Global fossil-fuel supply scenarios and their impact on Kenyan households

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Abstract

It was found that there was a wide body of evidence supporting two views over the future of oil supply: an 'optimistic view' stating that there is enough oil to provide for increases in supply at least until 2030, and a 'pessimistic view' that oil supply will decline before 2015. The differences in forecasts stem from disagreement over the total reserves remaining, the quantity of resources available from 'unconventional sources', and future predictions of reserve growth. Both views agreed that dwindling supply in non-OPEC countries will increase the amount of oil controlled by OPEC nations, increasing supply volatility.

As a substitute for oil, natural gas supply is closely related to that of oil and so 'pessimists' insist that gas production will peak shortly after that of oil. Known resources of coal are thought to be enough to last hundreds of years at current rates of consumption. Fuels such as petroleum, diesel, LPG and paraffin are derived from oil and gas and as such their supply is closely related.

The report discussed how three Kenyan households' livelihoods would be affected by the possible increases in fuel scarcity. It was found that without mitigation fuel scarcity could change employment patterns, increase migration, deforestation and social differentiation, and reduce gender equality, life expectancy, provision of education and healthcare.

The report recommends a mitigation strategy of increased technology transfer and funding to allow increased access to electricity and supply of renewable sources of fuel. The encouragement of exploitation of fossil fuel sources and increased use of LPG is not recommended as it will exacerbate climate change effects, have few benefits to the poorest, and be unsustainable under all three scenarios.

Word count: 277

"What gets us into trouble is not what we don't know,
it's what we know for sure that just ain't so."
—Mark Twain

"When the poor and rich compete for services,
the rich will always get priority."
—Kenyan quoted in *Voices of the Poor*, World Bank

"Every time I see an adult on a bicycle,
I no longer despair for the future of the human race."
—H. G. Wells

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Abbreviations used

ASPO	Association for the Study of Peak Oil and Gas
DFID	Department for International Development
GDP	Gross domestic product
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MDG	Millennium Development Goal
NGO	Non-governmental organisation
OPEC	Organisation of Petroleum Exporting Countries
URR	Ultimately recoverable resource
USD	Dollars, United States
USGS	United States Geological Survey

Units used

bbo	billion barrels of oil
GWh	gigawatt hours
kt	thousand tonnes
mb/d	million barrels per day
mt	million tonnes
mtoe	million tonnes of oil equivalent
tcm	thousand cubic metres
TJ	terajoule

Notes on terms used

The terms 'low-income country' and 'middle-income country' refer to the World Bank categorisation as used in the *World Development Report* (World Bank 2007, 2).

The term 'agrofuel' is used to differentiate cultivated biofuels from fuelwood, and crop residues collected informally.

Introduction

The Problem

The *World Energy Outlook* states that there is enough oil of varying sources to maintain current production for 42 years (IEA 2006, pp. 88). We are told that supply of primary oil and gas resources, and their associated secondary fuels, are plentiful enough to supply global markets well into the twentieth century.

Yet an increasing number of analysts question this view fundamentally. They claim that due to dwindling reserves, rising demand, and persistent underinvestment, supplies of oil and gas will peak and rapidly decline in the immediate future (Bentley 2002, Campbell and Laherrere 1998, Deffeyes 2001, Hatfield 1997, Hirsch, Bezdek and Wendling 2005, Ivanhoe 1996, Korpela 2006, Leggett 2005).

With oil prices recently hitting historically unprecedented levels – over 140 USD (United States Dollar) a barrel in July 2008 (Bloomberg 2008) – the debate over fuel scarcity has never been fiercer. Governments across the world have been facing considerable pressure to take action to reduce end-use prices to for domestic and transportation fuels (BBC News 2008, 1). The importance of the issue is underpinned by studies showing a clear link between high oil prices and macroeconomic instability (Hamilton 1983, Essama-Nssah *et al* 2007, Dunkerley and Ramsay 1982), unemployment (Freeman 2003), and poverty (Hang and Tu 2006, Essama-Nssah *et al* 2007, Hope and Singh 1995). Oil price inflation has also affected development work (World Bank 2008, 1, United Nations 2005)

Rising prices and volatility in global fuel supply then, are capable of derailing much of the work of Governments in low and middle-income countries, as well as development donors working within them, to alleviate fuel-poverty and wider deprivation.

The cause of this link is the dependency upon oil held by the global economy including low and middle income countries with international development programmes. Yet today, not only do the governments, schools, hospitals, as well as many households, depend on these fuels for their every-day running, the *World Energy Outlook* (IEA 2006) recommends that liquefied petroleum gas (or LPG, a fuel derived from oil and gas refining) be used more in these countries to replace 'traditional' fuels with related negative health effects (Balakrishnan *et al* 2002, Ellegard 1996). All this in a context of looming catastrophic climate change largely attributed to the burning of fossil fuels (Pachauri and Reisinger 2007) and promises made by G8 group of nations to improve the quality of life of the poorest by achieving the UN Millennium Development Goals (MDGs).

If the view on the economic and environmental sustainability of oil and gas supply expressed in the *World Energy Outlook* (IEA 2006) and United States Geological Survey (USGS) assessment (2000) turns out to be wrong, the consequences for developing countries with little or no indigenous supply will be extremely damaging – for households, for the environment, for the wider economy, and for government services.

The Question

This reports aims to review the evidence on fossil fuel depletion and apply this assessment to households in a low-income country to discover the possible impacts on the welfare of these households, their communities, and the wider economy. The question of *peak oil* is a global issue with global ramifications – but few writing in the field have attempted to apply the forces of global fuel market fluctuations to the level of individuals; households in the global south – those often most at risk. By carrying out this household level study, this report aims to study some of the micro-level social, economic and environmental implications of these powerful extrinsic forces. In doing do so, the report will highlight a number of impacts that need to be addressed by mitigation efforts.

The Report

The first part of the report will consider differing forecasts in the literature regarding the availability and price of oil, gas, coal and their derivatives, such as LPG and paraffin. This section will conclude by creating fuel-market scenarios based on the literature.

The report will then consider these scenarios and see how they will affect a low-income country: Kenya. The scenarios will be applied using national contexts and local characteristics to see how individual households will be affected by the scenarios, and then these experiences will be analysed and their wider ramifications considered. The report will then aim to answer the question: how can the lives of the Kenyan households be improved in a world of increasing fuel scarcity?

Finally the report will conclude with recommendations for further work and a summary of the paper's findings. The time-scale in the report will be working from 2008 until 2030, in line with the time-scale used by the *World Energy Outlook* (IEA 2006).

Globally Traded Fuels

Introduction

Globally traded fuels form the bedrock of the globalised economy and supply of these fuels determines the growth of economies and the welfare of people worldwide (Dunkerley and Ramsay 1982, Hang and Tu 2006, Essama-Nssah *et al* 2007, Hope and Singh 1995). Fluctuations in this market, traditionally dominated by hydrocarbons, oil, coal and natural gas, have in the past pushed the global economy into recession (Hamilton 1983). Indeed, the current economic downturn has in part been attributed to record oil prices (BBC News 2008, 1).

Oil in particular has come to be the fuel that has defined the current age. Yet despite some forecasts predicting that the fuel has many years of production left (IEA 2006, Deming 2000, Deming 2003, USGS 2000) many are predicting that this age is coming to an end (Bentley 2002, Campbell and Laherrere 1998, Deffeyes 2001, Hatfield 1997, Hirsch, Bezdek and Wendling 2005, Ivanhoe 1996, Korpela 2006, Leggett 2005, Edwards 1997). This, in short is the *peak oil* scenario.

Shell's advertising does little to reassure us that oil scarcity is a far-off problem (Picture source: Shell 2008).

Supply of refined fuels such as road-vehicle petroleum, airline fuel, paraffin, LPG and diesel is dependent on supplies of oil and gas. In fact, the fates of all of these fuels are closely entwined. It is predicted that the peak in oil production will lead to increased exploitation of other hydrocarbons, nuclear fuels, agrofuels, solid biomass and renewable electricity technologies such as wind and solar.

Furthermore, the Intergovernmental Panel on Climate change (IPCC) tells us that the greenhouse gas (GHG hereafter) emissions from the burning of these fossil fuels is unsustainable (Pachauri and Reisinger 2007). Uptake of low-GHG emission fuels and technologies is fundamental to tackling anthropogenic climate change and if governments fail to tackle the problem of fuel scarcity they will also fail to halt dangerous climate change.

Forecasting the future of these fuels is therefore imperative to the accurate analysis of the future of the worlds economy, society and environment.

This section of the report will assess the future availability and price of global fuel supplies. The outlook for the three most prominent energy resources (oil, natural gas and coal) is considered, followed by a brief discussion of the future for secondary fuels derived from hydrocarbons. The section will conclude by summarising the various predictions in three 'fuel market scenarios.'

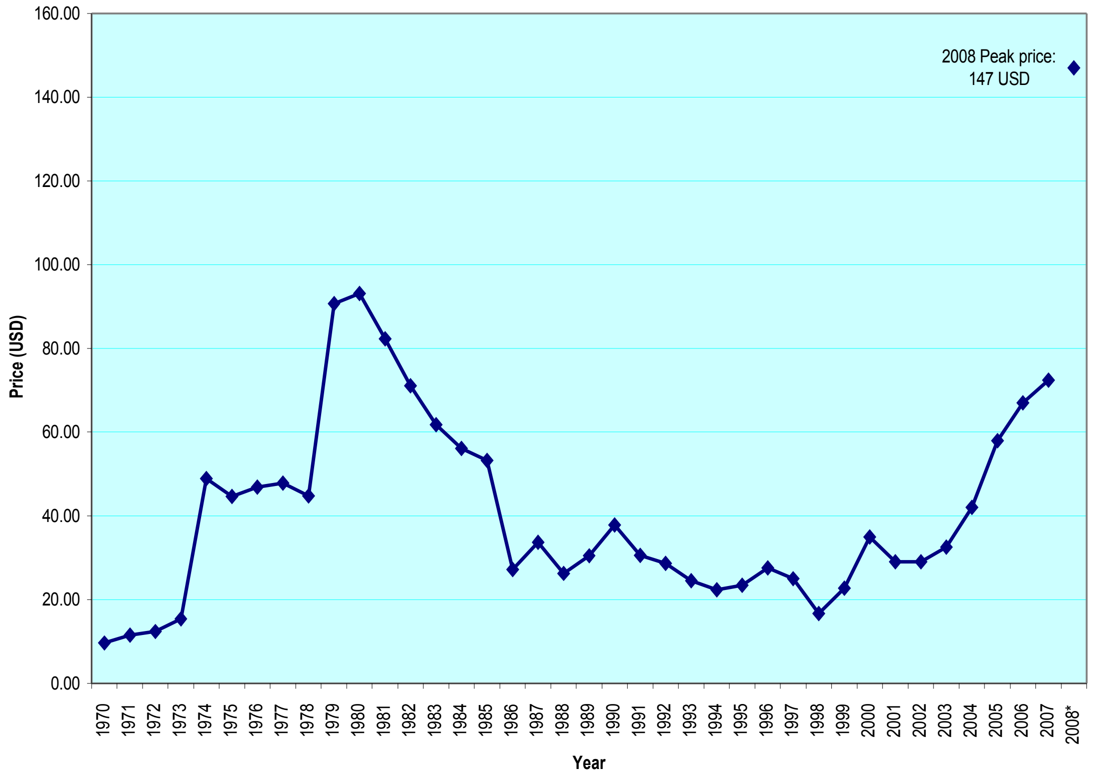
Oil

Clearly a finite resource, and such an economically important one, the size and ease of access to remaining oil resources has been the source of much discussion in academic and industry journals, as well as government and intergovernmental institutions and independent reports. Their conclusions about the future of oil supply vary considerably.

Oil was first drilled in Pennsylvania, USA in 1859 (Deming 2003). Production increased and exploration expanded worldwide as demand grew and by the middle of the 20th century oil had replaced coal as the world's primary globally traded fuel. It remains today the most abundant and convenient fuel resource that has been, and possibly will ever be available to humans (Korpela 2006).

In 2005 it was consumed at a rate of 83.6 million barrels per day (mb/d) (IEA 2006) and provided 35.2% of all the energy used by humans (IEA 2006). With increases in the worlds population and no mitigative action by governments, the IEA (2006) predicts that oil supply can increase to 116 mb/d by 2030. Its price, lower than 20 USD a barrel at the end of the last century, soared to its records of over 140 USD in July 2008 (see fig. 1).

Fig. 1. Crude oil prices 1970 - 2008



Yearly average oil prices from 1970-2008 normalised to 2007 USD. The 2008 peak price (*) is also shown.
Source data: 1970-1983 Arabian Light price and 1984-2007 Brent price (BP 2008). 2008 (*) Brent price peak in July 2008 (Bloomberg 2008).

Currently most crude oil is extracted from 'conventional' sources – fields of oil trapped in porous rock. 62% of oil in these fields is under member states of the Organization of Petroleum Exporting Countries (OPEC), and 20% are held by Saudi Arabia alone (IEA 2006). Recently, large scale production has begun on 'unconventional' sources such as Canada's oil sands, which alone could provide enough oil to last for several centuries (IEA 2006).

Drowning in Oil

Many sources offer an 'optimistic' view on the future of global oil production. In 2006 the International Energy Agency's (IEA) authoritative *World Energy Outlook* told us that there is enough oil of varying sources to "maintain current production for 42 years"

(IEA 2006, pp. 88). This assumes considerable future discovery, future upward revisions in size of current reserves, and increased exploitation of unconventional sources. This view is also held by the USGS who gave an even more positive outlook in their survey in 2000 (USGS 2000).

Going further, Deming (2003, pp. 6) declares that “rather than ending, the Oil Age has barely begun” and that new sources will provide enough oil “for perhaps 500 years”. Indeed, popular economics publications have within the decade declared the world as “drowning in oil” (Economist 1999, pp. 1).

These authors claim that 'reserve growth' (additions to reserves resulting from increased knowledge of a field and technological improvements) and new discoveries will continue to increase the world's conventional oil reserves, whilst massive reserves of 'unconventional' sources (such as oil processed from tar deposits) has to replace conventional supplies when they begin to fall. Although costly to extract (both financially and environmentally) they are viable when prices are above 32 USD per barrel (IEA 2006), and this price has been exceeded since early 2004. Unconventional sources are potentially vast with Canada's oil sands resource alone enough to sustain current total oil supply for 200 years (IEA 2006). 'Optimists' believe the biggest issue is whether a smooth transition can be made from conventional to unconventional sources (IEA 2006, Deming 2000, Deming 2003).

Hubbert and Peak Oil

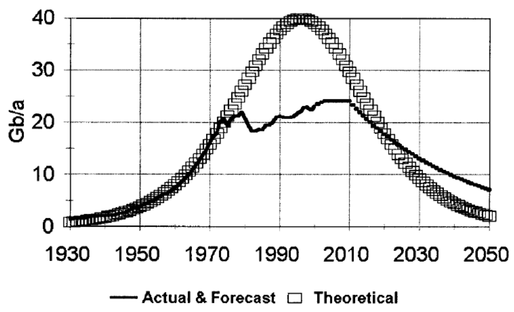
This optimistic view is not, however, shared by all writing in the field. A number of economic and geological oil analysts are concerned that global oil production is about to peak and then fall almost immediately. Many of them are members of the *Association for the Study of Peak Oil and Gas* (ASPO)[1].

They follow in the footsteps of M. K. Hubbert, the American oil geologist who achieved fame in geological circles when he correctly predicted that oil production in the 48 contiguous US States would peak in 1970. By utilising his ideas, and some his exact methods, they forecast that global oil production will peak and decline as shown (see

1 Association for the Study of Peak Oil and Gas (http://www.peakoil.net).

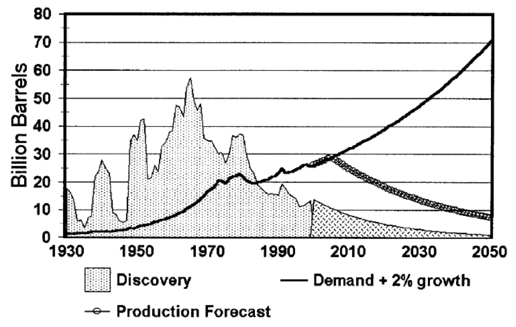
fig. 2 and fig. 3).

Fig. 2: Hubbert's curve applied to world production



When Hubbert's bell curve model is applied to global production, it doesn't fit. The 1970s oil crisis caused production to deviate from its geologically constrained trajectory. Diagram source: Campbell (2002).

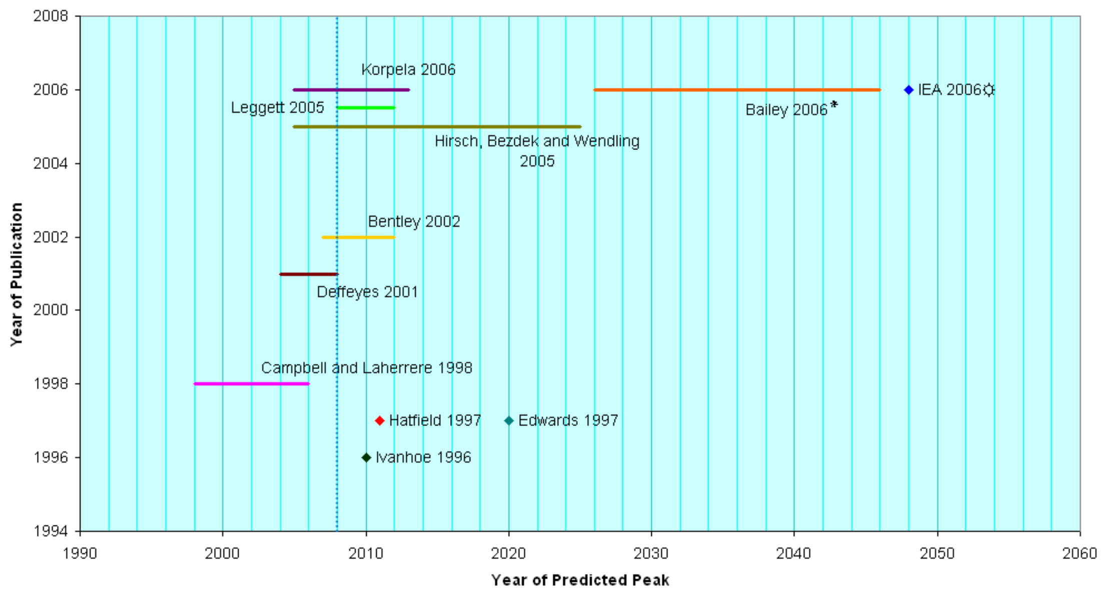
Fig. 3: Discovery, production and demand in the peak oil scenario



The peak of discovery in the 1970s is clearly visible with a gradual decline since. Campbell predicted demand would outstrip demand early in the first decade of the twentieth century. Diagram source: Campbell (2002).

This form of analysis creates wildly different production forecasts from those produced by the 'optimists.' At least eight of these authors predict a peak sometime between 2004 and 2014 (Bentley 2002, Campbell and Laherrere 1998, Deffeyes 2001, Hatfield 1997, Hirsch, Bezdek and Wendling 2005, Ivanhoe 1996, Korpela 2006, Leggett 2005) with production little exceeding today's level of 82 mb/d. Edwards (1997) predicts a peak slightly later, in 2020, with production reaching 90 mb/d and the World Energy Council supports a similar view (WEC 2007). The various predictions are summarized on fig. 4.

Fig. 4: Predictions of the year of peak conventional oil production



The current year, 2008, is marked with a dotted line (note that it is after some studies predicted that peak oil would occur).

Several 'optimistic' authors do not provide a prediction for the year of the peak (Deming 2000, Deming 2003, Maugeri 2004, Nicholls 2007). The IEA's study (2006) (☼) does not use the term peak oil but rather describes a time-frame "up to which current levels of supply can be maintained" which has been taken here to imply peak production (IEA 2006 pp. 85). Bailey (2006, pp. 1) (*) gives a vague prediction that oil supply will not peak before "the next generation", which has been interpreted as a prediction that peak oil will occur between 30 and 50 years from now.

The nature of the global peak described by each author varies with some claiming that steep drop-offs are likely after the peak (Ivanhoe 1996) and others saying that the point when the peak is passed will not be clear until several years after (Deffeyes 2001).

There is broad agreement, however, that from this moment of 'peak oil' lower production coupled with increasing demand will cause very steep price increases and fuel shortages. Investors will scramble to invest in the remaining reserves forcing a faster decline in production, speculators will buy up reserves forcing prices still higher, and a global economic decline will ensue.

How do peak oil analysts reach these conclusions?

The 'pessimists' reach different conclusions from the 'optimists' on account of several discrepancies. Firstly, *peak oil* proponents base their peak production dates on the slow down in global discovery: 80% of the oil produced today flows from fields discovered before 1973 and the peak year of global conventional oil discovery was 1964 (Campbell and Laherrere 1998) (see fig. 3). These authors cite the similar patterns of discovery, peak production and decline, successfully predicted by Hubbert in the United States, and also occurring more recently in the North Sea.

Secondly, peak oil proponents see exploration in more remote regions such as deep-sea oil, and the mining of 'unconventional sources', not as a positive display of technological triumph, but instead as a symbol of the decreasing inaccessibility of remaining reserves – a factor which will only increase the delay between discovery and production, and push up production costs.

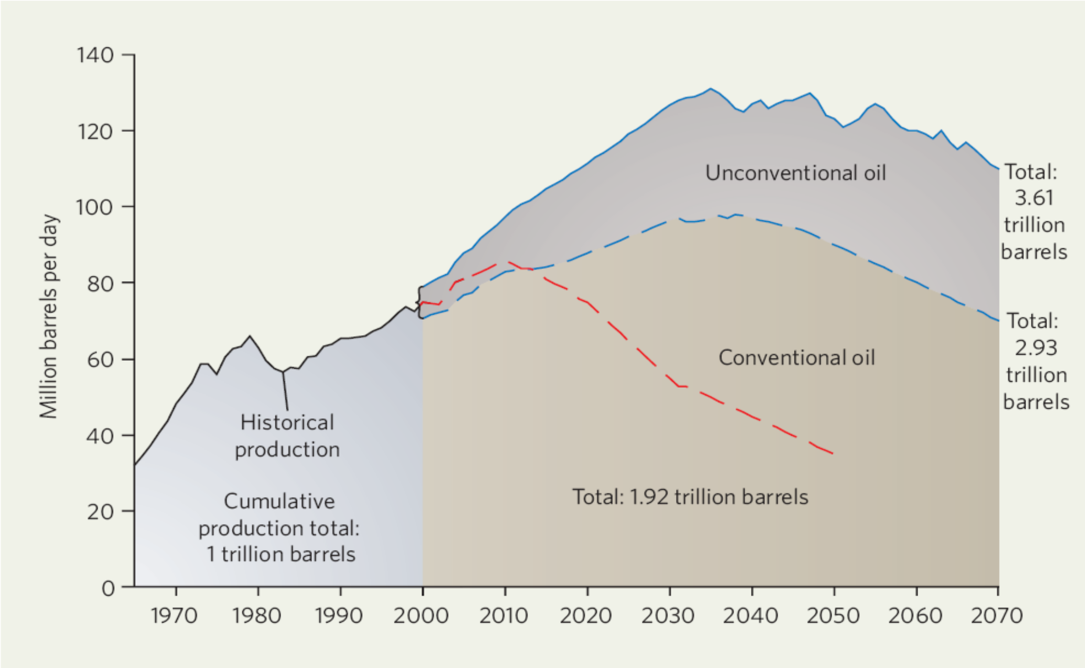
Thirdly, the credibility of data charting upward revisions in reserves or 'reserve growth' is called into question. Between 1985 and 1988 the collective action of six OPEC members upwardly revising 'proved reserves' raised the world's total oil reserves by over 200 bbo (billion barrels of oil) (BP 2007). Leggett (2005) alleges that these revisions do not represent genuine reserve growth but instead are a result of these countries trying to gain an increased share of production after the cartel reorganised to link production allowances with 'proven' reserves.

Lastly, peak oil proponents do not believe that future technological innovations will significantly increase our ability to extract oil from existing reserves or increase our ability to find (increasingly scarce) new fields.

Criticism of 'peak oil'

The total amount of oil consumed to date is 1 100 bbo (Witze 1997). The varying prognoses of the oil analysts gives us estimates of the world's total conventional oil endowment (known as the ultimately recoverable resource or URR) ranging from 1 800 bbo (Campbell and Laherrere 1998) to 3 800 bbo (Witze 1997). The figure for the URR defines the moment of peak oil (see fig. 5), and the difference produced is between there being no peak in production before 2030 (IEA 2006, pp. 86) and having passed the peak already.

Fig. 5: The URR defines the moment of 'peak oil'



The diagram shows historical oil production up until 2000 followed by three different production trajectories based on three different estimates of the URR. Diagram source: Wizte (2007)

'Peak oil' literature has been frequently criticized. Lynch (2002) accuses many models of being simplistic and when shown to be wrong, unrevised. It is clear, for instance, that the simple Hubbert curve doesn't fit historical global oil production (see fig. 2), yet writers continue to base their work on his models (such as Deffeyes (2001)).

Optimists also point out that oil crises have been readily predicted in the past and have not materialized (Deming 2003, Lynch 2002). Indeed, Colin Campbell has now published two papers predicting peak dates which have passed (Campbell 1989, Campbell and Laherrere 1998). However mistakes have been made on both sides: in 1965 the USGS gave a “conservative” estimate for global URR of 6200 Bbo (USGS 1965, pp. 17) – a figure many times higher than any current estimations.

Non-geological problems

In the 1973 oil crisis, market control by the OPEC cartel took production away from its purely geological constraints and therefore made actual production diverge from Hubbert's bell curve (fig. 2). Authors on both sides of the peak oil debate agree that future increases in OPEC's market share, coupled with an increased reliance on central Asia and Nigeria will cause prices to become increasingly volatile (IEA 2006, Deming 2003).

Leggett (2005) raises concern that industry complacency has led to underinvestment in exploration and infrastructure over the past 20 years, dramatically reducing the ability of oil companies to increase supply with demand. Leggett also predicts that increased scarcity will lead to a decrease in cross-border trade.

A further problem for analysing oil supply is the lack of publicly available data. Since the state-owned oil producers (including all members of OPEC) do not publish their reserves and output specific to individual fields it is difficult to asses the reliability of their figures. There is also considerable confusion in the popular literature about the terms used. For example, estimates of reserves include estimates based on different probabilities (a P10 estimate has 10% probability whilst P50 has 50% probability) but data of reserves estimates of different probabilities are often compares as if they are equal (Bentley 2002).

Conclusions

The aim of this report is to assess the current and future price and availability of globally traded fossil fuels. The wide reaching and highly significant disagreements about the future of oil in the literature make doing so very difficult. On the one side Maugeri (2004, pp. 1) accuses *peak oil* proponents of being "doomsters" with a "Malthusian bias" whilst optimists are accused of "wishful thinking" (Lynch 2002, pp. 1). One source even describes the debate as scientists versus economists (Lardelli 2007).

It is not debated that higher demand from low and middle-income countries (as defined by the World Bank (2007, 2)) is likely to increase total world demand at a rate of 2% per year until 2030 (IEA 2006).

It is also not debated that declining production from non-OPEC producers will increase the market share of OPEC members, while simultaneously increasing the importance of suppliers in Central Asian countries and and Nigeria where political instability will create supply volatility and contribute to irregular 'price spikes.'

Analysts do not agree, however, on the ability of oil producers to deliver an overall increase in supply in order to respond to demand. This debate centres on differing estimates on total oil remaining in all of these 'conventional' reserves, the viability of 'unconventional sources', and the likely success of future discoveries and technological improvements.

The most significant debate is that of the total conventional oil remaining. Hubbertists are right to point out dwindling discovery – but if past discoveries are sufficient for many more years (as is claimed), then its importance is reduced. New discoveries are so small as a proportion of overall supply as to be almost irrelevant in defining the moment of peak oil. Therefore the most important factor is how much production is left in the super-giant fields discovered in the 1960s.

The second key factor is the role of Governments. The IEA (2006) notes that environmental taxes have a considerable capacity to increase the costs of extraction of Canada's oil sands. In conventional fields, political volatility could hold supply rates down, forcing prices higher. When combined with increasing concern over GHG emissions, supply instability of this kind could create the political tipping point triggering reduction in fossil-fuel dependence and investment in renewable source of energy.

In an attempt to represent this variety of opinion, three scenarios: 'pessimistic', 'middle-ground' and 'optimistic' are created (see *Supply scenarios*).

Natural Gas

Basic Facts

Natural gas generally refers to a mixture of gases (primarily methane) which are extracted from oil fields and coal beds. Although historically natural gas has been considered a secondary fuel – discovered and extracted primarily as a side-effect of oil extraction – its availability and clean properties are making it increasingly desirable as a fuel for domestic use, electricity generation, and increasingly, transportation (IEA 2006).

In terms of the amount of energy released from its combustion, gas is second only to oil in its global usage. In 2004 2.8 tcm (thousand cubic metres) (IEA 2006) was consumed globally, with North America and Europe being the biggest consumers. This level is forecast to increase by around 2% a year – a modest reduction in the increases compared to the previous decade, with much of the increase in demand coming from Africa, the Middle East and China (IEA 2006). At present gas supply is thought to be sufficient to meet demand, with increases in production still occurring and forecast in all gas producing regions. Using proven reserves alone, the *World Energy Outlook* estimates production can grow 2% per year for 40 years (IEA 2006).

Trade

In contrast to oil, which is relatively cheap to transport, natural gas is primarily traded between adjacent regions (Campbell and Laherrere 1998). This means that prices vary significantly according to location. Nonetheless, the NYMEX[2] gas index, provides a guide to how various gas prices have increased. The index was over 13 USD in June 2008, having increased from below 6 USD in the previous September (Financial Times 2008). Although this is a smaller increase that has been seen with oil prices, such a steady, large rise remains significant.

Supply and demand varies by region. With production in the USA and Europe not forecast to grow sufficiently to meet demand (IEA 2006) gas will have to be transported over longer distances, raising costs and reducing energy independence. The *World Energy Outlook* predicts that 70% of the forecast increase in natural gas traded will be liquefied natural gas (LNG) (IEA 2006). LNG allows natural gas to be transported long distances at lower costs without a pipeline. Although infrastructure costs for liquefaction and regasification installations are high, production costs are falling (whilst

2 New York Mercantile Exchange, http://www.nymex.com/.

alternatives become increasingly scarce). Increased use of LNG can 'iron out' international differences in gas prices.

How much have we used and how much is left?

The *World Energy Outlook* (IEA 2006) states that only 25% of the total natural gas resource has been extracted to date – based on a URR of 314 tcm (trillion cubic meters) (for both conventional and unconventional sources). Other estimates vary from the low 283 tcm (or 1666 Bbo equivalent) (Bentley 2002) to the USGS's optimistic 436 (or 2567 Bbo equivalent) (USGS 2000). These are much smaller variations than to be found in estimations of the URR of conventional oil, and furthermore, the historical consumption of natural gas forms a much smaller percentage of total URR estimates than does oil.

Although most authors broadly agree that gas reserves are considerable, there is a significant difference between predictions of what could be termed 'peak gas.' Whilst the *World Energy Outlook* estimates that supply can meet demand until at least 2040 (IEA 2006), Bentley (2002) claims supply will begin to dwindle after 2020. The (at a minimum) 20 year gap between these sources' predicted peaks is due not to wide variations in estimates of gas URR but different estimations of future *oil production*. The *World Energy Outlook* predicts oil supply increasing well into the century, whilst Bentley sees oil production peaking between 2007-2012. With such an early oil peak, natural gas supply would be used increasingly as an oil substitute and therefore would deplete much faster. This 'early topper' view of gas is supported by Korpela (2006) and Campbell and Laherrere (1998).

Similarly to oil, increases in natural gas reserves are largely from reserve additions, as natural gas discovery appears to have peaked (Bentley 2002). Contention of this fact is owed to most gas discoveries being found 'by accident' – when the driller has been looking for oil (Bentley 2002).

It is not in contention though, that unlike oil production, gas supply from a field drops off steeply after the peak due to the nature of its extraction. This, coupled with recent falls in production from Russia's largest fields, gives rise to concern that investment after 2010 will be insufficient to increase supply accordingly (IEA 2006).

New, 'unconventional' sources of natural gas will help to increase production, particularly in Europe and North America where increased demand, lower conventional production, and a drive for energy security will make their otherwise expensive production attractive for investment[3]. These include gases extracted from coal beds ('coal-bed methane') and low-permeability sandstone and shale formations (known as tight sands and gas shales respectively) (IEA 2006).

Political problems

56% of reserves are held by just three countries: Russia, Iran and Qatar. With such a large proportion of gas reserves in so few countries the potential for political disruption to affect supply is very real. Most sources agree that in the future, gas supplies will become subjected to the same supply volatility that oil will be subject to (Nicholls 2007). Such an incident occurred in January 2006 when Russia cut off its gas supplies to Ukraine after failing to reach a supply deal with its national energy company following the Ukrainian Government's favourable policies towards the west at the expense of Russia (BBC News 2006). This incident illustrates how gas supply can be influenced as much by political wrangling as it can by long term geological constraints. Furthermore, Russia and Algeria's nationalised oil have recently made moves towards 'coordinating' their activities (IEA 2006) – suggesting the beginning of a gas cartel similar to OPEC.

Conclusions

Whilst natural gas has room to expand production into the medium-term, it is not a sustainable fuel source. With production levels more disposed to drop off steeply (and without warning) this makes the fuel's supply potentially volatile for the long-term. Even before then, the outlook for obtaining a steady flow of natural gas depends significantly on how close one is to suppliers. The geological constraints might not prove to be the factor that turns production into decline – if the rich world consumers aim for energy independence, they will have to turn to other fuels.

3 For example, 25% of current US domestic gas production comes from 'unconventional' sources (IEA 2006).

As natural gas is a substitute for oil, the lack of consensus over the future of oil production creates similar uncertainty in natural gas forecasts. The varied opinions in these forecast are summarised in the 'pessimistic', 'middle-ground' and 'optimistic' scenarios (see *Supply scenarios*).

Coal

Basic facts

Coal is a solid mineral extracted by mining near (and increasingly far from) the earth's surface. Its use as a fuel-source has been known for centuries and it was the fuel-of-choice for industrialised countries before oil took its place in the mid-twentieth century. Nonetheless it still remains globally important and in terms of the energy it provides, coal is currently the world's third most important fossil fuel (BP 2008).

Grades of coal vary considerably in their energy density and primary uses but can be broadly categorized into hard coal and brown coal. Hard coal (or anthracite) includes both steam coal and coking coal (or coke), the latter being useful as a smokeless fuel for low heat furnaces and cookers. Brown coal includes lower density grades of coal from lignite to sub-bituminous and bituminous coal[4]. Brown coal is rarely traded long distances due to its poor weight-to-energy ratio. It also has significantly higher carbon emissions than higher grades of coal. Bituminous coal, so called because it contains bitumen, can be converted into coke for further use by 'coking'. Coal-to-liquids technology is emerging as way of making coal more transportable.

Trade

In 2006 6195 mt (million tonnes) of coal were produced globally (BP 2007). This currently provides one quarter of global energy usage and this proportion is forecast to remain roughly constant until the end of the decade and beyond to 2030 (Melanie and Schneider 2002, IEA 2006). Overall demand for coal is expected to grow at around 1.9% per year in the near, medium, and long term[5]. The *World Energy Outlook*'s

4 Classification of coal used according to the OECD glossary of statistical terms (OECD 2008).
5 Melanie and Schneider (2002) forecast 1.9% increase per year until 2010, IEA (2006) forecast 1.8% growth per year until 2030 and Kovács (2007) predict 2% growth in consumption until 2050.

reference scenario foresees global coal consumption reaching 8 858 mt (IEA 2006).

In 2004 41.2% of global coal use occurred in the United States and Europe (IEA 2006). This proportion is forecast to fall to 19.6% by 2030 as most of the increase in the demand for coal will come from developing Asia, notably China and India (IEA 2006).

Unlike other fossil fuels, indigenous production of coal will remain key with most being consumed within the region of production, and trade only forecast to increase at the same rate as demand (IEA 2006). As such most production will come from the biggest consumers: United States, China and India, with Australia and South Africa, Russia focusing on export. These six countries together control the majority of the coal market with 85% of hard coal reserves and almost as large a proportion of brown coal reserves (Hook, Zittel, Schindler and Aleklett, in press).

Due to the high transport costs and local variations in geology, mining technology, transport infrastructure and labour costs, the price of coal varies significantly between producer countries. Most coal exported currently sells between 25 and 30 USD per tonne, but coal produced in the USA costs on average over 50 USD (IEA 2006). The *World Energy Outlook* forecasts that these prices will remain about constant, with improvements in technology and efficiency outweighing price increases due to geological constraints and increased average distances from source to market (IEA 2006).

How much is left and how much has been used?

Coal is the most abundant fossil fuel with the *World Energy Outlook* forecasting the 909 000 mt of proven reserves (as of 2005) (BP 2006): enough to last 155 years at current rates of consumption (IEA 2006) or 200 years according to Kovács (2007). These figures do not take into account growth in production and consumption, reserve growth or future discovery and therefore give a rough picture at best. Nonetheless coal is clearly more abundant than both oil and gas.

However, there is some dissent about *how* stable future coal production is likely to be. Zaipu and Mingyu (2007) and Hook, Zittel, Schindler and Aleklett (in press) use Hubbert curves to analyse coal production predicting global coal supply peaking in

2020. They reach such a different conclusion from the IEA (2006) because they do not see much of the coal resource under the earth's surface being economically exploitable claiming that many reserve estimates are outdated and overoptimistic. All three reports predict a faster decline in reserves in China. Production is predicted to peak there in 2020[6] increasing the regional price of coal, although Chinese imports are still only forecast to make up 7% of consumption by 2050 (Zaipu and Mingyu 2007).

The outlook for coal is perhaps less related to that of oil and gas than they are of each other because they are less close substitutes. Coal-to-liquids technology may increase the fuels substitutability, but since is it only viable when oil prices are above 40 USD, unconventional oil sources and gas, which can be refined at lower cost, are likely to grow faster initially.

Conclusions

Since the majority of coal produced to date has been for 'native' use, geopolitical constraints on its production have been low (IEA 2006, Kavouridis and Koukouzas 2008). This is likely to continue to be true for the foreseeable future (to 2030) – compared to other fossil fuels coal will remain 'secure, competitive, and predictable in price' (Kavouridis and Koukouzas 2008, pp. 692).

The biggest threat to coal supply is likely to come from environmental legislation. With concern over greenhouse-gas emissions rising with every year of record temperatures, pressure is increasing on governments to curb usage of coal, which is by far the most carbon intensive of the three main fossil fuels (Melanie and Schneider 2002). So called 'clean-coal' could allow for coal to meet the demands of the environmental agenda but are yet to be proven. Concern over safety and contribution to environmental degradation are likely to push up the cost of coal in the future.

The variety of opinion on the future of coal supply is summarised in the three supply scenarios: 'pessimistic', 'middle-ground' and 'optimistic' at the end of this section (see S*upply scenarios*).

6 Chinese production is forecast to peak ain 2020 by Hook, Zittel, Schindler and Aleklett (in press) and between 2025 and 2032 by Zaipu and Mingyu (2007).

Secondary fuels

Oil and gas are processed to make a number of secondary fuels. These include diesel, road-vehicle petroleum, jet fuel, paraffin , and LPG (a clean burning alternative to paraffin). Coal can also be processed into a liquid form using coal-to-liquids technology.

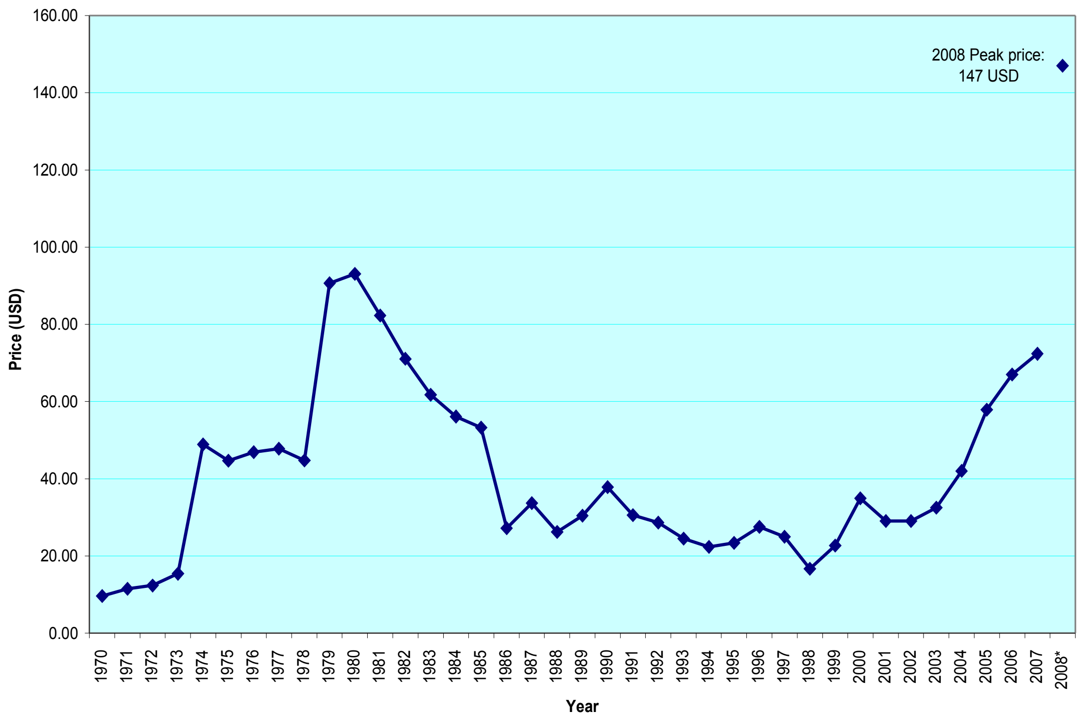
Paraffin, also known as kerosene, is most often used as domestic fuel for cooking and lighting (for example, 79.1% of the population of Kenya use paraffin as their primary source of fuel for light (KNBS 1999)). LPG, a mixture of propane and butane pressurised in cylinders for storage and transportation has similar usages in low- and middle-income countries (98% of households in Brazil have access to LPG (IEA 2006) and 17.5% of Indian households use it for cooking (ENTTRANS 2008)) whilst in the global north it is most commonly used as a portable fuel for recreational activities (ENTTRANS 2008).

These fuels are directly derived from fossil fuels. As such, they are highly supply-driven (Adland, Haiying and Jing 2007) with supply levels closely linked to that of primary fuels (IEA 2006).

Nonetheless, other factors do affect supply. Due to the expense of transportation, wide variations in price are found across the world (similarly to natural gas). In addition, decreased proliferation of the practise of flaring 'waste' gases by refineries (increasingly seen as wasteful and environmentally damaging) has the potential to increase supply levels (Adland, Haiying and Jing 2007).

Over the past four years, increases in the prices of oil (see fig. 1) and natural gas have pushed up the prices of butane and propane, the main constituent gases of LPG (see fig. 6).

Fig. 6. Propane and Butane prices 2004-2008



The graph illustrates price increase of propane and butane since 2003. These gases are the main constituents of LPG. Data source: LPG Australia (2008)

The constraints in supply of oil and gas described previously can be expected to be the main controlling factor in the supply level and price of these secondary fuels. Predictions of their future scarcity are summarised in the *supply scenarios.*

Supply scenarios

The various forecasts on the future of fuel market supply, demand and price are summarised here into three scenarios. Varied as they are, they are an attempt to cover the most likely futures as described by the literature. No attempt is made to weigh up the probability of each scenario, rather, they are shown as a range of equal possibilities. It should be noted that the 'middle ground' scenario is less defined by the literature than the 'optimistic' and 'pessimistic' scenarios, rather, it is included to show an intermediary – an attempt to find a compromise-view between the other two extremes of *peak oil doom* and a 21st century of continued fossil-fuel dependence.

Table 1. The three fuel supply scenarios.				
Scenario name		**Optimistic**	**Middle ground**	**Pessimistic**
Who are the main proponents of this view?		**Espoused by Government Institutions and oil companies (predominantly (USGS, IEA, Bailey, Deming)**	**A middle-ground, compromise-view between the two extremes (support by WEC, Edwards).**	**The peak oil view, as told by ex-oil industry insiders and 'Hubbertist' geologists (prominently Campbell, Leggett, Deffeyes)**
Oil	**Conventional sources supply**	>3 Bbo URR. Supply will increase 2% per year beyond 2030 (IEA 2006, Bailey 2006). By then, production will stand at 116 mb/d (IEA 2006).	2-3 Bbo URR. Supply will peak between 2015 and 2030 at a daily production of 90 mb/d (Edwards 1997).	2 Bbo URR. Supply will peak imminently (before 2015) or may have done so already. Current levels of production (82 mb/d in 2005 (IEA 2006)) will not be significantly exceeded (Campbell and Laherrere 1998, Leggett 2005, Korpela 2006, Bentley 2002, Deffeyes 2001, Hatfield 1997, Ivanhoe 1996).
	Unconventional sources supply	Will increase to replace current conventional production (IEA 2006, Deming 2000, Deming 2003).	Some production will replace lower output of conventional sources.	Technological difficulties will severely restrict supply (Leggett 2005, Bentley 2002, Campbell and Laherrere 1998).
	Other issues	OPEC will control a larger proportion of supply. Political volatility will lead to price spikes.	Price spikes will occur before peak. Future after the peak is unclear.	Future after the peak is unclear.
	Demand	Will increase just below 2% a year	Will increase just below 2% a year	Demand will vastly outstrip supply

		(IEA 2006).	until peak (IEA 2006).	before 2015.
	Price	Current prices will fluctuate permeated by 'price spikes' (WEC 2007).	In the short to medium term prices will be permeated by 'spikes' with considerable increases before 2030 (WEC 2007).	Prices will increase dramatically from their already historically high level and do not fall again due to fundamental scarcity.
Natural Gas		Gas demand and supply will increase at 2% a year (IEA 2006). Volatility similar to that in oil markets will cause prices spikes (Nicholls 2007). However increased production costs will be outweighed by technological improvements (IEA 2006).	Demand and supply will increase at 2% a year (IEA 2006) until drastic increases in demand around the incidence of peak oil cause supply to peak shortly after.	Supply will peak shortly after oil and before 2015, sending prices soaring (Bentley 2002, Korpela 2006, Campbell and Laherrere 1998).
Coal		Coal supply and demand will increase at 1.9% a year (IEA 2006, Kovács 2007, Melanie and Schneider 2002). Prices vary worldwide but will remain stable with indigenous production remaining key (IEA 2006).	Demand and supply will grow at 1.9% a year and prices remain stable (IEA 2006, Kovács 2007, Melanie and Schneider 2002) until peak oil occurs, after which coal prices will rise with increased demand. Coal-to-liquids substitutes some oil and gas production.	Peak oil leads to much higher demand. Supply will rise more slowly causing price to rise. Coal-to-liquids will substitute some oil and gas production.
Secondary fossil-fuels		Supply of LPG, paraffin, petroleum and other refined liquid hydrocarbons will increase with	As supply of LPG, paraffin, petroleum and other refined liquid hydrocarbons are closely linked	With oil and gas supplies dwindling, supply of fuels derived from them will fall too. Supply

	that of oil and gas (IEA 2006). Reduced flaring will increase supply above 2% a year (Adland, Haiying and Jing 2007).	with supply of oil and gas (IEA 2006), their supply will fall after peak oil. Supply of coal-to-liquids will increase short after.	of coal-to-liquids will increase.
Mitigative action taken	Increased exploitation of oil, gas and coal and efficiency measures follow 'price spikes' although demand growth is merely slowed (IEA 2006, pp. 159, 'Alternative Policy Scenario').	Increased exploitation of oil, gas and coal and efficiency measures to follow 'price spikes.' After *peak oil* investment in coal, nuclear, agrofuels, and renewable sources increase sharply.	Peaks in oil and gas production lead to investment in coal, nuclear, agrofuels, and renewable sources.

Households in Kenya

Introduction

The fuel price scenarios outlined previously represent three strikingly different futures for globally traded fuels. These fuels – primarily oil, natural gas, coal, and secondary fuels derived from these – provide the vast majority of the world's economically-traded energy supplies (BP 2008) and energy for the globalised economy to produce and move capital and goods. They are necessary for the functioning of governments, corporations and institutions worldwide. Households in the rich north and increasingly, in poorer countries also, depend on these fuels for cooking, heating and lighting. Even those who use little or none of these fuels directly cannot escape the wide reaching economic and social impacts of fluctuations in their supply (Leggett 2005, Lardelli 2007).

As with many global problems it is the poorest who are set to suffer most from fuel market disruption (Essama-Nssah *et al* 2007). This means that countries with high-levels of poverty are most vulnerable to such disruption. Their governments have the least capital and financial weight to take mitigative action, and their populations have limited adaptive capacity, many of them surviving with little financial security. The UN Millennium Development Goals set out a vision to see the lives of the poorest improved, but any improvements cannot be sustainable if the poor do not have reliable sources of fuel: much of the development work undertaken by international institutions and NGOs is threatened by fuel-price inflation (World Bank 2008, 1).

In this global economic context one of the key units which will ultimately suffer is families: parents supporting their dependent children. In many low-income countries they are the smallest unit through which individuals form a part of a community. Francis and Hoddinott (1993, pp. 9) state:

> *The conjugal unit of husband, wife (or wives) and children is most appropriate for analysing processes of differentiation in these sub-locations, not least because part of the story of social change is the ascendancy of the economic significance of the household over other social groupings such as compounds and lineages.*

(Francis and Hoddinott 1993, pp. 9)

It is as part of a household that the poorest function: working the land, labouring and buying and selling goods. It is therefore the most appropriate level at which to study the micro-level effects of the fuel-price scenarios.

With 22% of its population living on less than 1 USD a day (World Bank 2007, 2); life expectancy of only 52.1 (UNDP 2007); 68.8% reliant on wood as their main source of cooking fuel; 79.1% using paraffin for most of their lighting needs (KNBS 1999); and limited access to electricity (CCK 2008) poverty, and particularly *fuel*-poverty is an acute problem in Kenya. The country currently has no native sources of fossil fuels; importing all of their oil, gas and coal needs (IEA 2008, 2). Within Kenya there is also a number of specific social issues pertinent to fuel-poverty and wider poverty. As such, the country has been chosen as the location through which to study the impacts of the various fuel-scenarios at a country-specific, household level. To explore these impacts in greater detail, three 'typical' examples of Kenyan households have been created based on information from their localities. Where locally specific data were unavailable more general information from country-specific and other relevant studies.

The households include a subsistence-farming family in Ndueni, Eastern province struggling to send their children to school; a Luo fishing family in Nyanza Province suffering falling productivity with gender issues and economic migration as key aspects; and a relatively wealthy Nairobi couple that 'straddle' the rural and urban economies.

It should be noted that these example households are not intended to cover comprehensively the experience of Kenyans affected by fuel price fluctuations. There are many other livelihoods being lived in Kenya which are not included, such as pastoralist Somalis in the North-East, Maasai in the South, those in Western province and on the slopes of Mount Kenya who live entirely on income from cash-crop labouring, and those living in the extensive slums of cities such as Nairobi. Instead of being comprehensive, this study aims to be specific: to consider those families included at the micro-level.

First the social and economic contexts present in Kenya will be outlined. Then each of the household's situations and how they are likely to be affected by the fuel-price scenarios will be discussed. The case studies will then be drawn together with a discussion considering wider social, economic and environmental impacts. Finally, there will be a brief discussion of the mitigative action required.

Contexts

This sections aims to provide the country specific context necessary to analyse the impacts of the fuel supply scenarios on Kenyan households. Firstly, a number of assumptions will be outlined about the state of Kenya today and how it will change over the period up to 2030 (not taking the fuel supply scenarios into account). Secondly, the impact of the three fuel supply scenarios on the Kenya's fuel market and the wider economy will be considered. Thirdly, the mitigative action being undertaken by various organisations to improve Kenya's fuel markets and supply infrastructure will be discussed.

Baseline assumptions and trends

Population and poverty

Population growth remains high in Kenya due to a high fertility rate of 4.9 births per woman (KNBS 2003). Annual growth is forecast to be 2.6% between 2005-2015. This is a decrease from the previous twenty years (UNDP 2007) which is also attributed to decreasing fertility rates (Robinson 1992, Dow *et al* 1994).

In 1997 Kenya's Gini coefficient (measuring the inequality of income distribution) was 42.5, among the lowest in Africa and comparable to the United States. In 1997 the richest 20% accounted for 49.1% of expenditure (UNDP 2007). At the other end of the scale, 22% of the population lives under the UN-defined level of extreme poverty, 1 USD a day (World Bank 2007, 2). Furthermore, social differentiation and the emergence of classes are forecast to continue (Murton 1999). This has become an issue of increased focus in Kenya with several analysts attributing the December 2007 election violence to unemployment and growing inequality (Africa Research Bulletin (2008), BBC News (2008, 3)). Rural to urban migration is a continuing phenomenon in Kenya as increasing numbers leave rural areas to find prosperity in the cities (Agesa

2004) and the IPCC predicts that climate change could result in increased displacement and migration both fuelling and being caused by increased inequality (Buko *et al* 2007).

As land has been passed down through the generations, the average size of land holdings in Kenya has decreased (Boko *et al* 2007, Murton 1999). Colonial attempts at land registration and subsequent reforms have allowed the buying and selling of land which has led to more land being held by fewer people (Shipton 1992). Traditional tribal systems of land entitlement remain strong in some areas but have broken down in others (Shipton 1992). Several studies report that in rural areas, income from employment carried out away from household's own landholdings is of increasing importance, and often more important than income generated on the land (Murton 1999, Boko *et al* 2007).

Government

In November 2004 Kenya's public debt totalled 752.49 billion Kenyan Shillings (10.03 billion USD in 2004) amounting to a staggering 63% of GDP (gross domestic product) (Government of Kenya 2005). Government corruption is also a recognised problem with and in recent years the a number of pieces of legislation have bee introduced to combat it (Government of Kenya 2005). However, perception of corruption, as measured by Transparency International (2007), remains very high (150 out of 179 countries) and development agencies such as DFID have lowered the proportion of their aid spent through government channels compared to NGOs.

Both of these problems affect the Government's ability to deliver services with the government stating that its level of debt was prohibiting the achievement of the MDGs (Government of Kenya 2005).

Energy and fuel

In terms of the total energy used every year, biomass is by far the most important fuel source in Kenya. Rural Kenya has some of the highest levels of dependence on biomass for fuel in the world (Boko *et al* 2007), and its use of these sources is increasing year on year. In 2005 biomass provided 538 786 TJ (terajoule) of energy, up from 70 898 in

2000 and 326 625 in 1980 (IEA 2008, 2). Much of this is burnt in homes as fuel-wood – the primary fuel for 68.8% of Kenyans (KNBS 1999). Of the remainder, the majority is used to produce charcoal. Although charcoal production has been illegal since 1986 its production and transportation are on the increase, and still employ 300 000 people (WRI 2007). It provides the primary cooking fuel for 9.7% of Kenyans (KNBS 1999) with 82% of urban Kenyans using the fuel in some capacity (WRI 2007). A small proportion of Kenya's biomass resource is also used to generate electricity – producing 321 GWh in 2005 (IEA 2008, 2).

Other domestic sources of energy in Kenya include 'renewable' electricity sources, most significantly hydroelectric and geothermal power stations, but also including wind turbines and various solar technologies. Hydroelectricity is a growing source of electricity in Kenya, generating 3 026 GWh (gigawatt hours) in 2005. Geothermal has doubled production since 2000 and in 2005 generated 886 GWh (IEA 2008, 2). Coal has recently been discovered in the Mui Basin although full-scale production may be some years away (Ministry of Planning and National Development 2006).

Despite the proliferation of these native fuel resources, Kenya is still economically dependent on fossil fuels – none of which it is currently able to source domestically. The imported fuel which provided Kenya with the most energy in 2005 was crude oil. That year, 1 700 kt (thousand tonnes) of crude oil, approximately 13 million barrels[7], were imported and then refined in Kenya (IEA 2008, 2).

640 kt of this was processed into diesel and petrol, with a further 817 kt of these fuels imported, supplying Kenya with a total of 1 337 kt of diesel and petrol in 2005 (IEA 2008, 2). The majority of this was used in road transportation with a smaller proportion being used by industry. 92 kt of Kenya's imported oil was processed into paraffin, which, added to imports of 307 kt, gives a total supply of 399 kt (IEA 2008, 2). The vast majority of this was used by the 79.1% of Kenyans who use it as their primary source of lighting and the 17.2% who use it as their main source of cooking fuel (KNBS 1999). Paraffin use in all sectors has doubled over the last 20 years (IEA 2008, 2).

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7 Conversion from tonnes to barrels cannot be exact due to the varying densities of oil. The conversion used is based on a factor provided by the IEA (2008, 1).

Kenya's main coastal port, Mombasa, handles the majority of this fuel which is then sent via pipeline to Nairobi (World Bank 2008, 2). Waste gases and oils produced in the refining process provide a minor fuel source: 26 kt of LPG are produced in this way, with a similar amount imported directly. About half of Kenya's LPG supply is used by residences with much of the rest going to industry (IEA 2008, 2). Levels of oil imports have increased slowly in the past 20 years compared to other fuel use (IEA 2008, 2).

Kenya is also a small importer of Bituminous Coal, 108 kt of which in 2005 provided energy for the minerals industry. As of 2005 the country imported no coal for electric power generation or natural gas of any kind (IEA 2008, 2). The country also has no access to nuclear fuels, nor does it employ wave or tidal power generation.

In total, Kenya's electricity production has increased significantly in previous years, from 4 103 GWh in 2000 to 6 003 GWh in 2005, and becoming a net exporter for the first time in 2004 (IEA 2008, 2). Of the 4912 GWh finally consumed after transmission losses, 3 131 GWh was used by industry, 1 206 GWh by residences, 526 GWh by commerce and the government, and the remaining 49 GWh in agriculture. Whilst urban areas are well connected to the grid, rural electrification is limited (CCK 2008) and where a connection is available, uptake is restricted by lack of income.

Education and employment

Education is an important dividing factor in Kenya and numerous studies have shown a link between high quality of education and upward economic mobility (Francis 1995, Francis and Hoddinott 1993, ISIS 2001).

In 2005 73.6% of Kenyans were literate – higher for younger age groups, reflecting a generational improvement in quality and reach of schooling, but lower for women (70.2%), reflecting gender imbalances in enrolment (UNDP 2007).

In 2003 the Kenyan Government declared that primary education would be compulsory and free. However, universal primary education (a Millennium Development Goal) remains some way off: in 2005 net enrolment stood at 79% (UNDP 2007) and considerable funding shortages are reported (BBC News, IEA 2008, 2). Nonetheless enrolment is still far better than for secondary-level education, which remains costly for the poor (UNESCO Nairobi Office 2006). As a result, enrolment in secondary education was 42% in 2005 (UNDP 2007).

The government has increased the proportion of the budget it spends on education. Two-thirds of this goes to primary education with the rest split between secondary schooling and universities (UNDP 2007).

Despite some improvement, a significant gender balance remains and increases with the level of study. In 2005, 48.6% of pupils entering primary school were girls but that proportion was 1% lower by the end of middle school. At university, only 36.8% of university students were women (UNESCO Nairobi Office 2006).

Gender differentiation is also significant in the employment sector in Kenya, although this varies significantly by region depending on tribal customs and local attitudes (Francis 1995). Participation of women in the formal economic workforce represent only 78% of the total male participation. This is lowest in industry and agriculture, whilst in services, women make up a larger proportion of the workforce than men.

Health

Health care in Kenya is patchy. In 2000-2004 there were 14 physicians per 100,000 people – very low by global standards, but not exceptional for Africa (UNDP 2007). The government has a 'medium term goal' (World Bank 2004, 1) of providing a social health insurance programme. Currently though, only 42% of births are attended by skilled health-care workers, and private health expenditure is higher than in the public sector (UNDP 2007).

The life expectancy in Kenya is only 52.1 (UNDP 2007) and is diminished by inadequate health-care provision and a number of public health problems. In 2005 6.1% of Kenyans ages 15-49 were infected with the HIV virus (World Bank 2007, 2).

The burning of solid-biomass (discussed in *energy and fuel*) as a fuel contributes to a number of respiratory problems, most seriously affecting women and children due to their higher exposure (Balakrishnan *et al* 2002, Ellegard 1996, Boko *et al* 2007).

By 2050 more areas in Kenya are predicted to be at risk from Malaria, including

Nairobi, which is currently at too high an altitude to be significantly affected by the disease (Boko *et al* 2007).

Food, water, and the environment

Kenya remains a predominantly agricultural economy and society with the majority (79.3%) of the population living in rural areas and depending on substance farming (World Bank 2007, 1). 75% of the population are employed in agriculture (CIA 2008) and many supplement the food they grow by collecting wild native vegetables (Memon and Lee-Smith 1993). Despite the high productivity of many areas, most notably the Kenyan highlands, malnutrition is a major problem with 31% suffering on average (UNDP 2007) and this level is forecast to increase, even in areas where food productivity is rising (Murton 1999). According to the UNDP (2007) only 61% of the population have access to improved water sources.

Climate change will cause increased incidences of extreme weather and long term changes in climate patterns and rainfall in Kenya (Boko *et al* 2007). These trends will impact upon the population through a variety of pathways, including increased migration and health risks, as already mentioned. It will also affect Kenya's hydrology. Although the World Resources Institute predicts an increase in water shortages between 2000 and 2010 for many central areas of Kenya (WRI 2007), the IPCC predicts that overall, water stress in Eastern Africa will decrease over the next century (Boko *et al* 2007). However, changes in the seasonality of rainfall and impacts on local drainage patterns and soils are predicted.

All of these impacts are highly dependent on the degree of climate change, defined as it is by a plethora of variables. In Kenya, population growth, not climate change, is the most significant variable determining future water deficits.

The impact of Kenya's strong dependence on biomass as a fuel source has been debated with with some claiming that it encourages good forest management (as shown in India (Heltburg 2004)) and others claiming it is a major contributor to deforestation (Boko *et al* 2007, others).

The Impact of the Scenarios on Kenya

Fuel markets

With no native production of hydrocarbons at present, and minimal government intervention in these markets (such as subsidies), Kenya's oil, natural gas and coal markets can be expected to reflect wider regional and global fluctuations in supply and price. For example, higher border prices of oil occurring in 'price spike' periods (predicted under the optimistic and 'middle-ground' scenarios) would create sharp rises in oil prices in Kenya (Essama-Nssah *et al* 2007). This would in turn increase the cost of refined oil products such as diesel, petroleum, paraffin and LPG.

A study by Borenstein, Cameron and Gilbert (1997) showed that petroleum prices in the United States rose much quicker as oil became more scarce than they fell once supplies returned to previous levels. In the case of Kenya this would mean global fuel 'price spikes' prolonged by local traders. Increased costs of oil-derived fuels would encourage households to switch to alternative domestic fuels such as charcoal and fuel-wood, increasing their price and encouraging higher production (in the case of fuel-wood, more wood being collected). As fossil-fuel imports are used to generate electricity in Kenya, any increase in the cost of oil would increase the cost of production of electricity. However, as over half of Kenya's electricity is generated from hydro power sources (3026 GWh of a total of 6003 GWh generated in 2005 (IEA 2008, 2)), Kenya would be less affected by such price increases than many countries. Instability in global markets would also drive Kenya's ambitions for energy independence (see 'Current fuel and energy policy and mitigation in Kenya' below).

Several studies have considered the effect of fuel price increases on households. Clements, Hong-Sang and Gupta (2003) show that fuel price increases resulting from market liberalisation in Indonesia (primarily the removal of subsidies) reduced household consumption in the short-term. Hope and Singh (1995) show that in the short-term fuel price increases lead to reductions in the use of appliances (such as cookers) and in the long-term, replacement of those appliances. They also suggest that high prices can contribute to deforestation by increasing demand for fuel-wood and charcoal. In their paper Essama-Nssah *et al* (2007) look at South Africa and note that such effects have the largest impact on the poor, for whom fuel costs make up a larger proportion of expenditure.

Macroeconomic effects

Against a background of environmental and social change, fuel price scarcity has a wide reaching set of local-level impacts in Kenya. However, these impacts will be discussed through the lens of the household examples in *household studies.* The aim of this section is to establish wider contexts.

The connection between wider economic performance and fuel prices was established in 1983 when Hamilton found a strong link between recessions in the United States and oil 'price spikes' (Hamilton 1983). This connection stems from the important role imported fuels have in the functioning of the economy – providing energy for transportation, electricity generation, and heating and lighting both in homes, factories and offices. Any increase in fuel prices will increase the cost of governance, state service provision (including healthcare and education), and consumer goods and services. Agriculture and industry will also be affected with higher input costs and lower demand. The combination of these effects has the power to increase unemployment, force social change, and alter environmental pressures. In short, all of the contexts described in 'baseline assumptions and trends' are affected by the fuel supply scenarios via their influence over the macroeconomy.

The negative effects on the macroeconomy are exacerbated by the reluctance of traders to reduce prices after a shock (as discussed in contexts: *fuel markets*). Furthermore, Ferderer (1996) finds that reduced prices following a shock had little effect on GDP compared to the reduction they caused on the up-side.

Essama-Nssah *et al*'s (2007) study of South Africa's response to oil price shocks showed that employment effects were mixed. Agricultural and informal labour demand increased. This may be a result of the increased price of mechanisation – i.e. if a tractor uses diesel but the price of diesel rises, the relative cost of employing labourers to pull a hand-drawn plough is decreased. On the other hand, employment in the services sector and real wages decreased as a result of the shock.

The rising cost of transport and energy increases the cost of food and consumer goods (Essama-Nssah *et al* 2007). The cost to the government and local trusts of running healthcare and educational services is also increased. The rising cost of service provision would be expected to increase government deficits and a study by Dunkerley and Ramsay (1982) make a case that the high oil prices following the Iranian revolution greatly contributed to the debt crisis faced by many 'developing' countries in the 1980s. Such a debt burden would further reduce their ability to provide services in the future.

The impacts of fuel price rises on fuel markets are strong and causally proven. However, Essama-Nssah *et al* (2007) state that "the effects of an oil price shock on households will be felt primarily through the effects on prices of final goods" (pp. 10). This is mostly because energy costs represent a far smaller proportion of household outgoings than other items such as food (Hope and Singh 1995, Essama-Nssah *et al* 2007). The link between poverty and the macroeconomy is well established (Freeman 2003) and it is fluctuations in the wider economy, not just in fuel prices, that will affect the future welfare of households in Kenya.

Current fuel and energy policy in Kenya

Kenyan Government

The Government of Kenya outlined its plans for economic growth and poverty reduction in its Poverty Reduction Strategy Paper (PRSP) – a document required by the IMF and International Development Agency (of the World Bank) in order to receive funding (World Bank 2004, 1). The document largely focuses on its plans to boost economic growth with some consideration of poverty alleviation and improvements in governance. In line with the Government's aim to facilitate growth in business and reduce its dependence on imported fossil fuels and hydroelectric power, the document explains the Government's aim to privatise KenGen (the state-owned power generation company) and to the partially privatise the Kenya Power and Lighting Company in order to increase investment. Increasing the percentage of rural Kenyans with access to electricity by 1% per year was planned and achieved in the first year of operation (from 4% to 5%) (Ministry of Planning and National Development 2006). This goal is to be facilitated by the creation of a Rural Electrification Authority. Investing in the current power infrastructure is seen as key in order to reduce transmission losses (which represented 18.2% of capacity in 2005) and limit "extreme voltage fluctuations and intermittent power outages which impose significant costs on production" (Ministry of Planning and National Development 2006, pp. 51). Money is also being invested to increase power station capacity and as of 2005 the KPLC has negotiated lower price tariffs.

In order to reduce dependence on fuel imports there are plans to encourage oil exploration in the Anza Basin and Lamu Basin (although no exploitable deposits have been found to date). These plans also encourage the mining of coal which has recently been discovered in the Mui Basin (Ministry of Planning and National Development 2006). The government also aims to expand use of solar and wind power by setting up a national centre of excellence in renewable energy (although the progress report says this is yet to occur (Ministry of Planning and National Development 2006)); additionally by working in partnership with NGOs and the private sector, although specific policies are not explained (World Bank 2004, 1). The establishment of a state-owned Geothermal Development Company is planned. To date, a wind resource atlas has been produced and a programme to install photo-voltaic systems in boarding schools is ongoing (Ministry of Planning and National Development 2006). These technologies are particularly seen as useful for remote rural areas. There are no plans to encourage the production of agrofuel (fuels derived from purpose-grown crops) or to encourage the production of fuels from waste such as crop residues. The government aims to promote sustainable wood resource management but does not offer any specific policy to this end (World Bank 2004, 1).

The Government's ambitions are large but the policy and funding to make them reality are lacking. Although specific plans have been outlined, there has been slow progress in the implementation of rural electrification (Ministry of Planning and National Development 2006). Karekezi and Kimani (2004) claim that the emphasis on economic growth has meant that rural electrification has not been a priority for electricity generation reform.

Development agencies

The Millennium Development Goals do not include goals specific to fuel poverty or energy supply. However, the goals of eradicating extreme poverty, achieving gender equality (since women are most at risk from the health risks posed by indoor pollution), and environment sustainability[8] require that fuel supply is considered in development work. This has traditionally involved large scale projects such as oil pipelines and hydroelectric dams (both having been undertaken in Kenya) but increasingly this money is going toward small-scale projects.

A number of non-governmental organisations (NGOs hereafter) are working in Kenya to disseminate technologies to rural communities that are not dependent on imports of fossil fuels. One such organisation is 'Practical Action', whose work in Kenya includes providing improved stoves, micro-hydropower, solar power, biogas and wind power (Practical Action 2008). These technologies are proved on the basis of local suitability and energy independence: in the past fuel market instability and climate change have been secondary issues.

The International Development Agency of the World Bank support the plans of the Kenyan Government (outlined above) with development funding, as recorded in its Country Assistance Strategy (World Bank 2004, 2). National development agencies such as the UK's Department for International Development (DFID) have similar partnership agreements.

These agencies have recognised the challenge to development work produced by high external fuel prices ('Rising oil prices play havoc with UN aid for Bhutanese refugees in Nepal,' United Nations (2005); and 'Rising Prices Affect World Bank Projects in Central African Republic,' World Bank (2008, 1)) as well the impact upon households that price changes brought about by tax and regulatory reforms can have (Hope and Singh 1995, Essama-Nssah *et al* 2007). In addition, DFID has stated that:

> *Scarcity of resources [...] could stop development in its tracks.*
>
> (DFID 2006, preface, pp. vii)

8 Increased demand for fuel-wood has been shown to lead to deforestation (Boko *et al* 2007). MDG indicator 25 is 'proportion of land area covered by forest.'

> *Rising energy costs threaten to reverse the gains we've made in development in recent years and we remain concerned about high and volatile oil prices. It's important that global oil supplies are sufficient to ensure that the market has flexibility to respond to potential supply shocks and changes in demand. Both producers and consumers need to respond flexibly to market signals.*
>
> (DFID 2008, 1)

DFID has also recognised the importance of fuel prices in increasing food prices:

> *[Food] prices are rising because of increasing demand for food due to population growth, and increasing oil prices and their impact on the cost of food production, processing and distribution.*
>
> (DFID 2008, 2)

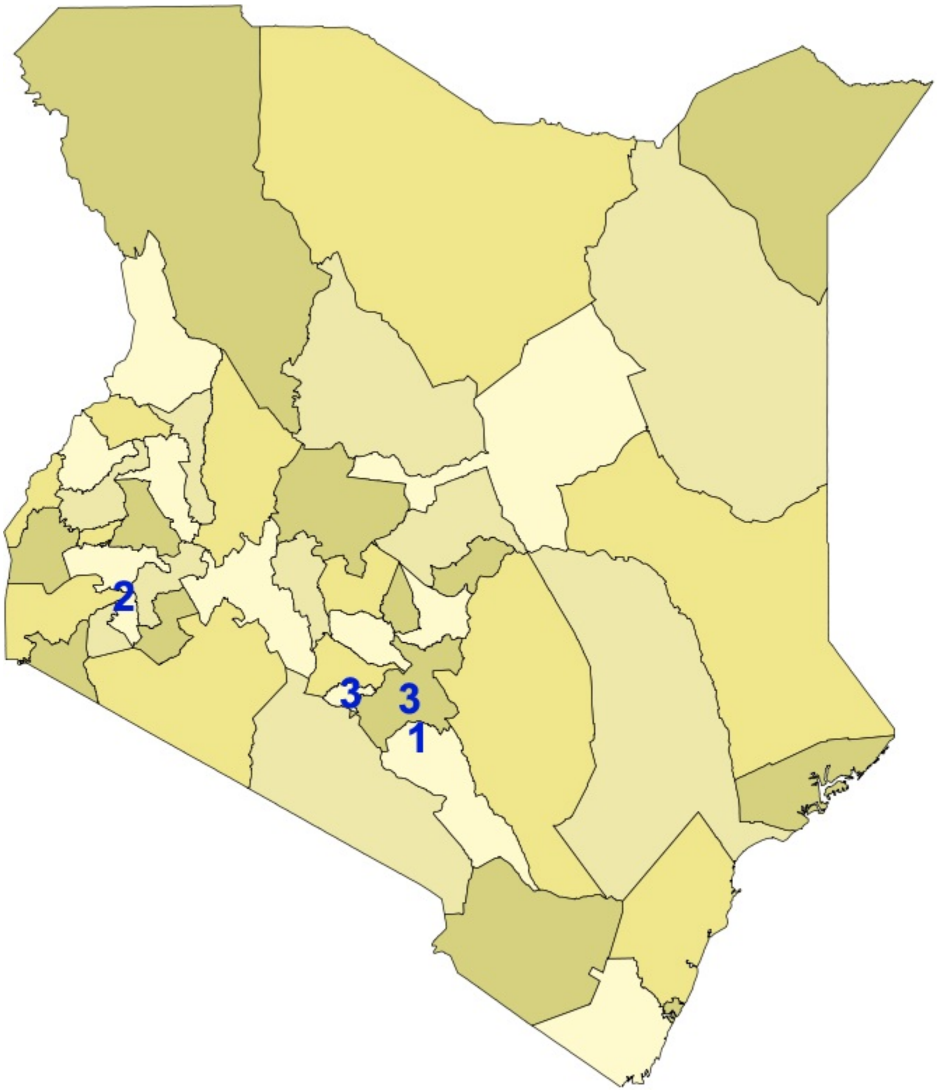
However, neither DFID nor the World Bank have considered the possibility that current high prices may be the result of a more long term, structural problem:

> *The recent price increase is only a cyclical recovery and has yet to reach the peaks of 1979-80.*
>
> (Essama-Nssah *et al* 2007)

This statement, already dated by the increase in prices following its publication, illustrates that that development agencies believe strongly in the 'optimistic' scenario, and as such have little response to the policy implications of *peak oil*. If these agencies are convinced that oil price rises are cyclical or simply 'price spikes', and lend on that basis, they may encourage governments into unsustainable debt.

Household studies

Fig. 7. Map showing the locations of the three households.



The locations of the the households in Kenya: 1. Ndueni, Eastern Province; 2. Lake Victoria, Nyanza Province; 3. Nairobi, Nairobi Province and Machakos, Eastern Province.
Map source: self made.

Household 1: Young family in Ndueni, Eastern Province

Characteristics of the locality

Makueni District, Eastern Province supports mainly upland rural farmers who benefit from relatively high rainfall allowing for rain-fed horticulture of high productivity (Murton 1999). In the village of Ndueni, 35km along a dirt, sometimes impassable, road from Machakos Town, the population farms the steep terraced hills which prohibit extensive mechanisation and require labour intensive methods (only 2% of farmers own a plough (Murton 1999)). 60% of farmers in the village sell crops such as coffee for cash, and most rely heavily on non-farm income such as casual wage labour on larger farms – upon which many are dependent on for as much as eight months of the year (Murton 1999). In a highly productive agricultural region, the high differentiation in land distribution and population growth contribute to high levels of malnutrition (Murton 1999), and two-thirds of the predominantly Akamba population live under the state-defined poverty level (CCK 2008).

Services are limited with no connection to the national grid, no postal service, and no television reception (CCK 2008). Supply of 'improved' fuels is also limited with most of the population reliant on paraffin for lighting and fuel-wood for cooking (KNBS 1999) (although the level of fuel-mixing is unknown).

Although average plot sizes are falling, an emerging class is seeing landholdings increase. Those with less land are forced to sell their labour and the amount reliant on non-farm income sources is increasing over time (Murton 1999).

Government plans to increase the availability of primary education have increased enrolment, but secondary education remains a luxury for many. The government plans increased electrification and health-care provision for the area although progress is slow (World Bank 2004, 1).

Water stress is predicted to increase by 2010 (WRI 2007) although in the long term, climate change may increase rainfall in the region (Boko *et al* 2007) where crop yields have fallen over recent years (Murton 1999).

Household characteristics

The key characteristics of household one have been gathered from a variety of sources are summarised in table 2. The family are subsistence farmers, but rely on casual labour for income for large parts of the year and sell some crops. They have limited physical and financial capital with a small farm and few physical or financial assets. Whilst the quality of the natural environment makes their land productive, non-farm income is of

Table 2		
Household 1 - Key characteristics		**Data source**
Location	Ndueni, Mbooni Division	
District	Makueni	
Province	Eastern	
Social characteristics		
Tribal background	Akamba	95% of people in the district are Akamba (Murton 1999).
Household composition and dependents	Mother (age 30), father (32), four daughters (5, 7, 8, 11), two sons (3 and 9). Three relatives: two grandparents, and the mother's sister are partially dependent on the family.	Fertility in district was 5.8 in 1999 (KNBS 1999)
Income and production		
Landholding and physical capital	0.8 Ha of land. No farming machinery, transportation or electronics.	Average landholding in the village was 1.3 Ha in 1996 but poorest have far less (Murton 1997).
Climate	Average annual rainfall of 800-1200 mm/month allows rain-fed horticulture. Two rainy seasons: the long rains fall from March to May and the short rains in October - November.	Rainfall and climate from WRI (2007), agriculture described by Murton (1999).
Food production	Some food is grown on smallholding including coffee. This is supplemented with wild vegetables. Several chickens provide eggs.	Murton (1999) describes this as a typical poor household in Ndueni. Memon and Lee-Smith (1993) describe wild vegetable harvesting in Kenya.
Income	Coffee is grown as a cash crop, but most of the family's cash income is from casual labour on larger local farms, carried out by the father for 6 months of the year. The family's total income amounts to less than one dollar-a-day - the UN defined extreme poverty level.	60% of villagers sell cash crops, often coffee, and 40% of villagers are dependent on selling labour for food between 2 and 10 months of the year (Murton 1999). 22% of Kenyans live on less than a dollar-a-day (World Bank 2007, 2).
Costs		
Main Expenditures	Food bought at local market makes up 45% of their costs. 5% of expeniture is spent on paraffin with the rest going toward household items, farm inputs, farm tools, healthcare and transportation. These items support the household and dependent relatives.	A World Bank study in South Africa (whose rural areas are comparable to Kenya) showed that of the poorest 20%'s expendidture, 45% was spent on food, 23% on housing/energy/water, 5% on fuel, with the remaing quarter going towards other costs (Essama-Nssah *et al* 2007).
Fuel sources available	No electric grid connection. Fuel-wood is available and paraffin is sold in the village. LPG is not available.	There is no grid connection to the area (CCK 2008). Only 2.2% of the population of the province use 'other fuels' (including LPG) as their main cooking fuel indicating a lack of availability (KNBS 1999).
Fuel sources used	Paraffin for lighting, fuel-wood for cooking and also provides some heat.	87.2% of those in the province use paraffin for most of their lighting fuel and 84% use wood-fuel for cooking (KNBS 1999).
Services		
Education level	Four of the six children attend primary school - two boys and two girls. The eldest daughter will not be sent to secondary school. The father received primary education, the mother did not.	21% of Kenyans of primary school age do not attend primary school (UNDP 2007). Only 42% of Kenyans of age attended secondary school and fewer of this figure are girls (UNDP 2007).
Healthcare	Dependent relative with HIV/AIDS. There is no free healthcare available, the family must pay for a clinic in Machakos town, 60km away. The cost of travel and care is prohibitive.	6.1% of Kenyans aged 15-45 were infected with the HIV virus (World Bank 2007). Universal provision of free health-care in Kenya remains far off (World Bank 2004, 1).
Other services	The house has no television, no postal service and no telephone. Their communication services are severely limited.	CCK (2008) states the area has no television signal or postal service. In 2004 there were only 9 mainline and 76 mobile telephones for every 1000 Kenyans (World Bank 2006).
Miscellanious		
Local issues	High malnutrition levels in region due to inequitable distribution of land.	Murton 1999.
Major trends faced (excluding fuel prices)	Climate change, falling and increasingly differentiated sizes of landholdings, the emergence of classes, increased water stress, falling yields due to falling soil quality, and population growth.	Climate change trends described by Boko *et al* (2007). Water stress data found in WRI (2007). Socioeconomic and agricultural shifts are described by Murton (1999).

greater importance to their livelihood. Under both World Bank and Kenyan-government definitions this household lives in absolute poverty.

Gender inequality is clear within the family. The father carries out most of the casual labouring which bring in non-farm income and thus allows him to control this money. A lower proportion of the girls attend school, lowering their future prospects relative to the boys (ISIS 2001). The burden of water collection, wood collection, and cooking, with their related health effects, falls primarily on the children not in school (more of whom are girls) and the mother (Heltberg 2004). Although in the area, managing the livestock is traditionally the domain of women (Murton 1999), the family have none.

The social capital held by the family ties them closely to their extended family. However this comes at a very real cost to the household which supports both the mother and father's parents, as well as the mother's sister who is suffering from AIDS.

Household outlook

The future of the household depends on a variety of factors already described and how they interplay with the external fuel-price scenario. Under the optimistic scenario the household's direct and indirect fuel costs are not projected to increase significantly. Fluctuations in supply caused by price spikes may impact on the household for short periods.

The availability of work and resources (including water and fuel-wood) will affect the livelihood of the household more significantly than external supplies of fuel. If the family's income increased and fuel distribution was increased, the household might be able to purchase 'improved' cooking fuels such as LPG – although it is not clear that this would be a high priority compared to investing in education or capital assets such as livestock.

The 'middle ground' scenario outlines a future of stable fuel supplies in the short term, but constraints would emerge within 20 years. The increased cost of paraffin after *peak oil* would force the household to consume less or lower expenditure in other areas. Any decreased use of lighting would decrease the household's capacity to work, study and recreate after nightfall (Heltberg 2004). Higher petroleum, LPG, and electricity prices will cause widespread inflationary pressure which will increase the cost of other services. Higher transportation costs will affect the market for their coffee sales. Higher costs of farm inputs (such as seeds and fertiliser), tools and household items will affect the household directly. It will also lower the profits of the cash-crop farms – either forcing decreased mechanisation, which may increase labour demand, or a decreased operation, reducing demand (it is unclear which of these is more likely). There is little chance of them being able to afford improved stoves or cooking fuels. With increased costs and lowered income the household will need to sell assets, losing financial security as well as social status, to maintain their standard of living.

Under the pessimistic scenario these costs will increase almost immediately. The prospects for increased quality of education and health-care decrease as higher costs make these services unaffordable. The replacement of paraffin with increased fuel-wood usage will have further negative impacts on health, and the family will find supporting their dependent relatives increasingly difficult. Higher usage of fuel-wood combined with population growth will increase local deforestation (as discussed in C*ontexts: Food, water and the environment*) which could in turn further exacerbate water stress. The household would be left working harder for less water, food and services, increasing their susceptibility to disease and malnutrition. With no external help, they would almost certainly see their life expectancy and quality of life decreased as they fall further into poverty and malnutrition.

Household 2: Fishing family on Lake Victoria, Nyanza Province

Characteristics of the locality

Upper Nyakach, on the shores of Lake Victoria, forms part of the predominantly Luo-populated Nyanza Province in Western Kenya. The majority of people live in scattered homesteads on the flat-lands adjacent to the lake's shore and the area benefits from favourable farming conditions. A wide variety of crops is grown including millet and white maize as staple foods and other crops including millet, pulses, cassava, green vegetables, groundnuts, sweet potatoes, bananas and sugar cane (Francis and Hoddinott 1993, Shipton 1992). Many own cattle, sheep and goats, as much as status symbols as sources of food. Ownerships of chicken and donkeys (for transportation) are also common, and fish forms a further source of food for many – and a source of income for some (Shipton 1992). Mechanisation of agriculture has been slow (Shipton 1992) and despite the climate, labour migration has caused productivity to fall steadily over the last 60 years and production does not fit need (Francis 1995).

A reduction in the productivity of fisheries in the Lake, related to eutrophication caused by damaging agricultural practices, threatens the livelihoods of fishing families (Verschuren 2002). Water stress in the area is also set to increase by 2010 (WRI 2007) and climate change will bring a wide variety of impacts to the region (Boko *et al* 2007).

Traditional systems of landownership remain important and ownership of land comes with affiliation to the local tribal community (Shipton 1992). Nonetheless non-farm income is becoming increasingly important and can come from a wide variety of sources even within a single household. These sources include remittances from migrant working-men (most significantly), petty trading, labouring on larger farms, and help from locally resident relatives and friends (Francis 1995, Francis and Hoddinott 1993). The increased importance of non-farm income has also seen the role of women significantly reduced and those who take part in the formal economy are scorned (Francis 1999).

Whilst electrification is planned, its execution has been limited: fuel-wood for cooking and paraffin for lighting still dominate the fuel market (KNBS 1999). Rural poverty is high in the district at 63% (ILRI 2008), but this is lower than many neighbouring districts (KNBS 2005).

Household characteristics

Data on households in the area have been used to create the second example household and is summarised in table 3. Their meagre landholding makes earning income elsewhere an imperative for the family and they do so in a variety of ways. The eldest son, who has received both primary and secondary education, lives and works in a factory in Kisumu town and sends the majority of his income back to the family as remittances. The father, often with the help of the children, brings in food and earns

Table 3		
Household 2 - Key characteristics		**Data source**
Location	Lake Victoria	
District	Nyando	
Province	Nyanza	
Social characteristics		
Tribal background	Luo	Shipton 1992.
Household composition and dependents	Mother (41), father (40), two sons (19, 8), three daughters (6, 15, 17). No grandparents survive.	Fertility in district was 5.0 in 1999 (KNBS 1999). Life expectancy is 52.1 (UNDP 2007) so few forty year olds have surviving parents.
Income and production		
Landholding and physical capital	0.21 Ha of land. Only other significant physical capital is a small fishing boat.	Average landholding in nearby Koguta is 0.21 Ha (Francis and Hoddinott 1993).
Climate	Mean monthly rainfall is 1200-1600 mm over the year. Most of this falls in the rainy season that runs from March to September.	WRI 2007.
Food production	White maize, onions and tomatoes are grown, and fish are caught from the lake. This is supplemented with wild vegetables. Chickens provide eggs and goats and sheep occasionally provide meat.	The household's food production is typical according to descriptions by Francis and Hoddinott (1993) and Shipton (1992). Memon and Lee-Smith (1993) describe wild vegetable harvesting in Kenya.
Income	Remittances from the son (19), who works in a factory in Kisumu Town, and casual labour carried out by the father provides the majority of income source. Onions, tomatoes, and fish are sold at market to supplement this income, as well as providing a food source. Their total income is between 1 and 2 dollars a day per person.	According to Francis and Hoddinott's survey (1993) of nearby Koguta, 41.6% of income in the area came from 'other' sources such as local trading, with 35.9% coming from remittances and pensions, and only 22.5% coming from agriculture. 58.3% of Kenyans live on between 1 and 2 dollars a day (World Bank, 2).
Costs		
Main Expenditures	42% of the family's expenditure is spent on food supplies bought locally. Other items and services make up the rest of their budget including household goods, farm inputs, farm tools, healthcare and transportation. 4% is spent on fuel including paraffin and diesel for the boat.	A World Bank study in South Africa (whose rural areas are comparable to Kenya) showed that of the second poorest quintile's expenditure, 42% was spent on food, 21% on housing/energy/water, 4% on fuel, with the remaining quarter going towards other costs (Essama-Nssah *et al* 2007).
Fuel sources available	No electric grid connection. Fuel-wood is available and paraffin is sold in the village. LPG is rarely available.	There is no grid connection to the area (CCK 2008). Only 1.6% of the population of the province use 'other fuels' (including LPG) as their main cooking fuel indicating a lack of availability (KNBS 1999).
Fuel sources used	Paraffin is used for lighting, fuel-wood is used for cooking and also to provide some heat.	82% of those in the province use fuel-wood for cooking predominantly and 92.5% rely on paraffin for lighting (KNBS 1999).
Services		
Education level	The youngest son (8) and daughter (6) attend primary school. The eldest son (19) completed secondary school. The other children did not.	Francis and Hoddinnott (1993) describe a community funded secondary school in Kogata. 42% of Kenyans of age attended secondary school and fewer of these are girls than boys (UNDP 2007).
Healthcare	Healthcare is available but is not free. The family can only afford treatment infrequently.	Universal provision of free health-care in Kenya remains far off (World Bank 2004, 1).
Other services	With no electricity, the family has no phone, television or radio. Their only means of communication is by post.	CCK (2008) states the area has television and radio signal and a postal service. In 2004 there were only 9 mainline and 76 mobile telephones for every 1000 Kenyans (World Bank 2006).
Miscellanious		
Local issues	Role of women in economic activity, especially non-farm income, is low due to social pressures. Labour migration sees many of working age leave the area.	Gender differentiation discussed by Francis (1999) and labour migration by Francis and Hoddinott (1993).
Major trends faced (excluding fuel prices)	Climate change and the continued decline in productivity of Lake Victoria as a fishing ground.	Climate change trends are described by Boko *et al* (2007). Declining productivity of Lake Victoria is charted by Verschuren *et al* (2002).

income by fishing on the lake. Declining productivity of the lake has forced him to seek supplementary income from casual labour on larger farms nearby and from petty trading, the success of which relies on trust he shares with local people. The last, and smallest source of household income, is the sale of onions and tomatoes grown on their smallholding. In total, their income is sufficient to keep them out of the UN-defined extreme poverty level, but is not more than two dollars a day per person.

All the children are currently attending primary school or did so in the past, but in contrast to the eldest son, the two eldest daughters (15 and 17) do not attend secondary school – instead they assist their parents on the smallholding and with fishing. Their relative lack of education, combined with tribal gender prejudice, reduces their future opportunities (ISIS 2001).

Household outlook

The second household has direct and indirect fuel needs, both of which are important in sustaining their livelihood. As a fishing as well as farming family, environmental factors affect their income in different ways to the first household. Gender roles and education are also a prominent feature of the household. These issues will be altered by the fuel-price scenarios in different ways.

Under the 'optimistic' scenario, relative fuel price stability give the household the opportunity to put more of their children through secondary education, invest in more animals, and purchase improved stoves and improved fuels (if available), improving their quality of life and resilience. If price spikes increase the price of paraffin and diesel beyond that which they can afford, they may have to temporarily reduce the amount of lighting they use and the amount they fish. Regardless of the fuel scenarios, the Lake's depleted fishing stocks may make fishing in the Lake non-viable before 2030 (Verschuren 2002). This would also reduce their income and may necessitate the selling of animals. However, such 'price spikes' are not forecast to be long lasting so those measures should pull them through. If the children are educated they will have the opportunities of their older brother to migrate to the city and earn a higher wage.

In the 'middle-ground' scenario they will see paraffin and diesel fuel prices rising in the medium term with no sign of a recovery. This would reduce their profits from fishing and impact upon their income from other areas with real wages decreasing (Essama-Nssah *et al* 2007). Inflationary pressure from increased fuel and transports costs would also make food (their biggest single expense), education and healthcare more expensive. The household would have to reduce expenditure by cutting back on fuel, as they would to cope with a 'price spike,' but for the long-term: they would need to find an affordable lighting source that is not dependent on electricity. If rural electrification is carried out as planned this may be possible although the cost may still be prohibitive. If they go without lighting they will forfeit economic activity and benefits to education and welfare during the night (Heltberg 2004). Their opportunities for investing in capital, 'improved' stoves and fuel, and further education are lower.

However, compared to the 'pessimistic' scenario, the extra time the children will have spent in education gives them improved chances. If fuel prices were to increase permanently within the short term, the household would face the problems described with less time to acquire the human and physical capital which would help them through such difficulties. They would be forced to sell their animals or suffer malnutrition. Although their land is a valuable asset, social pressures in their tribe are such that selling it would lose them their local allegiances (Shipton 1992) – migration is their last resort.

Household 3: Affluent couple straddling the rural and urban economies

Characteristics of the locality

Nairobi, Kenya's capital city, is one of the largest cities in Africa and an important regional economic and cultural centre. The average per capita income far exceeds those of most rural areas (KNBS 1999) and a wide variety of goods and services is available including 'improved' fuels, grid-provided-electricity (over 50% of homes are electrified), mobile phones and television (CCK 2008). According to Government measurements, 44.3% of the city's population live in poverty (ILRI 2008). Although this proportion is comparable to other cities and towns in the country, the high population of Nairobi (almost three million) means it harbours the greatest concentration of urban poor in Kenya. The city's extensive slums have infant mortality rates that exceed that of many rural areas (Montgomery and Hewett 2005).

Although space is a constraint, one survey found that 65% of Nairobians grow food. The very poorest do so on public land and in yards, but the majority do so outside the city's borders and thus work in both the urban and rural zones (Memon and Lee-Smith 1993). Population growth contributes to water stress and deforestation, especially at the city's fringes – however, the provision of education and healthcare services is generally improved compared to remote areas.

Household characteristics

The third example household are residents of both Nairobi and Machakos Town – a short distance from Ndueni (where the Ndueni household reside). The key characteristics of the couple, which have been gathered from a variety of sources, are summarised in table 4. It is an upwardly-mobile household whose income falls inside the top 20% of Kenyans: the couple do not live in poverty as defined by either Governmental or international measures.

They support their relatively high standard of living by straddling the urban and rural economies. The husband inherited much of his landholding in Machakos Town, but like other large farms in the location, has increased its size through purchases (Murton 1999). The woman lives in Machakos where she employs several casual labourers during the year to work on the farm and uses mainly paraffin for cooking and lighting. Her position as an employer in the community means she has useful connections with other local landowners and local politicians: social capital.

The man has migrated permanently to Nairobi, 60 km away, where he benefits from his secondary education as a skilled employee in the services sector. He lives in a rented flat with connection to the electric-grid, an LPG stove, a mobile telephone, and food imported into Nairobi. This livelihood strategy is known as 'split migration' (Agesa 2004) and allows the household to benefit from high-skilled high-wage jobs in urban

Table 4		
Household 3 - Key characteristics		**Data source**
Location	Nairobi/Machakos Town	
District	Nairobi/Machakos	
Province	Nairobi/Eastern	
Social characteristics		
Tribal background	The wife is Kikuyu and the husband is Akamba.	Machakos is primarily Akamba (Murton 1999). The Kikuyu are the predominant tribe in the central region bordering Nairobi.
Household composition and	Wife (23), husband (23). They have no children and few connections with their extended family due to their movements.	Fertility in Nairobi is among the lowest in the country at 2.7 (KNBS 2003).
Income and production		
Landholding and physical capital	The couple rent a flat in the inner city of Nairobi and owns a landholding and homestead in Machakos Town.	One third of households in Kenya aim to 'straddle' the urban and rural economies (Agesa 2004). Many more affluent city-dwellers still live in poorer neighbourhoods (Montgomery and Hewett 2005).
Climate	Average annual rainfall of 800-1200 mm/month in both the city and Machakos comes in two rainy seasons: the long rains fall from March to May and the short rains in October - November.	WRI 2007.
Food production	They do not grow any food in Nairobi, instead, they buy it all at market. Almost all the food they grow in Machakos Town is sold as a cash crop.	Murton (1999) describes wealthy landholders in Machakos and Mukeuni districts who grow cash crops and hire local people.
Income	The woman works mainly on the farm in Machakos Town whilst the man has a job in services in the city. Their income comes from sales of produce and the husband's salary.	Agesa (2004) describes the rural-urban straddling livelihood strategy, which allows them to make money in the city, but reduces living costs, as well as diversifying income sources. More often, it is the better educated husband who lives in the city.
Costs		
Fuel sources available	Fuel-wood is scarce in Nairobi but electricity, paraffin, charcoal and LPG are all readily available. In Machakos Town paraffin is more freely available than alternatives.	52.3% of Nairobi households have electricity (CCK 2008) and use of 'improved' fuels is the highest in Kenya (KNBS 1999).
Fuel sources used	In Nairobi they use primarily LPG for cooking and electricity for lighting. In their home in Machakos Town, they use paraffin for cooking and lighting.	In Nairobi, those with electricity use it for lighting (KNBS 1999). 75.7% use paraffin as their main cooking fuel and 18.4% use 'other sources', including LPG (KNBS 1999).
Services		
Education level	The couple both attended primary school but only the man attended secondary school.	79% of those of age attended primary school in 2005 (UNDP 2007). 42% of Kenyans of age attended secondary school, lower for girls (UNDP 2007).
Healthcare	The household has access to clinics in both of their hometowns and can afford care for more serious ailments.	Universal provision of free health-care in Kenya remains far off (World Bank 2004, 1).
Other services	They have a mobile phone which is used for trading. In Nairobi they have a television and radio.	Nairobi has television, radio and postal services (CCK 2008). More affluent Kenyans are more likely to own telephones.
Miscellanious		
Local issues	High socioeconomic differentiation between affluent areas and slums. The poorest lack access to land to grow food.	Averages for the city are better than the rest of Kenya but 44.25% of inhabitants live below the government's poverty line (ILRI 2008) and infant mortality rates in poor areas are as bad or worse than rural areas (Montgomery and Hewett 2005). Despite lacking access to land, many of the poor grow food where they can (Memon and Lee-Smith 1993).
Major trends faced (excluding fuel prices)	Climate change could bring higher rainfall to central Kenya. Population growth continues although it is slowing.	Climate change trends described by Boko et al (2007). Population growth is discussed in *assumptions*.

areas as well as the lower living costs of the rural area.

Whilst the woman has considerable control over income generated from the land, the couple's incomes are ultimately shared and they regularly travel between the towns. The couple's direct fuel needs are diverse requiring paraffin, LPG and diesel to run a generator used to pump water on the farm. Indirectly the husband is reliant on fuel imports to transport food (the largest single expense) into the city.

The diverse income they receive is dependent on fuel-market stability. The success of their farm depends on affordable input costs and economic prices being offered for their produce whilst the man's job depends on the success of his employers which in turn, reflect wider economic stability in the country.

Household outlook

The Nairobi couple's higher and more diverse consumption of fuels makes them more dependent on imports of fossil-fuel products. However, most of this dependence comes not through direct fuel consumption, but indirectly. These indirect relationships are complex (as discussed in *Contexts*) and their impact on the more affluent are particularly so.

There are a number of key factors that fundamentally alter this household's response to the scenarios compared to the other two households: they have a highly varied income; many capital assets; no children; considerable transport costs; and they have widely varied direct fuel needs. These factors affect the households outlook differently under the three scenarios.

Under the 'optimistic' scenario fuel prices remain stable over the period to 2030. This would provide the household with dependable income from their farm and employment opportunities in the city, allowing them to maintain and improve their current livelihood. For example, if rural electrification was rolled out to Machakos, they could afford to electrify the rural house. Again infrastructure-depending, they would also be able to use LPG instead of paraffin in Machakos (with related health benefits discussed *Contexts: Health*). Stable fuel prices will allow them to keep in contact both at a distance and at by using transport. If the couple chose to have children, they would have a good chance of affording both primary and secondary education for them. If fuel 'price spikes' did make supplies of hydrocarbon fuels scarce (creating related inflationary pressure) the family would have a number of options. They would be able to cut back on consumption of food (their largest single expense); electricity (by decreased use of appliances); fuel (for cooking and lighting); and transportation (the husband walking rather than using the bus to work, and fewer trips between their homes). Of these, use of appliances is likely to be the first to change (Hope and Singh 1995). They would also be able to sell assets such as electronics.

In the 'middle ground' scenario, price increases and reduced fuel supply are a certainty in the medium term. Higher fuel costs will increase the cost of living for the couple (through higher electricity, food and fuel costs), and make travel relatively expensive compared to other goods. Higher costs will tighten profit margins for their cash-crop income and general economic instability caused by the price shock will increase unemployment (particularly in the services sector (Essama-Nssah *et al* 2007)). Their coping strategies are similar to those already mentioned – but as this scenario represents a permanent shift in the market (rather than a temporary blip), further measures may be required. The household would consider selling their paraffin and LPG dependent-appliances (Hope and Singh 1995) in exchange for ones that use other fuels such as coal, biomass variants and charcoal (accepting the related health effects discussed in Contexts: Health). On the farm, rising diesel costs will increase outgoings. They may be able to replace it with a wind-powered pump common in the region (Karekezi 2002). With the infrastructure currently in place, there is no alternative to road transport to move between their residences so they may have to simply reduce the amount of time they spend together. Higher costs of healthcare, education and other goods and services will increase the cost of raising children, dissuading the couple from doing so.

Despite these changes to their living habits, the couple is expected to survive without a significant loss of welfare. Although their fuel requirements are greater, they make up a smaller proportion of expenditure than in poorer households (Hope and Singh 1995). Overall, their relative stability as an economic unit in a time of turmoil will allow them to take advantage of those with less capital.

Under the 'pessimistic' scenario the couple would face rising fuel costs in the short term – causing many of the problems discussed to arise much sooner. However, their strategic options remain similar. One difference would be that Kenyan coal supply would not yet be on stream. As a result, charcoal and biomass would be preferable replacements for oil and natural gas based fuels.

Discussion

A wider analysis

As discussed in *Households in Kenya: Introduction,* it was not the intention of the example households to provide a comprehensive experience of Kenyan households, but rather, to look at the micro-scale implications of the fuel-price scenarios. Nonetheless, the collective experience of these families provide an indication of a number of wider impacts which may be felt by the population. It is the aim of this analysis to consider the implications of the extrapolation of these experiences to a wider scale in the light of current policy and mitigation being undertaken.

Fuel supply

Increased fuel scarcity reduced the demand for 'improved fuels' and paraffin by the households. It also reduced the availability of these fuels in rural areas, making it improbable that the poorest households would be able to increase their consumption of them. The lower consumption of 'improved fuels' and paraffin increased the demand for fuels derived from biomass. The switch from improved fuels to biomass brings with it detrimental health effects and, in the case of fuel-wood, increased collection time (usually incumbent on women and children (Heltberg 2004, IEA 2006). If timber demand (for fuel-wood and charcoal production) increases over a whole community, the ability of current woodland cover to provide this fuel source will be put under pressure resulting in deforestation. This may cause environmental problems including reduced biodiversity; erosion; loss of non-timber forestry products; and ecosystem services including water retention and increased fuel-wood scarcity. It will also increase the collection time incumbent on everyone reliant on the resource (this burden also falling disproportionately on women and children).

Although increased demand for charcoal would result in higher employment in the industry, it would accelerate deforestation and provide a direct challenge to the government who have made charcoal production and transportation illegal (WRI 2007).

The reduced desirability of hydrocarbon-fuel-powered water pumps, generators, farming machinery and road vehicles will increase demand for technologies powered by 'renewable' sources of energy such as solar water heaters, wind powered water pumps, and systems which process crop residues into liquid fuel.

Water

Water shortages already present in large areas of Kenya's central belt (including the Nairobi and Ndueni households) (WRI 2007) will be exacerbated by changes in hydrology predicted to result from climate change (Boko *et al* 2007). Deforestation (mentioned above) will contribute to this problem by reducing water retention and increasing erosion. These combined effects will reduce agricultural productivity and increase the risk of drought, famine and water shortages. Falling agricultural productivity will also increase pressure on other food sources such as fisheries – further damaging Lake Victoria's already degraded ecosystem.

Furthermore, higher fuel prices would reduce the profits obtainable from growing produce for sale long distances away. Such products would include the coffee grown by the Ndueni household, the vegetables grown by the Lake Victoria household, and the cash-crops grown by the Nairobi couple. Lower demand would decrease prices of food in Kenya, but simultaneously reduce the income generated from cash-cropping.

Resilience

The household analysis highlights the importance of physical and financial capital in giving the households resilience in times of difficulty. Such capital traditionally includes animals (such as cattle and goats) but for urban households may also include savings held in a bank account. Housing and land are also a form of physical capital but, as they provide the basic need of food and shelter, households will be highly reluctant to sell them as a temporary measure. For the Lake Victoria household, tradition is a strong factor in keeping their current home.

The poorest households, as discussed, have very little physical and financial capital currently and therefore lower resilience to the hardships brought about by fuel price scarcity. This in turn makes them more vulnerable to shocks such as flooding, disease and famine.

Non-farm income

Whilst agriculture is an important income source for all the households, non-farm income is of increasing importance (Murton 1999). Essama-Nssah *et al* (2007) suggest that an oil 'price shock' would increase the supply of agricultural and casual labour. This in part a result of households such as those in Ndueni and at Lake Victoria seeking more labour to meet their rising costs. Decreased scarcity of casual labour would benefit those farmers who were able to employ labourers, such as the Nairobi couple, who may find that decreased mechanisation coupled with lower per-unit labour costs reduces their outgoings overall. With wages lower labourers will also see the value of their time spent on their smallholding increase relatively. This would result in a broad intensification of agriculture (but particularly on smallholdings) and increased labour intensification.

Essama-Nssah *et al* (2007) show that an oil price shock may cause changes in the labour market with increased employment of agricultural labour and casual labour but decreased employment in the services sector. This could encourage migration towards areas with more employment, potentially reversing some of the depopulation suffered by Nyanza province, increasing the productivity of the land. However, it would also increase water stress and pressure on fish stocks.

Fuel scarcity could decrease population growth by generally reducing the ability of households to support any future children. Conversely, a decreasingly mechanised economy may result in children being potentially valuable as labourers. The effects will differ between households and according to affluence with the poorest valuing children as a source of support and the richest seeing children as a burden. Population growth in Kenya, particularly amongst the poorest, would lead to further reductions in the size of landholdings, which in turn could contribute to migration.

Social capital

The household studies illustrate a number of ways in which social capital is important for the livelihoods of the families. DFID defines social capital as “the social resources upon which people draw in pursuit of their livelihood objectives” (DFID 2001, section 2.3.2 'Social capital,' pp. 9). These resources may include vertical or horizontal networks, formal organisations and shared trust. In the households, the Lake Victoria family needed trust to provide the basis for petty trading. All three households benefited from their social capital when pursuing work, and the affluent Nairobi couple held considerable political influence which enabled them to operate more effectively and affect local policy making (this is often known as political capital). The social capital held by the Ndueni household acted as a burden on their livelihood: whilst their relatives benefit from the family bond, the household themselves expend money and time in assisting them (although in the past these relationships may have operated with benefits flowing in the other direction).

In times of hardship such bonds become increasingly important. For example, the affluent Nairobi couple might be able to use good relations with local traders to ensure a steady supply of fuel during scarcity. Although the overall effect of social capital on the scenarios is unclear it is possible that activities such as these could serve to exacerbate social differentiation.

Social differentiation and migration

Murton (1999) warns that social differentiation and the emergence of classes is already well under way in rural Kenya. With the affluent household gaining relatively with fuel scarcity (Essama-Nssah *et al* 2007) and the poorest households losing out (see *households*), the 'middle-ground' and 'pessimistic' scenarios will exacerbate such a differentiation. This would entrench the social divisions already in place and erode trust between villagers (social capital) creating local tension.

Social differentiation would also be exacerbated on a national scale. The 'Geographic dimensions of well-being in Kenya' report (KNBS 2005) shows graphically the variations in the distribution of wealth across the country. These divisions will be widened with fuel scarcity in the same way that they are at a micro-level: more affluent regions will be better resourced to maintain their living standards during hardship. This increased regional differentiation would not continue unchecked. Increased geographic variations in wealth, combined with changes in agricultural productivity and resulting from climate change (Boko *et al* 2007) will encourage significant internal migration.

Civil unrest

Cities such as Nairobi already suffer from considerable urban problems resultant from a lack of infrastructure investment, rapid rural to urban migration, and high levels of poverty. This potentially fragile social environment is threatened by increased fuel scarcity, fuel-poverty, and related impacts discussed. If migration to the cities did increase it would be likely to entrench social divisions, eroding community cohesiveness and increasing crime and civil unrest (Portes 1995).

Election violence in Kenya

A group of Kikuyu-owned houses burn out of control in Kericho, Rift Valley Province, February, 2008.

Photo credit: BLAIRHLL (2008)

In late 2007, the weight of poverty and increased social differentiation contributed to the election violence which killed 300 people (African Research Bulletin 2008). The risk of such violence will be much greater as more and more people begin to suffer from fuel poverty, malnutrition, poor health and unemployment.

Education and health

Education was the most important factor differentiating the success of the members of each household: in the Ndueni household lack of basic education gives the children low prospects for obtaining skilled employment; for the Lake Victoria household, secondary education gave the eldest son the confidence to find work in Kisumu; and for the Nairobi household secondary education allowed the husband to obtain work in the services sector.

Increased fuel scarcity would increase the cost to the Government and local community groups of providing education services. Much of this will be passed onto families making education less affordable, and reducing enrolment.

Gender inequality is visible in Kenya at a national level but also in the household examples. In the Lake Victoria household, tribal views define the economic activity carried out by women, and the Nairobi couple's division of labour is strongly affected by the differences in education level received. With many households losing income under the scenarios, their ability to afford education will fall and it is likely that the women will lose disproportionately as parents decide to use their limited funds on educating their sons rather than daughters. This will have future impacts on gender inequality in labour markets (ISIS 2001).

The difference between the 'optimistic' scenario and the 'middle-ground' and 'pessimistic' scenarios is clear: the former gives a chance for equality, quality and quantity of Kenyan education to increase, the latter do not. A more subtle difference is also clear: children whose households are facing fuel scarcity in the medium term will have spent more time in education than children facing fuel price scarcity immediately.

Healthcare provision in Kenya is patchy and rising costs would reverse recent improvements. This will increase susceptibility to disease (such as Malaria and HIV/AIDS), reduce maternal health, and ultimately decrease the life expectancy. Atzberger (2007) traces a link between peak oil and a resurgence of the AIDS epidemic. With increased malnutrition, lower levels of family care, and increased use of solid-biomass fuels, Kenyans will be more unhealthy and have fewer healthcare services available.

The increased cost to government of education and health services will also put further strain on limited resources. Furthermore, rising oil prices will reduce tourism revenues. These trends would explain the reduced employment in skilled professions and the services sector following an oil price 'shock' observed by Essama-Nssah *et al* (2007) in South Africa.

Government

Under the 'optimistic' scenario, Kenya has a chance to overcome the numerous development challenges that face it as a nation over the next 22 years. Relative global economic stability will allow Kenya to strengthen its place as an important political player in Africa, a growing tourist destination, and financial centre, and generate wealth to fund improvements in infrastructure, health, education and other services. 'Price spikes' will provide a considerable challenge to the government who may be forced to choose between intervening in the market (with the subsequent cost) and risking economic stability. All three scenarios forecast a future for Kenya that is less stable than the previous decades have been.

However, it is the 'middle-ground' and 'pessimistic' scenarios that provide the widest ranging and most acute set of problems for the Government to overcome. Rising costs of service provision and governance will come at the same time as falling tax revenue. The cost of projects such as rural electrification and free primary education will rise significantly.

As one of the poorest countries in the world (World Bank 2007, 2), Transparency International (2007) placed Kenya 150th out of 179 countries on perception of corruption, and the Government suffers a high debt burden. These factors play a sizeable part in restricting the ability of the state to manoeuvre in tight fiscal and monetary situation of high inflation and low investment.

In the 1980s high oil prices contributed to the debt crisis faced by countries such as Kenya (Dunkerley and Ramsay 1982). If the Government is encouraged into more debt by international lenders convinced that the fuel scarcity is a 'price spike' (as found in the 'optimistic' scenario) their debt burden could once again become unsustainable.

The macroeconomic problems and reduced service provision will reflect badly on the ruling party and challenge the Government's regional political profile.

International migration

The optimistic scenario presents considerable challenges for the neighbouring countries. The increasing power of OPEC and, potentially, a gas market cartel, will present an ever-present threat to fuel-market stability. Those countries with sizeable indigenous fossil-fuel supplies (including African nations such as Egypt, Libya, Nigeria, and neighbouring Sudan), will have an increased share in oil and gas markets and with it, increasing political influence. Oil producing countries have faced a history of connected conflicts and as these resources fall in the domain of fewer countries, such conflicts could become more frequent (Leggett 2005). Any regional instability would increase the burden of refugees on Kenya (already a host of many refugees from Somalia).

Climate change

Instability in the supply-chain of oil and gas in all three scenarios will encourage increased exploitation of coal (recently discovered in Kenya (Ministry of Planning and National Development (2006)) as well as unconventional sources of oil and gas in other countries. This would have the effect of increasing GHG emissions significantly. It will also increase demand for sources of energy which are not dependent on hydrocarbons such as agrofuels, crop-residues, wind power, solar power, hydroelectricity and fuel-wood. The 'pessimistic' and 'middle-ground' scenarios will also lead to increased deforestation in countries with high solid-biomass dependence, such as Kenya, releasing large amounts of GHGs.

At the same time, increased scarcity of fossil-fuels will decreased consumption causing recession and, subsequently, reduced demand. The net impact on GHG emissions is unclear, but in the very long term, any reduction in GHG emissions would be expected to benefit parts of Kenya at risk of drought and flooding due to climate change effects.

Mitigation required

The analysis in this report has highlighted many areas in which the current fuel policies of the Government of Kenya and development donors (as described in *Contexts: Current fuel and energy policy in* Kenya) are not sufficient to mitigate the various challenges that the fuel supply scenarios present. This section of the report will consider those shortfalls and what policies would help prepare Kenya for the situations provided by the scenarios.

Given the risks involved and the strength of the arguments in all three scenarios, it is clear that Kenya needs to be prepared for *all three scenarios*. Similarly to climate change, inaction cannot be justified on the grounds of uncertainty. The 'peak oil problem' presents such a diverse range of challenges that even the likelihood of it occurring is negligible, these challenges need to be addressed – and quickly.

Mitigating the source of the problem

The discussion highlighted a broad range of issues in Kenya that will be affected by fuel supply instability. However, policy that seeks to address these individual issues will be less successful than a policy that cuts the problem off at the source – by securing a future of affordable indigenous fuel supplies.

With LPG prices already prohibitive, and supply networks insufficient, the analysis suggests that despite the health benefits, increased use of LPG is neither practical, a priority for households (compared to investment in education or animals), or sustainable (considering the likelihood of future price volatility). Instead, the Government should encourage the production of domestic fuel alternatives such as biogas and ethanol gel derived from waste and crop residues, and increase the availability of electricity either through localised sources or grid connection. The Government should also look to disseminate cleaner and localised fuel technologies such as solar crop dryers, wind pumps, waste-biomass fuel processors, and clean-burning stoves (as recommended by Karekezi (2002) and Pachauri and Reisinger (2007)). Plans have been made to increase rural electrification (and thus decrease reliance on paraffin for lighting), but these plans have not been delivered. There also needs to be a drive to encourage energy conservation to reduce demand and increase efficiency. This must include investment in the grid which currently suffers considerable transmission losses.

The Government is aiming to increase indigenous sources of fuel for electricity generation including geothermal, solar, and hydropower, as well as oil and coal exploration. However, the high value of oil would lead to most of it being exported and it is doubtful whether this investment would benefit the poorest without further measures. Increased use of coal without carbon capture technology will ultimately exacerbate climate change effects already faced by Kenya, and there is a risk that all investment in electricity generation will overlook the poorest without increased electrification and funding helping the poorest afford electricity supply. The current emphasis of reform on privatisation needs to be carefully managed to ensure that supply is not channelled to the rich with the poor ignored.

Changes to Kenya's energy policy need to be designed in participation with households such as those included in this study (and those not). Energy policy that meets the needs of one section of society and ignores another will ultimately fail. The Government must also seek to educate people about the changes ahead using appropriate communication methods. For example, households will not invest in new stoves if they do not understand the benefits of the technology. Equally a community is more likely to invest in crop-residue biofuel processing if it understands the uncertain future in the supply of other fuels.

Reactive policy

Much of this investment will require time which, under the 'pessimistic' scenario, will be short. If the Government is backed into being responsive in responding to fuel price scarcity rather than proactive, a number of more difficult decisions may need to be taken.

This presents a number of problems. As described in *discussion,* the rising cost of direct fuel will increase the cost of running Government services such as electricity generation, education, and healthcare. In order to avoid increased borrowing, the Government would need to reduce expenditure by cutting back on plans such as rural electrification, free education and healthcare improvements. This avenue would hit the poorest hardest by increasing fuel-poverty and related effects such as increased social differentiation (as described in *discussion*). Alternatively, the Government could borrow to fund sustained provision of these services or to subsidise prices – but such borrowing would quickly become unsustainable as in the 'middle-ground' and 'pessimistic' scenarios, higher prices of fuel imports are a permanent phenomenon. Clearly proactive, not reactive policy is desirable.

Other problems

There are several baseline trends that will affect Kenya over the next 22 years, which the government will need to address alongside tackling the fuel-supply problem. A degree of climate change is inevitable for Kenya and the potential impact of this on agriculture, water supply, already discussed, is significant. In addition, changing rainfall patterns may threaten current hydroelectric infrastructure.

Rural to urban migration is a continuing phenomenon in Kenya. Yet the discussion concluded that decreased mechanisation and a fall in employment in services would occur as a result of oil price rises. This could reverse any such migration leading to urban degradation and increased pressure on rural areas to provide food and services. These changes need to be monitored and managed carefully.

Continued gender inequality is not addressed by current policy and requires proactive measures. The current policy focus on reducing the disparity in education is appropriate but must be followed by with action. Employment discrimination and life expectancy discrepancies must also be addressed: reliance on polluting domestic fuels is a gender issue and should be given high priority by donors and the Government alike.

The election violence in Kenya showed the world what the impact of increased social differentiation in a low income country could be. The Government must address the growing divide in Kenya and consider ways of supporting the least well off.

Supporting role

Development agencies and NGOs have an important role in supporting Kenya's efforts to reduce fossil-fuel dependence. The current emphasis on increasing use and exploitation of fossil fuels (including LPG) must be dropped. In its place there should be wide scale technological and monetary support for localised, indigenous supplies of clean burning sustainable fuel sources and technologies – an emphasis already championed by NGOs such as Practical Action. Electricity generation networks should be improved in order to increase access for the poorest and development banks should fund supplies for those who cannot afford supply. Both NGOs and development banks should undertake these projects in partnership with the Government of Kenya and local people to ensure domestic control over decisions made.

Increased funding of these projects will not only help Kenya achieve energy independence; they will help ensure that the development donors keep their Kyoto Protocol promises on the dissemination of low-carbon technologies as well as supporting the Millenium Development goals to reduce extreme poverty, achieve gender equality, and ensure environmental sustainability. The World Bank, IMF, regional development banks, national development agencies and other global institutions, funded by their membership Governments (and controlled by G8-countries) must ensure provision of this funding is given high priority. Only by doing so will they be able to avert the dual-problems of fuel scarcity and climate change. If Kenya does not receive funding to invest in renewable sources, peak oil will have a highly damaging effect on population's welfare.

Further work

The analysis presented in the report is clouded by the lack of certainty provided by the many variables included. Many of these, such as migration, climate change and social change are naturally hard to predict. However, there are some uncertainties that are avoidable.

The complete lack of consensus about the future of oil supply, and therefore the other fuels discussed, is a great source of uncertainty for anyone attempting to forecast the future trends in this increasingly globalised world. The disagreement and confusion over the future of oil can partly be blamed on the lack of transparency in the field. Nationalised oil companies such as Saudi Aramco's jealous guarding of field-specific data gives us few clues in assessing how valid their reserve figures are, only exacerbating speculation of false reporting – and the insistence of BP (2008) and the IEA (2006) to report these figures as unquestioned truth (BP 2008) do little to educate the debate. Analysts must always be careful of how trustworthy their data is – but when the questions are as important as they are as here, the slightest discrepancies must be questioned.

Transparency is worsened by the lack of freely available data. Industry journals such as

World Oil, the Oil and Gas Journal, AAPG Bulletin, whilst considered authoritative, are not generally available in universities, so researches are forced to rely on second hand reporting of their data. Furthermore, the *World Energy Outlook*, a renowned annual publication on these matters costs €120 in the year of publication, despite having the backing of the OECD. The International Energy Agency should consider how their publication's recommendations on fuel-poverty are devalues when the high price mean that less wealthy institutions and researchers cannot afford to read it.

The Kenyan census (KNBS 1999) would be a more useful to the discussion of domestic fuel if the questions asked were more in depth (for instance, rather than only recording the main cooking fuel used, recording the two main fuels used and the approximate proportion).

The *World Energy Outlook* and USGS need to answer the questions raised about their conclusions by peak oil proponents. So far, peak-oil criticism has been confined to a small number of academics writing in a reactionary rather than considered style (Deming stands out among such writers). If the peak oil thesis is incorrect, its critics must be clear what mistakes is is making.

However, even if the Hubbertists are wrong, the twenty-first century fuel-market problem is far from resolved. The impact of 'price spikes' on households and development work needs to receive careful attention. The work of Essama-Nssah *et al* (2007) contributes to this field but it stands alone. Comprehensive mitigation strategies need to be developed: can countries develop immune from the economic turmoil caused by these crisis – or can they at least be given a way to cope with rising fuel prices that doesn't lead to restrictive levels of of debt or declining welfare?

The future role of coal must be addressed by academics. Without further incentives, and with coal reserves so large, it is inevitable that lower income countries will exploit these fuels. In order for this not to have a catastrophic effect on GHG levels, these countries either need to be provided with a viable alternative, or carbon-capture and storage need technology must be developed.

Finally, the role of climate change in affecting the fuel markets as both drivers of climate change, and a system that could be fundamentally changed by climate change should be investigated.

Summary and conclusions

Oil is the world's most economically traded fuel and this report began by assessing the debate over its future supply prospects. It was found that there was a wide body of evidence supporting both the institutional view, that there was enough oil to provide for increases in supply at least until 2030, and the 'Hubbertist' or 'peak oil' view, that oil supply will decline before 2015. The debate centred over the total reserves remaining, technological improvements, the importance of the declines in discovery, and the quantity of resources available from 'unconventional sources' and reserve growth.

It was found that there was less debate over the total natural gas reserves remaining. However, as a substitute for oil, its supply is closely related to that of oil and as such, proponents of the *peak oil* thesis insist that gas production will peak shortly after that of oil. Natural gas will become increasingly important as instability in oil supply grows.

Known resources of coal are thought to be enough to last hundreds of years at current rates of consumption with the benefit that many coal reserves are held in countries with high demand.

The future of secondary fuels such as road-vehicle petroleum, diesel, LPG, paraffin and emerging technologies such as coal-to-liquids was discussed. As they are derived from the primary hydrocarbon sources of oil, natural gas and coal their supply is closely related. The analysis assumed that future government action to mitigate fuel scarcity was minimal.

The analysis was summarised into three fuel supply scenarios: an 'optimistic' future where fuel supplies increased albeit with occasional 'price spikes', a 'middle-ground' future where *peak oil* occurs between 2015 and 2030, and a 'pessimistic' scenario where oil supply peaks before 2015.

The report then considered how three Kenyan households' livelihoods would be affected by the fuel scarcity under the scenarios until 2030. The context of Kenya's electricity network, highly reliant on hydroelectric sources, its domestic fuel supplies, largely dependent on biomass, and social and environmental trends were outlined, followed by a discussion of fuel policy in Kenya.

These provided the background for discussing the impact on the example households in Ndueni, Eastern Province, Upper Nyakach, by Lake Victoria, and Nairobi. Each household had better prospects under the 'optimistic' scenario but the wealthier Nairobi household fared relatively better under the 'middle-ground' and 'pessimistic' scenarios.

The pressures of fuel scarcity were predicted to change employment patterns, increase migration, deforestation and social differentiation, and reduce gender equality, life expectancy, provision of education and healthcare services.

The report recommends a mitigation strategy of increased technology transfer and funding to allow increased access to electricity and supply of renewable sources of fuel. The encouragement of exploitation of fossil fuel sources and increased use of LPG is not recommended as it will exacerbate climate change effects, have few benefits to the poorest, and be unsustainable under all three scenarios.

Finally, the difficulties encountered in the report, such as the lack of transparency of oil companies reporting, and recommendations for further work including further investigations into the implications of 'price spikes' on the poor, and the interaction of fuel markets and climate change.

The optimistic scenario is often mistakenly characterised as a 'business as usual' or 'status quo' future. This is far from the truth: the oil market future described in the *World Energy Outlook* sees political disruption and price spikes becoming ever more frequent. Yet the peak oil scenario provides far greater constraints on fuel supply. All three of the fuel supply scenarios discussed in this paper present considerable challenges to Governments and development donors globally – challenges which are yet to be addressed seriously. New policies and practices need to be adopted in order to prepare for and adapt to the changing world fuel market over the next 22 years.

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Dates follow the format date-month-year or, where the date is unknown,'month-year'.

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