Association for the Study of Peak Oil & Gas – South Africa
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Peak Oil and South Africa:

Impacts and Mitigation

Jeremy Wakeford[1]

Jeremy.Wakeford@uct.ac.za

8 March 2007

[1] Senior Lecturer, School of Economics, University of Cape Town. This paper draws in places on two previous papers (see Wakeford, 2006a and 2006b). I would like to thank Rodger Duffet, Michael de Wit, Lisa Kane and Jacqui Wakeford for providing helpful comments on earlier drafts. Any remaining errors or omissions are my sole responsibility. Please note that this paper is a work-in-progress; this version supersedes all previous versions of the paper.

Contents

1 Introduction: The Importance of Oil

Oil is the quintessential commodity in the modern industrial economy. Although the industrial revolution was initially powered by coal, since the first commercial oil well was drilled in Pennsylvania in 1859 oil has gained increasing prominence in terms of its share of the world's primary energy supply. It now accounts for over 35 per cent - the largest share. As an energy source oil is used for electricity generation, heating and – most importantly – as a liquid fuel for transportation. The world's transport systems (including ships, trains, airplanes and road transport) depend on oil for some 90 per cent of their energy (Leggett, 2005; Heinberg, 2006). Consequently, the tourism sector in most countries is also highly reliant on oil. Industrial agriculture depends heavily on oil and natural gas for the production of fertilizers, herbicides and pesticides, as well as to power mechanised farm machinery and transport products to markets. The manufacturing sector uses oil both for energy and as a feedstock for a myriad of products from plastics to paints to pharmaceuticals. Almost all goods and most services involve the use of oil at some point in the production or distribution process.

Rising production of oil has underpinned world economic growth for the last century. However, this trend of increasing supplies of the global economy's most critical resource cannot continue indefinitely. Most simply, this is because oil (like other fossil fuels) is a finite resource. This raises the vital questions of when and how the depletion of oil will impact on societies. This paper makes an initial attempt to answer these questions, with regard to South Africa in particular, recognising that much more research needs to be done on this issue.

2 The Theory and Evidence of Peak Oil: Hubbert's Curve

In the 1950s, a petroleum geologist named M. King Hubbert theorised that oil production in any given region would roughly follow a bell-shaped curve, rising to a peak when approximately half of the total oil had been extracted, and thereafter gradually falling toward zero as extraction became progressively more difficult and costly. This production curve would mirror a similar pattern of oil discoveries, although after a substantial time lag. Hubbert applied a logistic probability distribution function to historical data on reserves and production in order to forecast the timing of peak production in a region.

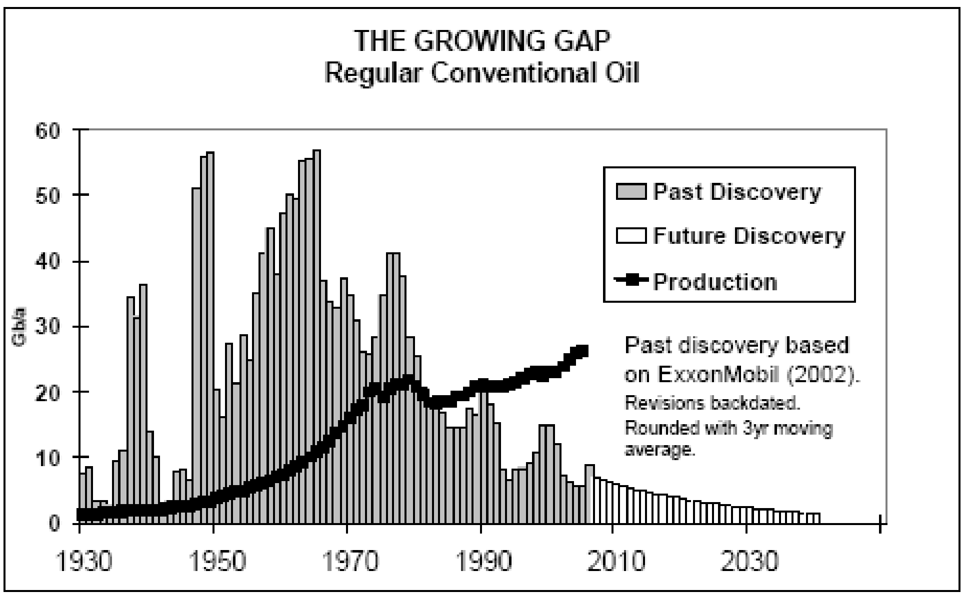
In 1956, Hubbert used his model to make the, then, highly contentious prediction that oil production in the lower 48 United States would peak some time between 1966 and 1972 (Heinberg, 2003: 88). He based his forecast on the pattern of oil discoveries, which had peaked in the 1930s. Hubbert turned out to be correct: the actual production peak occurred in 1970, after which date production has followed a declining trend. (Overall US production never regained its 1970 peak rate despite more recent discoveries in Alaska's Prudhoe Bay and the Gulf of Mexico). Hubbert hypothesised that world oil supply would follow a similar bell-shaped curve, mirroring the pattern of (earlier) oil discoveries. His theory has been the subject of intense debate, particularly in recent years. The debate now centres on *when* the *inevitable* peak in world oil production will occur, not on *whether* it will occur (see Hirsch, 2005). Nobody can credibly deny that production of a finite resource must eventually decline toward zero.

Economists, amongst others, correctly point out that higher oil prices tend to stimulate increased exploration activity. However, more *exploration* does not necessarily translate into more *discoveries*: it depends on the extent to which undiscovered oil fields still exist. Colin Campbell, the founder of ASPO, believes that over 90 per cent of recoverable conventional oil has already been found. At some point, no matter how high the price of oil rises, it cannot overcome the physical limitations of a finite resource.

There is growing evidence that we are nearing the world Hubbert peak:

- Globally, new oil discoveries peaked in the 1960s and have been on a declining trend ever since (see Figure 1). This is despite spectacular improvements in exploration and recovery technology over the past few decades and the incentives provided by high oil prices in the 1970s and in recent years.
- About half of global oil reserves are contained in the largest 100 fields, almost all of which were discovered more than 25 years ago. Production from many of these super-giant and giant fields is in decline.
- Since 1981, more oil has been consumed each year than has been discovered (see Figure 1). In the past few years, about five or six barrels have been used for each new one found.
- Thirty-three of the 48 significant oil-producing nations have already passed their individual production peaks (Hirsch, 2005).

Figure 1: Conventional oil discovery and production



Source: ASPO (2007)

2.1 The nature of the peak

In the US, the oil production curve has been largely unimpeded by political influences and determined chiefly by geological and economic factors. This resulted in a ‘classic’ Hubbert curve profile, with a well-defined, absolute peak being reached in 1970 and a fairly symmetrical shape (in the lower 48 states). In other countries, however, notably some members of the Organisation of Petroleum Exporting Countries (OPEC) and Russia, production has been more volatile, having been influenced by political decisions or economic turmoil, respectively. Such factors have resulted in two or more local peaks in the production curve of some oil producers.

For the world as a whole, production will not necessarily (or even likely) reach a well-defined, sharp peak. Many experts are predicting a 'bumpy plateau' lasting for several years (Heinberg, 2004: 34-37). This is due partly to the smoothing effect of aggregating national or regional production profiles which peak at different times, and partly to anticipated supply disruptions and recoveries resulting from political and economic upheavals. However, geologically and mathematically it is clear that production must at some date reach a global maximum (even if it is a plateau lasting several months or years).

2.2 The timing of the peak

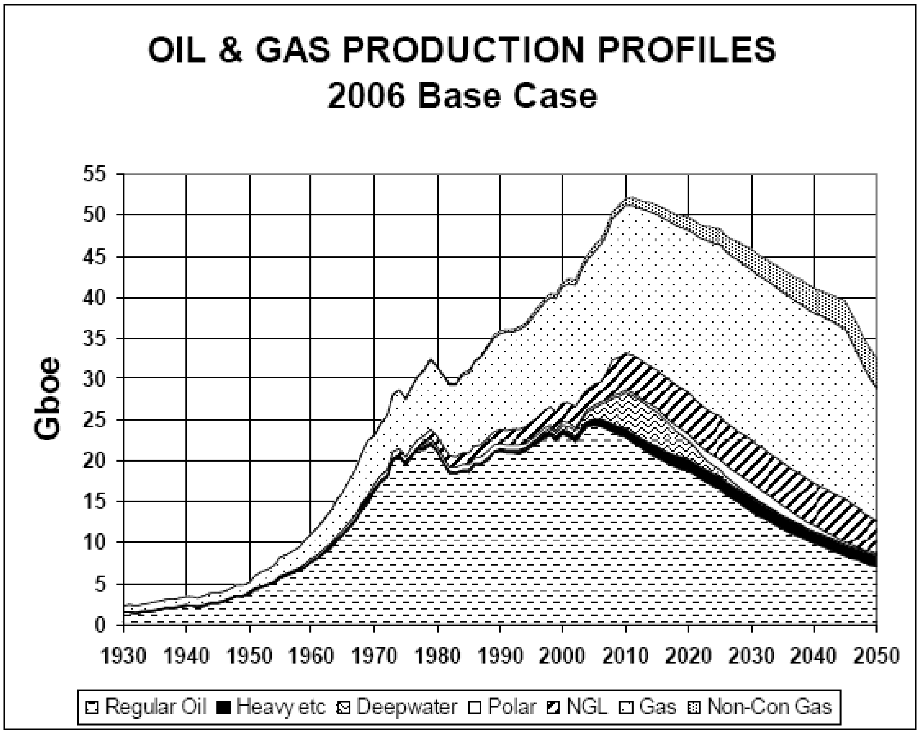
Predictions about the timing of the world peak vary amongst individual oil geologists and energy agencies. As can be seen in Table 1, a significant number of experts expect oil to peak within the next decade. For instance, the latest projection by veteran oil geologist Colin Campbell, founder of ASPO, is that 'regular conventional' oil production peaked in 2005, and that all petroleum liquids (including heavy, deep-water and polar oil, and natural gas liquids) will peak around 2010 (see Figure 2). In contrast, forecasts by Cambridge Economic Research Associates (CERA) and the US Geological Survey (USGS) are more optimistic. However, these predictions are based on arguably unrealistic assessments of future oil discoveries (Campbell, 2005: 39-41). Actual discoveries over the past few years have been considerably below the USGS's F95 high probability forecast, which predicts a world peak in 2016. Thus all of the most credible estimated dates of the world peak lie within the next decade, and many within the next five years.

Table 1: Predicted Dates of World Oil Peak

Source	Affiliation	Date	Notes
Kenneth Deffeyes	Princeton University (retired)	2005	Regular oil
Richard Duncan	Institute for Energy and Man	2006	Regular oil
Ali Samsam Bakhtiari	Iranian National Oil Company (retired)	2006-2007	Regular oil
Chris Skrebowski	Oil Depletion Analysis Centre, UK	2007-2008	
Colin Campbell	ASPO-Ireland	2005 2010	Regular oil All petroleum liquids
David Goodstein	Cal Tech University	Before 2010	
Michael Smith	Oil geologist & analyst	2011 2013	Regular oil All liquid fuels including biofuels
Cambridge Economic Research Associates		After 2020	
US Geological Survey		2016 2037	F95 (high probability) scenario F50 (median) scenario

Sources: ASPO (2007); CERA (2005); Deffeyes (2005); Duncan (2003); Goodstein (2005); Hirsch (2005); Smith (2007).

Figure 2: ASPO's world oil and gas production profiles – history and projections



Source: ASPO (2007)

Approximately 90 per cent of crude oil production to date has been regular conventional oil. ASPO's forecast includes so-called 'unconventional' sources of petroleum, but does not anticipate that these will extend the date of the peak by more than a few years, although they will lessen the steepness of the descent. This is because each of the unconventional sources of petroleum has significant disadvantages and/or limitations:

- HEAVY OIL: Mostly produced in Venezuela, this source has a low net energy return (or energy return on energy invested, EROEI). Political action in that country, notably the recent nationalisation of the oil industry, has helped place an upper limit of just a few million barrels per day on the volume of heavy oil production that can reasonably be expected.

- OIL SANDS and SHALE OIL: While Canada's oil sands and Colorado's oil shale are vast potential resources, the processing thereof into useable crude oil requires large amounts of fresh water and energy (at present mostly natural gas), and creates extensive environmental damage. Crucially from an economic perspective, the EROEI is very low.

- DEEP WATER OIL: Spectacular technological advancements have allowed offshore production of oil in very deep water, notably in the Gulf of Mexico and the Gulf of Guinea. However, production costs are much higher than for conventional crude. Production in the Gulf of Mexico has proven to be susceptible to disruption by hurricanes. In the case of some fields this is permanent as the costs of repairing oil rigs exceeds the value of oil remaining.

- POLAR OIL: Deposits of oil are thought to exist within the Arctic Circle. However, working conditions and production costs are daunting obstacles. The Antarctic continent is currently off limits to oil exploration by international agreement.

- NATURAL GAS LIQUIDS: Natural gas condensates constitute an important, but limited, additional source of liquid petroleum.

Matthew Simmons (2005), a prominent energy investment banker and former advisor to the Bush Administration, has argued that Saudi Arabia is much closer to peaking than is commonly thought, and that when Saudi production peaks, the world will peak. Over the past year the Saudi oil production has dropped from approximately 9.5 million barrels per day (mbpd) to around 8.6 mbpd. According to the Saudis, this decline has resulted from deliberate cuts as part of OPEC agreements. But there is speculation that their largest field, Ghawar, could be in a state of collapse (as is Mexico's Cantarell field, the fourth largest field in the world).

Simmons presented US Department of Energy data in a submission to the ASPO-USA conference in Boston in October 2006, showing that oil production had reached a high of some 85 mbpd in December 2005, but had fallen slightly to a fairly consistent rate of 84 mbpd in 2006. This potentially indicates that production has already peaked. However, the International Energy Agency published a production figure of 85.4 mbpd for December 2006. This illustrates one of the problems in identifying the peak, namely the contentious and unreliable nature of oil production (let alone reserve) estimates.

It is important to note that depletion alone will not determine the date of the peak. Geopolitical events (such as wars in oil producing countries), extreme weather conditions (e.g. hurricanes in the Gulf of Mexico) and economic factors (e.g. an international recession) could all play a role by influencing either supply or demand for oil.

Ultimately, as Heinberg (2003: 202) points out, the timing of the peak in world oil production may only be apparent several years after the fact. This is partly because there is likely to be considerable supply volatility in the years immediately before and after the peak as a result of economic and political disruptions. Even if the peak occurs after 2012, there may be a further run-up in oil prices before then. According to Leggett (2006), there is a very high probability that new oil production coming on-stream will be insufficient to match the combination of rising demand and depletion of existing oil reserves between 2008 and 2012, resulting in excess demand for oil (even though supply may not yet have peaked).

2.3 The post-peak depletion rate

Estimates of the world depletion rate vary from one expert to the next, from around 2 per cent to about 8 per cent per annum (see Heinberg, 2006). Colin Campbell (of ASPO-Ireland) estimates a world depletion rate (of all petroleum liquids) of approximately 2.6 per cent per annum, which may be considered a reliable – if perhaps fairly conservative – benchmark.

In summary, it appears highly likely that oil production will not increase substantially beyond its current level (perhaps by about 5 million barrels per day at most, according to ASPO's projection), and that within five to ten years' time, it will begin to decline. The longer that production is maintained at or above current rates, the faster it will fall on the far side of the Hubbert curve.

3 Peak Oil and Climate Change

Climate change resulting from anthropogenic global warming (caused mainly by the burning of fossil fuels and the destruction of natural forests) is a very serious issue in its own right. The evidence of global warming is mounting day by day: icecaps and glaciers are melting (e.g. the Artic sea ice has shrunk considerably and in summer no longer covers the North Pole), and air and sea temperatures are rising (IPPC, 2007). The effects of global warming on the Earth's climate and weather systems are already evident, manifesting in increasing prevalence and severity of extreme weather conditions, such as heat waves, droughts, floods and storms. In addition, there is already evidence of rising sea levels owing to the melting of icecaps and glaciers as well as thermal expansion of the oceans. In the long term, climate change poses threats to food and water security, increases the risk of epidemic diseases spreading, will destroy some coastal settlements, and will result in massive displacement of peoples as some regions become uninhabitable.

There are strong linkages between Peak Oil and Climate Change. Most obviously, the burning of oil (as well as coal and gas) reserves have been identified as a major contributor to global warming. But does fossil fuel depletion – and specifically the impending peak in oil production – imply that concerns about future carbon emissions are unwarranted?

The long-term climate change forecasts of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2007) assume continued fossil-fuel based economic growth and rising carbon emissions. If indeed the peak of oil (and gas) production turns out to occur in just a few years' time, this might seem to imply that greenhouse gas emissions will decrease irrespective of mitigation policies such as voluntary emission reductions or those agreed to under the Kyoto Protocol. On the other hand, however, oil depletion raises the spectre of a substitution of coal for oil and gas, especially in the US, China and India, each of which have abundant coal reserves. Increasing reliance on coal, which produces more CO_2 per energy unit than oil or gas, may mean increasing net emissions in the future and even faster planetary warming.

This raises another question: can we afford to burn all the remaining fossil fuels? In the view of Jeremy Leggett, a specialist on both oil and climate change, "we have plenty [fossil fuels left] to tip us into global economic ruin as a result of climatic meltdown" (see *Half Gone*, 2005: 117). Consequently, Leggett argues, "we cannot afford to burn all the oil [that remains], much of the gas must remain below ground, and the great majority of the coal shouldn't even be considered" (p. 128).

Peak Oil and Climate Change must be understood and tackled together. Some (albeit partial, unsustainable) remedies for Peak Oil, such as the more intensive use of coal, will exacerbate the global warming problem. On the other hand, the development of clean, renewable energy sources (such as solar and wind power) will help human societies to cope with both challenges. It is possible that effective mitigation of global warming will require faster reductions in the use of oil than will be imposed by natural depletion. However, given the current state of international climate change negotiations and the limited mitigation targets agreed under the Kyoto Protocol (e.g. the fact that the US, Australia, China and India are not signatories to the protocol), and the likely imminence of Peak Oil, the latter issue will have to be addressed directly. Otherwise, the economic destabilisation caused by the peak could seriously hamper future climate mitigation efforts.

4 Energy Substitutes, Conservation and Technological Progress

This section considers the potential of alternative energy sources, energy conservation measures and technological development to mitigate the impending shortfall in oil supply.

4.1 Alternative energy sources

4.1.1 Non-renewables

- COAL currently contributes about a quarter of the world's primary energy supply. Consumption of coal is growing faster than that of any other energy source, thanks mainly to its increasing rate of exploitation in China (and to a lesser extent India). Coal can be converted into liquid fuels, and therefore is a partial substitute for oil. However, the conversion process involves a considerable loss of energy. Coal in any case is less energy dense than oil or gas. Most importantly, coal is highly polluting, giving rise to smog, acid rain and the highest carbon dioxide (CO_2) emissions of any hydrocarbon. Although sequestration of carbon dioxide has been proposed, this depends on the suitability of local geology and on effective monitoring and policing. (South Africa does not have the requisite geological conditions for subterranean carbon storage.)

- NATURAL GAS, like oil, is a highly versatile and efficient energy source. In addition, it can be converted into liquid fuel; although worldwide the scale of current gas-to-liquid conversion is very small. For the most part, natural gas is traded in regional markets via pipelines, because transportation by ship is very costly and carries substantial risks (e.g. vulnerability to terrorist activity). Although its CO_2 emissions are less than those of coal and oil, it nevertheless contributes significantly to global warming. Perhaps the main limitation of gas aside from its emissions is that its global rate of production will at some point reach a peak itself and decline rapidly. This has massive implications for heating, agriculture and electricity generation in its own right (see Darley, 2005). Since oil and gas are partial substitutes, their prices are to some extent correlated, meaning that oil depletion with push up the price of gas.

- NUCLEAR POWER is derived from uranium, which is also a finite resource. Nuclear power has several other disadvantages: initial investment is extremely costly; it has a very low EROEI when measured over the full life-cycle; uranium mining and the manufacture of cement require fossil fuels, which emit carbon dioxide; there is a danger of disasters such as Chernobyl; decommissioning costs are very high; and as yet no permanent solution has been found for radioactive waste disposal. Nevertheless, nuclear power is already becoming more politically fashionable as oil prices rise. However, Goodstein (2004: 19) warms that it will take "at best a decade or more for the new power plants to come on line." Moreover, even if more nuclear reactors are built, they will produce only electricity and not liquid fuels directly (production of hydrogen fuel is discussed below). Finally, given the uncertain economic future in the context of Peak Oil and climate change, there is a considerable risk that insufficient resources will be available to decommission all nuclear power plants, leaving some dangerously radioactive.

To summarise, non-renewable energy sources are by definition not a long-term, sustainable proposition. Their use is constrained by natural depletion; coal, gas and uranium extraction will – like oil production – reach peaks and then decline. Even if governments and corporations decide to expand investment in these non-renewables, it will take many years to bring sufficient new production capacity on stream. This will most probably be too late and of insufficient quantity to offset the rate of oil depletion. Perhaps most seriously, though, large-scale replacement of oil with coal will most likely result in catastrophic consequences for climate change and the environment. Nuclear power similarly poses great risks for the environment and human health.

4.1.2 Renewables

- BIOFUELS – including bio-ethanol and biodiesel – can power internal combustion engines and are therefore a ready substitute for liquid petroleum fuels. Ethanol is produced from crops such as corn and sugar, and is rapidly growing in popularity, especially in the US. Biodiesel can be made from various oil crops, including soybeans, canola, sunflower and canola, as well as from algae. Biofuels have two main disadvantages: (1) they have a low EROEI compared to oil (possibly negative net energy in the case of ethanol); and (2) crop-based biofuels will inevitably compete for suitable arable land with food production, which is required to meet the needs of a growing and unsustainably large population. Algae shows more promise, but once again enormous investments will need to be made to scale up production and this will take many years.

- BIOMASS – chiefly in the form of wood, but also including animal dung – is highly polluting and contributes to deforestation if used on a large, unsustainable scale (as is currently the case in many developing countries and was previously the case in many industrialised nations). Most importantly, the burning of timber contributes to greenhouse gas emissions and simultaneously destroys carbon sinks.

- SOLAR and WIND power possess the great advantage of being (relatively) clean sources of electrical energy. The main disadvantages are that they are localised and intermittent sources, which necessitates forms of storage (e.g. batteries or using hydrogen as an energy carrier). Since solar and wind currently contribute less than half a per cent of the world's energy (and 0.1 per cent of South Africa's energy), massive resources will have to be mobilised to scale up their capacity. Nonetheless, they will most likely have to form the main basis of a sustainable energy supply in the future.

- HYDROELECTRICITY currently constitutes the world's biggest source of renewable energy, contributing nearly 20 per cent of electricity (Heinberg, 2003: 150). Hydro plants are a convenient means of storing energy, and the net energy returns are generally quite high. On the downside, some plants are affected by seasonal rainfall, and this is likely to be increasingly problematic as climate change tightens its grip. Moreover, dams are generally very damaging to the local and downstream environments.

- GEOTHERMAL energy is used for heating as well as for electricity generation. Its main disadvantage is that it has limited geographical availability; only some countries have the necessary geology. In addition, natural replenishment of underground steam may take many decades, which effectively limits the useful lifespan of most geothermal fields (Heinberg, 2003: 151).

- HYDROGEN can be used to power combustion engines or to produce electricity in fuel cells. However, hydrogen is an energy carrier, not a primary source. It has to be produced from fossil fuels or by using electricity to electrolyse water. Moreover, a hydrogen-based economy would require a very different and expensive infrastructure and will thus be costly and time-consuming to adopt. Despite these disadvantages, it will probably form an important component of future sustainable energy supplies, mainly as a way of storing solar and wind energy.

In summary, while some renewable energy sources hold great promise for the future, there are three main problems from the point of view of oil depletion: (1) with the exception of biofuels, they cannot readily be substituted for liquid petroleum fuels (but some biofuels require substantial fossil fuel inputs); (2) they currently contribute a miniscule fraction of the world's energy supply, so that a large amount of time and resources will be required to scale them up sufficiently to replace depleting fossil fuels; and (3) they currently require fossil fuels for manufacture and distribution.

Currently, no energy source is fully substitutable for oil, given its high degree of versatility both as a fuel (especially for transport) and as an input into the petrochemical industry, as well as its high energy density. Consequently, a transportation network of automobiles, aeroplanes and ships on anything like the present scale is simply not feasible with existing energy technologies. This brings us to the question of whether conservation of oil can ameliorate its declining availability in the future.

4.2 Energy conservation

There are two principal conservation strategies, namely increasing energy efficiency and reducing consumption (see Heinberg, 2003: 160-164). The scope for both of these conservation measures is large – technically if not politically. For instance, energy consumption per capita in North America is twice that in Europe and Japan, due in no small part to Americans' notorious preference for large vehicles as well as comparatively low taxes on gasoline.

Conservation measures include reduced road speed limits, encouragement of car-pooling, greater use of bicycles (especially in city centres), and mundane actions such as switching off lights and heating in unoccupied rooms and buildings. Greater energy efficiency may be achieved through the use of more fuel-efficient vehicles, better building insulation, more efficient lighting, and technologically superior electric power plants and industrial processes (for instance using cogeneration techniques), to name but a few.

Measures aimed at curtailment and efficiency of energy use are a vital component of any strategy to deal with oil depletion (see sections 6 and 7). However, given our current energy and transport infrastructure, and the diminishing returns to investment in efficiency, there are limits to the amount of energy that can be conserved while maintaining current patterns of economic and social activity (Heinberg, 2003).

Smith (2007) considers the future 'oil supply gap', i.e. the discrepancy between likely supply and 'business as usual' demand (growing at 1.8% per annum). He then models the potential effect on this gap of liquid fuel substitutes (including gas and coal liquefaction and biofuels), energy efficiencies (improved vehicle efficiency, electrified mass transport, airline rerouting, more efficient heating and power), and substitutes for petrochemical feedstock. Under reasonable assumptions about the growth of these substitutes and efficiency measures, his model suggests that they will delay the opening of the gap by just three years (from 2013 to 2016), and that by 2025 the gap will be of the order of 15 million barrels of oil per day. His conclusion is that substantial demand destruction is unavoidable.

In conclusion, although energy conservation will be increasingly important in the future, it is not a panacea that will avert the consequences of Peak Oil.

4.3 Technological progress

If existing energy substitutes and conservation options will not be adequate to offset declining oil supply, can we rely on technological developments to take us painlessly past the oil era? Clearly, technological improvements are an unpredictable wildcard. It is conceivable that major strides will be made within a short time period when the incentives are adequately strong (e.g. when the price of fossil fuels is sufficiently high or renewables are sufficiently subsidised). But relying on possible short-term technological fixes on a large scale seems imprudent at best and wishful thinking at worst. It should also be noted that any transition to new technology will likely need to be created and driven by current oil-based technology until a sufficiently large base is installed. In an unstable oil environment on the downside of the Hubbert curve, this will be difficult; the sooner research and development initiatives are undertaken, the better.

5 Implications of Peak Oil

Humanity has never before confronted the situation whereby supply of its primary energy source declines on a global scale. Therefore it is impossible to predict with certainty what impact the peaking of world oil production will have on societies and economies. However, on the basis of past experience (including episodes of local energy depletion and previous international oil shocks) and reasoned argument, we can sketch plausible scenarios. South Africa will be affected indirectly via global economic and political upheavals, as well as more directly via higher prices and limited supply of imported oil.

5.1 Global implications

5.1.1 Economy and financial markets

Global demand for oil has been growing for decades as a result of both population expansion and economic growth (at an average rate of approximately 1.5 per cent per annum over the past 30 years). Supply has for the most past risen to meet this demand, aside from two interruptions in the 1970s and a brief one in 1990. The oil shocks of 1973/4 and 1979/80 resulted in rising inflation together with severe recessions and higher unemployment (i.e. stagflation) in the industrialised economies. However, these shocks had political origins and lasted for a few years at most. Peak Oil, being imposed by Nature, will have both short-term and long-term impacts on the economy.

The severity of the short-term economic impact of an oil shock depends on several factors, including the magnitude and rate of the price increase, and whether it is sustained or transient. Rapid, large and sustained price shocks have historically had the biggest impact. After oil output peaks, a gap will open up between demand (desired oil) – which is highly inelastic in the short run – and supply (available oil). As discussed earlier, a conservative estimate of the post-peak depletion rate is about three percent per annum. Considering that oil prices trebled in 1979/80 after a mere five percent reduction in output (Iran's contribution), the potential for runaway oil prices becomes evident.

Another important factor is the monetary policy response of central banks. If central banks allow higher energy prices to work through the economic system, then the increasing scarcity of fossil fuels will manifest appropriately in altered relative prices and act as a stimulus to both energy conservation and investment in substitutes. In the short- to medium-term this new investment could help to offset declines in demand and investment in other sectors. However, most central banks are primed to respond aggressively to signs of rising inflation, especially if oil prices rise rapidly. In this case the likelihood of a recession is increased. Consumers will already be curbing spending as a result of higher energy prices (and second-round price increases for energy-intensive goods and services), and if this demand destruction is exacerbated by higher interest rates, which also depress investment, the economic situation could deteriorate significantly.

Leggett (2005) argues that the crucial timing may not be the actual date of the oil peak, but rather when a critical mass of investors recognises that Peak Oil is unavoidable and imminent. (Admittedly the tipping point may occur only in retrospect, after the actual production peak becomes evident). Given the sensitivity of oil prices to news of even small interruptions to supply, this realisation is likely to spark wide-spread panic and hoarding behaviour among investors, leading to a dramatic price spike. Such a spike could have devastating effects on financial markets as investor confidence in the growth economy dissolves.

Indeed, the integrity of the world financial system is deeply dependent on continuous economic growth. This is because new money is created as debt, on which interest payments are required. The only way that the interest can be repaid in future is if more new money is issued, which itself increases the stock of debt. The collateral for this debt is continuous economic growth, which is itself dependent on growing supplies of energy. Should growth fail for an extended period, the financial system may implode, compounding the economic adversity.

In the medium term, an economic recession and/or investor confidence crash would reduce global demand for oil and – somewhat perversely – result in the oil price falling again. This in turn could stimulate a partial economic recovery, only for another price spike to be triggered and the cycle to repeat itself.

In the long term, the world faces a virtually endless sequence of supply-side oil shocks on the down-slope of the Hubbert curve. Thus we can reasonably expect a rising oil price trend due to cumulative shocks along with greater volatility as a result of economic and political fallout. Certainly, efforts will be made to conserve oil (and energy more generally), and there will be heightened efforts to find substitutes for depleting oil. However, it will take many years – if not decades – to replace the vast infrastructure that currently relies on oil. The problem is that economic conditions will be far less conducive to such investment after Peak Oil as a result of less energy being available, rising costs, and the business environment being characterised by greater volatility and uncertainty.

Given the combination of repeated supply-side oil shocks and the likelihood of a major stock market crash, a prolonged economic depression is a distinct possibility if no mitigating action is taken, or it is begun too late. The US Department of Energy commissioned a report on Peak Oil by Robert Hirsch *et al* (2005: 4), who concluded that:

> "The peaking of world oil production presents the US and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking."

5.1.2 Transport and mobility

The rapid process of globalisation over the past two decades has been driven by a number of factors, including neoliberal ideology favouring free trade and technological progress (especially with regard to telecommunications). However, globalisation has to a large extent been underpinned by the availability of abundant, cheap oil to fuel the world's transportation systems. In the era of declining supplies of oil, we can expect a partial reverse of the globalisation process in favour of localisation of production and consumption (especially of material goods). More specifically, all sectors that rely heavily on oil-fuelled transport will be adversely affected. Chief amongst these is the aviation industry, a large fraction of whose operating costs are fuel. As a result of reduced international and national mobility, the tourism sector will shrink significantly.

5.1.3 Agriculture, food and population

Oil and natural gas are essential inputs into modern industrial agriculture, both for the production of fertilisers and pesticides, and for the operation of farm machinery (e.g. tractors and harvesters). Furthermore, oil-based transport is used to deliver food products to consumers.

The so-called 'Green Revolution' in agriculture, which took place from the 1960s, involved the extension of Western farming methods (including fertilizer and pesticide use) and crop varieties to developing countries, massively boosting agricultural yields and thereby supporting rapid growth in their populations. Globally, the use of fossil fuels enabled the human population to grow from less than one billion in 1800 to approximately 6.4 billion today. The world population is currently growing by some 80 million people per annum, which implies a growing demand for food.

After oil output has peaked, the world faces the prospect of declining food production and therefore rising world food prices. Some authors suggest that without fossil fuels, the sustainable world population is probably in the region of about two billion (see Heinberg, 2003: 177). Others, however, are much more optimistic. Ultimately, the impact of fossil fuel depletion on agriculture needs to be viewed in conjunction with other environmental problems such as soil degradation, depletion of water resources and climate change. Together, these factors pose a significant threat to food security.

Another concern is the growing competition between food and fuel. Rising oil prices have prompted governments in several countries (including notably the US and Europe, as well as South Africa) to promote biofuel industries. Together, market forces and government support are making it increasingly profitable for (e.g. maize) farmers to supply their produce for the production of ethanol rather than for food. Growing international production of ethanol from maize and sugar is already pushing up the world prices of these staples, threatening the food security of certain food-importing nations and especially poor, landless consumers.

5.1.4 Geopolitics and conflict

As oil production begins to wane after the peak, international competition for remaining supplies will intensify. Given how critical oil is for economic and military power, there is a strong likelihood of further regional military conflicts over energy resources, especially in the Middle East and Caspian region, but also in other significant oil-producing regions such as West Africa and Latin America.

In some cases local conflicts are already deepening (as in Nigeria, for example), and may possibly descend into civil wars. In addition, the occurrence of wars between powerful consuming nations (e.g. the US) and weaker producing states (such as Iraq) will probably increase (see Heinberg, 2004). There is a very strong likelihood that such intervention will seed even more terrorist activity in the future. Certain regional conflicts may conceivably result in a new military rivalry among the great powers, notably the US, EU, China and Russia.

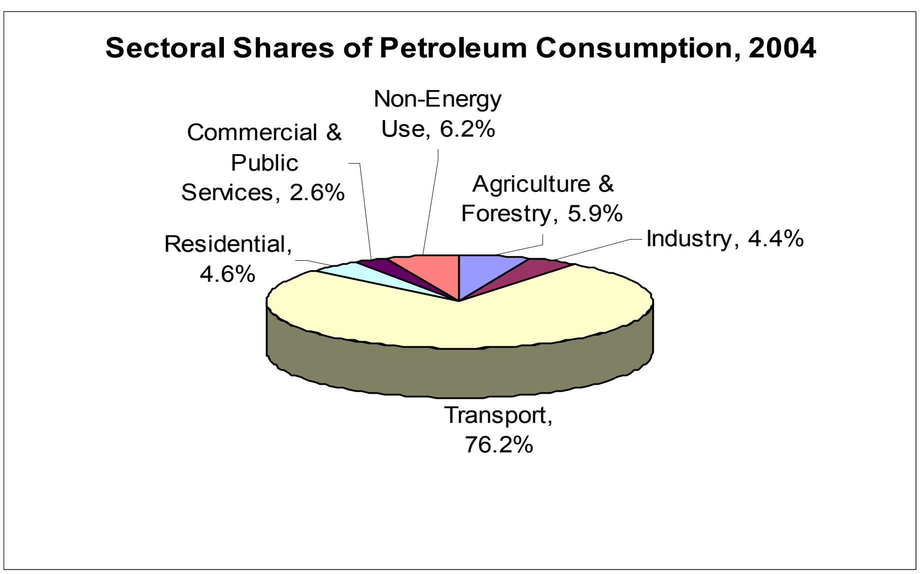
The US is clearly continuing its long-standing policy of positioning and utilising its military forces in order to ensure or control the flow of oil, especially in the Middle East. Russia is now the world's leading oil producer and boasts the world's largest natural gas reserves. Already this resurgent nation has begun to use its energy resources as a political weapon in Europe. China has a voracious appetite for energy, and has been concluding bilateral trade and investment agreements with several oil producing countries (e.g. Angola and Canada).

Escalating geopolitical tensions, outright conflict over energy resources, and terrorism will in turn erode economic confidence and hamper investment, making the transition to alternative energy sources and infrastructure that much harder.

5.2 Implications for South Africa

South Africa relies on its indigenous coal reserves for nearly three quarters of its total primary energy requirements. In 2004 only 14 per cent of South Africa's energy needs were met by oil (IEA, 2007). Imported oil makes up about 65 per cent of South Africa's annual petroleum consumption. The remainder comes from domestic production of oil (meeting about 5 per cent of domestic needs) and the well-developed synthetic fuels industry (supplying approximately 30 per cent of domestic consumption). South Africa processes imported crude oil into liquid petroleum fuels (petrochemical feedstock for production of plastics and other synthetic materials is derived from coal). Three quarters of petroleum products are used for road transport (see Figure 3).

Figure 3: Sectoral shares of petroleum consumption in South Africa, 2004



Source: International Energy Agency (2007)

Therefore, Peak Oil represents first and foremost a threat to liquid fuel prices and availability in South Africa. However, as will be discussed below, our country can also expect to experience various indirect effects of Peak Oil via its impact on the global political economy. It is important to understand that increasing our reliance on coal as a substitute would be an extremely short-sighted response, both because of climate change and because coal production will itself reach a peak, probably within the next few decades.

5.2.1 Macroeconomy

Rising crude oil prices push up domestic petrol and diesel prices. Since most goods in South Africa are distributed by road freight, higher liquid fuel prices raise the overall rate of inflation to a certain degree. When severe enough, this impact of oil price shocks on inflation usually prompts the monetary authorities to raise the interest rate – particularly if it is concerned about second-round inflationary expectations. Higher interest rates in turn have a depressing effect on aggregate demand and economic activity (which are already suffering from the effects of higher prices and therefore reduced purchasing power) and may ultimately result in a recession.

Furthermore, being a small, relatively open economy (exports comprise a quarter of the gross domestic product or GDP), South Africa is vulnerable to global economic shocks. An international recession (in addition to rising transport costs) would impact negatively on our economy by reducing the demand for many of our exports. However, declines in manufactured export revenues may be counterbalanced to some extent by rising receipts in the mining (gold, coal and uranium) and possibly agricultural sectors. (This is provided the country is still able to produce significant quantities for export in the face of climate change and oil depletion). Considering that oil imports are the single largest import item by value, the overall effect of rising oil prices on the balance of payments is likely to be negative. This will put pressure on the rand exchange rate and depreciation would further contribute to rising inflation.

South Africa’s stock exchange usually takes its lead from the major world bourses, although the dominance of the commodity sector makes its dynamics somewhat different. A major international stock market crash would almost certainly spill over to the JSE to a large extent. This is especially so considering South Africa’s status as a relatively risky emerging market and the recent surge in foreign portfolio investment in the local bourse.

In general, those sectors that use oil most intensively will suffer the greatest impact of declining global oil production. In South Africa, the most vulnerable sectors include:

- TRANSPORT: The bulk of South Africa’s oil imports are used by the transportation sector, which is highly dependent on liquid fuels (for 97 per cent of its energy requirements).
- RETAIL TRADE: The heavy reliance on road freight in South Africa means that a wide range of goods prices are affected by oil prices.
- TOURISM: South Africa’s tourism sector will contract as international transport becomes progressively more expensive – particularly considering South Africa’s distance from wealthier nations (US, EU, Japan) whose citizens are generally in a better financial position to travel. Local tourism will also suffer from higher transport prices.
- AGRICULTURE: See following section.

5.2.2 Agriculture and food security

South Africa is at present a net exporter of agricultural products, including the main staple, maize. However, it does import various agricultural commodities, such as soybeans, as well as most of its fertilizer inputs. Mirroring the global situation, South Africa's agriculture and food security face two main challenges as a result of oil depletion: increasing scarcity and costs of inputs as oil (and gas) prices rise; and competition between drivers and food consumers for maize. The Government has decided to promote a biofuels industry, the main component of which appears to be large-scale production of ethanol from maize (DME, 2006). In the short term, this may lead to an increase in the maize crop as farmers are guaranteed a larger domestic market and indirect subsidy, but in the longer term it may result in the poor being deprived of their staple food. Rising transport costs will further raise the prices of foodstuffs in this country, harming the poor even more.

5.2.3 Cities and urban planning

South Africa's major urban areas are characterised by sprawling suburban areas surrounding concentrated commercial centres. In general, public transport systems are inadequate. Many urban residents rely on private road transport or taxis, although the majority depend on public transport or walking (Department of Transport, 2003). Diminishing availability and rising prices of petrol and diesel present an enormous structural challenge to cities. Presently, the bulk of food and other commodities are trucked into and within cities; rail freight is currently underutilized. In future, urban areas will have to densify and allow mixed zoning such that a wide variety of activities (e.g. work, schooling, commerce and food production) can take place along localised patterns. Public transport systems, such as light rail, will have to be expanded as well.

5.2.4 Security

Peak Oil has potentially important security implications at the global, regional and local scales.

South Africa is unlikely to be the site of major international conflict over fossil energy as it does not possess significant oil or gas reserves (although exploration is continuing off the west coast). Although this country ranks seventh in terms of national coal reserves (possessing some 5 per cent of the world total), it seems unlikely that this poses a geo-strategic risk. This is because some of the highest energy-consuming countries (e.g. the US, China and India) possess large domestic coal reserves while others (e.g. Europe) are geographically proximate to countries well endowed with energy resources. On the other hand, South Africa has the world's fourth-largest deposits of uranium, which could conceivably make it a target if nuclear power production takes off globally.

While some of South Africa's immediate neighbours do depend partly on her for energy, it seems implausible that they pose a significant military threat. On the other hand, the relative size and strength of South Africa's economy in the context of Southern Africa means that this country is something of a regional magnet in times of crisis. South Africa is already receiving a flood of refugees from neighbouring countries suffering from the effects of droughts, HIV/AIDS and especially Zimbabwe's economic collapse. Such immigration is likely to increase as the effects of Peak Oil and climate change are increasingly felt by our neighbours. This will place extra strain on already over-stretched social services and aggravate social tensions.

Domestically, rising food and transport costs will affect the poor most, thereby worsening already high levels of inequality and poverty in South Africa. Increasingly, satisfaction of the poor's basic needs will be in jeopardy. HIV/AIDS mortality will be rising and will be compounded by increasing prevalence of joblessness and hunger. This in turn will place added strain on social services. At the same time, the provision of such services will be hampered as economic activity contracts and costs mount. The past few years have already witnessed an increase in social protests over lack of service delivery, so the scene is set for heightened social tensions in the future. The taxi industry in particular, well known for its extreme violence, could react adversely to rising fuel prices. Food protests are a distinct possibility, especially as global and national maize-ethanol production increase.

6 Vision of a Sustainable Future

The gloomy picture painted above would be the likely result of attempting to maintain business-as-usual in the way we organise our economies and societies in the face of declining oil production. However, a better future is possible. This section presents a very brief vision of a sustainable future as a target toward which South African society can strive. It summarises some broad principles of sustainability and then draws attention to practical steps that can be taken to achieve that goal and to directions that should be avoided. The objective is to 'point an arrow' towards a future that will ultimately be better for the great majority of today's population as well as future generations.

The term 'sustainable' essentially means "that which can be maintained over time." When applied to human societies the term is relative, since life on Earth will ultimately cease to exist (albeit perhaps in a few billion years' time). Heinberg (2007) suggests as a yardstick the durability of previous civilizations, which lasted up to several hundreds or even thousands of years.

The World Commission on Environment and Development (1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This focus on inter-generational equity logically implies that intra-generational equity should also be an accepted value. Thus poverty and a high degree of inequality are seen as incompatible with sustainable development. Sustainable development is usually understood to include economic, social and environmental dimensions.

Environmental economist Herman Daly has suggested three conditions for sustainability, focusing on the resource base (see Meadows, Meadows and Randers, 2004):

(1) the rate of use of renewable resources must be less than or equal to their rate of regeneration
(2) the rate of use of non-renewable resources must be less than or equal to the rate at which they can be replaced by sustainable renewable resources
(3) the rate of pollution emissions must be less than or equal to the rate at which they can be absorbed and processed by the environment

Daly (1996) also emphasizes the difference between *growth*, defined as an increase in size or quantity (e.g. of populations or resource throughput) and *development*, defined as qualitative improvement. Growth will ultimately run up against finite limits, since we only have one Earth. William Rees introduced the notion of humanity's Ecological Footprint, the total land and water area needed to support the global population. Currently our collective footprint is calculated as nearly 25 per cent greater than the capacity of the biosphere to support us (Heinberg, 2007).

By any of these definitions, current global (and South African) society is living – and growing – unsustainably. Peak Oil will merely serve to highlight this reality by making it clear how much we depend on a finite fossil fuel whose supply will inevitably decline. The path we are currently on is leading toward collapse – the ultimate fate of many previous complex societies (see Diamond, 2005). Making the transition to a sustainable economy and society – and avoiding collapse – will be no easy or automatic adjustment. This is especially the case in South Africa, where 90 per cent of our energy resources are non-renewable.

Attempting to delay the transition from oil to renewables through more intensive use of other non-renewables, such as coal, gas and nuclear power, has two major disadvantages. The first is the contribution to global warming and climate change resulting from the burning of more fossil fuels (which are also required to extract uranium for nuclear power generation). The second drawback is that less oil (and other fossil fuels) will be available further into the future, and their cost will be much higher, making the ultimately necessary transition to renewables much more difficult and costly. It would therefore be wise to embark proactively on a crash (i.e. large scale and rapid) programme aimed at conversion to sustainability before oil, gas and coal prices rise further and the consequences of Peak Oil manifest themselves.

In order to help chart a course toward sustainability, Table 2 lists both unsustainable and more sustainable options for population, energy, transport, economy, agriculture and urban planning. This list is not meant to be exhaustive, but rather indicative of the directions we need to be taking and avoiding. The following subsections discuss the proposals in more detail.

6.1.1 Population

It must be recognised that the fundamental problem underlying resource depletion, environmental degradation and climate change is the unsustainable level and growth rate of the human population. Quite what is a sustainable level of population at the global and national levels is a contentious and complex matter. But at the very least, we should seek to stabilize populations as fast as possible by humane methods. Otherwise, Nature will probably perform the task for us in unpleasant ways.

6.1.2 Energy

Economies and societies utilizing finite resources must at some point make a transition to renewable resources. For South Africans this means replacing fossil fuels and nuclear power (which uses a non-renewable mineral – uranium – as a feedstock) with renewable energy sources. Ultimately, the only sources of renewables are solar, gravitational (as captured in hydro and tidal power) and geothermal energy. Solar power can be harnessed directly as heat or converted into electricity by photovoltaic cells. It can also be captured indirectly in the form of wind and wave energy, and via photosynthesis as in the production of biofuels. Biodiesel produced from algae may be the most promising form of renewable liquid fuel, as it need not compete with food production and can use waste or saline water. Since solar and wind energy are intermittent sources, they need to be supported by a storage medium; hydrogen may fulfil this role to an extent. In addition to renewable energy sources, South Africans will need to vastly improve the efficiency of energy use. This could include the use of high efficiency electrical appliances, When resources permit, ‘smart’ technology could be adopted that optimises household and business energy usage by switching on appliances when sufficient power is available.

6.1.3 Transport

A transport system based on non-renewable fuels is unsustainable. In addition, it is important to recognise that a car-based transport system has many costs beyond fuel use. These costs include the significant amount of energy and oil products that go into the manufacture of cars (Heinberg, 2003: 161) and the construction of roads. Furthermore, the use of land for roads and parking lots carries negative environmental consequences, such as their contribution to urban and global warming, habitat destruction and loss of arable land. Improving vehicle fuel efficiency standards will not address these additional costs of road transportation, and will merely delay the inevitable transition away from petroleum fuels. Hydrogen-powered vehicles have similar disadvantages, and are not efficient as hydrogen first has to be created from other energy sources.

A sustainable transport system will have to be powered by electricity generated from renewable resources, as well as from biofuels that do not compete with food production (e.g. biodiesel made from algae). Given petroleum's high energy density compared with these alternatives, transport will have to be scaled down and made much more energy-efficient. Cycling and walking will have to replace cars for short journeys, particularly in urban areas. Cities will require light electric rail systems, and heavy electric rail will be essential for bulk transport and freight between cities and towns. Electric road vehicles will also have a place in the transport mix, but not on anything like the scale of current internal combustion engine vehicles. Telecommuting will be an important way of reducing transport needs, as will home delivery services.

6.1.4 Economy

Economic growth is usually measured in terms of the GDP of individual nations (which are summed to give the Gross World Product). GDP is the total value of goods and services produced annually in the respective economy – measured in monetary units. Those sectors of the economy that involve the use of physical resources cannot continue to grow indefinitely in the face of finite resources and limited capacity of environmental sinks. These sectors include activities such as agriculture, forestry and fishing, mining and quarrying, and manufacturing. However, most services depend on energy inputs as well, including electricity and transport. Essentially, every economic process or transaction involves the use or exchange of energy, however small. Therefore GDP or GWP cannot grow indefinitely. What we need instead is a steady-state economy where the throughput of materials is both highly efficient (aimed at zero waste and based on circular flows) and on a scale commensurate with the physical conditions for sustainability. Additional value can be created through innovation and technological development, raising the quality of goods and services over time.

Given that our transportation system will shrink as oil and other fossil fuels deplete, trade in physical goods and tourism will have to become increasingly localised. Local communities should aim at self-sufficiency in the first instance and resort to longer distance trade when necessary. Much more business will have to be conducted via the Internet and other forms of telecommunication in the future. Existing oil-based industries such as automobile manufacturing will need to be replaced with or retooled in favour of mass production of solar panels, wind turbines, hydrogen electrolyers and fuel cells, and biodiesel reactors.

Table 2: Towards a sustainable future

NO / reduce	YES / increase
POPULATION	
• uncontrolled growth	• stabilise and reduce by humane methods
ENERGY	
• coal • natural gas • nuclear power • wood • bio-ethanol • biodiesel (using arable land or food crops) • tidal power (when damaging estuaries) • hydrogen produced from fossil fuels	• solar, wind and wave power • biodiesel (especially from algae) • hydrogen storage of electrical energy (including fuel cells) • increased efficiency • ‘electranet’ with smart technology to manage electricity use • reduced distribution distances
TRANSPORT	
• petrol & diesel-powered road vehicles • hydrogen fuelled cars • air travel • coal and oil-powered railways	• cycling • walking • electric rail (heavy & light) • electric road vehicles (limited) • home deliveries • telecommuting
ECONOMY	
• growth economy • globalisation (of goods trade) • over-specialisation • intra-industry trade • capital-intensity • planned obsolescence • linear production processes • throw-away products • excessive packaging • poverty & inequality	• sustainable economy • localisation (of goods trade) • self-sufficiency (where possible) • labour-intensity • mass production of most efficient and durable models of consumer goods • zero waste • circular production & consumption processes • reduction, re-use & recycling of materials • reduced packaging • more equitable distribution of income & wealth • equality of opportunity
AGRICULTURE	
• petrochemical fertilizers & pesticides • fossil fuelled mechanisation • large-scale • capital intensive • mono-crop • irrigation-intensive	• organic & permaculture (e.g. mixed cropping) • biodiesel-powered • small-scale • labour-intensive • zero waste • rural & urban • drip irrigated
URBAN PLANNING	
• suburban sprawl • low-density housing • energy inefficient architecture • poorly insulated buildings • car-dependence	• community-centred • mixed land-use zoning (agricultural, residential, commercial, community services) • suitable for cycling and walking • densification along existing railways • factories, warehouses and worker residences lose to railways • energy efficient, well-insulated buildings

6.1.5 Agriculture

As mentioned earlier, industrial agriculture relies heavily on fossil fuels for fertilizer and pesticide inputs as well as to power tractors and harvesters and to transport products to markets. Moreover, the use of petrochemicals gradually degrades the quality of soil and pollutes rivers, lakes and oceans. This unsustainable form of agriculture has to be replaced by organic and permaculture methods that do not rely on fossil fuel inputs. As a result of transport restrictions, agriculture will have to be much more localised and small-scale, and include urban food production. It will also necessarily be more labour-intensive. Biodiesel will likely be an important fuel source for operating farm machinery and transporting produce to rail links and local markets.

6.1.6 Urban planning

Changes in agricultural methods and food availability will probably result in a partial process of de-urbanisation as city-based populations struggle to feed themselves and more labour is required for agriculture. For those remaining in urban areas, significant changes will have to occur. Suburbia in most countries has been built on a foundation of cheap, private oil-powered transportation and is unsustainable. In the future, cities will have to densify close to their centres and along railway lines. Suburban areas will have to be restructured so that local communities have easy access to work, schooling, entertainment, etc. via walking and cycling. Dwellings will need to be constructed with sustainable use of materials and in energy-efficient ways (e.g. well insulated).

7 Policy Recommendations

Having outlined a vision of a sustainable society, it remains to discuss the practical policies that can be adopted to help society get there as rapidly as possible.

7.1 Mitigation

As motivated above, South African society needs to embark on a crash programme of mitigation – comparable to a war-time effort – that reconfigures key elements of our energy and transport infrastructure, economy, agriculture, and urban design. This needs to be done before the prices of oil (and gas) become much higher and more volatile, and while enough fossil energy resources are left to build the new infrastructure. Furthermore, fossil fuels need to be conserved for manufacturing useful materials until such time as renewable substitutes can be found and scaled up.

Two quotes from Hirsch *et al* (2005) on managing the risks related to peak oil are instructive:

> "with adequate, timely mitigation, the costs of [oil production] peaking can be minimized. If mitigation were to be too little, too late, world supply/demand balance will be achieved through massive demand destruction (shortages), which would translate to significant economic hardship." (p. 59)

> "The world has never confronted a problem like this, and the failure to act on a timely basis could have debilitating impacts on the world economy. Risk minimization requires the implementation of mitigation measures well prior to peaking." (p. 60)

The three principle means of achieving these mitigation aims are education, economic incentives and regulations. All three instruments will need to be utilized to alter people's behaviour before the negative impacts of Peak Oil arise. A very important component of a mitigation strategy is to run education campaigns in schools and the media (radio, television, print, Internet) explaining the need for sustainability. Such awareness campaigns should cover all areas of impact. While rising oil and other fossil fuel prices will provide incentives for many of the switches advocated, they will only do so when prices reach certain thresholds. This will probably be too late for effective mitigation. Therefore taxes and subsidies should be implemented to incentivise sustainable practices and investments ahead of the peak. In addition, it may be best for certain unsustainable activities or products to be banned outright through regulations.

Table 3 lists a range of specific education, incentive and regulatory policies that can be introduced. Some of these can be enacted immediately, while others would need to be phased in over time (or take effect some time in the future, such as banning cars from city centres).

7.2 Adaptation

Some of the mitigation measures described above will take years to be implemented, even if undertaken as part of a crash programme. This is because it takes time to build and replace infrastructure, and to retool factories and develop new industries. Also, there will inevitably be resource, financial and capacity constraints (including management and technical skills). It may therefore be necessary to have on hand a range of adaptation plans in the event of an oil price spike and/or sudden supply constraint. It must be stressed, however, that these adaptation measures should be seen as a set of short-term responses only and should not interfere with the long-term structural changes that are required in the transition to sustainability.

In the event of a sudden liquid fuel shortage, Government will need to consider prioritising key sectors and introducing a general consumer rationing system. The danger of allowing the price to be the sole rationing mechanism is that the wealthy minority will continue to consume petroleum products while the majority poor and lower-income sections of the population will find the costs prohibitively expensive and will be unduly affected (since energy costs comprise a greater portion of their household expenditure). In addition, essential government services (such as security and emergency services) will need a guaranteed supply of fuel in order to function.

The International Energy Agency (IEA, 2005) published a report in 2005 entitled “Saving oil in a hurry: measures for rapid demand restraint in transport”. The report proposes a range of measures that can make an immediate difference to fuel consumption, including: reducing national road speed limits (e.g. to 90 kilometres per hour); introduction and enforcement of car pool lanes on highways; driving bans and restrictions (such as alternating between allowing only odd- or even-numbered vehicle registrations into city centres); encouraging increased use of public transit (e.g. by reducing fares); and promoting telecommuting and changes in work schedules. Another measure would be banning certain fuel-intensive leisure or sporting activities, such as motor racing.

While interventions such as these may seem draconian, they may prove essential in order to preserve the social fabric and economic integrity of the country in the event of a sudden crisis, and to allow effective mitigation strategies to be implemented. Importantly, the IEA (2005: vii) state that “pre-planning is essential in order for transport demand restraint measures to succeed during a crisis” and that countries “must be ready to implement… measures on very short notice.” The report also stresses the importance of providing clear information to the public to explain the rationale for the measures. In addition, existing fuel taxes and road charges should not be lowered during a fuel crisis as such action would distort the price signals incentivising motorists to make alternative plans.

Table 3: Policies in pursuit of a sustainable future

Area	Policy Measures
Population	Expand availability of family planning clinics Provide free contraceptives & sterilization Ensure universal education of women Empower women and ensure their right to choose
Energy	Encourage energy efficiency awareness Phase out incandescent light bulbs Raise user costs of non-renewable energy sources Subsidise (or rebate) renewable energy infrastructure
Transport	Ban internal combustion cars from city centres Subsidise mass public transportation based on renewable energy Subsidise electric vehicles Enforce car-pooling
Economy	Tax unsustainable goods and services (e.g. use of carbon) Subsidise sustainable goods and services (e.g. solar & wind power) Tax waste and subsidise recycling Ban certain throw-away products and packaging (e.g. beverage containers)
Agriculture	Enact land reform encouraging small-scale, co-operative farming Provide training in sustainable (organic) farming methods Legalise production of hemp for sustainable manufacture of materials Ban destructive, unsustainable genetically modified crops and related pesticides (including terminator technology)
Urban design	Ban further urban sprawl Re-zone suburban areas to allow mixed land use Incentivise densification along existing and planned rail networks (e.g. by linking rates to size of plot, not dwelling) Include energy efficiency in building regulations

7.3 Cooperation

As discussed earlier, Peak Oil is a global issue with global consequences, many of which will spill over to South Africa. Every country will be affected by oil depletion to some degree. Like climate change, Peak Oil is thus a challenge which demands collective action and cooperation on a global scale.

Heinberg (2006) outlines an Oil Depletion Protocol as a cooperative response to declining oil supplies. The Protocol in essence requires all oil importing nations to agree to reduce their annual imports by a percentage equal to the world oil depletion rate. This rate has been estimated by Colin Campbell to be approximately 2.6 per cent per annum. Heinberg (2006) suggests that the Oil Depletion Protocol could operate along-side carbon emissions-based agreements such as a strengthened and extended Kyoto Protocol. This would be vital in order to ensure that coal is not used as a substitute for dwindling oil.

The Protocol is intended to help stabilise oil prices and avoid wars over remaining oil, and thereby ensure that economic and social conditions are more conducive to the crash programme of mitigation required to take us toward a sustainable future.

8 Conclusions

Peak Oil is arguably one of the most critical challenges confronting the world and South Africa. The impacts will be wide-ranging and deep, affecting all sectors of society. Poorer members of society will suffer disproportionately as they are the most vulnerable to crises. Given the complexity of the issues and their relationship to other pressing concerns such as environmental degradation, climate change, poverty and inequality, an integrated response strategy is essential.

While previous oil shocks were precipitated largely by unforeseen political events, Peak Oil is a certainty and therefore mitigating action – employing currently available technologies – can and should be taken. The longer that mitigating interventions are postponed, the more costly they will be in the long run, both in direct terms (as a result of rising energy and energy-related prices) and indirectly in terms of the economic and social dislocation that could have been avoided. What is required is a massive programme of investment into renewable energy and sustainable transport infrastructure on a scale – and with the urgency – of a war-time effort.

Viewed in the broader historical context of the rise and fall of civilisations, Peak Oil represents a turning point for humanity. Either industrial societies will begin a cascading collapse towards diminished complexity, or they will make a transition to a sustainable, post-fossil fuel socio-economic model on a scale commensurate with available sources and sinks in the biosphere. Either way, we are likely to experience a period of wrenching transition that will require an unprecedented level of national and international cooperation, as well as the support and understanding of the the civil society, business and government.

References

Association for the Study of Peak Oil & Gas (ASPO) (2007) Newsletter No. 74, February 2007. Available online: https://aspo-ireland.org/Newsletter.htm; accessed 4/02/2007.

Campbell, C. (2005) "The Assessment and Importance of Oil Depletion", in McKillop & Newman (eds), *The Final Energy Crisis*, London: Pluto Press.

Cambridge Economic Research Associates (CERA) (2005) "The Future of Oil Supply." Available online: http://www.cera.com/eyeonthemarket/; accessed 22/09/2005.

Daly, H.E. (1996) *Beyond Growth: The Economics of Sustainable Development*. Boston: Beacon Press.

Darley, J. (2005) *High Noon for Natural Gas*. Chelsea Green Publishing.

Deffeyes, K.S. (2005) *Beyond Oil: The View from Hubbert's Peak*. New York: Hill & Wang.

Department of Minerals and Energy (DME) (2006) "Draft Biofuels Industrial Strategy." Pretoria: DME.

Department of Transport (DoT) (2003) Key Results of the National Household Travel Survey. Pretoria: DoT.

Diamond, J. (2006) *Collapse: How Societies Choose to Fail or Succeed*. London: Penguin.

Duncan, R. (2003) "Three World Oil Forecasts Predict Peak Oil Production," *Oil and Gas Journal*, May 26, pp. 18-21.

Goodstein, D. (2005) *Out of Gas: The End of the Age of Oil*. New York: Norton.

Heinberg, R. (2003) *The Party's Over: Oil, War and the Fate of Industrial Societies.* Gabriola Island, Vancouver: New Society Publishers.

Heinberg, R. (2004) *Powerdown: Options and Actions for a Post-Carbon World.* Gabriola Island, Vancouver: New Society Publishers.

Heinberg, R. (2006) *The Oil Depletion Protocol: A Plan to Avert Oil Wars, Terrorism and Economic Collapse*. Gabriola Island, Vancouver: New Society Publishers.

Heinberg, R. (2007) "Five Axioms of Sustainability." Museletter No. 178, February 2007.

Hirsch, R. (2005) "The Inevitable Peaking of World Oil Production." The Atlantic Council of the United States, Bulletin Vol. XVI, No. 3, October 2005.

Hirsch, R.L., Bezdeck, R. & Wendling, R. (2005) "Peaking of World Oil Production: Impacts, Mitigation and Risk Management," Science Applications International Corporation (SAIC). Report commissioned by US Department of Energy, February 2005.

International Energy Agency (IEA) (2005) "Saving Oil in a Hurry: Measures for Rapid Demand Restraint in Transport." Draft Report, 28 February 2005. Available online: http://www.iea.org/; accessed 27/10/2006.

International Energy Agency (IEA) (2007) *IEA Energy Statistics*. Available online: http://www.iea.org/Textbase/stats/index.asp; accessed 7/02/2007.

Intergovernmental Panel on Climate Change (IPCC) (2001) Climate Change 2001: Synthesis Report. Available online: http://www.ipcc.ch.

Intergovernmental Panel on Climate Change (IPCC) (2007) Climate Change 2007: The Physical Science Basis – Summary for Policymakers. Available online: http://www.ipcc.ch; accessed 5/02/2007.

Leggett, J. (2005) *Half Gone: Oil, Gas, Hot Air and the Global Energy Crisis*. London: Portobello Books.

Leggett, J. (2006) "What They Don't Want You to Know About the Coming Oil Crisis." *The Independent, U.K.*, 20/01/2006.

McKillop, A. & Newman, S. (eds) (2005) *The Final Energy Crisis.* London: Pluto Press.

Meadows, D.H., Meadows, D.L. & Randers, J. (2004) *Limits to Growth: The 30-Year Update.* London: Earthscan.

Simmons, M.R. (2005) *Twilight in the Desert: The Coming Saudi Oil Shock and the World Econom*y, London: John Wiley and Sons.

Smith, M.R. (2007) "Is There a Painless Way to Fill the Oil Supply Gap?" *Petroleum Review*, February 2007. Available online: http://www.energyfiles.com/oilsupplygap.html; accessed 8/02/2007.

Wakeford, J.J. (2006a) "Risks to Global Trade and Implications for South Africa's Economy and Policy." DPRU Working Paper No. 06/111, July 2006. Development Policy Research Unit, University of Cape Town.

Wakeford, J.J. (2006b) "The Impact of Oil Price Shocks on the South African Macroeconomy: History and Prospects." Paper presented at the South African Reserve Bank Conference on Macroeconomic Policy Challenges for South Africa, Pretoria, 22-24 October 2006.

World Commission on Environment and Development (1987) *Our Common Future*. United Nations.