the UK White Paper intends, it effectively places extra burden on developing countries to reduce their emissions [6]
- In the first phase, generators benefited from windfall profits by passing the notional cost of carbon permits onto customers even though they had paid nothing for them. The customers may have to pay again when carbon allowances are no longer free for generators from 2013 [7].
- The EU ETS is concerned only with carbon dioxide and does not include other important GHGs such as methane and nitrous oxide [8].
- The data set used by the EU ETS does not extend back before 2005 with the result that some countries are likely to receive over-allocations of carbon credits [6].
- If carbon trading is to be effective, the price of carbon needs to be at a level that encourages countries to reduce emissions while also promoting new technology. In general, carbon trading schemes advantage old companies over new entrants, yet it is the latter that are more likely to be employing low carbon technology [4].

reductions in developing economies." In other words, the UK will reduce its carbon emissions by less than it has agreed to and the developing countries will reduce theirs by more.

The effect could be very large indeed. About 70 percent of UK emissions come from industrial sectors that are within the EU Emissions Trading Scheme (ETS) and the Government does not propose to limit the number of credits that can be bought to meet the reduction target for this sector. Only that can explain why the Government can issue a White Paper detailing the swingeing cuts in emissions that are going to be required and at the same time give the go-ahead for a third runway at Heathrow and at least four new coal-fired power stations without CCS [9].

If we go ahead with nuclear power, our children and grandchildren are likely to find themselves picking up a bill for waste disposal that will make our £73 billion look pretty small beer. They will be burdened with toxic and radioactive wastes of mammoth proportions including those we haven't been able to deal with

CARBON CAPTURE & STORAGE

At present, about 45 percent of our electricity is generated from gas and about 32 percent from coal. (See Fig. 1.1). The White paper estimates that in 2020, those figures will still be 29 percent and 22 percent respectively. The Government is placing great reliance on carbon capture and storage (CCS) in which the carbon dioxide produced in burning fossil fuels is captured and transported to an underground repository such as a depleted oil field. As the White Paper itself admits, this has never been tried on a commercial scale, and while the three stages have each been shown to work, the process as a whole has not [10] (see Chapter 9).

The new Department of Energy and Climate Change is to support up to four demonstration plants, and as other countries are going to build them as well, the Government is confident that a way will be found to make CCS safe and economical on the scale required. If not, it is hard to see how the targets will be met, because there is no plan B.

If CCS does work, there will be increased worldwide demand for fossil fuels; thereby hastening the arrival of peak gas and coal in addition to oil, especially because the CCS system is estimated to use up between 10 and 40 per cent of the energy produced by the plants to which it is fitted [10].

NUCLEAR ENERGY

At present, about 13 per cent of our electricity comes from nuclear. This will be reduced to 8 per cent by 2020 because old stations will be decommissioned faster than new ones can be built; the proportion is intended to rise again after 2020 but there is no target figure.

One of the strongest arguments against nuclear power is that it is not economical. The nuclear industry has been notorious for cost overruns during construction of power plants. But that is nothing compared to the downstream costs of decommissioning and waste management and disposal [11, 12]. When the Thatcher government privatised the electricity generating industry in 1989, they were unable to sell off the nuclear power stations because they were not seen as good investments. The taxpayer had to take over all the liabilities and the costs of running the dirtiest, loss-making parts of the industry at Sellafield, now £3 billion a year and rising. Meanwhile the cost of clean-up and decommissioning has ballooned to over £73 billion. Sellafield has become the world's nuclear waste dump with no end in sight, its waste

Box 1.3

CHILDHOOD CANCERS LINKED TO NUCLEAR POWER STATIONS

For years there have been conflicting reports about whether the incidence of childhood cancers, especially leukaemia, is higher in the vicinity of nuclear power stations. As the numbers are small it can be difficult to decide whether an observed cluster represents a real effect or merely due to chance [16].

Now research commissioned by the German Bundesamt für Strahlenschutz (BfS, Federal Office for Radiation Protection) [17, 18] found a significantly increased incidence of leukaemia in children living within 5 km of a nuclear power plant, and a smaller but still significant increase in children living between 5 km and 10 km. They also found a statistically significant regression coefficient between the increased incidence of leukaemia and distance from the power station; this correlation is more compelling evidence than the existence of clusters. Their conclusions have been confirmed in a recent detailed analysis [19]

But the UK Government dismissed this evidence in its White Paper [2] on the grounds that the correlation does not prove that ionising radiation emitted by German nuclear power stations was the cause of the leukaemia. It also stressed that the report of the UK Committee on Medical Aspects of Radiation in the Environment (COMARE), which found no link, was based on a considerably larger number of cases, but did not mention that the BfS report was based on a "case-control" study in which each information such as the distance from the home to the power station was known exactly for each child in the study [20].

In fact, while COMARE found no greater incidence of cancer near nuclear power stations, it did find a greater incidence near the nuclear installations at Sellafield, Aldermaston, and Rosyth.

The UK Government is applying as usual the *anti*-precautionary principle with regard to childhood cancer and nuclear power stations. This is much the same argument that the tobacco industry used: just because the incidence of lung cancer is higher in smokers and correlated with the number of cigarettes smoked, that does not prove smoking causes lung cancer and there is no need to stop manufacturing and marketing cigarettes.

reprocessing plants non-functional, and there is as yet no designated final waste repository.

According to the White Paper, "it will be for energy companies to fund, develop and build new nuclear power stations in the UK, including the full costs of decommissioning and their full share of waste management and disposal costs." That means the Government will build a facility to dispose of the waste from existing plants and the industry will be expected to pay only the extra cost of adding waste from the new ones. The Government has not yet decided how to estimate those costs but it seems likely that the companies will pay a risk premium in return for which there will be an upper limit to what they will be required to contribute. Anything above that limit will be again for the taxpayer to cover.

If we go ahead with nuclear power, our children and grandchildren are likely to find themselves picking up a bill for waste disposal that will make our £73 billion look pretty small beer. They will be burdened with toxic and radioactive wastes of mammoth proportions including those we haven't been able to deal with.

Safety is decidedly a major issue with nuclear power [13] (see Chapter 4). It turns out that no nuclear power plant, not even the 'generation 3' reactors under construction are proof against malfunction or malevolent attacks. In addition, a main source of hazard is spent fuel stored on site in overcrowded cooling ponds before they are shipped out for storage in the final repository. These can easily catch fire and cause explosions. Sellafield has been declared "the most hazardous place in Europe" by its deputy managing director [14], and a "slow motion Chernobyl" by Greenpeace.

The fallout from Chernobyl was 30 to 40 times that released by the atom bombs of Hiroshima and Nagasaki in Japan during World War II. A 2005 report attributed to Chernobyl 56 direct deaths and an estimated 4 000 extra cancer cases among the approximately 600 000 most highly exposed, and 5 000 among the 6 million living nearby [15].

There is also strong new evidence from Germany linking childhood leukemia and proximity to nuclear power stations, This gives a hint on the health burdens of accumulating toxic and radioactive wastes from the nuclear industry to present and future generations.

But the White Paper persists in dismissing such evidence, as the UK Government has been doing for years (see Box 1.3).

RENEWABLES

In principle, the White Paper [2] is encouraging about the future of renewable energy, and the detailed strategy laid out in a separate report [5]. The Government says it will encourage wind power, both onshore and offshore; it will retain the Renewables Obligation and Climate Change levy to encourage investment in renewables, and make it easier to connect to the grid. Feed-in tariffs for renewables will be introduced [5]. It will investigate the possibility of power from the Severn Estuary; it will support anaerobic digestion, and so on. But there is certainly nothing like the enthusiasm expressed by the German Federal Ministry of Economics and Technology, which sees renewables as a major industry in Germany and boasts that "Renewables made in Germany" are already highly successful in world markets [21].

TRANSPORT

Domestic transport is responsible for about a fifth of the UK's emissions, and the White Paper proposes many measures for reducing this contribution, from electric cars to improving the tyres on heavy goods vehicles. There is a lot on making cars more carbon efficient and some on incentives to move from car to rail or bus or even bicycle. But there is nothing about redesigning our cities to make a car less of a necessity.

It is not easy to make this sort of change, but the White Paper is about the period up to 2020 and looks ahead to 2050. This gives the government the opportunity to introduce long term policies that will make it possible to move away from dependence on car ownership without detracting from the quality of life.

Another disappointing feature is that the government assumes there will be even more air travel in 2050 than today. While there are plans to move traffic from road to rail, the Government seems to have little interest in discouraging air travel. On the contrary, it reiterates the importance of expanding the capacity of Heathrow. Shortly after the White Paper was published, however, plans were announced for a high speed rail service connecting London and Glasgow. We have not heard the last of this debate.

LAND & WASTE

Farming, forestry and land management are responsible for about 7 per cent of UK greenhouse gas emissions; and the release of methane from decomposing waste accounts for a further 4 percent

Most of the emissions from farms come either from animals or from fertiliser, and farmers will be shown how to reduce these. The Government does not, however, mean to take this as far as giving additional support to organic farming. This is most disappointing in view of the enormous potential that organic agriculture and localised food and energy systems have for saving energy and mitigating climate change, as documented in our report [22] *Food Futures Now: *Organic *Sustainable *Fossil Fuel Free*, and updated since [23].

THE INTERNATIONAL ASPECT

Climate change is a global problem and needs global solutions. Up to a point, the government is conscious of this. It recognises, for example, the need to have globally agreed targets for the reduction of CO_2 emissions and an agreement on how to include international air and sea transport in the total.

But a document that looks forward to 2050 should be thinking more about what the world will be like by then. We will have reached the end of the era in which the relatively few of us in the North have a life style very different from the rest. You only have to visit China or India or many other developing countries to see this change happening. By 2050, what is now the third world will have caught up economically and will be able to pay for oil, coal, gas and even uranium at the same rate that we do, and emit CO_2 at the same per capita rate. Buying emissions credits from developing countries is immoral; there will soon come a time when we also won't be able to afford it.

Buying emissions credits from developing countries is immoral; there will soon come a time when we also won't be able to afford it

CONCLUSION

Parts of the White Paper are, as the curate said, excellent. It makes the case that climate change is real and it commits the UK government to doing something about it. The plan is detailed enough that every sector knows what is expected of it; no one is going to be able to do nothing on the grounds that their contribution to the total is too small to matter.

There are, however, important shortcomings; notably the heavy reliance on nuclear energy, the hazards and the problems surrounding waste disposal very much played down; and carbon capture and storage that has never been properly tested either for safety or for economic viability.

Most of all, the White Paper is remarkably unimaginative in envisaging a UK in 2050 very little different from today: still relying heavily on fossil fuels, still travelling by air and in private cars, still taking it for granted that as a wealthy country it has first call on the world's non-renewable resources and will be able to buy all the emissions credits it needs, leaving the real reductions to be made by others.

Recent events are making the White Paper obsolete almost before the ink is dry. In the USA, the nuclear power industry has so far failed in its efforts to overturn any ban on building more reactors, and the Obama administration had put a freeze on Yucca Mountain as long-term waste disposal site. Even Canada, which has its own supplies of uranium and its own design of reactor, the CANDU, has put its programme on hold (see Chapter 3). The UK Committee on Climate Change told the Government that if air travel is not curbed, the rest of the economy will have to cut emissions by 90 percent rather than the currently expected 80 percent [24]. What's more, the Chair of the Intergovernmental Panel on Climate Change is advising that rather than allow the greenhouse gas level in the atmosphere, currently 385 ppm, to stabilise at 450 ppm, we must reduce it to 350 ppm if we are to avoid irreversible climate catastrophe [25].

The Government will have to think again, and be both bolder and wiser.

2

GERMANY
100 PERCENT RENEWABLES BY 2050

Sets an example for all industrial nations

Vista by Mae-Wan Ho

The UK's Low Carbon Transition Plan (Chapter 1) falls well short of the challenges that face us. Fortunately, we need look no further than across the North Sea to Germany for inspiration. Germany is a large, prosperous, industrialised country rather like the UK in many ways. It has traditionally relied heavily on coal for electricity generation, and has a number of nuclear power plants. But there the similarities end.

RENEWABLE ENERGY EXCLUDES NUCLEAR

While the UK's White Paper envisages the Great Britain of 2020 or 2050 as much the same as today, Germany is looking forward to a quite different future in which Germany will guarantee itself a secure energy supply and maintain its position as a world leader in new technology. It is forging ahead in the development and use of renewable energy; and nuclear power - seen in the UK as a major component of the future energy mix - is being phased out altogether.

The nearest equivalent in Germany to the British White Paper is a document issued by the German government in January 2009, with the title *New Thinking – New Energy. Ten Guiding Principles for a Sustainable Energy Supply* [1].

The document sets out the following objectives: