The Twin Crises Revisited

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Introduction

In `The Impending Twin Crises – One Set of Solutions?' published in 2005, the linkage was explored between the impending peak in the world production of conventional oil and the increasingly pressing need to reduce emissions of carbon dioxide to the atmosphere arising from the excessive consumption of the fossil fuels.[1] These two crises were assumed to be in a race to ring a `gong' sufficiently loudly and decisively to force immediate action around the world. The implicit assumption was that no serious corrective measures would be taken until there was a clear, unambiguous signal obvious to just about everybody. For this reason, the problems arising from a peak in the world production of conventional oil were thought to ring the gong first. The consequence is that measures needed to deal with the second crisis of excessive greenhouse gas emissions could be undertaken in the wake of those directed at coping with oil depletion. With this sequence, or even when the crises occur simultaneously, the difficulty with dealing with climate change is much reduced, and the options available more straight forward, than if these events arose in the opposite order.

Nevertheless, climate change is an intractable problem made worse by the relatively easy successes in dealing with two other atmospheric issues that immediately preceded it. Despite much opposition at the time, the need to control excessive emissions of sulphur dioxide – a regional problem arising from the generation of electricity from sulphur-bearing fossil fuels and from the non-ferrous smelting industry – was resolved surprisingly easily by introducing a system of tradable permits. The depletion of ozone at high altitudes by the chlorofluorocarbons – a global problem with its strongest effects at the Poles – was also resolved relatively easily because chemical replacements became quickly available and because only a relatively few producers of these chemicals were involved. These two early successes lulled many into believing that carbon dioxide emissions could also be controlled without much difficulty using the same techniques. The contrary proved to be the case. However, given the large increase in the price of oil expected as the peak in world conventional production is approached, many more options become feasible.

This paper reviews the developments of the past year for the principal avenues identified in the earlier publication. In broad terms, the way forward recommended in the underlying paper focused on the transfer of as much as possible of the oil requirements of the transportation sector to the electrical network. Possible ways of generating this extra

electrical requirement were explored, as were techniques to keep the network balanced under this much greater load. In general, the developments of the past year have been supportive of the options advanced in the earlier paper.
There have also been a number of recent publications is which the twin crises have been considered together rather than treated as separate subjects as in the past. A major contribution from the Brookings Institute by Lackner and Sachs of Columbia University offering a somewhat parallel set of options was especially notable.[2]

The Impending Peak in World Oil Production

Over the past year, there has been a remarkable growth in both interest in and understanding of the importance of the impending peak in world conventional oil production. One of the most interesting aspects of this development has been the formation of a number of groups to consider this problem at the community level including one organized in the Ottawa/Gatineau region. Affiliates of the Association for the Study of Peak Oil and Gas have been established in several countries outside Europe where ASPO was first founded. The affiliates in the Netherlands and the U.S. have begun publication of their own bulletins that appear regularly (weekly in the case of the U.S.) in addition to the official ASPO monthly *Newsletter*.[3] There are also an increasing number of Web sites and Weblogs devoted to this subject.

This past year has also seen the publication of several papers of importance dealing explicitly with this question. Three contributions of special interest will be cited here. The major study prepared for the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy by Robert L. Hirsch and his associates at the SAIC group of consultants was particularly noteworthy and not only because of the semi-comic efforts that were made to suppress it.[4] Though Hirsch and his coauthors did not assign a date for the peak, their paper set out the serious consequences of reaching this milestone in the energy economy in concrete terms especially as related to the transportation sector. Another set of related papers of particular interest was prepared by Chris Skrebowski of the Petroleum Review of London which illustrated that it is possible to predict future near-term oil production quite accurately by compiling lists of projects underway around the world from announcements by their developers and other trade sources.[5] This technique was employed by other authors notably at Cambridge Energy Research Associates and The Oil and Gas Journal with reasonably similar results. The past year also marked important contributions from Canadians. Jeffrey Rubin and his colleagues at CIBC World Markets in Toronto published reports that explored the effect of a known inflexible new supply – one not influenced greatly by price changes in the near term similar in nature to the situation explored independently by Skrebowski – and its relationship to future price changes.[6] Given the inflexibility in supply, the process of `demand destruction' resulting from the action of higher prices is required to allow markets to clear.

The dimensions of the problem of the peak in oil production may best be understood by considering two numbers: the world's transportation system depends on oil for about ninety per cent of its energy requirements, and, in the developed economies at least, some seventy per cent of the oil consumed is devoted to this sector. Further, the consumption of oil around the world accounted for some 42.2% of the emissions of carbon dioxide from the fossil fuels in 2005. Thus to deal with the impending peak oil crisis, as well as to reduce the emissions of greenhouse gases substantially, it is important to focus directly on the transportation issue. Without some mitigating factor, there is now grave concern that the present pattern of suburban living favoured by so many of our people will become less and less viable over time.

The New Options to Power Transport

The past year has seen at least two non-oil options for the transportation sector reach the early marketing stage. Ethanol is now routinely added to gasoline in several jurisdictions. In Canada and the U.S., this alcohol is produced mainly from corn and to a lesser extent from other grains, though in Brazil and some other hot countries, production is usually based upon sugar extracted from cane. Already about three per cent of the U.S. automotive fuel market is supplied from this renewable source. New to the field are efforts to process cellulosic materials as the source rather than the foods themselves; this procedure has among its advantages a much better return on the energy invested in the process and a reduction in the competition for food, or land needed to grow food. The major efforts in this latter field will soon be tested at a large scale including an enzyme–based process under development in the Ottawa region. There is thus the possibility of converting waste cellulosic materials, wood, or specially grown grasses to produce a workable fuel for engines to both replace oil and at the same substantially reduce emissions of carbon dioxide. This reduction results because the biomass sources derive their carbon from the atmosphere in the first place. A further possibility is emerging involving the genetic modification of source plants to increase their susceptibility to subsequent conversion to alcohol.

The second non-oil source is a liquid fuel for diesel engines derived from the conversion of biological sources. Waste cooking oil may be processed into an acceptable fuel for compression ignition engines quite easily, and what is in effect a new cottage industry has spread around the world as a result of higher fuel prices. (There is doubt, however, whether the normally heavy road taxes are paid on much of this small-scale production.) In tropical countries, palm oils and the like may be used for this purpose. Diesel engines are inherently more efficient than spark ignition engines due to their characteristically higher compression ratios, and are generally more tolerant of lower quality fuels. Rudolf Diesel himself experimented with powered coal along with other unusual fuels. Already cars powered by small diesel engines are a commonplace on the streets of Ottawa and these could also run on such biofuels. The combination of a small engine powered by fuels produced essentially independently of the oil supply provides both high fuel economy and low net greenhouse gas emissions. However, there is also a major need to reduce a wide range of other emissions to the atmosphere from vehicles, not just the greenhouse gases, and this restriction may limit the number of practical options for diesels fuelled in this way.

During the past year, a sizable number of hybrid vehicles have entered service based upon conventional gasoline engines working in conjunction with electrical motors powered either by on-board generators or by batteries. This combination allows the installation of a smaller, more fuel efficient engine which may then operate more of the time in its most favourable performance range. Additional fuel may also be saved by re-charging the batteries with otherwise wasted energy recovered from braking. Already a few cars powered in this way may be found in most neighbourhoods during the past year. Most major car manufacturers will soon offer similar vehicles in addition to the two Japanese producers who first entered the field.

Operated in the autonomous hybrid mode (no external electrical source), these vehicles offer higher fuel economy particularly under city driving conditions. But it is the extension of the hybrid design to partial operation based on energy drawn from the electrical grid that offers a major near-term option to both save oil and reduce emissions. The so-called `plug-in' hybrid allows the charging of the battery with sufficient energy during non-service periods to permit many frequent short-distance driving requirements, such as commuting to work or trips to the shopping mall, to be undertaken without consuming any liquid fuel at all. Already small companies in California and now one in the Toronto area specialize in converting the vehicles presently in production to this practice, and the major manufacturers are themselves contemplating the regular production of such models.

The widespread adoption of the `plug-in' hybrid option depends fundamentally on progress in the battery field. There have been important advances in battery technology over the past year of which two of the most important are noted here. Both improvements arose as a result of research activities in the field of nanotechnology. The traditional lead battery has been greatly improved in terms of specific performance (about double the specific power and capacity of the conventional battery), and also in terms of extended service life. Such batteries may well find renewed application in electric vehicles because of their reasonable cost and the extensive experience of their use. In the field of lithium-ion batteries, there has been a discovery in the materials field that has led to marked improvement in both their performance and safety. New batteries of the latter type will be tested this year to power portable power tools, lawn mowers, etc., and with success, larger units may well prove attractive for application to hybrid vehicles. One way or another, larger and better batteries will almost surely become available for hybrids.

Such improved batteries are also important to vehicles powered with fuel cells. With adequate battery performance, the fuel cell itself may be reduced to a manageable (and cheaper) size because the battery will share the supply of additional energy needed to cope with surges in demand during acceleration. Energy recovery from braking becomes possible as in a hybrid. It is also possible improved capacitors or hydraulic devices will serve the same function in both the hybrid and fuel cell cases. There has been significant progress reported during the year in the performance of advanced capacitors, again with important contributions from nanotechology.

Some proponents of the plug-in hybrid vehicle believe cars so equipped will be sold in much the way computers are at present: in the case of computers, to lower first costs, a minimum workable amount of memory is offered but the purchaser may opt for additional capacity at any time to meet individual requirements. Similarly, the purchaser of a plug-in hybrid vehicle may opt for only sufficient battery capacity to allow routine short-distance trips to be undertaken in the all-electric mode according to individual need. In this way, the high cost of batteries and their dead weight may be minimized for those that live not far from their regular destinations. Moreover, the advances in the battery field have been so rapid that there may be a revival of a niche market for an all-electric vehicle as well. Nevertheless, whether plug-in hybrid or all-electric, the energy taken from the electrical network must come from somewhere.

Meeting More of the Energy Requirements for Transportation from the Electrical Network

The widespread early adoption of plug-in hybrid vehicles will place a large new load on the electrical distribution system in the nearer term. In the longer term, if indeed hydrogen-based fuel cells become the dominant option to power both personal vehicles and trucks at some later time, it is likely that part of the requirement for this gas will be supplied by the electrolysis of water produced in either centralized or local facilities. Thus this longer-term option poses major issues for the electrical network as well.

There are two related questions to be addressed that arise from the emergence of such a major new electrical requirement: How would the additional power be generated in the first place? How would the network be kept in balance? Fortunately, the plug-in hybrids will likely enter the market slowly at first so these early vehicles may be re-charged at night during off-peak periods without placing great strain on the network. (The current introduction of `smart meters’ in Ontario is a major step to encourage people to consume electricity at lower load periods.) The rate at which such vehicles may be introduced is nevertheless subject to two major imponderables. The first is the uncertain rate of progress in the development of the improved batteries (especially reducing their cost), and the second concerns the length of time electrical energy will continue to be sold for transportation purposes without attracting road taxes because, under the present circumstances without this burden, the economic driving force is high. Apart from the production of the batteries themselves, the manufacturing stage seems to pose few additional problems because hybrid vehicles may be assembled using conventional assembly methods in the existing facilities of the automotive industry. Moreover, the supply of both the liquid fuel (whether in the gasoline or diesel grades) and the electricity needed, may be provided through the existing distribution system.

The electrical network is likely to be supplied at margin in three different ways in the years ahead. Generation in major central stations will no doubt likely remain the main supplier but significant contributions are to be expected from large-scale co-generation facilities based upon natural gas as the fuel and from small-scale local distributed generation located at the extremities of the grid. Generation from the central stations will itself be derived incrementally from three quite different types of sources: (1) from large wind turbine farms and other such renewable sources; (2) from a re-vitalized nuclear option or from coal facilities equipped for the capture and sequestering of carbon dioxide both operated in base load mode; and (3) from `clean coal' facilities capable of the co-production of hydrogen and the generation of electricity.

The past year has seen a dramatic growth in wind power installed around the world particularly from turbines exceeding one megawatt of name-plate capacity. In 2005, 11,769 MW of turbine capacity were installed - 43% more than that installed in 2004. World wind turbine capacity totalled 59,322 MW at the end of 2005 - an increase of 25% over the previous year – and this capacity is expected to grow to about 210,000 MW by 2014. Germany has the greatest installed capacity at present at 18,428 MW and generation capability is expected to grow to 25,000 MW in that country by 2010. Denmark obtains the greatest fraction of its electrical supply from this renewable source at a little over 20%. The U.S. alone expects to install 3,000 MW in 2006. The present installed wind capacity in Canada is about 570 MW, and the industry expects this to reach 10,000 MW, or 5% of domestic electrical generating capacity, as soon as 2010.

The large-scale co-generation of electrical power and thermal energy from natural gas will also grow rapidly in the years ahead particularly in the context of the development of the oil sands of Alberta. This source will become a large intermediate level of generation located in essence between the larger central generators at the core of the network and the micro distributed generation units at its delivery end. This option is driven by its high inherent total conversion efficiency, but is limited by the number of sites where sufficient thermal energy is required. There is a particularly successful application of mid-scale co-generation at the Ottawa Hospital.

At the delivery end of the electrical network, micro wind turbines are being installed in some countries that are attractive to homeowners when purchased power is relatively costly as in the United Kingdom. Though these roof-top units generally provide only some fraction of the average electrical needs of an individual household, when generation exceeds the immediate requirement such as on windy days, the surplus energy is fed back into the grid. The prospect for such options depends significantly upon the price offered for this returned energy. This is true for other such household small-scale return options including solar cells and generation from natural gas in mini-fuel cells or micro-gas turbines that also supply heating and hot water requirements. Ultimately, in the aggregate, these micro options may supply sufficient energy at the extremes of the network to add importantly to its resilience. Such sources can, however, complicate its management because on days of high demand, such as in very cold weather, the entire additional load tends to fall upon the centralized generators at the heart of the system.

The Return of Nuclear Energy in the Developed Countries

The past year has seen a revival of interest in nuclear power that currently accounts for about 16% of the world's electricity supply. In 2005, there were 440 power reactors in service in 31 countries. Mothballed reactors in Ontario are in course of rehabilitation. Some 130 new reactors are being planned around the world with 25 under active construction. New reactors are also proposed in the U.S. – the largest generator of electrical energy from this source -and the operating performance of most of the 103 units in service in that country has been extraordinarily good in recent years. In 2005, the unit capability factor – a measure of service performance - exceeded 90 percent for the fourth time in the last five years. France, with 59 reactors, continues to generate a higher fraction of its electricity in this way (78.5 % in 2005) than any other country. Nevertheless, no new units are actually under construction in the U.S. at the time of writing and only one in the European Union in Finland.

A new generation of reactors is being planned based mostly upon the extension of existing technology but in some countries, notably China and South Africa, there is renewed interest in the pebble bed reactor which is cooled by circulating helium. Steam can be raised from this gas to power turbines in the normal way but because the circulating helium is sufficiently hot, the thermal splitting of water into hydrogen and oxygen may be contemplated employing certain complex chemical cycles. The advantage of this procedure is that the classical Carnot cycle that limits the conversion of heat into work may be side-stepped. More of the thermal energy produced in the reactor may thus be applied for this purpose. Without the development of such high temperature reactors, the production of hydrogen for transportation requirements via the nuclear route would be restricted to the generation of electricity followed by the electrolysis of water. This is a more capital-intensive route of lower energy conversion efficiency. The electrolysis process, however, does have the advantage of allowing local production of hydrogen (including in the home garage) using power from the grid.

Whether public opposition to nuclear energy is waning in the developed countries may be debated but there is much less controversy in the rapidly developing world – especially China and India - where expansion of the industry has always continued. The vexing problem of nuclear waste management continues to plague the industry though from a technical viewpoint, there is a growing consensus that the problem may be managed satisfactorily. Notable during the past year was the call for more reliance on nuclear energy by Sir James Lovelock, an environmentalist of high reputation. (He offered his back garden to the industry to store nuclear wastes.)

The Clean Coal Processes

There is growing interest in perfecting `zero-emission’ coal processes mainly because of the large resources of this fuel available around the world at reasonable cost and because these resources have the additional advantage of being more widely distributed than their oil and gas counterparts. China has become the world’s largest producer and consumer of coal, and the current conventional patterns of use in that country are clearly reaching local environmental limits for reasons quite apart from the need to restrict the emissions of carbon dioxide.

Most of the new coal processes complement nuclear power for base-load generation in central stations. The technology varies in the means selected to facilitate the expensive stage required for the capture of carbon dioxide for subsequent sequestering. Two smaller-scale installations that burn coal with oxygen (re-circulated flue gas is usually used to cool the flame to acceptable limits) are under construction in Australia and Germany. Still other facilities are under study in which this greenhouse gas is extracted from the unpressurized dilute flue gas that ensues when coal is combusted in the normal way with air by chemical absorption (a major study of a new plant so equipped will be undertaken in Saskatchewan over the coming year). Other process options involve the separation of carbon dioxide from combustion gases produced under pressure by the cheaper physical absorption (solution) means such as in specially equipped pressurized fluidized bed combustion units using air. In still another option, coal may be gasified with oxygen under pressure to produce a fuel gas for gas turbines with the carbon dioxide separated before combustion again by physical absorption techniques. All these new techniques for the capture and separation of carbon dioxide depend upon the development of successful sequestering operations such as those now operating routinely in Norway in saline off-shore aquifers and in Weyburn, in Saskatchewan, where carbon dioxide captured from the only U.S. synthetic natural gas (SNG) plant based upon coal is piped from North Dakota for the enhanced recovery of oil from this mature reservoir.

Zero-Emission Generation of Electricity and Hydrogen from Coal

The clean-coal gasification option may be extended to the co-production of hydrogen with the generation of electricity. As in the electricity-only versions of this option, of which four units are operational around the world at the end of 2005 (two in the U.S.), the coal is converted into a fuel gas normally by reaction with oxygen and steam under pressure. This gas stream is treated as before to remove minor constituents and then reacted with more steam over catalysts (the so-called `shift' reaction) to convert the carbon monoxide produced in the gasifier to hydrogen and carbon dioxide. The carbon dioxide is separated from the hydrogen (there are a number of process choices at this stage) and sequestered. The remaining hydrogen may then be combusted in gas turbines for the generation of electricity without carbon dioxide emissions or directed to other purposes such as powering fuel cell-equipped vehicles.

As far as the technical issues related to the generation of electricity from hydrogen are concerned, the BP Company and its partners have announced a large generating station at Peterhead in Scotland where the hydrogen will be supplied by the conventional reforming of natural gas. The separated carbon dioxide will be applied to enhanced oil recovery at the declining Miller off-shore field. In California, it has been announced that petroleum coke will be gasified to produce sufficient hydrogen to fuel a 500 MW turbine installation again with the separated carbon dioxide being used for enhanced recovery of oil. In Norway, an agreement has been announced between the Shell Group of Companies and Statoil to also generate electricity from hydrogen and at the same time supply carbon dioxide for enhanced oil recovery in an off-shore field. The U.S. Department of Energy estimated in early 2006 that there is the potential for an ultimate addition of 89 billion barrels of oil to its domestic oil reserves as this practise comes into widespread use. This quantity of oil corresponds to twelve years of the current total oil requirements in the U.S. Given these announcements, there are few lingering doubts remaining about the efficacy of the combustion of hydrogen in large gas turbines for the generation of electricity.

Sites for large-scale sequestration operations are available in Alberta either in saline reservoirs or for application to enhanced recovery processes. It is thus entirely feasible to produce hydrogen from coal for power generation in turbines and for chemical processing in the oil sands industry although other options are to date less costly. Hydrogen may also become a favoured feed for large-scale stationary fuel cells in the future but it is the application to power vehicles that is the subject of this paper. On board fuel cells are envisaged as the ultimate outlet but it may not prove necessary to wait for the widespread introduction of this technology to consume appreciable quantities of hydrogen in the transportation sector. One German auto manufacturer plans to offer dual-feed hydrogen/gasoline internal combustion models as early as 2008, and other companies are planning similar niche vehicles such as shuttle buses.

Planning is now well advanced to build prototypes of zero-emission coal facilities. There is interest in this class of process in Alberta. International agreements were reached during the year among the principal coal-producing countries – Australia, China, India, the U.S. and possibly South Africa - to perfect this approach. Canada may participate in some of these activities and negotiations are presently underway.

Keeping the Electrical Network in Balance

Electrical energy derived from the wind is only available when it blows. Other renewable sources tend to have the same variable characteristics: power from solar cells is highest when the sun is strongest, generation is reduced on cloudy days, and none is generated at night. Generation from nuclear sources has the opposite characteristics in that for both economic and technical reasons, this capital-intensive technology (though with low operating costs) normally provides electricity continuously in base-load operation. Adding large additional loads from the transportation sector would exacerbate the problem of balancing the incremental supply from these two sources. It is here that the new coal gasification processes may play an important additional role. In essence, the coal facility would produce hydrogen and carbon dioxide in continuous operation. After separation, the latter gas would be piped to sequestration sites as a liquid at supercritical conditions. (Long pipelines moving carbon dioxide in this way have been in service for many years in the U.S.) The hydrogen remaining would be used to generate electricity in turbines at peak times as required by the network. At slack load conditions, the hydrogen would be diverted to other purposes. In the near term, such already established technologies as the upgrading of bitumen in the oil sands industry and the reduction of iron ore in the steel industry could be supplied with this gas, but with the passage of time, more and more of the hydrogen would be directed to meeting the needs of the increasing number of fuel cell-equipped or dual-fuelled vehicles entering the market.

By combining generation with the production of hydrogen, the electrical system would meet more of the energy requirements of the transportation sector in two different ways: some of the electricity generated would power plug-in hybrid cars (including a smaller number of all–electric vehicles) while the hydrogen produced off-peak would be supplied to fuel cell-equipped cars. This hydrogen would originate in two different ways: (1) from centralized zero-emission coal facilities (no local production is possible) and (2) from both centralized and local facilities for the electrolysis of water. New developments in the materials field announced during the year promise substantial reductions in the high capital cost of the electrolysis option by allowing acid-resistant plastics to be used for cell construction along with cheaper catalysts to replace the platinum normally used as electrodes, such as sprayed nickel alloys of high surface area.

When the electrolysis process is located within reasonable pipeline distance from the large facility producing hydrogen from coal, the inescapable oxygen by-product could be consumed with advantage in the coal gasification stage for greater overall efficiency. Thus it is possible hydrogen would be produced by two different means on the same site. The neighbourhood hydrogen `filling' station could either be supplied by truck or pipeline from the two centralized sources, or from smaller electrolysis installations operated on the premises. In the latter case, there is little prospect of finding an economic outlet for the associated oxygen.

To balance the electrical network in this way depends crucially on the future price of natural gas. Supplies in North America derived from conventional sources may well have peaked already though prices have fallen substantially in mid-2006. In the underlying paper, it was shown that the future price will be determined at margin mainly by the supply of liquefied natural gas (LNG) shipped from competitive sources in a number of countries that still enjoy a gas surplus.[1] This limiting (or floor) price may be only about $(US) 4 per million BTU on trading markets for the next decade or so under something approaching equilibrium economic conditions. This equilibrium price is too low to allow nuclear energy to be competitive with combined-cycle gas turbine installations based upon natural gas for the generation of electricity. It is also too low to justify the production of hydrogen from coal even as a by-product of integrated-gasification combined-cycle generation technology in comparison with the conventional natural gas reforming process also equipped for the capture and sequestering of carbon dioxide. Nevertheless, the equilibrium price is not likely to be reached except during unusual situations such as during some combination of a severe recession, mild weather in either winter or summer, and good results from exploration activities. There are few experts who believe that facilities for the LNG supply chain (especially the receiving re-gasification ports) can be approved and installed fast enough to let equilibrium conditions dominate the price over any appreciable length of time. This uncertainty in the future price of natural gas in the increasingly integrated North American market is one of the main impediments to taking effective action on either the peak oil or climate change problems.

The continuing uncertainty in the price of oil also complicates the situation. Before the peak in the world production of conventional oil is reached, it is quite possible there will be circumstances under which the price could fall substantially though probably not for long. After the peak is past - this author expects this significant event in the world energy system to occur in the 2015-2020 period - a fall in the price will become increasingly unlikely given the high level of the least costly alternatives. This supporting price is not low because, aside from some conservation activities of the `shut the window type,' there are no replacement options with lower technical costs than those of the production and delivery of conventional oil

The Urgent Need for Action to Mitigate Climate Change

There was a major change in the tone of the debate on the need to take urgent action to deal with climate change during the past year. Though there may still be some surprises, the consensus view is emerging among a broad sector of the public that the validity of the underlying science has been effectively established. Most of the remaining uncertainties and anomalies in the field have been addressed. In effect, the debate is over and public discussion now centres upon the degree of seriousness of the problem and the priorities for action. In the past there was a tendency for the ranges of the temperature increases predicted from the modelling studies to fall with time, but the opposite is now true. The major concern at present is that temperatures may rise to higher levels than set out in the previous studies. The draft text of the next regular report of the Intergovernmental Panel on Climate Change (IPCC) which is presently being circulated for comment prior to its final publication in 2007, states that experts in the field are no longer able to place a reliable upper limit on how quickly the atmosphere will warm.

The year 2005 was the warmest on record and carbon dioxide continues to accumulate in the atmosphere though until very recently there was also a tendency for the concentration of methane – a twenty times more virulent but more minor greenhouse gas – to stabilize. Carbon dioxide concentrations reached 381 parts per million by volume (about 100 ppm above the pre-industrial average), and the year saw one of the largest increases on record at 2.6 ppm. The rate of increase on average has doubled that of only 30 years ago. There were new reports on faster glacial melting around the world especially in Antarctica and Greenland. As a result, the level of the ocean is expected to rise more than previously anticipated. Sea ice in the Arctic failed to return to the previous extent of cover for the second consecutive winter suggesting that irreversible climate change has come to that region sooner than expected. Some experts predict a viable navigation season off Canada's northern coast will be possible within a matter of decades.

The objective set by the European Union is to limit the temperature increase to two degrees Centigrade over the chosen base period. To achieve this ambitious target requires a reduction in carbon dioxide equivalent terms of over half the present level of greenhouse gas emissions (probably about a 60% reduction) - much more than the relatively modest goals of the first phase of the Kyoto Protocol. This major reduction can only be achieved by a substantial change to the energy economy. Canada was the host of the Conference of the Parties (COP 11) of the Framework Convention of Climate Change held in Montreal between 28 November and 9 December of 2005. The most important of the forty or so decisions agreed at this difficult meeting was to open a dialogue on long-term cooperative action to address climate change. This Conference was held in conjunction with the first Meeting of the Parties to the Kyoto Protocol.(MOP 1) The adherents to this Protocol also started to consider their commitments beyond the first period of this agreement that ends in 2012. Progress was made despite the lack of participation of several nations in the Protocol (most notably Australia, Saudi Arabia and the U.S.), and the limited commitments from the developing world. Canadian efforts may be complicated by the subsequent election of a new government. Nevertheless, the major coal production countries, led by the U.S. and including China and India, whether signatories to the Protocol or not, agreed during the year to a much higher level of cooperation to advance the new coal technologies. It is fair to say there was significant progress at the institutional level so important to effective international agreements – steps that can only be helpful in the long run.

What Forces Action

In the previous paper, it was noted that the impediments to making major reductions in greenhouse gas emissions were so great that it is not likely significant action will be taken unless there is a major unequivocal event that in effect decides the issue for us all.[1] A well-received book published by Tim Flannery in March of 2006 identifies three such possibilities.[6] This Australian author believes any one of the following very real dangers would force aggressive action: a slow-down of the Gulf Stream warming Europe; irreversible damage to the Amazon rain forest; and the release of large quantities of methane from the decomposition of permafrost and methane clathrates in Siberia in a catastrophic self-strengthening loop.

The Growing Interest in Geo-Engineering

As the seriousness of the situation became better understood around the world, so has the interest in possible geo-engineering measures aimed at counter-balancing warming. At one extreme are the techniques advocated by the space community. In one proposal, what is in effect a variable blind would be deployed from satellites and located at the Lagrange Point where the attraction of the Sun and Earth are equal. The aim would be to reduce the quantity of energy reaching the earth in some controllable way. Space-based technologies have the additional advantage that solar energy might also be captured in related installations and, after conversion to electricity, be transmitted to the earth in the form of some benign radiation suitable for energy recovery on the ground. There are also proposals to release fine particles into the upper atmosphere to reflect some of the sun's rays back into space. This option has the advantage it is already known to work from the study of the effects of cooling from particles emitted from volcanic eruptions in the past. Unfortunately this practice may not be easily controllable. At the other end of the scale, there are possibilities identified aimed at lowering the carbon dioxide content of the atmosphere by fertilizing the world's oceans with iron to encourage biological reactions that would accelerate the normal rate of transfer of carbon dioxide to the oceans. There are also a number of proposals for removing carbon dioxide from the atmosphere usually by enhancing some biological process such as the controlled growth of algae, which could themselves in turn be processed into a liquid fuel for vehicles.

The advent of geo-engineering proposals is ironic in that even if such methods were in fact more effective than the other options open to the world, their implementation would require a level of international cooperation that would be indistinguishable from some form of world government. Those that oppose the modest goals of the Kyoto Protocol on the grounds of government `interference' or `planning' in the economy and for such like reasons, may have been able to delay action to the point that a much more controlled governance may have to be imposed to cope with a critical situation. Similarly, those that have caused the response to climate change to be so difficult and hesitant should not be surprised to find litigation beginning in the Courts. There are now actual and quantifiable effects around the world, and the assets of even the largest and wealthiest corporations would not likely be enough to compensate for this damage.

The Way Ahead

In the previous paper, the relationship between the twin crises was likened to a race to ring a gong. The problems arising from peak oil were expected to sound the alarm first as some experts believe the world has already reached this important turning point in the energy economy and the estimates of others are not much further behind. Which crisis sounds the alarm first is important. It is much easier to deal with either crisis if the price of energy is increasing because the higher price encourages the deployment of both conservation and new supply alternatives automatically. The important issue becomes to ensure that the alternatives chosen are those that lower greenhouse emissions. The reverse situation is more difficult because the economic cost appears much higher.

The objective of this paper was to provide a more precise road map than in the underlying paper to a viable way of dealing with both the problem of peak oil and the need to significantly reduce greenhouse gas emissions together. The basic recommendation is to transfer a rising share of the oil required by the transportation sector to the electrical network over time. The measures needed to generate this additional energy benignly in electrical form were also considered. The many technical advances during the past year, especially the development of improved batteries and capacitors for vehicles, and wind power for the electrical grid, are supportive of this option. The first signs of the re-birth of nuclear generation in North America and the development of the new clean coal processes based upon the capture and sequestering of carbon dioxide are also promising.

The difficulties should never be underestimated. Even if such a route proves successful in dealing with the twin crises, in the purported words of the Duke of Wellington spoken after the Battle of Waterloo, it will have been `a close run thing.'

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