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Oil Use and Economic Development in Sub-Saharan Africa

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Abstract

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A GDP growth of 7% has been suggested as a target to combat the current economic underdevelopment of sub-Saharan Africa (SSA). Historically, such rapid economic growth has not occurred without a simultaneous increase in energy use. Economic activity presupposes the use of energy, since energy is the capacity to do physical work. Of the commercial energy forms available, oil is of strategic importance for SSA due to its versatility, energy density and low infrastructural requirements. Recent surges in the world oil price have therefore resulted in serious hardships for many countries in SSA. Oil is particularly difficult to replace within the transport sector, which is the largest user.

This study presents two oil use scenarios for SSA given a 7% GDP growth 2008-2030. With no increase in the efficiency of oil use relative to GDP, consumption will increase from 1 million barrels per day in 2004 to 4.8 Mb/d in 2030. Assuming the most efficient oil use that appears reasonable in the light of past trends in relevant reference countries, consumption will still amount to 3.5 Mb/d by 2030. When put in relation to oil production scenarios for SSA, the conclusion is that the net export of oil cannot be maintained at the high level that major oil consuming nations expect, if SSA is to have a high GDP growth. Particularly in the context of a future global oil production peak, this result has serious implications for the economic prospects of SSA.

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Preface

This M.Sc. Thesis Work was supervised by Prof. Kjell Aleklett, Department of Nuclear and Particle Physics, Uppsala University, Sweden. Examiner was Ulla Tengblad, Department of Nuclear and Particle Physics, Uppsala University, Sweden. The work has been done within the Uppsala Hydrocarbon Depletion Study Group (UHDSG) at the Department of Nuclear and Particle Physics at Uppsala University, Sweden. The aim of UHDSG is to investigate issues of global energy supply that relate to the depletion of oil, gas, coal and other fossil hydrocarbons.

I wish to thank my supervisor Prof. Kjell Aleklett for his inspiring and enthusiastic guidance, Dr. Fredrik Robelius for his insightful comments on the technicalities of oil production, and also the other members of UHDSG, Bengt Söderbergh, Mikael Höök, Aram Mäkivierikko, and Kersti Johansson, for their input. A special thanks to my neighbor Anders Axén for his proofreading and comments.

Populärvetenskaplig sammanfattning

Att lösa problemen kopplade till fattigdom i Afrika söder om Sahara (SSA) antas allmänt förutsätta stark ekonomisk tillväxt. En årlig tillväxt av BNP på 7% har föreslagits som mål av den brittiska 'Kommissionen för Afrika' i en rapport från 2005. Som jämförelse hade Indien under 24-årsperioden 1980-2004 en genomsnittlig tillväxt på 5,8%; Kina hade en tillväxt på 9,8%. En stark ekonomiskt tillväxt i SSA antas vara praktiskt möjlig, förutsatt att stora investeringar i infrastruktur görs, samt att politiska och institutionella förändringar skapar ett gynnsammare företagsklimat.

En kritisk faktor för ekonomisk tillväxt, som sällan tas upp som en huvudfråga, är tillgången på energi. All ekonomisk aktivitet förutsätter fysiskt arbete i någon form, och energi definieras som förmågan att utföra fysiskt arbete. Alltså är energi en nödvändig och oersättlig resurs.

I SSA har olja en central plats bland kommersiella energislag, inte bara i och med att den dominerar energianvändandet i kvantitativa mått, utan också därför att den är strategiskt viktig, framför allt som bränsle för transporter. Oljans fysiska egenskaper gör den svår att ersätta med alternativa energislag i transporter och vissa andra viktiga tillämpningar. Därför är det inte förvånande att oljeanvändningen historiskt sett har ökat kraftigt i samband med stark ekonomisk tillväxt, exempelvis i Kina och Indien, länder som tidigare har varit jämförbara med SSA både ifråga om BNP och oljeanvändning per capita. Även de enstaka fall av stabil ekonomisk tillväxt som finns inom SSA, framför allt Botswana och Mauritius, bekräftar bilden av att oljeanvändning och BNP går hand i hand.

Ifråga om *oljeintensitet*, d.v.s. mängden använd olja i förhållande till BNP, kan ett antal viktiga observationer göras. OECD-länder har, trots tillgång till modern teknik och en förskjutning av ekonomin från industri till servicenäringar, inte lyckats sänka sin oljeintensitet under den låga nivå som t.ex. Indien har legat på sedan 1980. Majoriteten av de minst oljeintensiva länderna i världen finns faktiskt i SSA. De utmärker sig i allmänhet genom att fortfarande ha en låg urbaniseringsgrad. I takt med att dessa länder urbaniseras, kan de också förväntas förbruka mer olja.

Om SSA ska kunna ha en BNP-tillväxt på 7% fram till 2030, så kommer användningen av olja med all säkerhet att behöva öka dramatiskt. Enligt basscenariot, som antar oförändrad oljeintensitet, blir oljeanvändningen 4,8 miljoner fat per dag år 2030, att jämföra med ca 1 miljon år 2004. Enligt ett mer optimistiskt scenario, där oljeintensiteten antas sjunka till den lägsta nivå som förefaller rimlig utifrån historiska exempel, blir den totala användningen 3,5 miljoner fat per dag år 2030.

SSA's ökade behov av olja skulle inte innebära något allvarligt problem, om inte olja vore en begränsad global resurs. Utvinningskapaciteten kan inte ökas i godtycklig takt. Inom överskådlig framtid kommer oljeutvinningen dessutom att nå sin maximala nivå på grund av geologiska orsaker. Detta fenomen, 'Peak oil', har redan inträffat i ett antal enskilda länder, och måste även ske på global nivå.

Det är alltså en begränsad mängd olja som ska fördelas mellan världens länder. De länder som redan är stora och växande oljekonsumenter, framför allt USA och Kina, har börjat betrakta SSA's betydande oljetillgångar som en strategiskt viktig resurs för den egna ekonomin. De planerar att kunna öka sitt beroende av oljeimport från SSA under de kommande åren. Emellertid kommer även SSA’s oljeproduktion att nå en topp, sannolikt inom ett antal år när produktionen i djupvattensfält utanför Angola och Nigeria börjar gå ned. Det kommer att få till följd att SSA’s nettoexport måste minska, i synnerhet om den interna konsumtionen samtidigt ska öka.

Slutsatsen är att de stora ekonomiernas behov av olja står i motsättning till en ekonomisk utveckling i SSA. Det kommer att krävas avsevärda förändringar i det nuvarande sättet att använda olja, framför allt i de länder som idag använder mest olja men på sikt även i SSA, om löftet om ekonomisk utveckling för Afrika ska bli trovärdigt.

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Figures and tables

1 Introduction

1.1.1 An Ongoing Oil Crisis

The recent surge in the world oil price, from below $30 to around $60 in the period 2003-06, has passed largely unnoticed to the average western consumer. In contrast, a poor region like sub-Saharan Africa (SSA) has experienced consequences of an entirely different magnitude. The impact of a higher oil price is felt at the macroeconomic level, since oil is often one of the largest import products, and therefore a major drain on foreign exchange for African countries. But there are also plenty of examples of how more expensive oil has very tangible consequences for the workings of everyday life. In certain places food prices have soared, partly because more expensive gasoline and diesel raise the cost of all transports, partly because food processing, such as corn milling, is occasionally fuelled by kerosene or other oil products. (Buhanza, 2006) Health clinics cannot afford to fuel their backup diesel generators during blackouts. Raised gasoline retail prices and removed fuel subsidies are sparking strikes and riots. In many ways the urban Africans, dependent as they are on commercial household fuels and functioning transport systems, turn out to be the most vulnerable. (Cummins, 2006) The importance of affordable and reliable energy for modern life rarely becomes as obvious as when the energy supply falters.

1.1.2 A Sick Region Receives Its Diagnosis

Regardless of whether life expectancy, poverty headcount, Human Development Index (HDI) or Gross Domestic Product (GDP) per capita is used as an indicator of development, SSA stands out as a woefully underdeveloped region. Many developmental economists and influential agencies, perhaps most notably the World Bank and the International Monetary Fund (IMF), have considered it their mission to identify the reasons behind this frustrating underdevelopment. Although the diagnoses and prescriptions varies in their details, most experts appear to agree with the basic premise so succinctly formulated by the British ‘Commission for Africa’ that was initiated by Tony Blair: “Africa is poor, ultimately, because its economy has not grown.” (CFA, 2005)

In their final report released in March 2005, titled *Our Common Interest*, the commission went on by committing to a concrete GDP growth target for the continent: “The goal should be to increase the average growth rate to *seven per cent* by the end of the decade, and sustain it thereafter. These growth rates have been attained across Asia and in parts of Africa and can be achieved across the continent – but only if the obstacles of a weak infrastructure and a discouraging investment climate are overcome, releasing Africa’s entrepreneurial energies.” [emphasis added] (CFA, 2005)

1.1.3 Oil - An Important Factor

Although entrepreneurial energies certainly will play a crucial part in Africa’s economic development, there is also the issue of access to energy in the strictly physical sense. Development, as it is usually defined in terms of GDP growth, has hitherto not occurred without increased use of commercial energy. The recent Asian economic boom is no exception.

Of the forms of commercial energy that are presently available, oil has a special place. It is the world's largest primary fuel in terms of the amount of energy it provides. It is also very versatile, and in certain important applications it has no good substitute. In the light of the growing debate on future limitations of oil supply and its ultimate decline, it is obvious that understanding the role of oil in economic development should be a high priority for anyone who is concerned with the future prospects for SSA.

1.1.4 Purpose of Study

The premise of this study is that the relationship between oil use and economic development is relevant to analyze quantitatively within an African context. The more specific aim is to create a reasonable scenario of future oil demand in SSA given a GDP growth rate of 7% per year, and then put the empirical result into perspective based on what can be assumed about future oil supply and the oil demand of other countries. Since the year 2030 is a common time horizon in energy forecasts, it has been chosen also for this study.

1.1.5 Methodology and Data Sources

In order to construct a scenario of future oil use, it is necessary to investigate in more detail how GDP and oil use have developed historically in SSA and in comparable cases. It is also necessary to put some light on the underlying reasons behind the observed development. However, since everything about the future is uncertain, two different scenarios will be constructed based on different assumptions derived from historical experience. Ultimately, it must be up to the reader's own judgment to decide which scenario is the most probable.

If not stated otherwise, data on energy production and use has been obtained from the Energy Information Administration (EIA) at the U.S. Department of Energy. EIA is the only public source that publishes data in continuous time series 1980-2004 for every individual African country. Certain supplementary energy data has been taken from the statistical publications of the International Energy Agency (IEA). Data on GDP and other non-energy statistics has, if no other source is cited, been taken from the World Development Indicators Database of the World Bank (2006). All population figures, which the per capita measures are based on, have been obtained from the Population Division of the United Nations. In the construction of scenarios, the 'medium variant' of their population forecast has been used. (UNSD, 2006)

1.1.6 Delimitations

SSA is here taken to comprise the entire African continent plus surrounding island nations, except the North African countries and the Republic of South Africa. The latter country is sometimes considered part of SSA, sometimes not. In this context, the dominant size of South Africa's economy relative to the rest of SSA is taken as a justification for treating it separately.

Oil has several important uses as a chemical feedstock for plastics, pharmaceuticals and pesticides. However, this study focuses on its use as an energy source. Since oil production and consumption is usually expressed in volume – typically barrels per day (b/d, one barrel = 159 liters) – the same measurement has been adopted in this study for the sake of convenience and comparability. A quantitative analysis based on energy content would potentially yield a slightly different result, since different oil products have different energy content per volume. However, the oil product mix is not assumed to vary across time or countries to such a degree that the results would be significantly altered.

1.1.7 Issues of Data Quality

Obtaining reliable statistics on African countries is sometimes a difficult task. In some instances, such as population estimates in certain nations, the official figures have political consequences and are therefore controversial. In other cases, lack of data gathering capacity is an obstacle. For this latter reason some particularly uncertain data has been entirely excluded from the study, such as estimates on traditional woodfuel consumption. In general, the data sources have been chosen on the assumption that they are unbiased, although the data quality cannot be guaranteed for all countries throughout the time period.

1.1.8 Disposition

The report is divided into two main sections. *Background Topics* comprises chapters on the basic relation between energy use and economic growth, the more specific role of oil as a fuel, the ‘Peak oil’ debate and its implications, the present oil production in SSA and the circumstances surrounding it, and the growing strategic importance of African oil exports. The purpose of the first main section is to establish the background against which this study is relevant, and to make observations that are needed for the construction of scenarios.

The second section, *Empirical Study*, deals more specifically with the construction of oil production and oil use scenarios for SSA. The development of *oil intensity* – the oil use in relation to GDP – is studied in a number of reference countries as well as within SSA. Based on the resulting assumptions on possible future developments, the scenarios are constructed. Finally, the empirical results and their implications are discussed.

2 Background Topics

2.1 Oil, Economic Growth and Development

2.1.1 GDP and GDP (PPP)

The Gross Domestic Product (GDP) is the most widely used measure of a country's economic activity, and it is also commonly interpreted as an indicator of economic development. Continuous time series of annual GDP figures are available for virtually every country, which is a big advantage.

The standard GDP measure is calculated from currency exchange rates, which could be misleading in comparisons between countries since differences in price levels are not taken into account. The GDP adjusted to Purchasing Power Parity (PPP), expressed in 'international' dollars, addresses this problem and gives a somewhat more accurate picture of relative income levels and standards of living. Throughout this study, GDP (PPP) at constant year 2000 prices has thus been used instead of unadjusted GDP. For SSA, the choice of GDP measure has quite a dramatic impact on the result. While the average unadjusted GDP per capita in SSA was $352 in 2004, the GDP (PPP) per capita was $1211, more than three times as high.

2.1.2 The Quest for Economic Growth

Economic growth is widely thought to be essential, although not by itself sufficient, for the alleviation of problems such as poverty and malnutrition in SSA. An annual GDP growth of 7% has been put forward as necessary to halve extreme poverty in Africa by 2015. (World Bank, 2007b) The Commission for Africa, which was established by the British Prime Minister Tony Blair in 2004, set the same GDP growth rate of 7% as a target in its final report titled *Our Common Interest*. (CFA, 2005) In this report no specific timeframe is mentioned, only that a 7% growth should be achieved by the end of this decade and then sustained. If SSA was to have a GDP (PPP) growth of 7% throughout the period 2008-2030, that would translate to an increase in GDP (PPP) per capita from $1211 to $3529. To put this increase in perspective, China's GDP (PPP) per capita in 2004 was $5370, while India's was $2887. In other words, the growth target of 7% means that SSA in 2030 would be slightly wealthier than India is at present. Hardly anyone would be in a position to begrudge SSA such an economic development.

Since GDP growth is such an important goal for development policy, a lot of effort is put into identifying the factors that could explain the presence or absence of growth. The formulation of policy strategies is dependent on which factors that are emphasized. The Commission for Africa states that the targeted growth should be enabled following the advices that are put forward in their report. The main recommendations are in short:

- Increased investments in both urban and rural infrastructure, including roads, telecommunications, electricity, sanitation, water supply and irrigation.
- Promotion of the African "entrepreneurial spirit" through changes in governance, improved investment climate and removed business obstacles.
- Better coordination of public, private and aid initiatives, and new partnerships for the financing of infrastructural investments. (CFA, 2005)

In a recent report published by the World Bank, titled *Challenges of African Growth* (2007), there is a similar characterization of the critical growth issues. Four major factors of interest are highlighted and referred to as the four "big Is": Investment Climate, Infrastructure, Innovation and Institutional Capacity. (World Bank, 2007)

2.1.3 Research on the Connection Between GDP Growth and Energy

"During the past 25 years consumption of commercial energy in developing countries has risen in step with GDP growth. Assuming the same is true for Africa, commercial energy production will need to expand by about 5 percent a year if Africa's economies are to achieve the targeted annual growth rates of 4 to 5 percent [...]." (World Bank, 1989)

The above quotation, taken from the World Bank report *Sub-Saharan Africa – From Crisis to Sustainable Growth* published in 1989, illustrates that recognition of the relationship between GDP growth and increased energy use is not particularly new or controversial. Over the years, a fair amount of scientific publications have been written on the subject. Empirical studies typically consist of comparisons of GDP and energy use time series in order to detect statistically significant relationships. Some studies focus on African countries specifically. For example, a case study of Tanzania and Nigeria (Ebohon, 1996) found a significant relationship leading from total energy consumption to GDP. However, there is a methodological difficulty connected to the choice of total energy use as an indicator, since it is hard to add different energy sources together and get a meaningful measure (this problem is touched upon in chapter 2.2). Many studies avoid this methodological difficulty by focusing on one single type of energy use. The by far most common study object is the use of electricity. Ferguson *et al.* (2000) conclude, based on data from over 100 countries, that there is generally a stronger correlation between electricity use and GDP than between total energy use and GDP. A statistical analysis of GDP and electricity use data from 17 African countries (Wolde-Rufael, 2006) yielded a mixed result: a long-run relationship was established for only 9 countries, while unidirectional or bidirectional causality was detected for 12 countries.

2.1.4 Oil use and GDP

For some reason, oil use and its relation to GDP appears to have attracted far less attention from the scientific community than electricity use. One possible explanation could be that the World Bank's World Development Indicators Database, which is a standard reference, provides data on electricity and total energy consumption (measured in oil equivalents), but not on oil use specifically. These figures must instead be obtained from other sources, such as the International Energy Agency (IEA), the Energy Information Administration (EIA) or the *Statistical Review of World Energy* published by British Petroleum (BP).

The cross-country correlation between GDP (PPP) and oil use per capita, with figures on oil use taken from EIA, is illustrated in figure 1. It is quite obvious that there exists a strong positive correlation, although there are some notable examples of countries with a very high oil use in relation to their GDP. These outliers do not really contradict the importance of oil for GDP, since there is no reason to believe that a high oil use automatically would result in high GDP. More importantly: there are no examples of high-income countries with a per capita oil use at the same low level as the major developing countries. The large countries of SSA, not surprisingly, stand out as the low extreme in terms of both oil use and GDP (PPP) per capita.

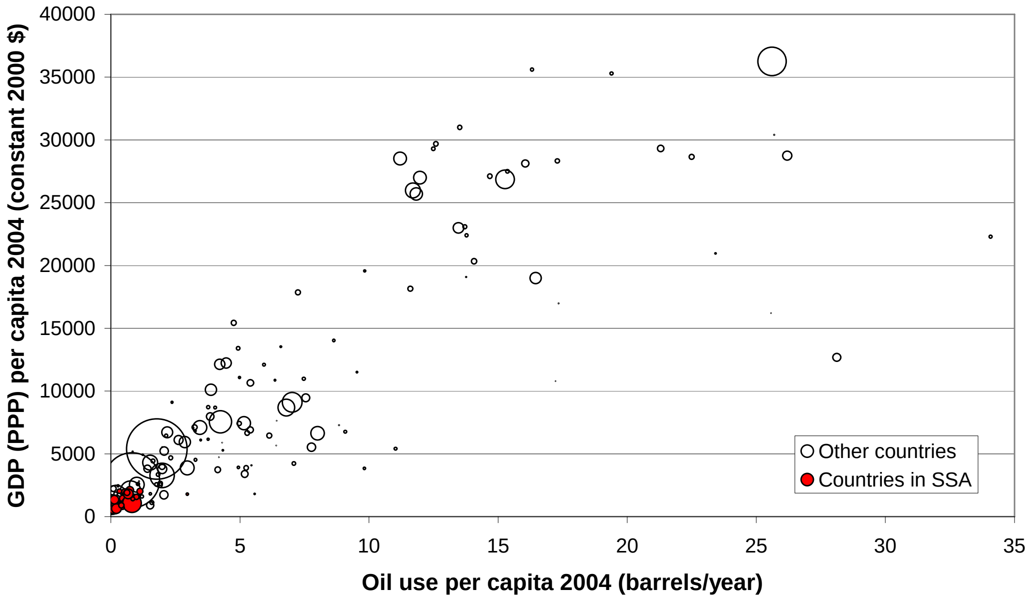

Figure 1. Oil use versus GDP (PPP) per capita in 2004 for all countries with available data. The size of a circle represents population size. A number of small countries, among those Luxembourg, Singapore, Kuwait and Qatar, have too large an oil use to be shown in the graph.

2.1.5 The Issue of Causality

It should be remembered that a positive correlation not necessarily means that a direct causal relationship is present. However, a strong correlation at least gives some reason to suspect that there indeed exists a causal link in either direction. The issue of causality is central in several empirical studies of energy use and GDP, and has motivated the application of statistical causality tests. The direction of causality is thought to have policy implications: if it cannot be shown that increased energy use causes GDP to increase, then that could be taken as an indication that restrictions on energy use would not harm GDP growth. (see e.g. Wolde-Rufael, 2006)

However, the hypothetical conclusion that energy is unimportant for GDP can be questioned from the perspective of natural science. Energy is commonly defined as the ability to *do physical work*. Since virtually all economic activities involve physical work to some extent (e.g. transforming, assembling, demolishing, sorting, or transporting of matter) it is inevitable that GDP, which is a proxy for economic activity, must depend on the use of energy. Put simply, energy is needed to make things happen. It is thus possible to conclude that a causal link must exist between energy use and GDP (given that GDP has any connection to the physical world), but it is impossible to say how strong this causal relationship is, based on only principal reasoning. It is plausible that improved technology would reduce the need for energy, although only to a limited extent, since technology in itself does not have the ability to do physical work. Some energy will always be needed. It is equally plausible that structural changes in the economy, leading to less energy consuming activities, could reduce the use of energy relative to GDP. The only way to determine the real importance of these factors is through empirical examination of historical data. Focusing specifically on oil use, that is the aim of the second part of this report.

For the sake of completeness, it should be stressed that a causal relation energy → GDP only implies that energy use is a prerequisite for economic activity, not that energy use automatically yields economic activity. Nor does it exclude a simultaneous causation in the other direction. The causal chain could look something like this:

> Increased GDP → increased incomes → more money to spend on energy services → increased energy use

2.1.6 Weaknesses of the GDP measure

Although GDP is the most widely used indicator of economic development, one should be aware of a few problems that could make it an unreliable measure, even when adjusted to purchasing power parity.

Firstly, GDP only measures the size of the *formal* economy. But in African countries, a substantial part of the economic activity takes place within the *informal* sector, and never leaves a trace in the national accounts. The GDP measure can thus be suspected to systematically underestimate the true level of economic activity in SSA relative to developed countries. However, this bias might be mitigated by the fact that informal economic activities to a large extent can be assumed to rely on traditional woodfuels and other non-commercial energy sources, which are not included in this study.

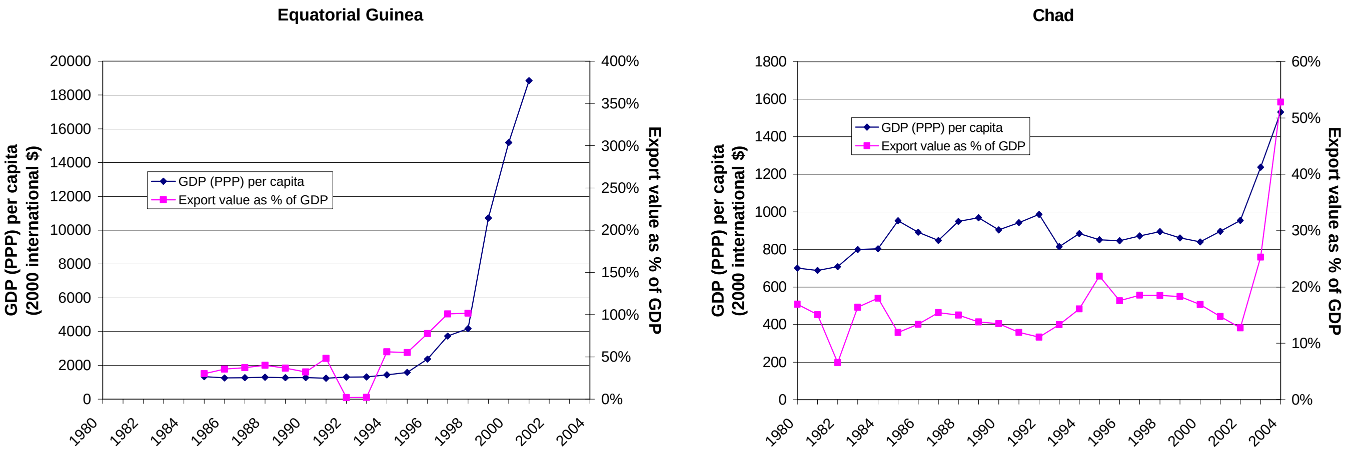

Figure 2. Sudden GDP increases in Equatorial Guinea and Chad can be traced to large surges in export revenues, in both cases oil exports.

Secondly, the GDP of a small, relatively poor economy can be greatly affected by changes in export revenues. Within SSA, Equatorial Guinea and Chad are illustrative examples. In both countries, GDP per capita increased dramatically in a short period of time, while the value of exports relative to total GDP increased similarly. Unfortunately, no export values are available for Equatorial Guinea after 1998 when the largest increase in GDP took place. In the case of Chad, the GDP surge can be traced to the opening of the Chad-Cameroon oil export pipeline in 2003. Obviously one cannot assume that this kind of sudden GDP growth reflects 'genuine' economic activity. Consequently, there is no reason to believe that GDP in these cases would show any strong correlation with energy use. The possibility of 'spurious' GDP growth must therefore be taken into account in empirical analyses. However, since it is conceivable that GDP growth induces an increased demand for energy services, it should not be ruled out that energy use would increase in the long run even in countries with spurious

GDP growth. Such a development would require that export revenues be channeled into productive activities that demand more energy, which is not necessarily the case.

2.1.7 An Alternative Measure: the Human Development Index

Since the GDP measure is afflicted with some problems that could compromise its reliability, it would be relevant to consider alternative indicators of development. Such indicators do indeed exist. The most established one is probably the Human Development Index (HDI), which is a composite index of life expectancy at birth, adult literacy rate, gross school enrolment ratio and GDP (PPP). For each indicator, every country is assigned an index between 0 and 1 according to its accomplishment relative to the best and worst performing countries. HDI is the average of the life expectancy, education, and GDP indexes. (UNDP, 2006)

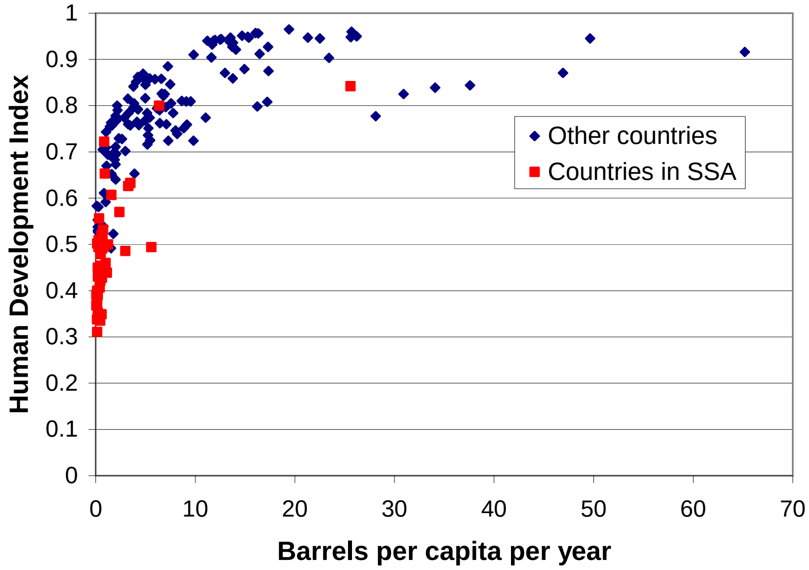

Figure 3. Oil use per capita versus Human Development Index 2004. The correlation is positive, but not linear. Source: UNDP, 2006; EIA, 2006c

Figure 3 illustrates the correlation between oil use and HDI. There is a positive correlation, but it is clearly not linear. Among more developed countries, there appears to be no advantage to be gained from higher oil use. Among countries of low development, on the other hand, the positive relationship appears to be very strong. Again, correlation does not necessarily mean direct causal relationship. But assuming that the implicated relationship actually exists, this result suggests that even a moderate increase in oil use would potentially do a lot more for human development in countries within SSA than in most other countries.

2.1.8 Conclusions

A 7% annual GDP (PPP) growth until 2030 would make SSA somewhat wealthier on average than India is at present. The factors that are commonly emphasized as crucial to enable such a development are infrastructural investments, institutional reforms and the removal of other internal obstacles. However, the use of energy is a prerequisite for virtually all economic activities. Although the GDP measure has some weaknesses as an indicator of economic activity and development, its widespread use motivates a study of the correlation between oil use and GDP. A positive correlation exists for GDP as well as the Human Development Index in relation to oil use per capita.

2.2 Oil - A Strategic Energy Resource for SSA

"Oil is unique in that it is so strategic in nature. We are not talking about soapflakes or leisurewear here."

- Dick Cheney at the London Institute of Petroleum, 1999 (Energy Bulletin, 2004)

2.2.1 The Usefulness of Oil

Energy is defined as the ability to do physical work. Since all human activities make use of physical work in some form, it is trivial to conclude that energy is an indispensable, *strategic*, resource. Moreover, as the first law of thermodynamics implies, energy cannot be created out of anything else than energy, but it can be converted into forms that society finds more useful. One example is the chemical energy of coal being converted to electrical energy in a power station.

In practice, society uses energy in many forms, several of which are solid, liquid, or gaseous fuels. The usefulness of a fuel is not only determined by its energy content, but also by its efficiency of use, transportability, storability, safety, cleanliness, and other physical characteristics. Different applications require different energy forms. However, oil and the liquid fuels derived from it have some important advantages:

- *Versatility.* They can be used as cooking fuels in simple stoves, in combustion engines and in electricity generators, to mention a few disparate applications.
- *Energy density*. They have a high energy content per volume and weight.
- *Transportability and storability.* Liquids are easier and cheaper to transport than gaseous and solid fuels, and they are easier to store than electricity.

The last point is particularly important within an African context, since it has implications for the amount of infrastructure that is needed to distribute and store energy. The distribution of liquid fuels only requires a minimum of physical infrastructure to be operational. Gasoline can basically be sold in glass bottles by the roadside. A fuel system based on gas or electricity, on the other hand, would require much larger investments in infrastructure to work effectively. Such a system would therefore be more difficult to implement, particularly in many rural parts of SSA.

Figure 4. Gasoline for sale in the countryside of Mali. With kind permission from Frederic van Haute.

While the physical properties of fuels determine their usefulness in different applications, there is also another important factor to be taken into account, namely how much the *production* of a fuel costs in terms of energy. If a fuel costs as much energy to produce as it contains, then it does not give any net contribution of energy to society. The problem with alternative liquid fuels such as ethanol and biodiesel is that they generally require a lot of energy in their production compared to the extraction of fossil fuels. (Cleveland, 2005)

2.2.2 The 'Oil Dependence' of SSA

It would be relevant to obtain some quantitative measure of SSA's 'oil dependence', the extent to which SSA relies on oil for its energy needs. In order to do that, it is necessary to add different energy sources together into some measure of total energy use. Such an addition is usually done on the basis of the *heating value* of the energy - the amount of heat that can be obtained. The heat is either measured in joules (J), calories (cal), British thermal units (Btu), or tonnes of oil equivalent (toe). However, this way of adding different energy forms together has a disadvantage: it gives the impression that a joule of oil and a joule of coal are interchangeable, which is not the case. It does not take into account all the physical properties that determine the usefulness of a specific energy form. Often these unique physical properties are more important than the heating value. (Zarnikau *et al.*, 1996)

Keeping in mind that heating value is a crude basis for measuring oil dependence, it still can give some indication of how important oil is as an energy source. Consequently, 'oil dependence' has here been defined as the heating value of the oil that is used, as a percentage of the total heating value of all the commercial primary energy sources coal, oil, gas, hydroelectricity, and geothermal electricity. Non-commercial energy such as traditional biomass is not included due to lack of data. According to figures from EIA, the heating value of all commercial primary energy sources consumed in SSA in 2004 was 3.296 quadrillion (10^{15}) Btu's, or 3.478 exajoules (10^{18}). Of this total amount, 2.062 exajoules, or 59%, was obtained from oil. (EIA, 2006c) In 1980, the fraction of oil was 62%, so it has not changed significantly in 24 years.

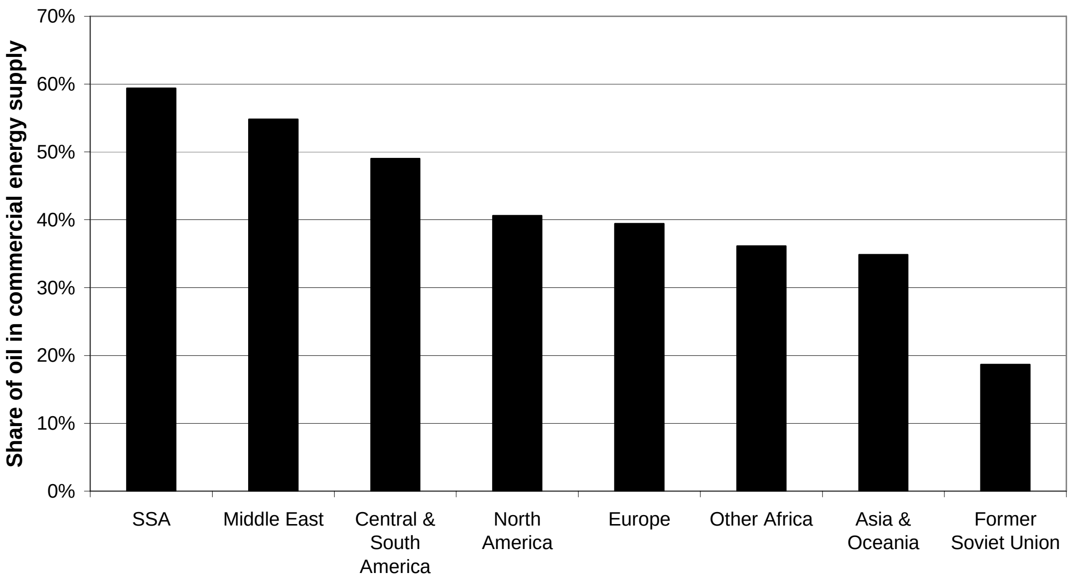

Figure 5. The share of oil in commercial primary energy supply by region in 2004. Source: derived from EIA, 2006c

A comparison with other major regions in the world reveals that SSA, by this measure, has the highest level of oil dependence. Oil thus appears to have a more dominating role as a commercial energy form in SSA than anywhere else in the world. It should also be noted that a number of countries, including Benin, Burkina Faso, Cape Verde, Chad, Comoros, Djibouti, Eritrea, Gambia, Guinea-Bissau, Liberia, Mauritania, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia and Sudan, depend on oil as a commercial fuel to more than 90%.

2.2.3 Where the Oil Is Used

In order to understand the importance of oil in more depth, it is necessary to look at the specific uses. In certain applications, oil is difficult to replace and therefore a strategic energy resource. In other applications, alternatives may be available.

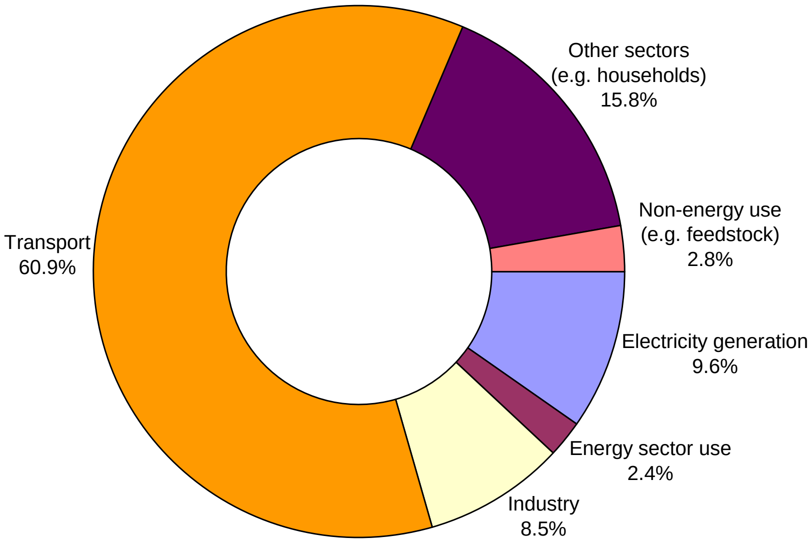

Figure 6. Oil use in SSA 2004 by sector. Consumption by weight has been converted to volume using the conversion factors in Appendix 1. Source: Derived from IEA, 2006c

IEA publishes oil consumption data by different end uses. (IEA, 2006c) From these data, it is evident that the transport sector by far is the largest oil user (60.9% of the oil in 2004), followed by unspecified sectors (primarily households, 15.8%), and electricity generation (9.6%). Since it is difficult to keep track of all end uses within SSA, these percentages should probably be viewed as approximates. The following paragraphs describe the strategic importance of oil within the three most oil consuming sectors transport, households and electricity generation.

2.2.3.1 Transport

Apart from the significant transport work done by humans and draught animals, transport in SSA is almost completely dependent on oil based liquid fuels. The bulk of the fuel is used by road traffic. Although some use of ethanol from sugarcane and biodiesel from plant oils occurs, renewable liquid fuels do not contribute significantly. In aviation, no economic alternative to liquid fossil fuels currently exists.

Increasing the fuel efficiency of motor vehicles is one feasible strategy to reduce oil use.

However, introducing cars with more efficient engines takes time, since the replacement of the existing vehicle fleet is slow. A study of the conditions in the U.S. revealed that the average age of an automobile was 9 years, and that replacing half of the automobile fleet would take 10-15 years under normal conditions. (Hirsch *et al.*, 2005) There is no corresponding data available for SSA. But since the vehicle fleet can be assumed to have a higher average age, replacement would probably take even longer than in the U.S.

The railroads of SSA currently lack the capacity to become a serious alternative to road transport. This puts SSA in a considerably more precarious situation than, for example, China and India, which both have comprehensive rail networks. The existing lines were primarily built to facilitate the export of natural resources, not to distribute goods or passengers domestically. Therefore, rail lines are often poorly integrated, and also often poorly maintained. Moreover, virtually no railroads are electrified, so rail traffic is dependent on diesel, or occasionally steam coal.

2.2.3.2 Households

Particularly in rural areas, traditional woodfuels still provide most of the energy needed for cooking, lighting, heating and running of small-scale businesses. However, the transition from woodfuels to commercial energy forms has become a political goal, since the burning of wood causes indoor air pollution and in some places contributes to deforestation. The Forum for Energy Ministers of Africa (FEMA) therefore has set as a target that 50% of inhabitants in rural areas should use modern energy for cooking. (FEMA, 2006) In practice, modern energy means either kerosene or liquefied petroleum gas (LPG), both oil based products. A few countries have been very successful in promoting the use of these fuels. For example, the government of Senegal encouraged and subsidized the use of LPG as a means to combat desertification, and Botswana managed to increase the penetration of LPG as a cooking fuel in urban and peri-urban households from 30% to 74% in 15 years. (FEMA, 2006)

2.2.3.3 Electricity Generation

Relative to other regions, SSA is quite dependent on oil for electricity generation. 14% of the electricity distributed by power utilities in 2004 was produced in oil-fuelled power stations. Since there are several alternative ways of generating electricity, this is not a very efficient use of the oil. As is illustrated in figure 7, while SSA has remained on the same level of oil dependence throughout the period 1980-2004, China has managed to reduce its reliance on oil-fuelled power stations dramatically from 29% in 1980 to 3% in 2004. This development has occurred mainly through an immense expansion of coal-fired power capacity. Extensive use of coal is also the main reason behind the low oil dependence of India. However, coal is a primary energy source unavailable to most countries in SSA.

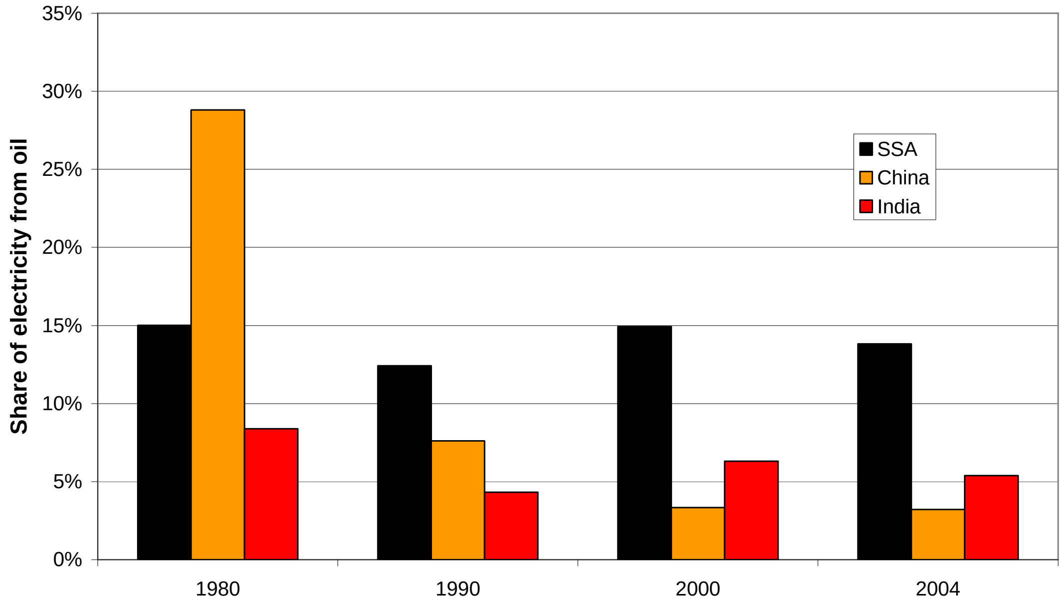

Figure 7. Dependence on oil as a fuel in power utilities. Source: Derived from IEA, 2006c

Power utilities are not the only sources of electricity in SSA. Many users rely on private diesel generators for their electricity needs. The reason might either be lack of a comprehensive power grid, or blackouts being so frequent that a backup supply is necessary anyway. A certain fraction of the diesel that is ascribed to transport in figure 6, is in reality probably used to run diesel generators. Unfortunately, it is impossible to determine how large a fraction of the total oil use these generators stand for. However, some indication of the reliance on private generators can be found in the company surveys performed by the World Bank (2007a).

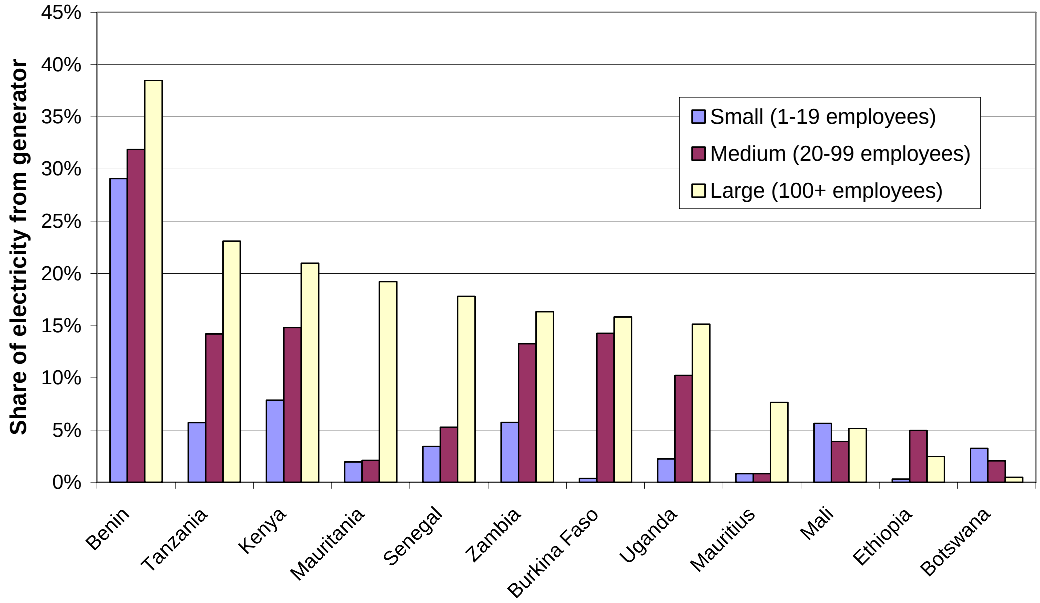

Figure 8. Reliance on privately generated electricity in selected countries, as reported by firms of different sizes. Source: World Bank, 2007a

The reliance on private generators varies quite substantially among countries. In Benin, firms on average report that they get more than 30% of their electricity from generators. In Mauritius, Mali, Ethiopia and Botswana, private generators appear to play a much smaller role. A general pattern is that large firms, which can be expected to be the largest electricity users, tend to be more reliant on generators than smaller firms.

It would in principle be possible to phase out all the oil that is presently used in electricity generation. The technology needed to do that is known. However, it is a matter of enormous investments in generating capacity and power grids. Even if all the oil-fuelled power utilities were replaced, it would only erase about 10% of the present oil use. Decreased use of diesel generators would save some additional oil. This could be achieved through improved reliability of the existing power grids, the extension of grids to currently unelectrified areas, and the promotion of small-scale renewable electricity generation. Naturally, this is a long-term project. An additional obstacle is that diesel generators are powerful enough to provide energy services that would be difficult to obtain from alternative systems such as photovoltaics.

2.2.4 Conclusions

Oil has several physical characteristics, such as high energy density, versatility and convenience in distribution, that makes it a particularly useful and strategic energy resource in SSA. A crude measure of oil dependence, based on heating value, indicates that SSA relies on oil as a commercial fuel to a larger extent than any other region. More specifically, oil is of strategic importance as a transport fuel. The lack of railway capacity makes road traffic particularly critical. In households, oil is becoming increasingly important as a superior substitute for woodfuels. In electricity generation there is a technical potential to replace oil with other energy sources. However, even in this sector the phasing out of oil-fuelled power plants and diesel generators will be a long-term project requiring large investments.

2.3 The 'Peak Oil' Concept

2.3.1 The Debate

It is an obvious fact that a finite and non-renewable resource, such as oil, cannot be extracted indefinitely at an ever-increasing rate. At some point, as the scarcity increases, naturally given constraints will force the extraction to peak and then decline. So 'Peak oil' is, in its essence, a trivial concept. To determine more precisely when Peak oil will occur, however, is not equally trivial. This is what the so-called Peak oil debate is all about. This debate is not only taking place in the realm of natural science. Most analysts recognize the crucial importance of oil to the world economy, and consequently understand that recognition of Peak oil is not only a matter of science, but also has profound economical and political implications. As a consequence, the debate has been polarized between 'pessimists' who predict a peak in the near future and want to give the issue a high political priority, and 'optimists' who see no immediate need to depart from business-as-usual. The 'pessimists' consist to a large extent of geologists and other natural scientists, while the 'optimists' are mainly economists, oil company representatives, and analysts at official agencies such as IEA and EIA.

A number of analysts, including geologists Colin Campbell and Jean Laherrère together with other members of the research network Association for the Study of Peak Oil and Gas (ASPO) forecast a global peak in the period 2010-2020. Some even set the magic date before 2010. (Koppelaar, 2005) In contrast IEA, whose director has outspokenly declared distance to the idea of an imminent peak, expects the oil supply to fill rising demand until "at least 2030", given that new oil is discovered as projected by the U.S. Geological Survey. (IEA, 2006a) Cambridge Energy Research Associates (CERA), a private consultancy firm, has also taken a stand in the debate by publishing a report titled *Why the 'Peak Oil' Theory Falls Down*. Instead of an imminent peak, they envision the onset of an 'undulating plateau' in oil production at some point after 2030. (CERA, 2006)

2.3.2 Predicting the Peak

Production from individual oil fields peak at some point during their lifetime and then goes into decline. Whether the decline can be offset depends on the availability of new fields that are ready to be brought into production. One self-evident precondition is that these new fields have been discovered. In the world's most thoroughly explored region, continental United States, discoveries peaked as early as in the 1930s. The American geophysicist M. King Hubbert extrapolated the declining discovery trend to get an estimate of the ultimately recoverable resource (URR), that is, the total amount of oil that would ever be found and produced. Hubbert draw the logical conclusion that production in the U.S. could not continue to grow as discoveries declined. Production would have to mirror the history of peaking and declining discoveries. In 1956, equipped only with his estimate of URR and a simple model assuming that production would follow a bell curve, Hubbert predicted that U.S. oil production would peak when 50% of the oil was gone, in the interval 1966-1971. Production did indeed peak in 1970. (Koppelaar, 2005) Since 1970, one oil province after another has passed the 'Hubbert peak'. Even North Sea, a young province that was aggressively developed in the wake of the oil crises of the 1970s with state-of-the-art technology, has been in rapid decline since 1999.

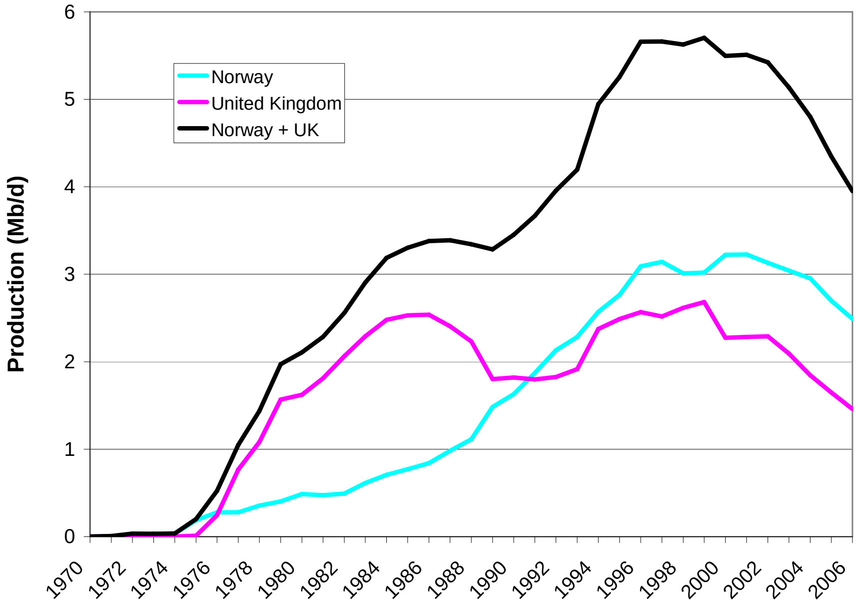

Figure 9. Oil production of Norway and the United Kingdom. Production in the North Sea peaked in 1999. Source: EIA, 2006d

Although the idealized bell curve was successful in predicting the peak in the United States, the model has weaknesses. It assumes that exploration and production are not limited by anything but geological circumstances. Figure 9 gives a good illustration of how other events can affect production. The drop in U.K. production in the early 1990's was not initiated by geology, but by a serious fire accident at the platform Piper Alpha in 1988. The following safety adjustments brought down production for a few years. (Robelius, 2005) Another difficulty when working with the bell curve model is the importance of a reliable estimate of global URR. New discoveries and reassessments of existing reserves make URR a dynamic variable. A large part of the Peak oil debate is therefore centered on the question how to make a good estimate of global URR. The difficulties and uncertainties associated with this task are touched upon in the following paragraphs.

2.3.3 How Much Oil Is There?

Defining what is meant by 'oil' is not completely straightforward. Oil is a liquid that comes in many grades. There is light oil and heavy viscous oil; oil that is high in sulphur ('sour') and low ('sweet'). The chemical characteristics affect the usefulness and commercial value of the oil. The light, sweet oil is easier to refine into products like gasoline, and is therefore more sought after. In addition to the regular crude oil, a compilation of the world's total oil supply usually includes condensates and other natural gas liquids (NGL). On top of this 'conventional' production from traditional petroleum reservoirs, there are also 'unconventional' sources: extra heavy bituminous oil (e.g. from oil sands), and synthetic oil from coal.

If one considers all resources, conventional and unconventional, to be potentially substitutable and equivalent oil reserves, then Peak oil does not appear to be imminent. According to a recent publication from the Cambridge Energy Research Associates (CERA), the world still has more than 3 700 Gb left of a global URR close to 5 000 Gb. (CERA, 2006)

Cumulative production	1 078 Gb
Known reserves: OPEC Middle East Other conventional	 662 Gb 404 Gb
Deepwater	61 Gb
Arctic	118 Gb
Enhanced oil recovery	592 Gb
Extra heavy oil	444 Gb
Oil shale	704 Gb
Exploration potential	758 Gb
Total	4 821 Gb

Table 1. Potential conventional and unconventional reserves, according to Cambridge Energy Research Associates. (Source: adapted from CERA, 2006)

However, a closer look at the parts adding up to this grand total causes some doubts. First and foremost: are these different resources comparable? Conventional reserves and deepwater can be developed with well-known technology, although deepwater production is complicated and expensive; extra heavy oil is currently extracted, but on a relatively limited scale; and large scale oil shale extraction has not yet even proved to be commercially feasible. The result one gets when adding these different 'oil' resources together is, in the words of oil analyst Chris Skrebowski, "a collection of apples and pears along with a couple of lemons." (Skrebowski, 2006a) The current development of the oil sands in Canada may illustrate the limitations of unconventional oil production. The Canadian oil sand resource is undoubtedly very large. When included in the officially proven reserves, it makes Canada the country with the largest reserves after Saudi Arabia, but large reserves do not automatically translate to a high rate of production. Oil sand extraction requires a lot more energy than conventional production, and most of this energy is obtained from locally available natural gas. The dependence on limited supplies of natural gas, together with problems of ground and water pollution, will put a limit to the practically achievable rate of extraction. (Söderbergh et al., 2007) In the light of these circumstances, it is doubtful whether the oil sands really ought to be included in the proven reserves along with conventional oil. To sum up: there is indeed plenty of 'oil' remaining in the ground, but since conventional and unconventional resources are subject to different production limitations, they cannot be treated as interchangeable.

2.3.4 The Problems of Reported Reserves

As for the estimated reserves of conventional oil, there is a lot of confusion. Geologists generally use a probabilistic approach when estimating the amount of recoverable oil in a field. This yields several estimates from a probability function: a low estimate that will be exceeded with 90% probability (this estimate is sometimes labeled P90), another estimate that is the median (P50), and the mean value ('best guess'). The problem is that there is no universal consensus as to how reserve estimates should be reported or interpreted. The American oil industry has traditionally distinguished between reserves that are ‘proven’ (1P), ‘proven+probable’ (2P), and ‘proven+probable+possible’ (3P). However, the US Securities and Exchange Commission for a long time only allowed American oil companies to publish the proven value (1P) as their reserve estimate. The consequence of initially publishing very conservative estimates is that the reserves are likely to be adjusted upwards as time goes by. The resulting *reserve growth*, meaning increased reserve estimates and extensions in already known fields, is commonly interpreted as a sign of technological progress that enables recovery of previously unrecoverable resources. However, a number of analysts dismiss a substantial part of this reserve growth as a product of misleading initial reserve reporting. (Laherrère, 2006) If reporting the ‘best guess’ estimate had been the standard procedure, subsequent upward and downward adjustments would cancel out, according to their view.

To complicate matters, different countries follow different practices when reporting reserves. As mentioned before, American companies have traditionally reported conservatively. Meanwhile, other countries have reported 2P values, and yet others have reported conspicuously large figures. Over a few years between 1985 and 1990, several OPEC members, including Saudi Arabia, Kuwait, Iraq and Iran, suddenly increased their proven reserves by almost 300 Gb in total. (Campbell & Laherrère, 1998) They had an incentive to report large reserves, since the OPEC production quota was set partially in proportion to the reserves. Moreover, several countries have then reported unchanged reserves year after year, despite the fact that they have been producing continuously.

The lack of transparency, and the fact that some countries have systematically underestimated their reserves while others most probably publish overestimates, has rendered the public record of proven reserves virtually useless for determining the true size of oil reserves over time. When reported by an official agency like EIA, the proven reserves appear to increase steadily over the years, showing no sign of leveling off. The main alternative sources of reserve data are the private databases of the two consultancy firms IHS Energy and Wood Mackenzie. When their data are used to adjust discoveries to their 2P value, and unconventional reserves and other suspicious additions are disregarded, the situation immediately appears to be a cause for concern. According to data presented by geophysicist Jean Laherrère (see figure 10) conventional reserves have been in decline continuously since around 1980, which means that the world has been consuming more oil than has been found for the last 25 years.

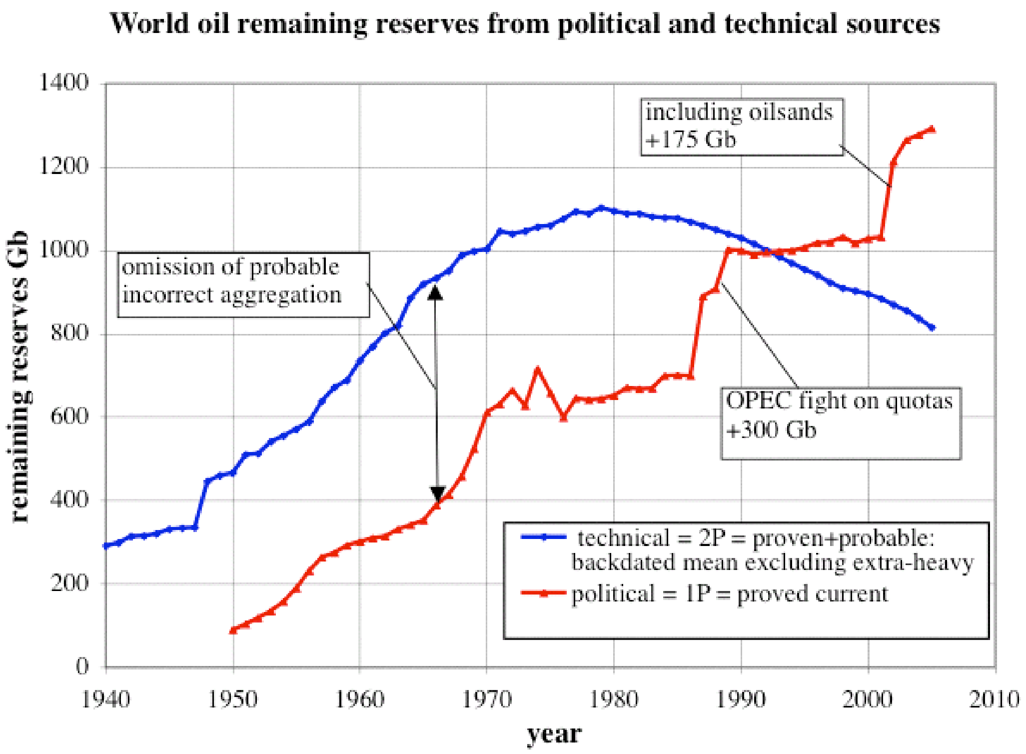

Figure 10. Comparison of 'political' reserve estimates from EIA and 'technical' estimates based on industry databases. (Laherrère, 2006)

2.3.5 Declining Discoveries and the Dependence on Giant Fields

A trend where consumption exceeds discoveries is obviously not tenable in the long run. A disturbing fact is that the discovery of 'giant' fields seems to be mainly a thing of the past. A giant is defined as an oil field with an estimated URR exceeding 0.5 Gb. Giants only constitute about 1% of the total number of discovered fields, but the production from just the 100 largest giants represented 46% of total world production in 2004. (Robelius, 2005) In other words, a relatively small group of large oil fields is the backbone of our present oil supply. Not only are the super giants few, they are also aging. The discoveries of new giants have been in continuous decline since the 1960s. Of the world's 20 largest oil fields ever found, the great majority is grouped around the Persian Gulf, and the last one of these 20 fields was discovered in 1979. (Robelius, 2007a)

That the average size of new discoveries tends to decline over time is not really a mystery. A large field is simply more likely to be found at an early stage than a small one, due to its sheer size. (Campbell, 2005) More sophisticated exploration technologies, such as 3D seismic, has not fundamentally altered this downward trend in discovery size, making it increasingly unlikely that any significant number of huge oil fields still waits to be discovered. The discovery trend is roughly reflected in the way developments are made. Developers naturally prefer to exploit the largest, cheapest, most convenient and safest fields available at any given time, and then move on to less attractive developments as the earlier fields mature.

The U.S. Geological Survey (USGS) published an influential assessment of the amount of petroleum resources yet to find (USGS, 2000), where they estimated the world URR for conventional oil and NGL to be 3345 Gb, of which the undiscovered resources that would be found in the period 1996-2025 amounted to 939 Gb. Both IEA and EIA refer to this study as the authoritative assessment in their *World Energy Outlook* and *International Energy Outlook* respectively. It is also the basis for the 758 Gb estimate of 'exploration potential' presented by CERA in table 1. However, by the end of 2004, when 30% of USGS's forecasting period had passed, only about 17% of the expected oil had been discovered. (Stark & Chew, 2006) This result is consistent with the observed decline in discoveries over the last decades. Lack of access to promising areas for exploration could possibly contribute to the disappointing result, but the development so far certainly does not add credibility to USGS's estimate of 939 billion undiscovered barrels.

2.3.6 The Promise of Technology

If there is one single issue where 'optimists' and 'pessimists' have particularly contrasting views, it is on the subject of production technology and its future potential. The 'optimists' claim that the idea of an imminent peak is based on a static view of technology and a disregard of the growth in reserves being caused by technology improvements (CERA, 2006), while 'pessimists' counter that reserve growth to a large extent is a reporting phenomenon, and present examples of fields where increased reserve estimates have not resulted in increased production. (Campbell, 2005)

It is important to distinguish between the impacts of different extraction technologies in order to understand what roles they might play in the context of Peak oil. It is of crucial importance whether a technology is mainly increasing the production rate or improving the ultimate recovery. Any technology that enables production from previously inaccessible regions, such as ultra-deepwater or the Arctic, contributes in both respects, since it makes feasible new production capacity and simultaneously adds to recoverable resources. As for new technology applied to already producing fields the picture is more complex. A number of technologies are available to developers when the spontaneous flow of oil diminishes as reservoir pressure goes down. Gas and water injection in order to maintain reservoir pressure is today routinely used, and is called secondary recovery. (Campbell, 2005) It is also possible to subsequently apply tertiary recovery, or enhanced oil recovery (EOR), in which the physical properties of the oil are altered with the injection of chemicals, CO_2, nitrogen or steam to make it flow more easily. Pumps can also be used when the reservoir pressure becomes insufficient. Advancements in drilling techniques have enabled horizontal and 'fishbone' well drilling as a complement to the common vertical wells. To what extent these technologies are production rate enhancing or recovery enhancing is subject to debate. Laherrère argues that horizontal drilling and other EOR technologies in several large fields actually have only boosted production rates for a short time without increasing the URR of fields. (Laherrère, 2006) If this turns out to be true in a majority of cases, then these technologies merely offer a trade-off between a high present production rate and the ability to maintain it in the long-term.

In some instances, changes in technology and production practices may genuinely increase the percentage of recoverable oil in a field, the so-called *recovery factor*. Under such conditions, technology indeed induces reserve growth. However, these measures are largely applied to mitigate decline rather than to restore production to peak level. (Campbell, 2005) Mitigating decline is indeed a good thing, since it could make a global production peak less dramatic. In that sense it might turn out to be much more helpful than any technology that enables a boost in production for a few years followed by a steep decline. Decline mitigation might even delay the arrival of the peak somewhat by decreasing the shortfall that must be replaced with new production capacity, but it cannot by itself postpone the peak. Ultimately, there will come a point where the addition of new capacity can no longer offset the decline in already existing production.

As with estimates of future discoveries, many estimates of future reserve growth can be traced to the petroleum assessment conducted by USGS in 2000. The authors of the assessment stated explicitly that the understanding of circumstances regarding global reserve growth was poor. Nonetheless, they drew the conclusion that reserve growth was too important a phenomenon to be entirely disregarded, despite the methodological uncertainties. In the lack of a better approach, USGS based their estimate of global reserve growth on the well-documented U.S. case, assuming that the rest of the world would experience the same pattern of growth in reserves as the U.S. The resulting best estimate of reserve growth outside the U.S. in the period 1996-2025 was 612 Gb of crude oil and 42 Gb of NGL, an increase of 44% and 56% respectively relative to known reserves. (USGS, 2000)

Skeptics have not been late to point out that the U.S. experience is hardly representative to the world as a whole. (Campbell, 2005) It has already been mentioned that the conservative reporting practices in the U.S. made reserve growth particularly likely. This is not necessarily the case in countries with different reporting practices. There are, in other words, indications that USGS's estimates are on the optimistic side.

With all the abovementioned factors in mind, there are three questions that should be asked when evaluating the 592 Gb that CERA has attributed to enhanced oil recovery in table 1.

(1) To what extent could this figure be an over-optimistic extrapolation of the U.S. experience?
(2) Are new technologies genuinely expanding reserves or mainly increasing production in the short-term?
(3) If new technologies indeed will expand reserves by 592 Gb, to what extent will that result in new production capacity, in addition to merely a slower decline rate?

2.3.7 Conclusions

Despite all the uncertainties that surround the Peak oil issue, it is possible to formulate a few general conclusions. The reserve data that is available in the public domain is unreliable. Consequently, any forecast that is based on these data is unreliable as well. Access to private industry databases removes some sources of error and bad reporting. However, there is still a lot of uncertainty regarding the short-term impact of new technology, market dynamics, political events, etc. How far the 'oil age' will stretch into the future depends on the ultimate size of reserves, but the timing of the peak will be determined by changes in production capacity, which is a different issue.

The Peak oil debate is not about whether oil production will peak or not, but whether it will do so very soon or a bit further on. Even analysts who rely on arguably optimistic estimates of future oil reserves do not rule out disruptions in oil supply within 30 years. In the perspective of long-term economic development, 30 years is not a long time.

2.4 Oil Production in SSA

2.4.1 SSA's Oil Industry at a Glance

There are currently 11 net oil exporters in SSA: Nigeria, Angola, Sudan, Equatorial Guinea, Cameroon, Gabon, Congo-Brazzaville, Congo-Kinshasa, Côte d'Ivoire, Mauritania and Chad. Ghana and Benin are or have recently been producing oil in amounts too small to cover their own domestic needs. The two dominant oil states are Nigeria and Angola, both in terms of present rate of production and estimated proven reserves.

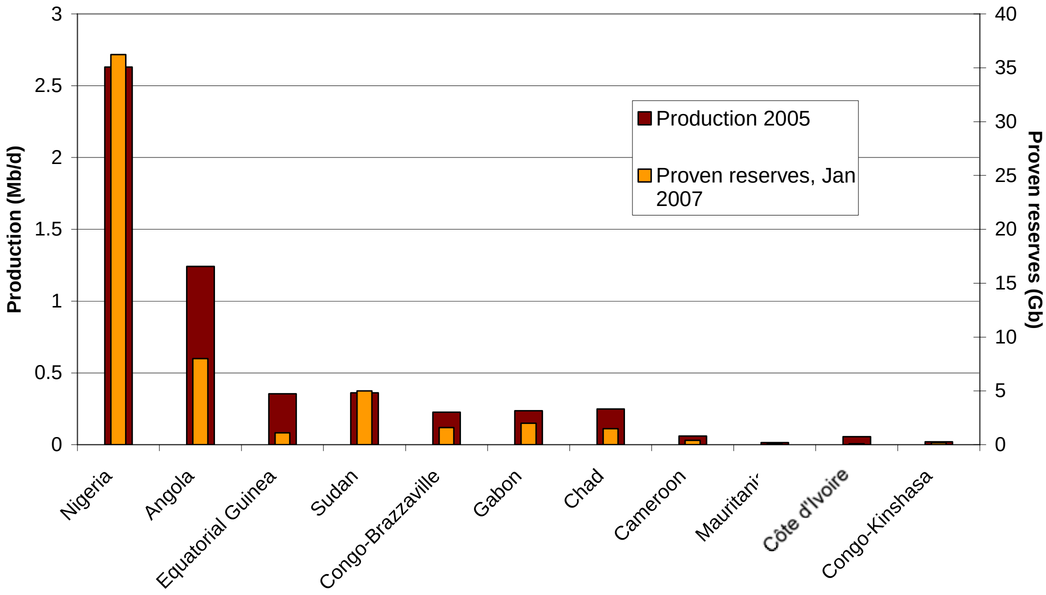

Figure 11. Oil production (all liquids) and estimated proven reserves according to Oil & Gas Journal. Mauritania's production figure of 15,000 b/d is from 2006. Sources: EIA (various Country Analysis Briefs); OGJ, 2006

SSA is currently not a major oil-producing region. It stood for only 6% of world oil supply in 2004. (EIA, 2006c) Its share, however, has the potential to increase in the next few years.

The geological provinces that are known to contain oil are limited in size compared to the total area of SSA. The lion's share of the known oil is located in the basins of the Niger Delta and further south along the west-central coast. Other identified oil provinces are the coastal area of Senegal and Mauritania, and an inland basin stretching through southern Chad and Sudan. (USGS, 1997)

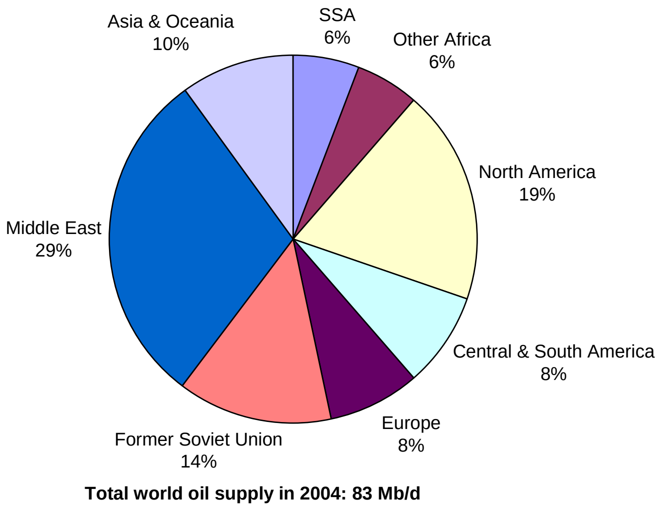

Figure 12. Regional contributions to world oil supply in 2004 (all liquids). Source: EIA, 2006c

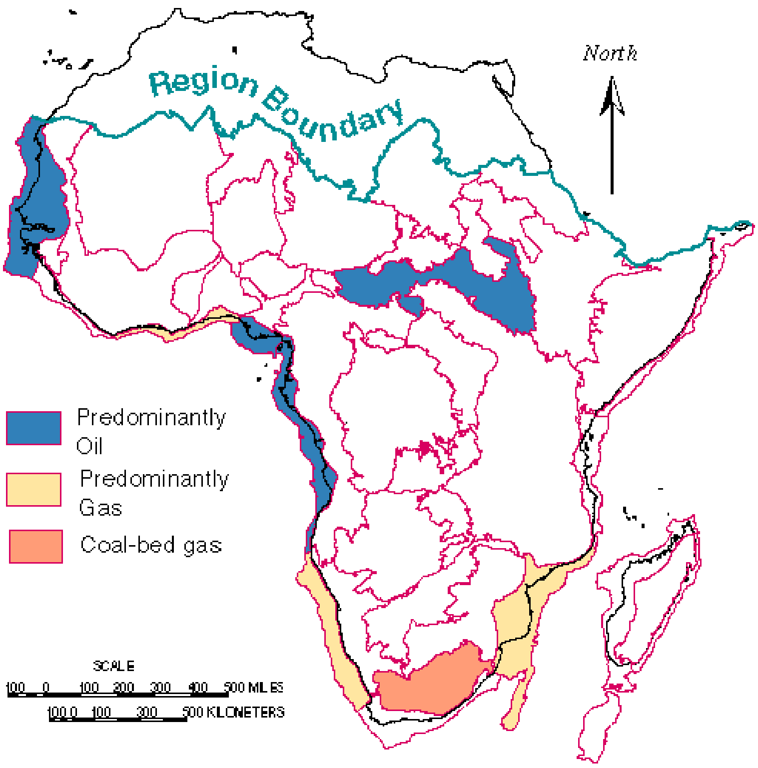

Figure 13. Oil and gas provinces in SSA. Source: USGS, 1997

2.4.2 Deepwater - Great Expectations

Along with the Gulf of Mexico and Brazil, West Africa is an important area for deepwater exploration and production. The region has been said to attract over 40% of the spending in deepwater exploration and production over the next few years. (Offshore West Africa, 2006) However, the history of discoveries gives cause for some concern. 1998 has hitherto been the most successful exploration year, and subsequent years have shown a clear downward trend in discoveries.

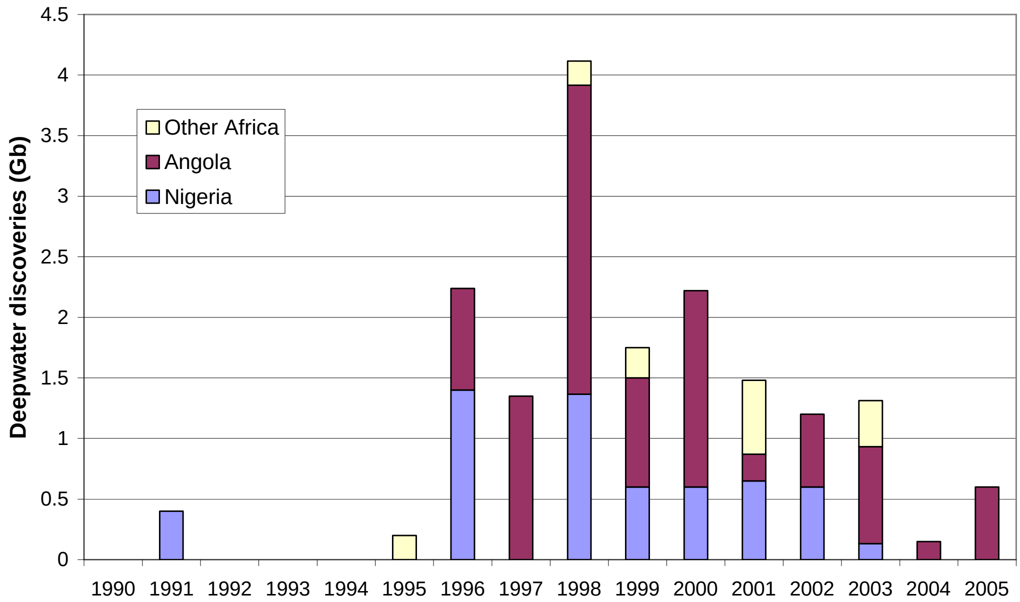

Figure 14. Deepwater discoveries in SSA. Source: Robelius, 2007a

What distinguishes deepwater from conventional offshore production is naturally the water depth. There is no universally agreed depth limit, but oil production from wells 400-500 meters under sea level is usually referred to as deepwater production. Fields at a depth that borders the limit of what is technically possible to develop, currently about 1 500 meters or more below sea level, are called 'ultra-deepwater'.

Just like any petroleum exploration, deepwater exploration is about identifying the special geological circumstances that indicate a promising *petroleum system*. If a petroleum system is to contain recoverable petroleum, it must fulfill three criteria:

- There must be a *source rock* containing ancient organic material, buried at a depth where it has been liquefied or gasified by the heat.
- There must be a porous *reservoir*, e.g. a sandstone layer, where the liquid or gaseous hydrocarbons can accumulate.
- The reservoir must be covered with salt or some other impermeable layer forming a *trap*, otherwise the hydrocarbons will migrate upwards and finally dissipate into the seawater. (Leffler *et al.*, 2003)

Explorers have advanced analytical tools and software to facilitate the examination of submarine geological structures from the sea surface and reduce the risk of throwing away large sums on failed projects. However, in order to finally prove the presence of hydrocarbons, an exploration well, a 'wildcat', must be drilled.

What really makes deepwater special is the complexity and expensiveness of all underwater operations. Drilling a well in deepwater may cost $25 million, or ten times more the cost of a well in shallow waters on a continental shelf. (Leffler *et al.*, 2003) For this reason no more wells than necessary are drilled, which means that a large oil flow from each producing well is needed for the project to be commercially viable.

Depending on the water depth and other environmental and infrastructural factors, a number of different production systems can be applied. The system of choice for West African projects is a Floating production, storage, and offloading (FPSO). An FPSO is basically a ship stationed above the oil field and hooked up to the risers that lead the oil from the wells. Several wells, sometimes drilled in individual but adjacent small fields, may be delivering oil to a single FPSO. On board are processing facilities where the oil is separated from associated gas and water. If there is a local market for natural gas, it may be pumped ashore. Otherwise it is usually re-injected into the oil reservoir through special injection wells. This helps to maintain the pressure within the reservoir that makes the oil flow into the extraction wells. It is also a way of avoiding gas flaring, which is a wasteful practice as well as environmentally destructive. Gas flaring still occurs to some extent in West Africa. The Nigerian government has had the ambition of phasing out gas flaring by 2008, but that will probably not be achievable. (Amadi et al., 2006)

The large upfront investments that are required in deepwater development, gives the operator a strong incentive to get revenues by up scaling production to the designed maximum capacity as quickly as possible. Therefore, deepwater production tends to plateau early. The plateau production is then maintained until the reservoir pressure drops. Mature fields that have been developed using this intensive extraction strategy, have shown a dramatic decline in production. (Robelius, 2007b)

2.4.3 The ‘Resource Curse’

Since oil is such a coveted and valuable commodity, one could believe that sitting on large oil resources would be most fortunate for a country, especially for a poor country with no other significant sources of income. In reality, the exact opposite has turned out to be true. Developing countries that rely heavily on oil exports tend to have more people in poverty, more corruption and more violence than non-oil exporting countries. Several causes for this ‘resource curse’ have been suggested:

- Oil production is a technically advanced business that has few jobs to offer to the unskilled local labor force. Therefore the oil industry becomes isolated from, and does not contribute to, the local economy. On the contrary, exchange rates are driven up by the oil exports, making other potential exporting sectors uncompetitive on the world market. This tendency of decreasing economic diversity is sometimes called the ‘Dutch disease’.
- The local government is awash with ‘easy money’ from oil rents instead of depending on tax revenues from its own population. This does not encourage accountability to the citizens or responsiveness to popular protests.
- The volatility of oil prices makes public finances vulnerable. Long term economic planning is rendered difficult.
- Whoever is controlling the state also controls the money flows. Struggle for control over the oil revenues may turn into civil war, especially if there are ethnic or religious tensions already present. (Karl, 2005)

To a larger or lesser degree, all the problems outlined above have plagued the oil exporters of SSA. Of the 16 nations that are ranked as the most corrupt in the world, eight are oil exporters in SSA. (TI, 2006) Not least the political and economic situation in Nigeria and Angola, given both countries' resource potentials, is commonly characterized as a 'paradox'. (e.g. Obi, 2004; Hodges, 2004) In the following paragraphs are presented the issues relating to the oil resources in the three major producers Nigeria, Angola and Sudan.

2.4.3.1 Nigeria

SSA's most populous country, with a population of around 130 millions, is also the largest oil producer. Nigeria has been a member of OPEC since 1971, and like the other member countries it has a tradition of strong governmental regulation of the oil industry. The great majority of the oil production is operated by one of the several oil multinationals that are present, such as Shell, ExxonMobil, Chevron and Total, but in joint ventures with the Nigerian National Petroleum Corporation (NNPC) as the major shareholder. (EIA, 2006a) A few projects are arranged as production-sharing agreements (PSA), where the operator takes the whole financial risk while the government, as the ultimate owner of the nation's natural resources, collects a share of the revenues.
In October 2006, OPEC decided to reduce Nigeria's production quota from 2.3 to 2.2 Mb/d. A further 42,000 b/d production cut is planned as of February 2007. (OPEC, 2007a) In contrast to this imposed production ceiling, the declared ambition of the Nigerian government is to increase production to 4.0 Mb/d until 2010. (EIA, 2006a)

Nigerian oil production is concentrated around the delta of the Niger river. The area contains several hundred small fields, both onshore and in the shallow waters outside the delta. Current exploration efforts are focused on the deepwater regions further south and in the Bight of Benin. The production from these areas is still small relative to the Niger Delta, but future production increases are dependent on the development of deepwater fields. (EIA, 2006a)

One incentive for oil companies to move offshore is the troublesome relation to the local population of the Niger Delta. In the view of local communities, they have come to pay the costs of oil production in the form of environmental destruction, without receiving a fair share of the profits from the federal Nigerian government and the oil multinationals. The Niger Delta is criss-crossed by a deteriorating pipeline network. Occasionally pipelines rupture and the resulting oil spill may destroy hundreds of acres of nearby farmland and pollute the water. (Amadi et al., 2006)

The sense of dispossession and injustice felt by the residents of the Delta has partially been channeled into peaceful protest movements, such as the Movement for the Survival of the Ogoni People (MOSOP) initiated by the activist Ken Saro-Wiwa, but increasingly also into organized violence. Vandalism of pipelines and kidnappings of oil company employees have become daily features in Nigerian news media. (Obi, 2004) During 2006, a group calling itself the Movement for the Emancipation of the Niger Delta (MEND) performed several well-coordinated attacks against oil facilities, took hostages even from an offshore platform, and sank navy gunboats. Their actions occasionally brought down up to 25% of Nigeria's oil production. (Junger, 2007) MEND's goal, unless its political demands of redistribution of oil revenues and development aid to the Delta were not met, was too clearly stated to be misunderstood:

“Our aim is to totally destroy the capacity of the Nigerian government to export oil.” (Junger, 2007) The federal government, both under the present civilian rule and under preceding military dictatorships, has given priority to the economic interests of oil companies. Acts of protest in the Delta, be it militant or peaceful, have repeatedly been answered with military raids. (Obi, 2004; Junger, 2007)

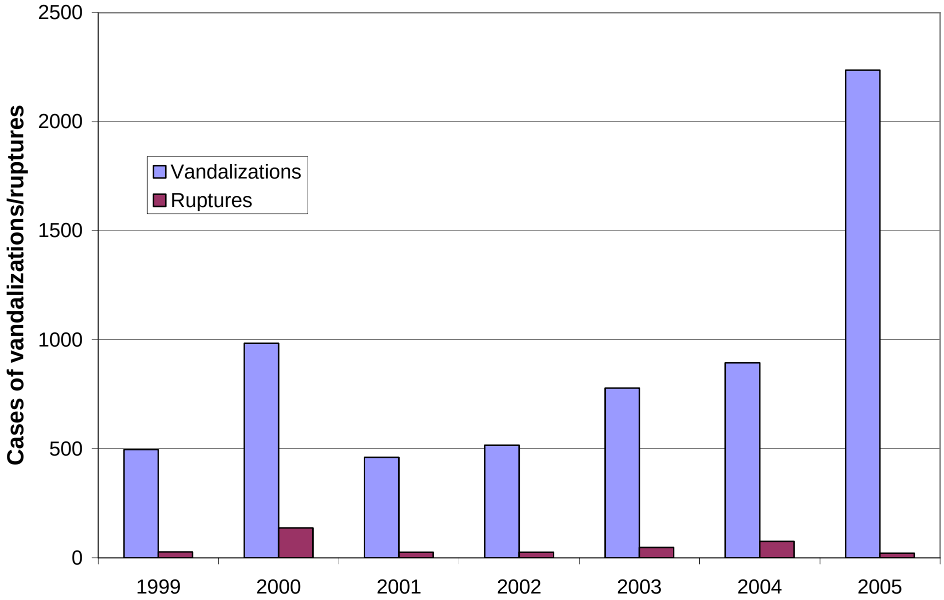

Figure 15. Cases of pipeline vandalizations and ruptures in Nigeria 1999-2005. Source: NNPC, 2005

In addition to vandalism of oil installations with political motives, oil and petroleum products are simply stolen, or ‘bunkered’, from pipelines at rates that are quite incredible. According to one estimate it amounts to 200,000 barrels per day. (Obi, 2004) Consider that the official total domestic consumption in Nigeria is around 300,000 b/d. The oil theft is well organized, and much of the stolen oil is apparently ending up on the black markets of neighboring countries. In August 2003, Nigeria even closed its border to Benin in protest of the rampant smuggling of petroleum and other goods. (IRIN, 2003) In return for the oil, militant groups and criminal gangs in the Delta are provided with the guns that enable continued violence. (Junger, 2007) Accidents related to illegal tapping of pipelines have claimed many lives. On Boxing Day in 2006, vandals had caused a leakage on a gasoline pipeline in a suburb of Lagos. Residents were busy seizing the opportunity to fill jerry cans when the pipeline suddenly exploded. An estimated 300 people were killed. (News Daily, 2006)

2.4.3.2 Angola

Oil has been produced in Angola since the 1950’s, when the country was still a Portuguese colony. Production did not scale up until after independence in 1975 and during the subsequent civil war. Since oil production was mainly located offshore, it was relatively unhindered by the political situation. The regions that were first developed, onshore and shallow offshore outside the enclave of Cabinda in the north, are now in decline. However, exploration in deep and ultra-deep waters since the 1990s have turned out to be extremely successful. Proven oil reserves tripled between 1999 and 2005, while production increased by 500,000 b/d, or 67%. (EIA, 2006b) This expansion is expected to continue in the next few years. (IEA, 2006)

Sociedad Nacional de Combustíveis de Angola (Sonangol), have a central place in the Angolan economy as the sole concessionaire of exploration and production. In practice, oil production is mostly operated by oil multinationals in joint ventures or production-sharing agreements with Sonangol. (EIA, 2006b) Angola has been accepted as a full member of OPEC as of January 2007. (OPEC, 2007b) It is still at the time of writing not clear whether this may put a restraint on future production increases.

The oil industry played a central role during the civil war as the government’s source of income for military spending. The Marxist influenced People’s Movement for the Liberation of Angola (MPLA) had seized power at the time of independence in 1975, but immediately came into conflict with the rivaling National Union for the Total Independence of Angola (UNITA), which was mobilizing other ethnic groups, and controlled the access to Angola’s other great natural resource: diamonds. Part of the reason why the civil war finally ended in 2002, was that UNITA gradually lost this source of income, while the increasing revenues from oil kept MPLA afloat. The civil war left Angola’s economy and infrastructure in ruins. (Hodges, 2004)

The end of civil war did not put an end to the simmering conflict between the Angolan government and several separatist groups in the enclave of Cabinda, where the bulk of Angolan oil is produced. Although a ceasefire was signed in August 2006, the fighting has continued. (Global Security, 2006)

The Angolan government has repeatedly been accused of severe mismanagement of oil revenues. A report from Human Rights Watch states that U.S.$4.22 billion of governmental revenues was unaccounted for between 1997 and 2002, a sum roughly equal to the total amount spent on humanitarian, social, health, and education programmes during the same period. (HRW, 2004)

2.4.3.3 Sudan

Chevron made the first discovery of oil in 1978 during drillings in the Upper Nile province in southern Sudan. However, security problems brought all attempts to develop these resources to a halt until the late 1990’s. In the footsteps of Chevron, several other foreign companies have or have had interests in Sudanese oil fields, including the Swedish Lundin Petroleum/International Petroleum Company since 1996. (HRW, 2003) The same year, the China National Petroleum Corporation (CNPC), the national Malaysian oil company Petronas and the Sudanese national oil company Sudapet joined the Canadian company Arakis (later Talisman Energy) to form a consortium. The most critical investment of the consortium was a pipeline stretching from exploration block 1 in the South via the capital Khartoum to the Red Sea. The completion of the pipeline in 1999 made Sudan an oil exporter overnight. Oil exploration has expanded into the western parts of the country, as the government has been issuing concessions for exploration in Darfur since 2003. (CIJ, 2006)

The religious and ethnic divides between the Arabized Muslim population of northern Sudan and the mainly non-Muslim black African southern parts, have spurred conflicts since independence in 1956. When oil first was discovered in 1978, it was during a time of peace between the government of Sudan (GoS) in Khartoum and the relatively autonomous Southern Sudan after years of civil war. When it was realized that areas crossed by the north-south border contained considerable oil resources, GoS made moves to seize control over the exploration blocks from the local government of Southern Sudan. Seeing that a large potential source of income for the underdeveloped south was withheld from them, the local leaders naturally opposed these attempts. The full-scale civil war that broke out in 1983 was triggered by GoS's decision to abolish the autonomy of Southern Sudan and impose Islamic law.

According to Human Rights Watch, not only has GoS been involved in direct military activities against civilians with the purpose of clearing the way for oil operations, it has also worked indirectly by encouraging existing ethnic tensions between tribes, providing them with arms and letting them do expulsions of southern residents seen as a threat and a hinder for oil production. It has mobilized militias, one of which was called "Protectors of the Oil Brigade", and it has denied access for humanitarian aid. (HRW, 2003)

When the first pipeline was completed in 1999, the response from SPLM/A was to declare all oil fields, pipelines and oil company workers legitimate military targets. (CIJ, 2006) "We will shut down these oil installations, because they are a weapon of war", one of the military leaders stated, referring to the arms purchases of GoS financed by oil revenues. (BBC, 2002)

The centrality of oil in the Sudanese civil war was expressed by the UN Special Rapporteur in March 2001, stating that "oil exploitation is closely linked to the conflict which, although it contains a religious component, is mainly a war for the control of resources and, thus, power." He also saw a risk of continuing conflicts, since "oil exploration is likely to expand to other areas and bring with it a pattern of insecurity." (ECOSOC, 2001) As a matter of fact GoS and SPLM/A finally signed a peace agreement in 2005, including an agreement to split oil revenues evenly between the north and the south. (CIJ, 2006)

2.4.4 Conclusions

The oil resources of SSA are concentrated to a small number of countries, and typically to small areas within those countries. Offshore and deepwater regions are the ones with potential of significant future production increases. Historically, oil wealth has not been of much benefit to the populations of SSA's oil exporters. On the contrary, it has often hindered development and spurred conflicts. Nigeria, Angola and Sudan harbor groups that are motivated to disrupt oil output in order to harm their national governments economically and politically. While offshore production is less vulnerable to sabotage, there is a continuous risk that onshore installations become inoperable, with consequences for oil export capacity.

2.5 The Global Need for African Oil

"African oil is of national strategic interest to us, and it will increase and become more important as we move forward. It will be people like you who are going to develop that resource, bring that oil home, and try to develop the African countries as you do it."

> – Walter Kansteiner III, U.S. Assistant Secretary of State for African Affairs, at a symposium arranged by the Institute for Advanced Strategic & Political Studies in Washington, D.C. (IASPS, 2002)

If export figures can be any guide to which among the resources of SSA the world finds of most interest, it is clear that oil has a prominent place. Petroleum related products stood for 63% of SSA export value in 2003, far ahead of food and live animals at 17%. (CFA, 2005) As the world market price of oil in recent years have risen relative to other commodities, the dominance of petroleum exports has probably further increased. SSA is the only region in the world that has not increased its share of non-oil exports since the 1980's. (Broadman, 2007) Of total foreign direct investment flow to SSA in the period 1983-2002, 47% went to the two major oil exporters: Nigeria (30%) and Angola (17%). (CFA, 2005)

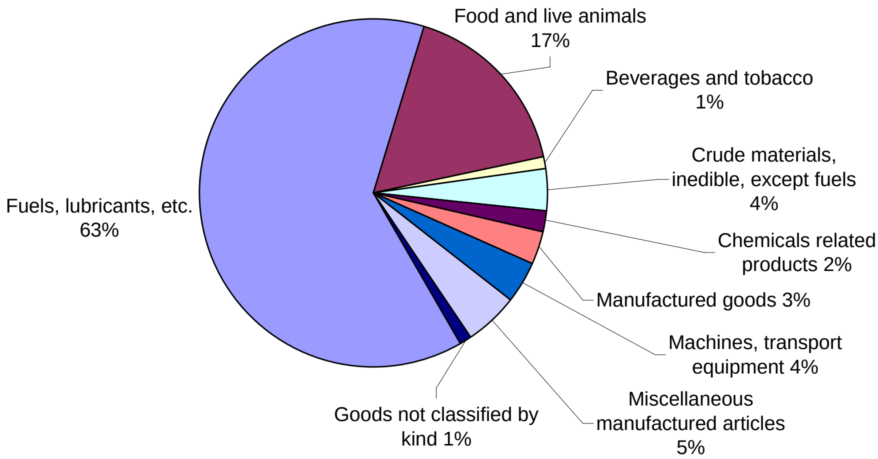

Figure 16. The relative value of export commodities from SSA in 2003. Source: CFA, 2005

The increasing interest in African oil has its logical explanation. The world's by far largest oil consuming nation, the United States, has had a steady increase in total oil use for several years, while domestic production is declining slowly but steadily. The U.S. now must import more than half of the oil consumed. Meanwhile, the populous Asian giants China, India and Indonesia, are increasing their oil use rapidly. All three have domestic oil production, but it has not been able to keep up with demand. China has gone from self-sufficiency to become one of the world's major net oil importers, and Indonesia, still being a member of OPEC, ceased to be a net exporter in 2004.

It would be technically impossible for a number of large countries to increase their net oil imports, if there were no regions with the capacity to increase their net exports commensurately. The key to become a big net exporter is, of course, a significant production paired with a small domestic consumption. With 6% of world production and a share of world total oil use of 1.2% - a mere one million barrels per day out of 83 Mb/d in 2004 - SSA fulfills that requirement.

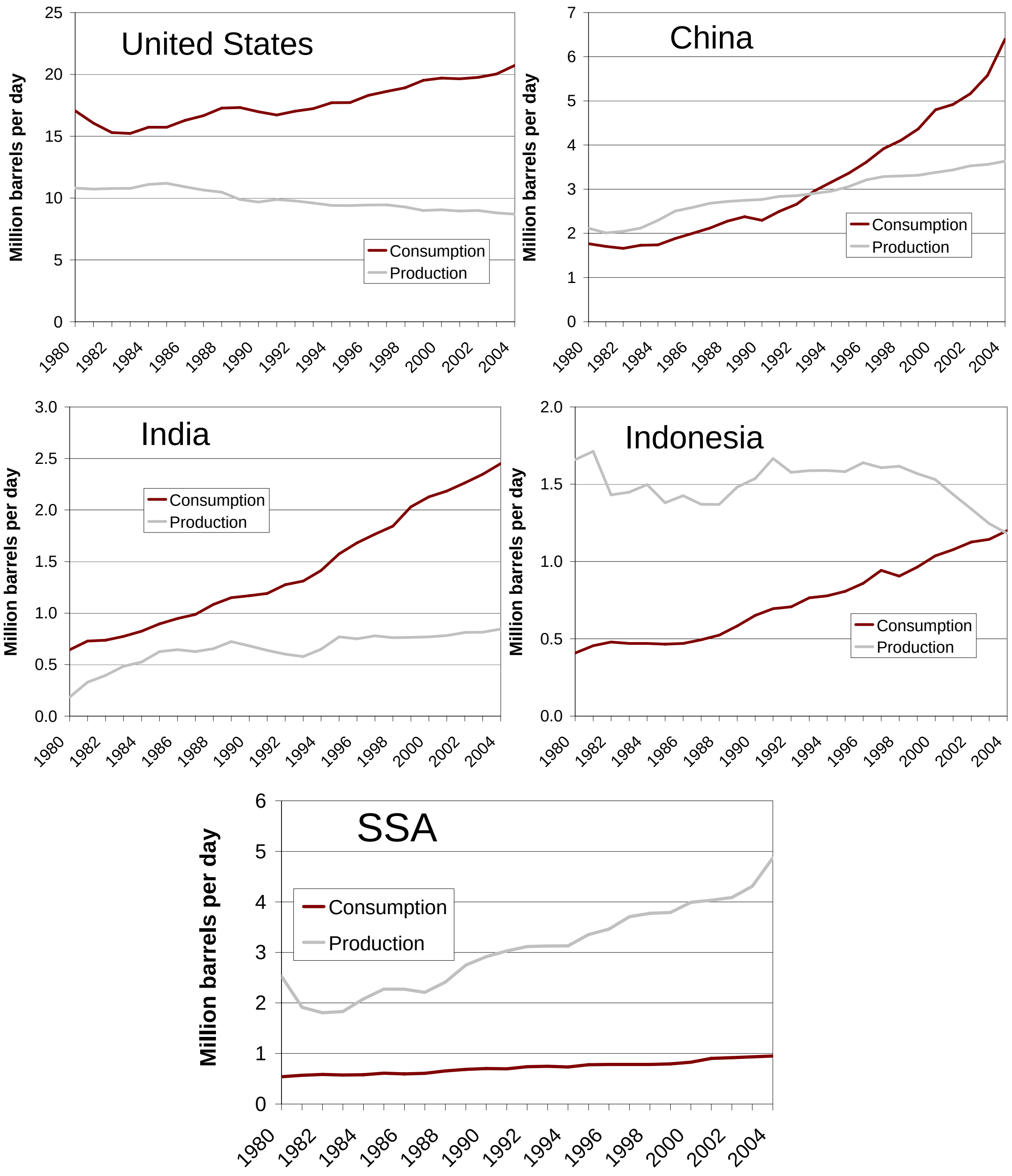

Figure 17. Oil use and production (all liquids) in the United States, China, India, Indonesia and SSA 1980-2004.

It is the world's two largest oil users, China and the United States, that have most outspokenly declared SSA to be of strategic interest to their present and future oil supply. Their respective relation to SSA in terms of oil imports is described below.

2.5.1 China

China has in recent years assumed an increasingly important role as a business actor in SSA, at the same time as good relations to African countries have become a strategic interest to the Chinese government. Perhaps it is telling that 2006 was declared to be China's "Year of Africa". The need for resources to support a growing economy has become the driving force behind Chinese foreign policy. (Zweig & Jianhai, 2005) Chinese interests are present in various extractive industries in SSA, but most of the recent growth in trade has been due to increasing imports of African oil. (Pan, 2007) From being self-sufficient in 1993, China today has become the world's third largest oil importer after the U.S. and Japan. Threatening conflicts around the Persian Gulf have made China to look for ways to diversify its oil imports away from the unstable Middle East. SSA now provides almost a third of China's imported crude oil. (Holmertz, 2006) Angola, which alone provides half of this oil, became China's single largest oil supplier in 2004. (Zweig & Jianhai, 2005) China also has oil interests in Nigeria, Equatorial Guinea, Gabon, Congo-Brazzaville, Mauritania, and Chad, and is the main consumer of Sudan's oil output. (Holmertz, 2006)

In the quest of securing oil supplies from SSA, China is pursuing what has been called an "aid-for-oil" strategy. (Pan, 2007) African governments have been offered debt relief, loans, aid packages, and heavy investments in roads, railroads, telecommunications, schools, and public buildings in exchange for oil contracts. The goal has been to nurture good bilateral relations to African regimes through long-term business agreements and, if possible, to exercise direct ownership over oil fields rather than to rely on spot markets. (de Oliviera, 2006)

The Chinese reluctance to make oil purchases within the open market has been met with some critique from western advocates of free trade. (Bozon et al., 2006) Causing even more indignation in the west, though, is the Chinese lack of interest in the human rights performance of the African regimes with which they are doing business. The Chinese oil company CNPC has had a leading role in the development of Sudan's oil infrastructure while the Sudanese government has waged war against guerillas and civilians. Fighter planes and helicopters used by the government have been supplied by China. (Pan, 2007) In Angola, China has appeared as an alternative source of funds when IMF has suspended loans in protest of corruption and lack of transparency in public finances. While critics say that these Chinese practices undermine attempts to achieve good governance and respect of human rights in certain African countries, the Chinese government maintains that business and politics are strictly kept apart, and that it respects national sovereignty on these issues. (de Oliviera, 2006)

2.5.2 United States

The United States has been facing the dilemma of rising oil consumption and declining domestic production for many years. The gap has mainly been filled with imports from Canada, Saudi Arabia, Mexico and Venezuela. However, with threatened security of supply from the Middle East, signs of production decline in Mexico, and Hugo Chavez as a Venezuelan president without sympathy for U.S. interests, alternative sources of oil supply has become an increasingly critical issue. Already during his second week in office, President George W. Bush established a "task force" under Vice President Richard Cheney to formulate the new government's energy policy. (NEPDG, 2001) The group's final report, published in 2001, identified growing energy supply as a vital precondition for a growing economy and an improved welfare. It was proposed that energy security should have a high priority in the formation of foreign policy. Diversification of oil supplies was emphasized as a security strategy. More specifically, it was expected that West Africa, along with Latin America, would be one of the fastest-growing sources of oil and gas for the American market. (NEPDG, 2001) The U.S. already got 15% of its oil imports from SSA in 2005 (EIA, 2007), but that figure is expected to increase significantly. According to one estimate from the National Intelligence Council, West Africa would provide 25% of American oil imports by 2015. (NIC, 2000) Nigeria alone stands for over 50% of SSA oil exports to the U.S. and was the fifth largest supplier in 2005. (EIA, 2007) The U.S. imports oil from all SSA producers except Sudan, with which all commercial exchange is blocked since 1997 in protest of human rights violations and suspected harboring of terrorists. (Holmertz, 2006)

2.5.3 Does the Importer Make a Difference?

It is legitimate to ask whether there is any fundamental difference between westerners and easterners doing oil business in SSA. The U.S. is, in contrast to China, an advocate of governance improvements and measures towards better revenue transparency in oil producing countries. It has also been unwilling to provide arms to Nigeria when the government has wished to strike against oil installation saboteurs. (Holmertz, 2006) However, there are signs that the U.S. is ready to increase its military presence in the areas of SSA that is vital to its oil supply, namely the Gulf of Guinea. The Director of the Pentagon's Office of African Affairs, Theresa Whelan, has been quoted as saying: "…it is true that we do have legitimate security interests in ensuring that the offshore oil is protected and that the states that own those offshore rigs are able to protect them." (Klare & Volman, 2004) President Bush announced the creation of a new military command for Africa (AFRICOM) in February 2007, which can be interpreted as an acknowledgement of the continent's increased strategic importance to the U.S. (White House, 2007)

There is no reason to doubt the sincerity of oil importers' declared ambitions to promote transparency, accountability and general economic development in SSA. What could be doubted, however, is their willingness and perceived ability to make these ambitions their first priority. In the years ahead, African oil may turn out to be too vital a resource to abstain from for security, humanitarian or political reasons.

2.5.4 Conclusions

Despite issues of supply security, large oil importers, notably China and the United States, are increasing their dependence on imports from SSA, and are planning to rely even more on these imports in the future. An increased reliance on oil from SSA is likely to have implications for the military presence in the region, since the strategic oil infrastructure must be protected. Oil is currently the largest source of export income for SSA, but remaining a net exporter of any significance presupposes a continued low domestic consumption.

3 Empirical Study

3.1 Oil Production Scenario

3.1.1 Modeling a 'Base Case'

The following look at the future of SSA oil production is not based on any Hubbert curve model. Instead it relies on assumptions concerning currently producing oil fields and the developments that are planned to be on stream in the near future. The advantage of this approach is that it gives quite a reliable picture of the short-term development, while it is less reliable when predicting long-term trends since possible future discoveries and developments are not accounted for. With this limitation in mind, it is more appropriate to talk about a 'base case' scenario rather than an actual forecast. What will be presented here is, in other words, a scenario of the future without any speculation on possible resource additions or radical events that are unpredictable. In a later paragraph it will be discussed to what extent this base case scenario might be altered. There will also be a comparison of the result with forecasts from other sources.

3.1.2 Assumptions

In the modeling of SSA's oil production, production data and assumptions on depletion rates have been taken from Robelius (2007b) for Nigeria, Angola, Gabon, Congo-Brazzaville, Equatorial Guinea, Mauritania, and Côte d'Ivoire. As for Sudan, Chad, Cameroon, Congo-Kinshasa, Ghana, and Benin, complementary data has been taken from EIA's *International Energy Annual* (2006c) and various Country Analysis Briefs. The latest year of historical data is 2005, unless otherwise stated.

In the course of modeling, oil fields have been divided into three categories subject to different assumptions: giant fields, deepwater fields, and 'other' fields. Data on giant fields is available for Nigeria, Angola, Gabon, and Equatorial Guinea. For each country, the production of the giants are modeled in three scenarios, where the decline rate from plateau production is 6%, 10%, and 16% per year respectively. The onset of decline is timed to fit the estimated URR of each field. Year by year, the three scenarios are compared, and the one that yields the highest total production is selected.

Deepwater fields are modeled in a similar manner. All projects in Nigeria, Angola, Congo-Brazzaville, Equatorial Guinea, Mauritania, and Côte d'Ivoire that are presently on stream, under development, or that may be initiated in the near future, are included. These projects are listed in Robelius (2007). Projects are assumed to reach their expected plateau production soon after start-up, and to ultimately produce their estimated URR plus an extra 10%. Decline is expected to be dramatic at the onset, 20% per year, later to stabilize at 10-15% per year.

Fields that are neither giants nor deepwater, or are situated in countries where such distinctions have been unavailable, are treated together in the 'other' category. In the lack of more specific information, these fields are assumed to decline at an average annual rate reflecting the natural depletion, sometimes referred to as the *capacity erosion*. The global capacity erosion rate has been estimated as being about 4-5%. (Skrebowski, 2006b; Koppelaar, 2005) Two decline scenarios are presented here, both of which are rather conservative: a low case where the capacity erosion is set to 3% per year, and a high case where the production from 'other' fields is unchanged during the entire period, meaning that the capacity erosion is continually offset by new production capacity. As for Sudan and Chad, both scenarios assume that they will be able to maintain a production of 400 000 b/d and 250 000 b/d respectively, due to their immaturity as oil producers. In the case of Chad, pipeline capacity will probably put a more effective limit to output than production capacity in the short-term. A simplification has been made regarding Nigeria's liquids production, of which about 190 000 b/d was gas condensate in 2005. (EIA, 2006a) The production of condensate does not necessarily stay in constant proportion to crude oil production. Therefore it has been assumed that production of condensate increases to 250 000 b/d and remains at that level throughout the period.

3.1.3 Results

The oil production in SSA is currently increasing rapidly, and will continue to do so in the next few years. According to the high base case, production will increase from 5 Mb/d in 2005 to around 8 Mb/d in 2010. It is Angola, or more specifically Angola's deepwater projects, that will stand for the bulk of this increase. About half of SSA's total production will come from deepwater by 2010. However, after 2010 the deepwater developments that are known today will decline rapidly, and by 2030 their contribution to total production will be insignificant. All production taken together, the high base case ends up at slightly above 3.5 Mb/d in 2030, while the low base case suggests a production of less than 2.5 Mb/d.

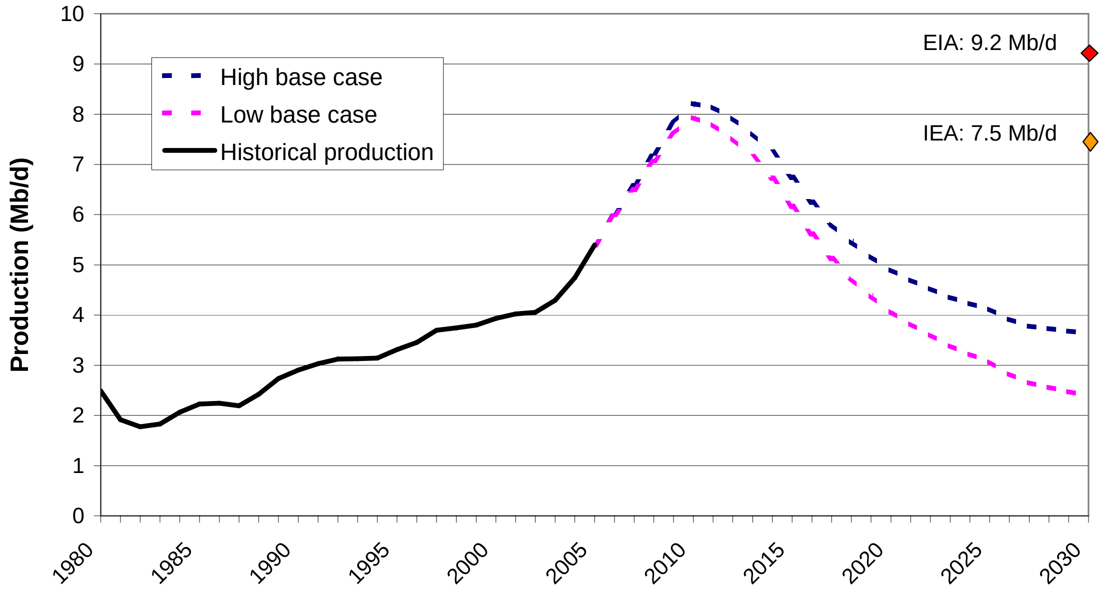

Figure 18. Two alternative base case scenarios of oil production in SSA, with the forecasts of EIA and IEA for 2030.

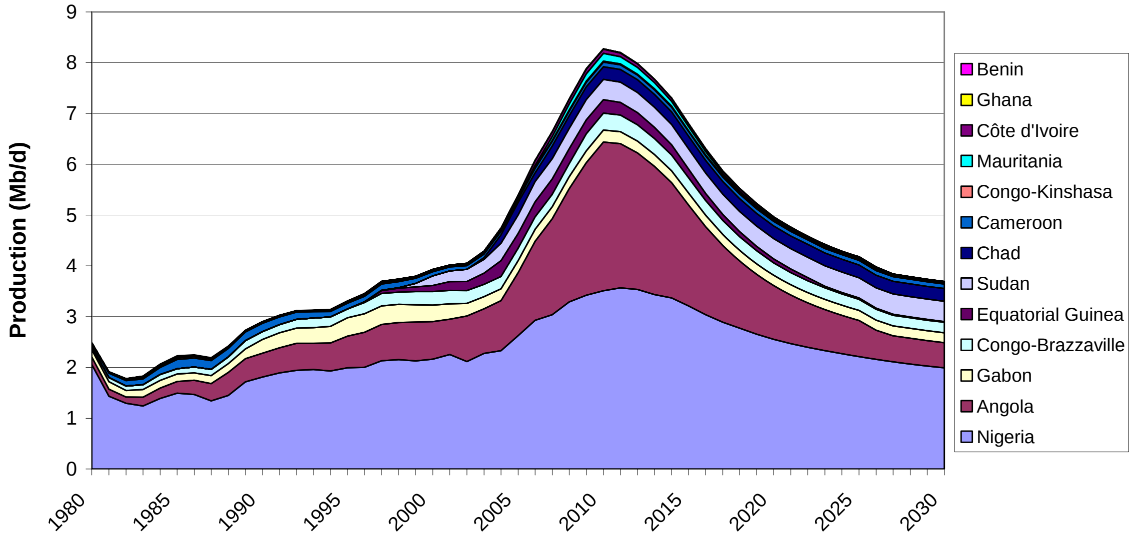

Figure 19. High base case scenario: production by country.

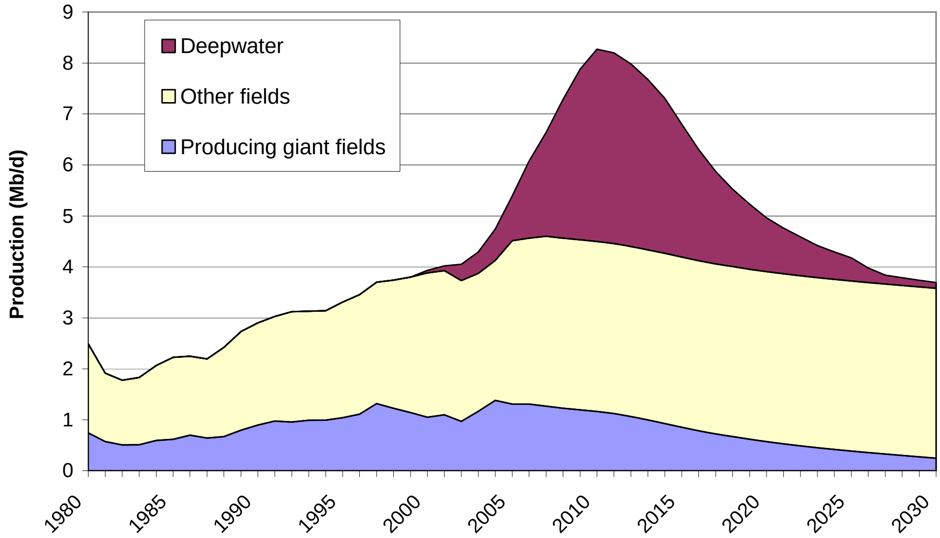

Figure 20. High base case scenario: production by type of field.

3.1.4 Other Forecasts

Since the energy scenarios published by IEA and EIA probably have the most influence on national energy policies, it is relevant to have a look at how they forecast future oil production in SSA. In the reference scenario of IEA's *World Energy Outlook 2006*, crude oil production in SSA is projected to reach 7.6 Mb/d by 2015, and then decrease slightly to 7.5 Mb/d by 2030. To this number should probably be added a certain amount of NGL, which is not shown for SSA separately. 3.2 of the 7.5 Mb/d are expected to come from Nigeria, while the other producers are not shown individually.

In the reference case of EIA's Annual Energy Outlook 2006, Nigeria is projected to produce 3.2 Mb/d by 2030, Angola 3.4 Mb/d, Sudan at least 0.5 Mb/d, and remaining

West African producers an additional 1.1 Mb/d above the rate of 2005. It adds up to circa 9.2 Mb/d. In other words, the high level of 2010 is not only to be maintained for at least an additional 20 years, it is also expected to increase by another million barrels per day.

Angola's future production is of particular interest, since it is likely to play a pivotal role in the timing of the peak for the entire SSA. Energy consultants at Wood Mackenzie have examined ongoing and probable projects, and have projected that conventional Angolan deepwater will reach a maximum in 2010, but ultra-deepwater projects will postpone the ultimate peak until 2012. Production will peak at around 2.5 Mb/d and decline to less than 1 Mb/d by 2020. (Morrison & O'Rourke, 2006) In other words, a slightly later and lower peak than in the base case scenario. The Wood Mackenzie consultants also note that lead-times between discovery and first production have tended to increase from typically 5-8 years for projects presently on stream to 8-10 years for upcoming projects. This means that fields discovered today are unlikely to come on stream until several years after the expected peak. It would therefore be difficult to maintain a plateau production after 2010-12.

3.1.5 Uncertainties

Discoveries are continuously made in the deepwater and ultra-deepwater of West Africa. However, discoveries have followed a sharply declining trend since the peak of 1998 as shown in figure 14. The amount of discovered reserves per successful wildcat in Angolan deepwater has also declined considerably since its peak in 1997, which could be a sign that the major fields have largely been tracked down. (Hayman, 2006) In any case, the ultimate size of the resource base is a source of uncertainty. Although West Africa by far attracts the most interest, some exploration activities are currently under way also in East and Southern Africa.

Non-geological events will probably have a more immediate impact on oil production than reserves. The security problems related to oil production in particularly Nigeria and Sudan are still present and may escalate. When Angola and possibly Sudan join Nigeria as members of OPEC, the lion's share of SSA's production might also be subject to production quotas within the near future. Such a development would significantly alter the base case scenario outlined above. However, this is only a likely outcome given that the oil price is sufficiently low as to motivate production ceilings. In the case of rising oil prices, the national governments and OPEC would presumably allow oil companies to develop the discoveries without restrains. Given such an economic context, a high rate of production would most likely be considered the highest goal, at the expense of long-term capacity replacement. The result would be a marked peak similar to the base case scenario. Delays due to technical difficulties, lack of equipment or skilled personnel, might push the peak a few years into the future.

3.1.6 Conclusions

If all deepwater fields are developed without obstacles, SSA will achieve a total oil production of 8 Mb/d around 2010. It is mainly production from the deepwater fields of Angola that will determine the production peak for the entire region. Due to the decline in deepwater discoveries, it is likely that the peak will occur early in the next decade.

3.2 Oil Intensity – An International Comparison

3.2.1 Definition of Oil Intensity

The level of future oil use in SSA, given a certain rate of economic growth, is determined by the development of the *oil intensity*, that is, the amount of oil used in relation to GDP. The term oil intensity has been borrowed from ESMAP/World Bank (2005), where it was defined in terms of heating value as:

Oil intensity = total oil use (Btu's) / total GDP (US$)

In this study, to enable comparisons with oil statistics based on volume measures, oil intensity has been redefined in terms of volume:

Oil intensity = total oil use (barrels) / total GDP (PPP)

The unit of oil intensity is barrels per $1000 of GDP (PPP). Oil intensity can be interpreted as a measure of how efficient the economy is in using oil to produce economic output: the less oil intense, the more efficient. The historical record gives the most straightforward guidance as to how the oil intensity in SSA might develop in a scenario of economic growth. In the following, the development of oil intensity over time is therefore studied in a number of reference countries.

3.2.2 China and India

In 1980, the two Asian giants China and India had populations of one billion and 700 millions respectively. The present population of SSA is about 700 millions. The GDP (PPP) per capita was $750 in China, $1176 in India in 1980. The GDP (PPP) per capita

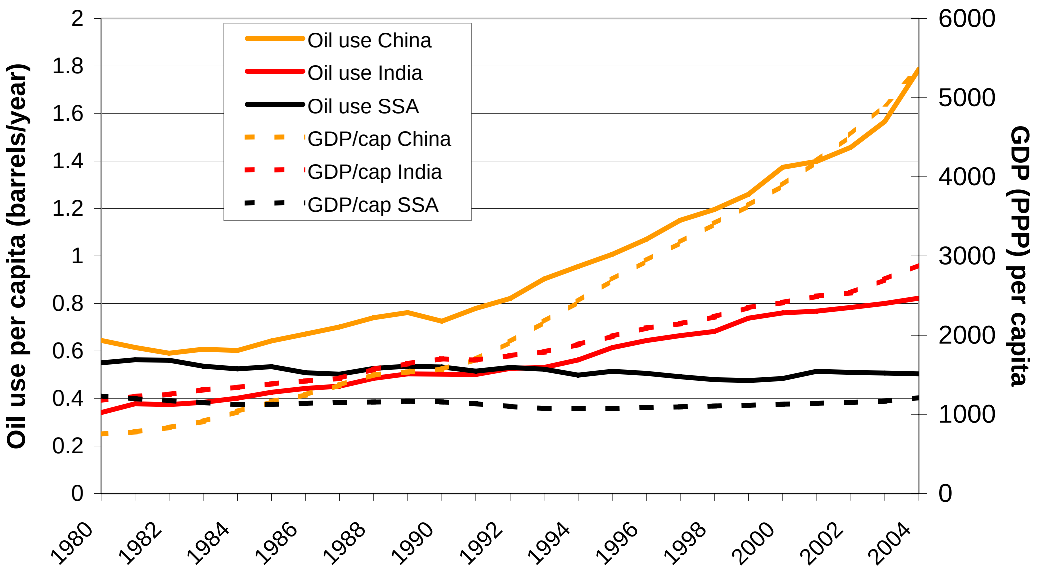

Figure 21. Development of GDP (PPP) and oil use per capita in SSA, China and India 1980-2004.

in SSA was $1211 in 2004. Consequently, though China, India and SSA differ in other respects, the population and general economic level of SSA in 2004 are roughly comparable to those of China and particularly India 24 years earlier. This observation motivates the use of China and India as reference cases.

In the period 1980-2004, total GDP (PPP) grew by 9.8% annually in China, by 5.8% in India. Figure 21 illustrates the different paths that oil use and GDP (PPP) per capita have followed in SSA, China and India during this period.

It is quite obvious that oil use and GDP have tended to follow the same development patterns. However, the fit between oil use and GDP has not been perfect, which implies that the oil intensities have changed over time. Most strikingly, the GDP of China increased significantly faster than oil use until the mid-1990s. Figure 22 illustrates the development in terms of oil intensity.

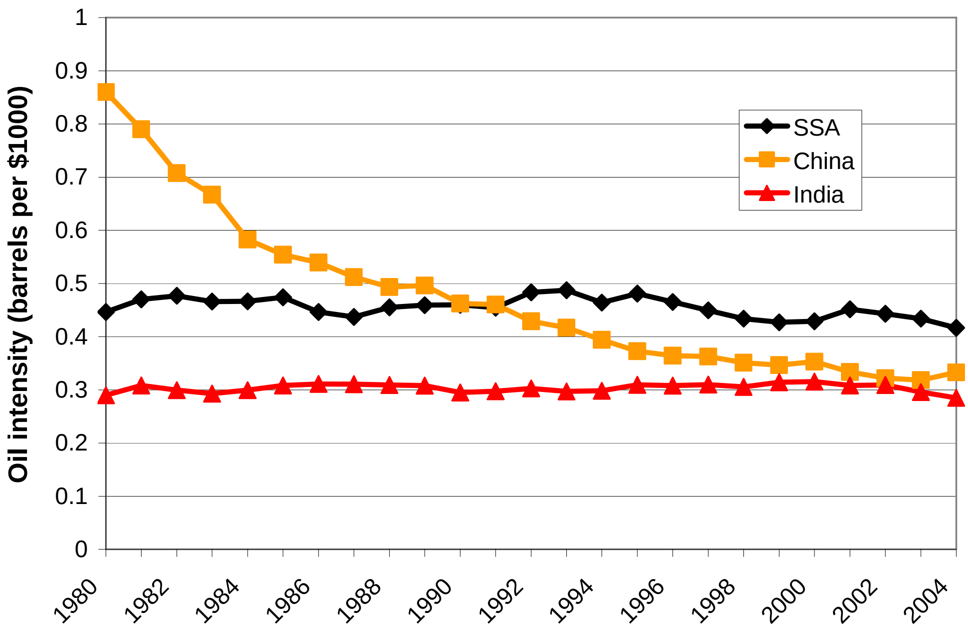

Figure 22. Oil intensity in SSA, China and India 1980-2004.

The oil intensity of India has remained virtually constant at a level of around 0.3 barrels per $1000 GDP (PPP), meaning that economic growth has been perfectly matched by growth in oil use. SSA also shows a more or less stationary, but higher, value of around 0.45. China, in contrast, has declined substantially from a high level of 0.85 in 1980 to just above 0.3 in 2004. The decline has followed an exponential trend, leveling off at the same oil intensity as India. Due to this pattern of slowing decline towards a stationary value, it is not justified to talk about ‘decoupling’ of oil use and GDP in the case of China. Oil intensity has indeed declined, but it has ‘recoupled’ at a lower level.

3.2.3 OECD Countries

It is relevant to look at the development of oil intensity in the industrialized countries of OECD. Figure 23 shows time series for a number of developed countries in relation to

SSA, China and India. In all cases, oil intensity has dropped between 1980 and 2004. However, in 2004 it is still higher than in China and India. Even SSA appears to be rather low in oil intensity relative to these developed countries. This is an important observation, since it may be counterintuitive. The OECD countries have, despite their shift towards service economies, access to various alternative energy sources, technical capabilities, and sometimes explicit policies of reduced oil dependence, not managed to become less oil intense than the developing economies of China and India. In fact, of all the countries outside Africa with available GDP (PPP) figures, only four currently have an oil intensity less than India's: Bangladesh, Cambodia, Laos and Nepal. None of these nations are regularly put forward as a model for economic development. This circumstance can be taken as anecdotal evidence that an oil intensity significantly lower than that of India (which was 0.28 in 2004) would be difficult to achieve for a country in the process of economic development, and apparently also for a country at the high end of the economic ladder.

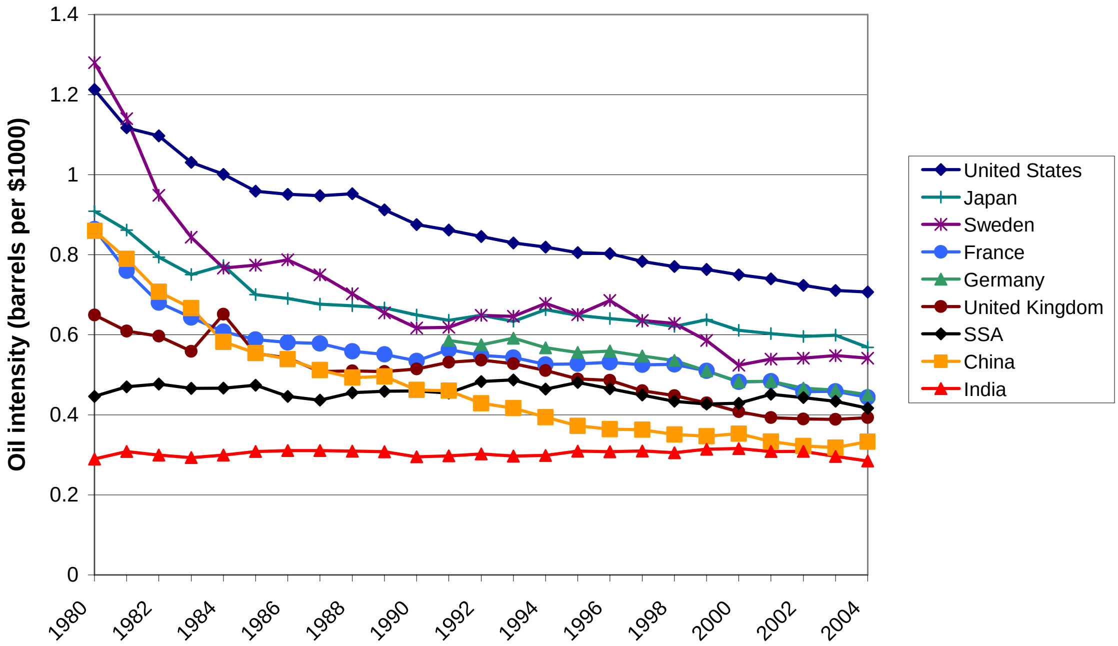

Figure 23. Oil intensity in selected OECD countries, with SSA, China and India as references.

3.2.4 Explaining the Slowing Decline

As was the case with oil intensity in China, the intensities of the OECD countries show a tendency to level off through exponential decline patterns, most markedly perhaps in the case of Sweden. Oil intensity declined by about 50% during the 1980's, and has since 1990 not changed significantly. The reason behind this interrupted decline can probably be derived from the data on historical composition of oil use by products, provided by the Swedish Petroleum Institute (SPI, 2007). In 1980, much of the oil consumption consisted of fuel oil for heating and industrial purposes. In these applications, there were readily available alternatives, which meant that oil could be phased out successfully. After 1990, in contrast, transport fuels have dominated the remaining oil use. Since there is currently no viable replacement for oil as a transport fuel, oil intensity has not continued to decline as rapidly.

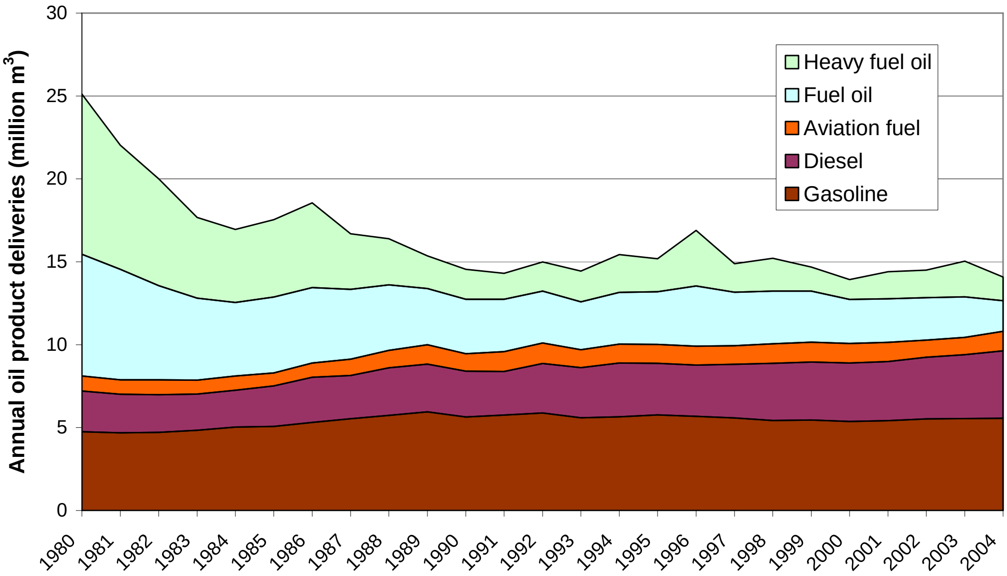

Figure 24. Annual oil product deliveries to the Swedish market 1980-2004. Source: SPI, 2007

To explain the exponential decline pattern of China, a parallel could be drawn to China's diminished reliance on electricity from oil-fuelled power plants, which declined from 29% of electricity output in 1980 to 3% in 2004 (see chapter 2.2). In electricity generation, as in heating, there are alternatives to oil available.

The general conclusion that could be drawn from these two examples, is that a pattern of exponential decline in oil intensity occurs when the easiest and most rewarding substitution measures are taken first, resulting in a rapid decline, which is then followed by more and more difficult measures causing the decline to slow down. Ultimately, oil is only used in applications where it is strategically important and very difficult to substitute with other forms of energy, as in the transport sector. At that point oil intensity is likely to remain constant, unless a major shift in transportation technology occurs.

3.2.5 Conclusions

In China and India, countries that were comparable to SSA in terms of oil use and GDP (PPP) per capita in 1980, economic growth has occurred in tandem with increased oil use. Oil intensity in China has declined substantially, but appears to level off at about the same low level as India. No OECD country has yet attained an equally low level of oil intensity, despite technical capabilities and a shift from industry to service economies. India has managed to maintain a constantly low level of oil intensity during its rapid economic development. This circumstance makes India suitable as a reference point in the following examination of oil intensity within SSA.

3.3 Oil Intensity Within SSA

SSA is the region in the world with the largest number of countries with low oil intensity. “Low” is here defined as being lower than India in 2004. 21 of the 44 countries with available GDP figures belong to this category. In other words, with the exception of the four relatively poor non-African countries Bangladesh, Cambodia, Laos and Nepal, low oil intensity can be described as a typically African phenomenon. This circumstance naturally gives rise to the suspicion that low oil intensity is connected to low economic development.

A number of specific determinants of oil intensity within SSA will be explored in the following paragraphs, with the ultimate purpose of identifying suitable role models that can be used in the forecasting of future oil intensity in the region as a whole. One question is of particular interest: is there any reason to believe that SSA could attain a strong economic growth, and simultaneously become less oil intense than the historical examples of China and India?

3.3.1 Economic Growth Performance

Since economic growth is of central interest to this study, it is relevant to look at how individual SSA countries have performed in terms of total GDP (PPP) growth. Figure 25 shows oil intensity in 2004 versus average annual GDP growth 1980-2004. In some cases the time period with available GDP data is shorter, which could mean that the average growth rate indicated is not really representative of the whole 25-year period. The key to the country letter codes can be found in Appendix 2.

Only three countries have had an economic growth of more than 7%. These are Equatorial Guinea, Botswana and Chad. A bit further down are Mauritius, Lesotho, Uganda, Eritrea, Sudan, Congo-Brazzaville, Swaziland and Mozambique. Apart from the three most well performing outliers, there is no apparent relationship between oil intensity and growth performance. The majority of countries seem fairly evenly distributed at growth rates between 1.0% and 4.5%, showing a wide range of oil intensities. In several countries, population has grown faster than GDP, leading to declining GDP per capita. In Congo-Kinshasa, GDP has even declined in absolute terms. This is probably also the case in Somalia and Liberia, nations with unavailable GDP figures due to internal conflict.

3.3.2 The Problem of Inflated GDP Figures

Although GDP growth rates may seem straightforward, due to circumstances mentioned in chapter 2.1 they should be interpreted with some caution. Chad and Equatorial Guinea in particular have experienced dramatic increases in GDP in only a few years time. In both cases the sudden GDP boom can be traced to the inflow of oil revenues, reflected in the increased size of export value relative to GDP. Such a surge in GDP due to export revenues is only weakly connected to the level of domestic economic activity, thus it cannot be expected that oil use would increase commensurately. As a consequence oil intensity would decline, possibly to very low levels.

The windfall profits of the kind that Chad and Equatorial Guinea have enjoyed is hardly a realistic growth option for most countries in SSA. Therefore it would be desirable to distinguish this particular source of GDP growth from more ‘genuine’ growth originating from domestic economic activity. One way to make this distinction is to look at how the value of exports has developed relative to GDP. Figure 26 gives an illustration of change in oil intensity versus change in the relative size of exports. An *export share ratio* greater than one indicates that the value of exports has increased faster than total GDP between 1980 and 2004. Likewise an *oil intensity ratio* greater than one means that oil intensity has increased during the period. As expected, Chad and Equatorial Guinea have a high export share ratio and a low oil intensity ratio. The export share ratio for Equatorial Guinea would probably be considerably higher if more recent figures than for 1998 were available. It can also be noted that Mozambique and Lesotho shows a similar pattern of export increases and oil intensity declines, as do several other countries to a lesser degree. However, it is obvious that the export share ratio is not a very sophisticated indicator for detecting windfall profits, since several countries, particularly Ghana, Guinea-Bissau and Madagascar, have increased their export revenues without any decline in oil intensity. Firstly, it is impossible to know whether the increased export value is due to larger amounts of exported goods, or only due to increases in world market prices; secondly, there is no way to know whether the exporting sector is less, equally or more oil intense than the overall economy. This is highly dependent on the type of goods. It can, however, be safely assumed that countries with an export share ratio close to or less than one do not have inflated GDP growth figures due to export revenues. Botswana, Mauritius, Eritrea and Swaziland belong to this category, so their good growth figures can be considered ‘genuine’.

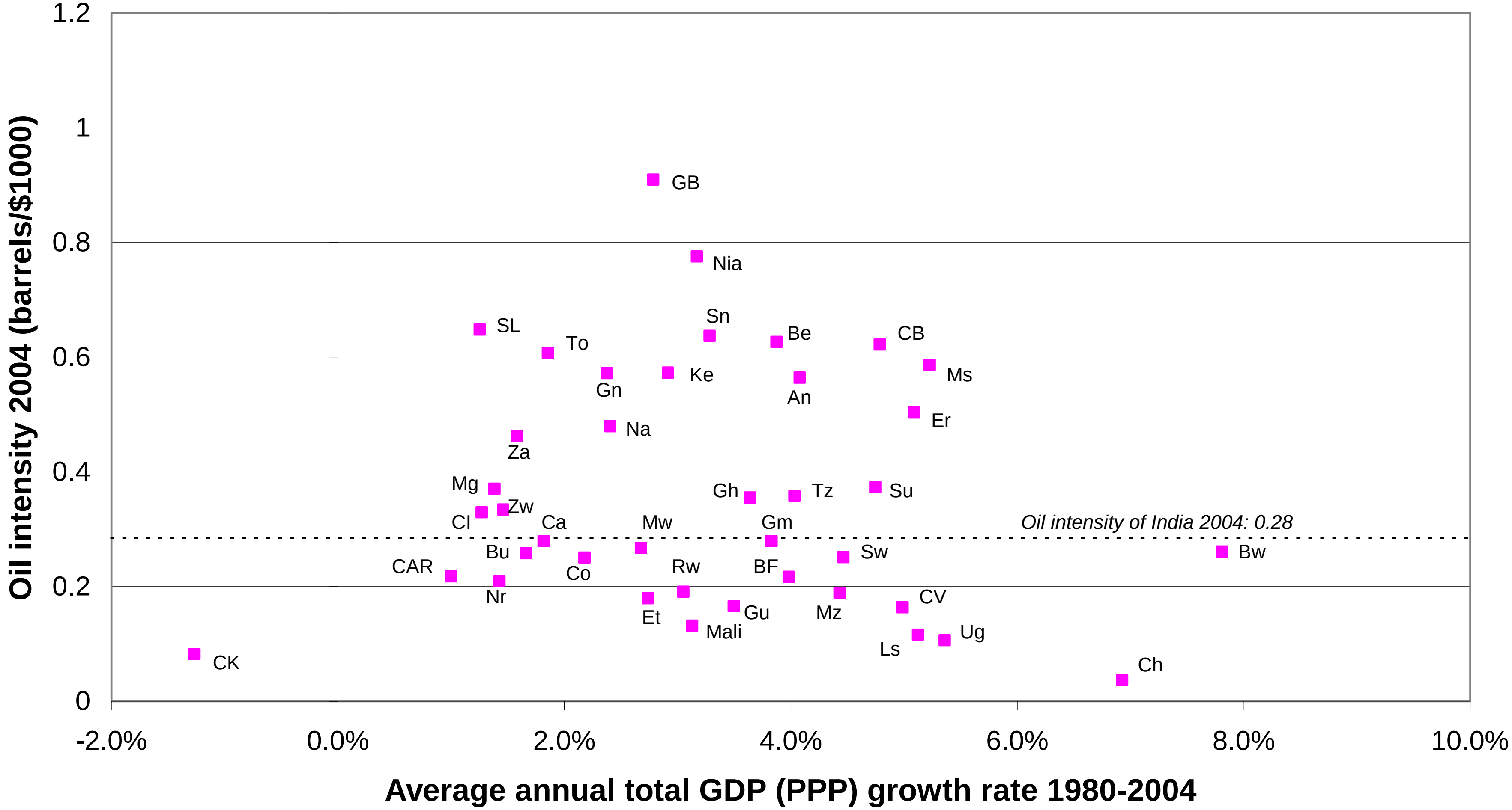

Figure 25. Oil intensity versus growth performance. The key to the country letter codes can be found in Appendix 2. Djibouti (oil int 3.10; growth 0.4%), the Seychelles (oil int 1.58; growth 3.0%), Mauritania (oil int 1.66; growth 3.1%), and Equatorial Guinea (oil int 0.05; growth 25.5%) are not shown in the graph.

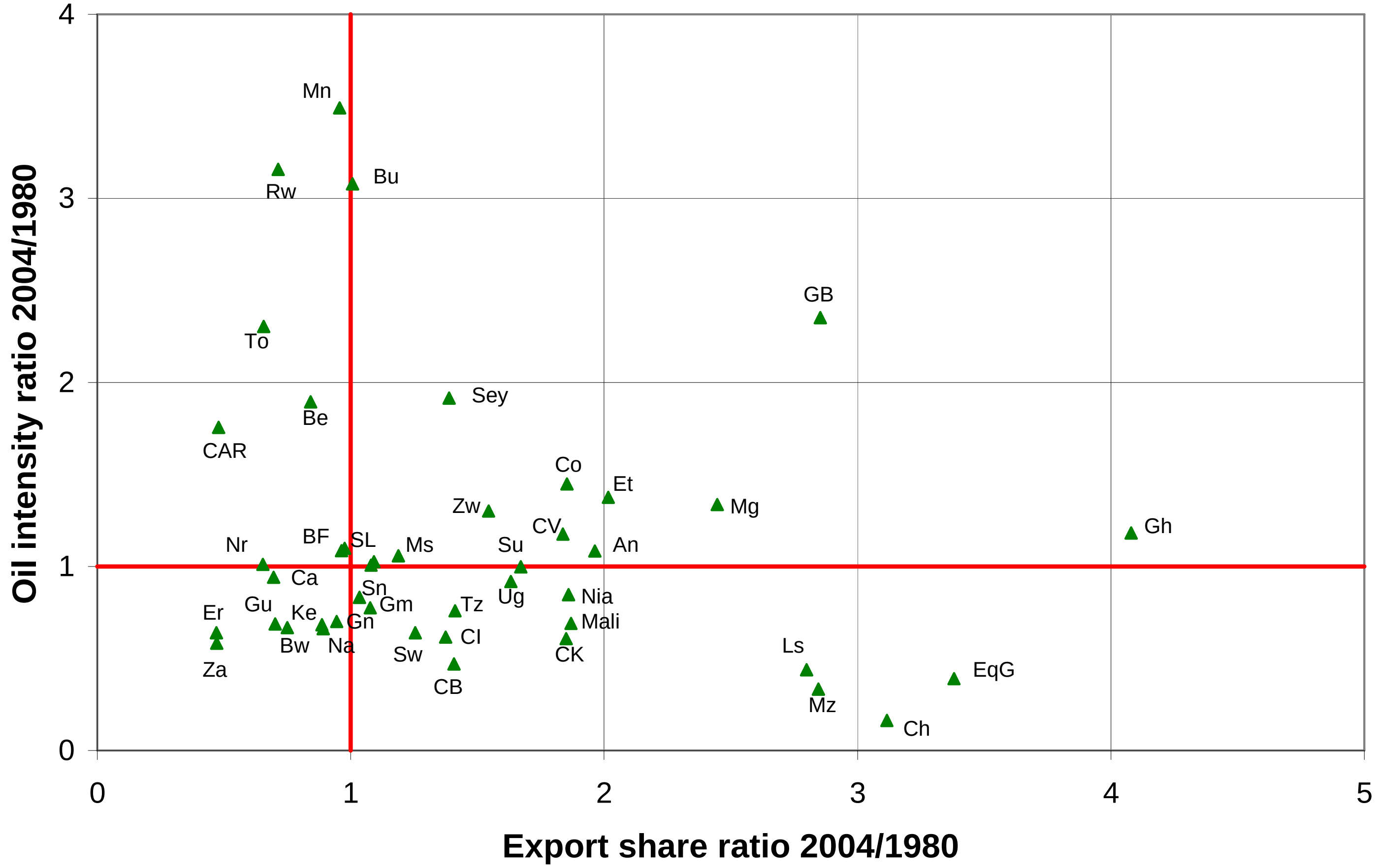

Figure 26. Oil intensity ratio versus export share ratio. An oil intensity ratio greater than one means that oil intensity is higher in 2004 than in 1980. An export share ratio greater than one means that the value of exports has increased faster than total GDP. The key to the country letter codes can be found in Appendix 2.

3.3.3 Changes in oil intensity 1980-2004

It has already been noted that oil intensity for SSA as an aggregate region has remained more or less constant since 1980. However, for several individual countries the oil intensity has changed considerably. Figure 27 shows the oil intensity in 1980 plotted against the relative change in intensity 1980-2004. An oil intensity ratio less than one (below the red line) means that the oil intensity has decreased. The graph is constructed in such a way that all countries below the black curve were less oil intense than India in 2004. There appears to have been some converging tendency insofar as a majority if the 18 countries that were less oil intense than India in 1980 have increased, while a majority of the 26 more oil intense countries have decreased. There are, however, several countries that do not conform to this pattern. Most notably, there are a number of cases where oil intensity was low already in 1980 and has decreased even further. Such countries are Congo-Kinshasa, Mali, Guinea, Uganda, Lesotho and Chad. Particularly the two latter ones should be regarded with some suspicion, since their low oil intensities might be the result of inflated GDP figures.

The reported oil use of Mauritania shows a striking discontinuity between 1991 and 1992, possibly due to a shift in reporting practices. Therefore, Mauritania's large increase in oil intensity may be spurious.

3.3.4 Oil Dependence

One plausible determinant of oil intensity could be the composition of the energy supply. It seems reasonable to hypothesize that a country with good access to alternative energy sources would be able to achieve relatively low oil intensity. In other words, the key to low oil intensity might be low *oil dependence*. In practice, however, it is not a trivial task to define a quantitative measure of oil dependence. The difficulty stems from the circumstances that were discussed in chapter 2.2, namely that a joule of oil cannot be directly equated to, for example, a joule of hydroelectricity. Still, the percentage of heating value derived from oil out of the total primary energy supply gives some rough idea of the reliance on oil. Therefore, oil dependence in this context is defined as the fraction of commercial primary energy (oil, coal, gas, hydro, geothermal plus imported electricity) that is supplied by oil, measured as heating value.

Figure 28 illustrates the relationship between oil intensity and oil dependence, as it was defined above. There appears to be some positive correlation, to the extent that the most oil intense countries also tend to be more oil dependent. However, it is obvious that the level of oil dependence cannot explain the many cases of low oil intensity. Of the 21 countries that are less oil intense than India, 19 are still more oil dependent. Other underlying factors are apparently needed to explain these cases of low oil intensity.

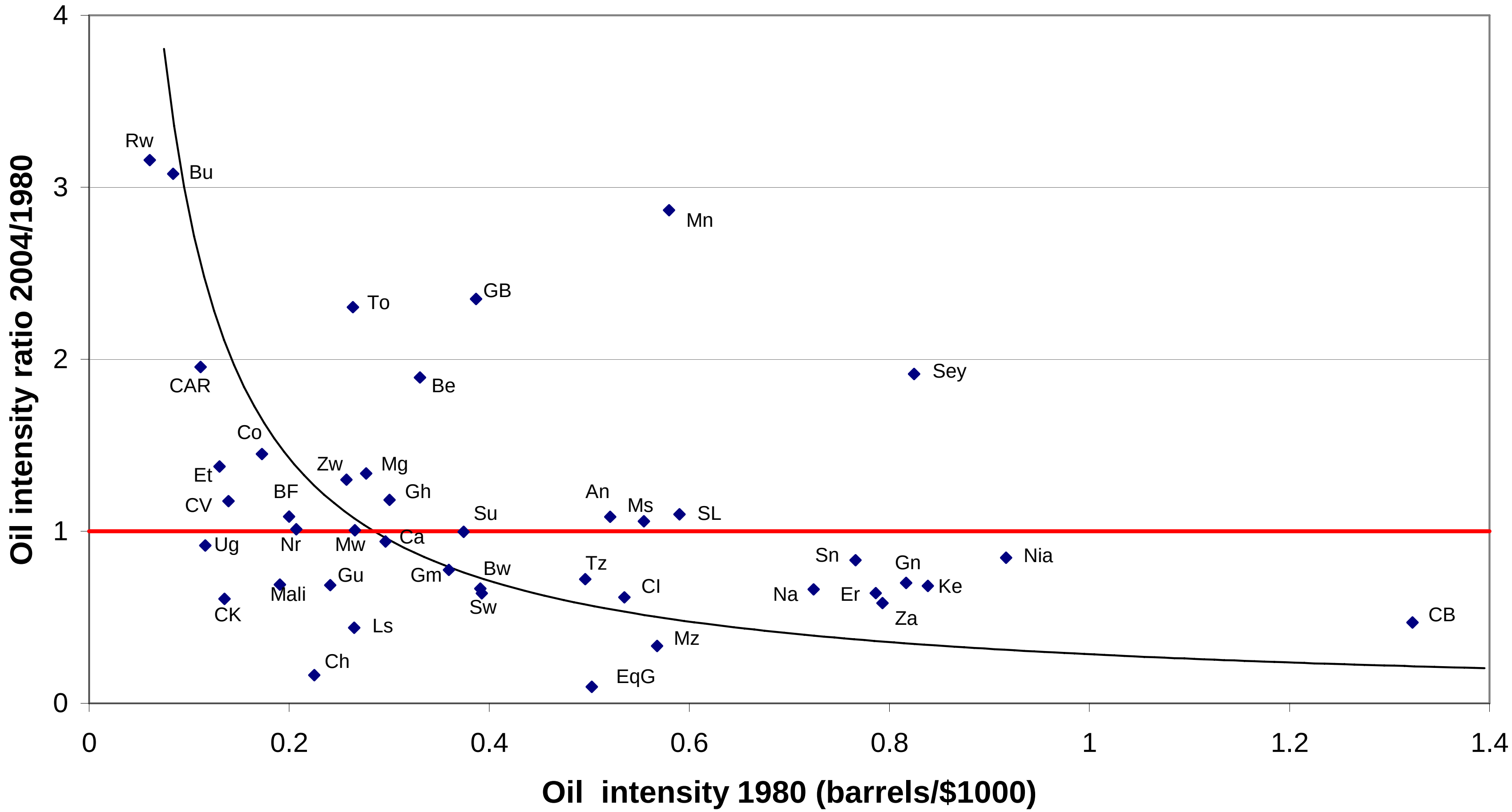

Figure 27. Oil intensity in 1980 versus relative change 1980-2004. Countries above the red line have increased their oil intensity. Countries below the black curve currently have an oil intensity less than India's. The key to the country letter codes can be found in Appendix 2. Djibouti (oil int 1995: 2.97; oil int ratio: 1.05) is not shown.

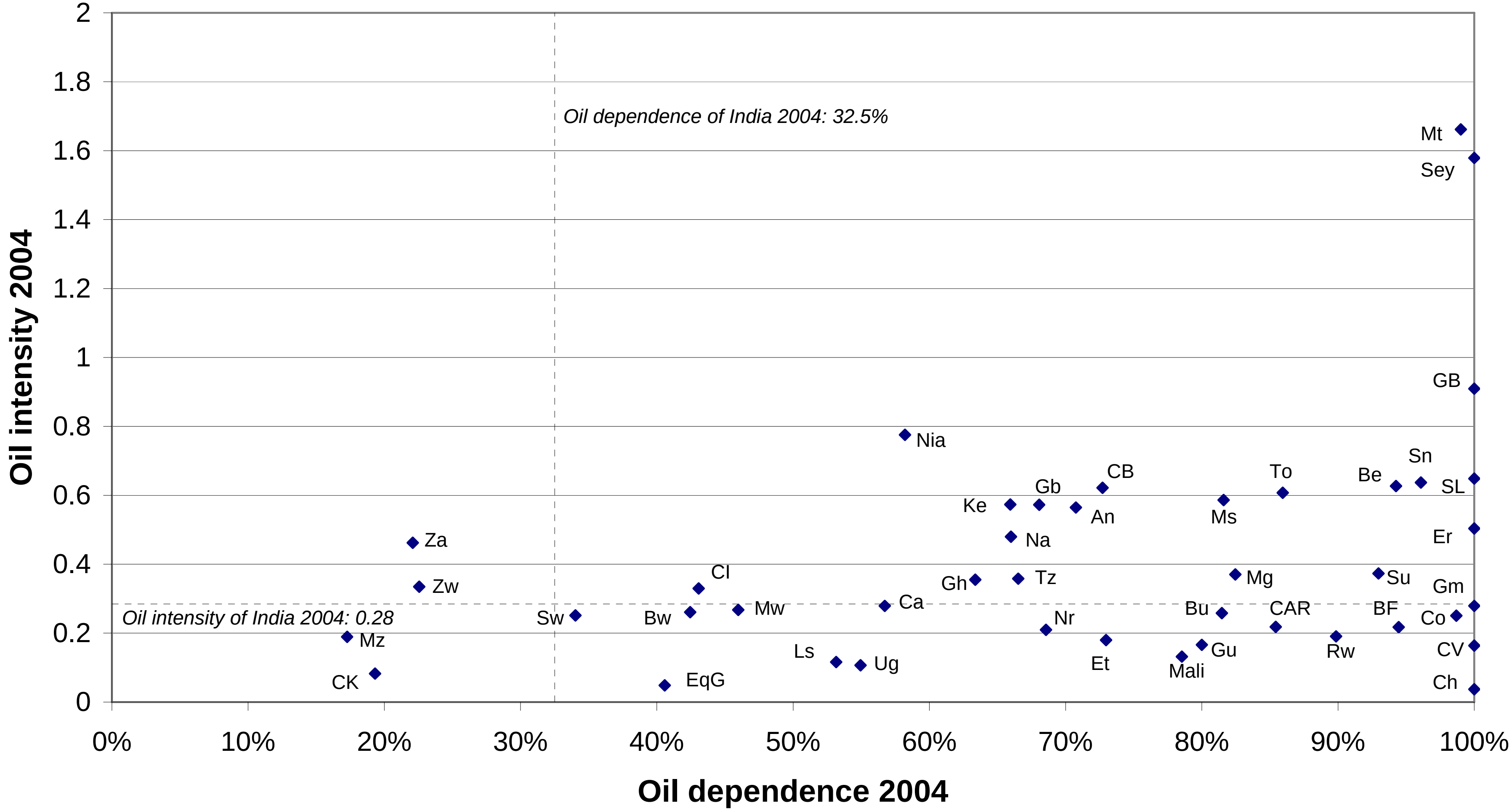

Figure 28. Oil dependence versus oil intensity 2004. The level of oil dependence does not explain the numerous cases of low oil intensity. The key to the country letter codes can be found in Appendix 2. Djibouti (oil int 2004: 3.10, oil dep: 100%) is not shown.

3.3.5 Urbanization

One reason why the oil dependence is insufficient to explain low oil intensity might be that it does not take the use of non-commercial energy into account. After all, most Africans depend on the burning of traditional woodfuels or agricultural residues for their energy needs. It is conceivable that the least oil intense countries are more reliant on traditional fuels than others. Unfortunately, data on the use of traditional fuels is not very reliable, and for many countries it is not even accessible.

One structural factor that affects the availability of woodfuels is the level of urbanization, that is, the percentage of the population living in urban areas. While people engaged in subsistence farming have good opportunities to collect their own fuelwood for free, city-dwellers to a larger degree are reduced to buying commercial fuels such as kerosene or LPG. Moreover, since urban areas are not self-sufficient in food and other raw materials, the need for transport is higher. In other words, there are several plausible reasons to believe that urbanization and oil intensity go together. Accordingly, a statistically significant positive correlation between urbanization level and oil intensity has been established using 1996 cross-country data from 32 African countries. (ESMAP/World Bank, 2005) More recent urbanization and oil intensity figures from 2004 are plotted in figure 29.

SSA is currently a rapidly urbanizing region. The United Nations Population Division forecasts an increase in average urbanization from 32% in 2005 to 43% in 2030. It is worth noticing that a large majority of the countries with low oil intensity are currently below this level of urbanization. The more urbanized ones are Botswana, Cameroon, Cape Verde and Gambia. It appears reasonable to expect that oil intensity will tend to increase as the currently less oil intense countries continue to urbanize.

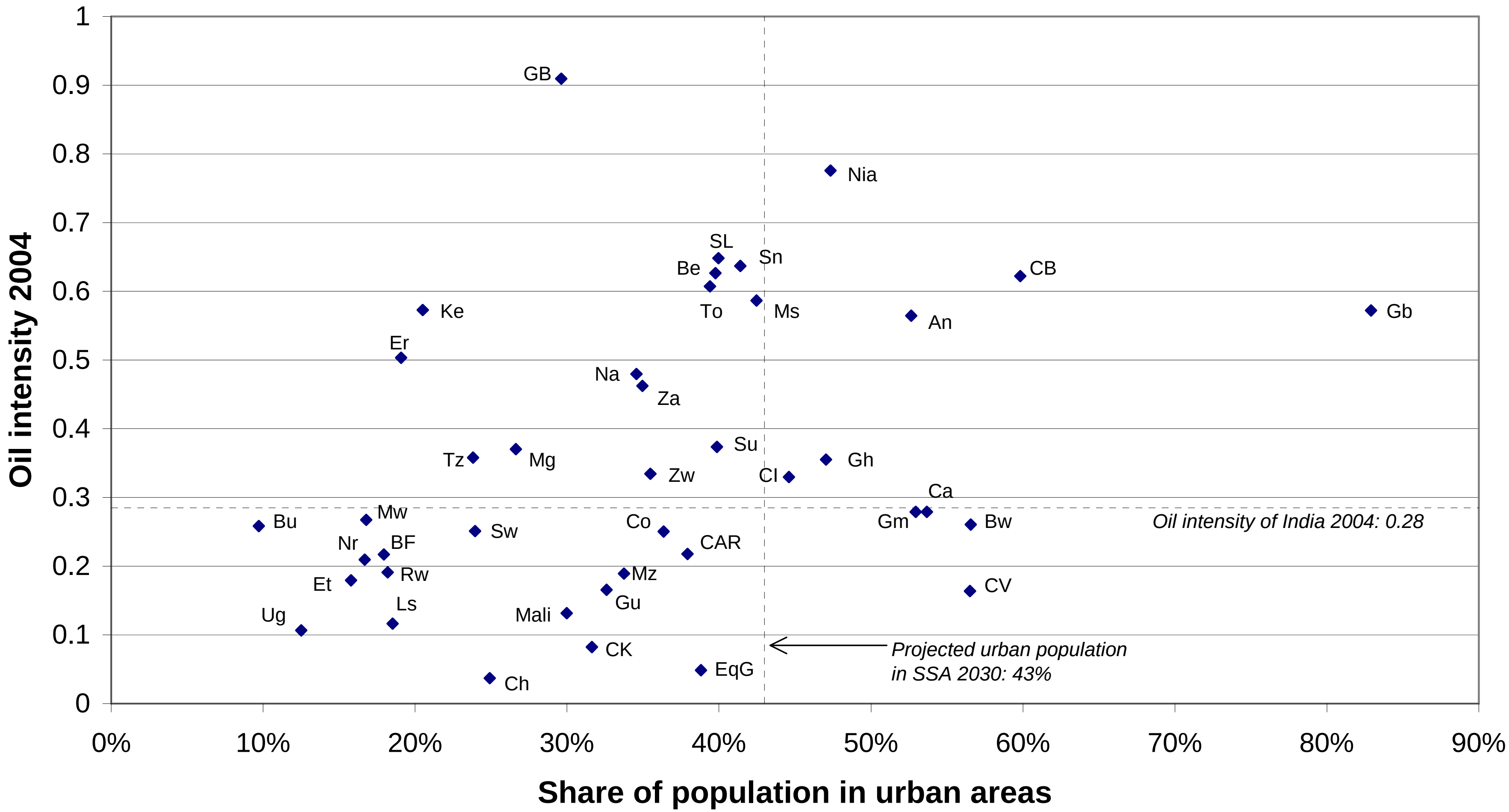

Figure 29. Degree of urbanization versus oil intensity 2004. The least oil intense countries tend to be less urbanized. The key to the country letter codes can be found in Appendix 2. Mauritania (oil int 1.66; urban pop 40%), the Seychelles (oil int 1.58; urban pop 53%), and Djibouti (oil int 3.1; 85.5%) are not shown.

3.3.6 African Role Models for Oil Intensity

The ultimate purpose of this chapter is to identify countries within SSA that can serve as role models for the entire region in terms of future oil intensity. The first prerequisite for such a role model is that it has experienced an annual economic growth of the same order as the 7% expected for the entire region. Most SSA countries must be disregarded due to their insufficient GDP growth performance. Of the good growth figures displayed by a handful of countries, several may be inflated by increased export revenues as is certainly the case in Equatorial Guinea and Chad. In addition to a good and reliable GDP growth performance, a role model country should also be reasonably representative of the whole region in respects that determine the level of oil use. Judging the representativeness of any single country is a difficult task, since many factors may potentially affect oil use. However, the level of urbanization has been identified as one such structural factor. Of the four countries that appear to have reliable GDP growth figures, Botswana, Mauritius, Eritrea and Swaziland, only Botswana and Mauritius reach the level of urbanization that is expected for the entire SSA by 2030. These two countries can therefore be considered reasonably good role models. Swaziland and Botswana have virtually the same oil intensity (0.25 and 0.26 respectively), while Eritrea lies substantially higher at 0.50.

While the average African consumed 0.5 barrels in 2004, a Mauritian consumed 6.4 barrels, or more than twelve fold the average. Mauritius had an oil intensity of 0.59 in 2004, which is significantly higher than the SSA average of 0.42. It has also increased slightly since 1980. Thus, if the region is to follow the development model set by Mauritius, there is no reason to believe that oil intensity will decrease under the present level. However, the example of Botswana suggests that it could be possible to attain a significantly lower level of oil intensity while developing economically. Therefore it is motivated to look into a little more detail at oil use in Botswana.

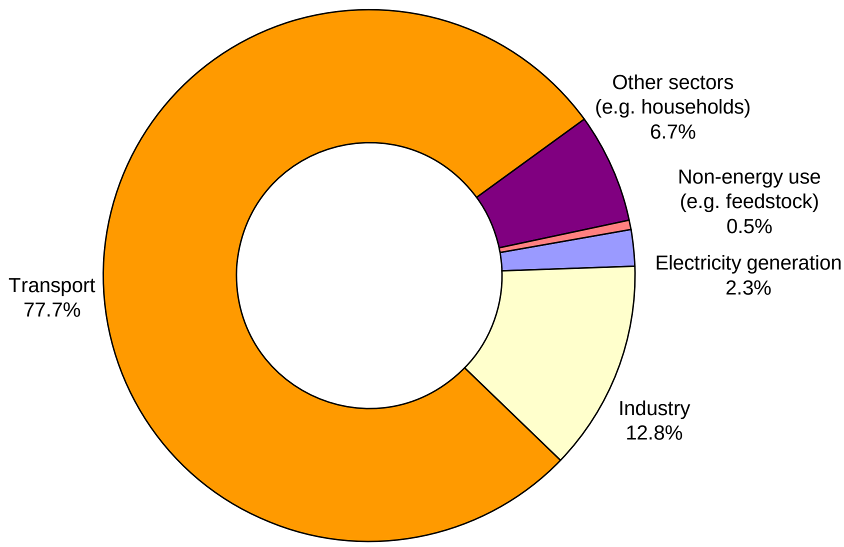

Figure 30. Oil use in Botswana 2004 by sector. Consumption by weight has been converted to volume using the conversion factors in Appendix 1. Source: Derived from IEA, 2006c

A citizen of Botswana consumed 2.4 barrels of oil in 2004, almost fivefold the average for SSA. The oil use is even more dominated by the transport sector than in SSA in general. More than three quarters of the oil is dedicated to transport fuel. Only 2.3% of the oil is consumed by power utilities. As is the case in SSA in general, a certain fraction of the diesel ascribed to transport is probably used in other applications, such as private generators. However, the reliance on diesel generators is likely to be comparatively small in Botswana, as is suggested in figure 8. In conclusion, there are reasons to assume that oil is used in a fairly efficient way, since the bulk of it is used for transport where there is no viable substitute. The potential for savings in oil use through energy substitution must therefore be considered limited.

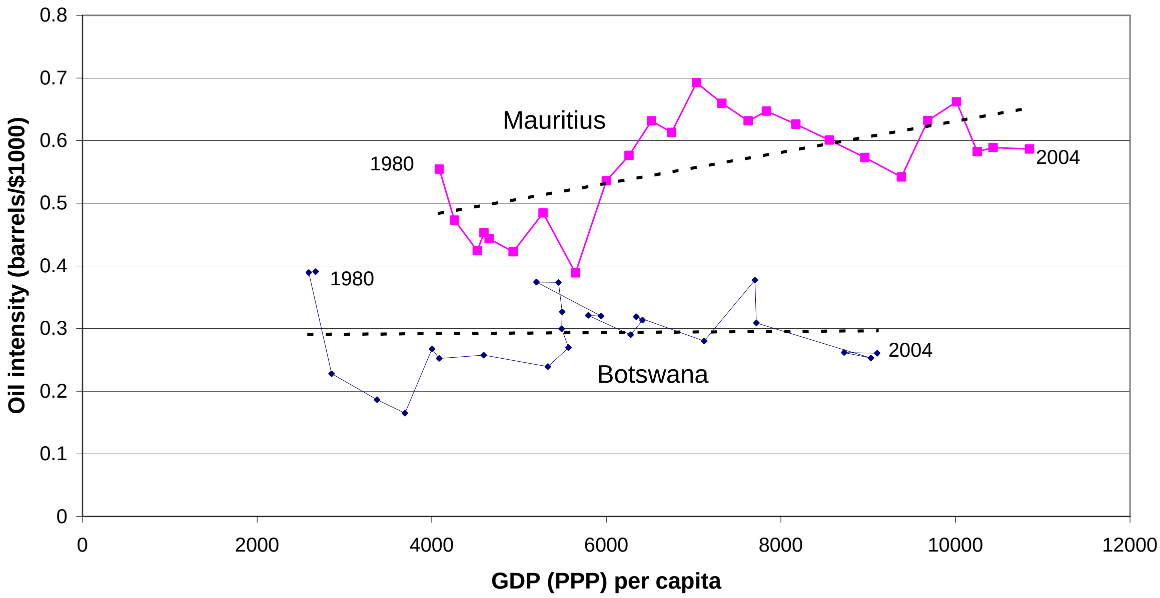

Figure 31. Development of oil intensity in Botswana and Mauritius year-by-year 1980-2004 relative to GDP (PPP) per capita.

As for the oil intensity, it shows quite large fluctuations over time. Partly this can be due to the small size of the economy, which allows rounding errors to have a big impact. Occasional oil use reporting errors may also be a cause of some fluctuation. Given that these errors are not systematic, some conclusions can be drawn from the derived average trend. Oil intensity does not appear to have neither increased nor decreased as GDP per capita has grown. The average oil intensity level, slightly under 0.3, virtually coincides with that of India. The conclusion is that Botswana, which is the most ‘optimistic’ case study within SSA of good growth performance combined with low oil intensity, strengthens the assumption that an oil intensity close to India’s is the lowest reasonable to expect for SSA.

3.3.7 Conclusions

Though SSA harbors the majority of the least oil intense countries in the world, the countries in question appear to have a low degree of urbanization as a common feature. A high level of oil dependence, on the other hand, is not sufficient to explain the cases of low oil intensity. From the few indigenous cases of ‘genuine’ strong economic growth, of which Botswana is the lowest in terms of oil intensity, there is no reason to believe that SSA would be able to achieve significantly lower oil intensity than India in a future scenario of economic growth.

3.4 Oil Use Scenarios for SSA

3.4.1 Construction of scenarios

The following scenarios of total oil use in SSA have been constructed in two steps. Firstly, assumptions on future development of oil intensity have been made in order to model two alternative cases. Secondly, for each case the assumed oil intensity has been multiplied with the expected GDP (PPP) to arrive at the expected total oil use. GDP (PPP) is assumed to grow by 7% annually between 2008 and 2030, which is the growth rate that the Commission for Africa has suggested should be the target. For the average African, this would translate to an increase in GDP (PPP) per capita from $1211 in 2004 to $3529 in 2030. Since the period 2004-2007 is covered neither in the growth scenario nor in historical data, it has simply been assumed that both GDP (PPP) and oil use during this period increase in proportion to the expected population increase, meaning that per capita figures are kept constant at their 2004 values. This appears to be a reasonable extrapolation of the general stationary trend since 1980.

3.4.2 Oil intensity: two alternative scenarios

Oil intensity has, at least in the case of large economies, been shown to develop according to rather predictable patterns where sudden discontinuities are rare. This is true for stagnant economies like that of SSA as well as rapidly growing ones like China and India. Against the background of this empirical experience, it is reasonable to assume that the oil intensity of SSA will continue to develop according to fairly predictable trends even as its economy starts to grow more rapidly. Two possible cases of future oil intensity trends are presented here.

The base case is that oil intensity remains constant at its 2004 level throughout the period 2004-2030. The justification for this scenario is that oil intensity in SSA remained fairly constant 1980-2004, despite substantial changes in oil intensity for individual countries. The base case assumes that future intensity declines in certain countries and the increases in others will cancel out, as they have in the past. Most likely the more oil intense countries will have the potential to decrease, while the currently less oil intense will increase as they go through fuel transitions in the wake of urbanization.

The alternative low case is more optimistic. China, India and the indigenous example of Botswana show that an oil intensity lower than the current could be possible for SSA in combination with economic growth. Consequently, the low case assumes that oil intensity will decline towards the 2004 level of India, which was 0.28 barrels per $1000 GDP (PPP). This is the lowest level that appears reasonable for a region with a population and an economy the size of SSA. This is not to say that the low scenario should be considered very likely. It presupposes that efficiency measures and energy substitutions will enable a 28% decline in oil intensity by 2030. This would probably require the phasing out of oil in power generation in addition to more efficient use in other applications. The decline is modeled to develop exponentially, that is, at a fixed relative decline rate, which mirrors experienced decline in oil intensity for countries such as China. The specific decline rate is set to 9% annually, which was the decline rate of China relative to India 1980-2004. Other decline rates are equally plausible, but the choice of decline rate only has a transient impact, since the asymptotic lower limit is constant. The projected oil intensity in 2030 therefore becomes virtually the same, independent of the assumed decline rate.

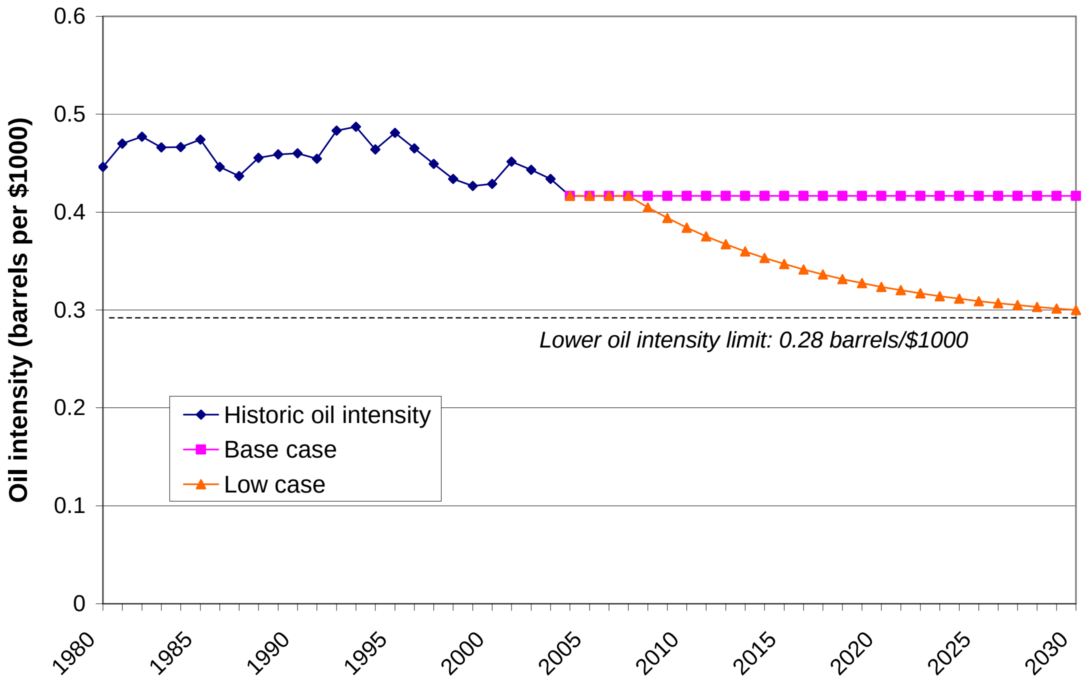

Figure 32. Two alternative scenarios of oil intensity in SSA.

3.4.3 Total oil use

The scenarios of total oil use are obtained by multiplying the oil intensity with the projected total GDP. The result is displayed in figure 33. In the base case, oil use will increase to 4.8 Mb/d by 2030, in the low case to 3.5 Mb/d. When these consumption figures are put in relation to the two oil production scenarios previously constructed, it is obvious that the net oil export capacity of SSA will diminish rapidly. If all deepwater projects are implemented according to plan, SSA will have a net export of about 7 Mb/d in 2010. However, no matter which production or consumption scenario one chooses to consider, this net export will be completely erased by 2030.

Due to the methodology used when forecasting future oil production, it is possible that SSA’s production capacity in 2030 has been underestimated. The production forecasts of EIA and IEA could therefore be considered as well. However, not even when assuming these arguably optimistic production forecasts of 9.2 Mb/d and 7.5 Mb/d respectively, and simultaneously the lower oil use scenario, a net export of 7 Mb/d can be maintained until 2030. Such a large net export would only be maintainable if oil use in SSA is kept significantly lower than the lowest scenario.

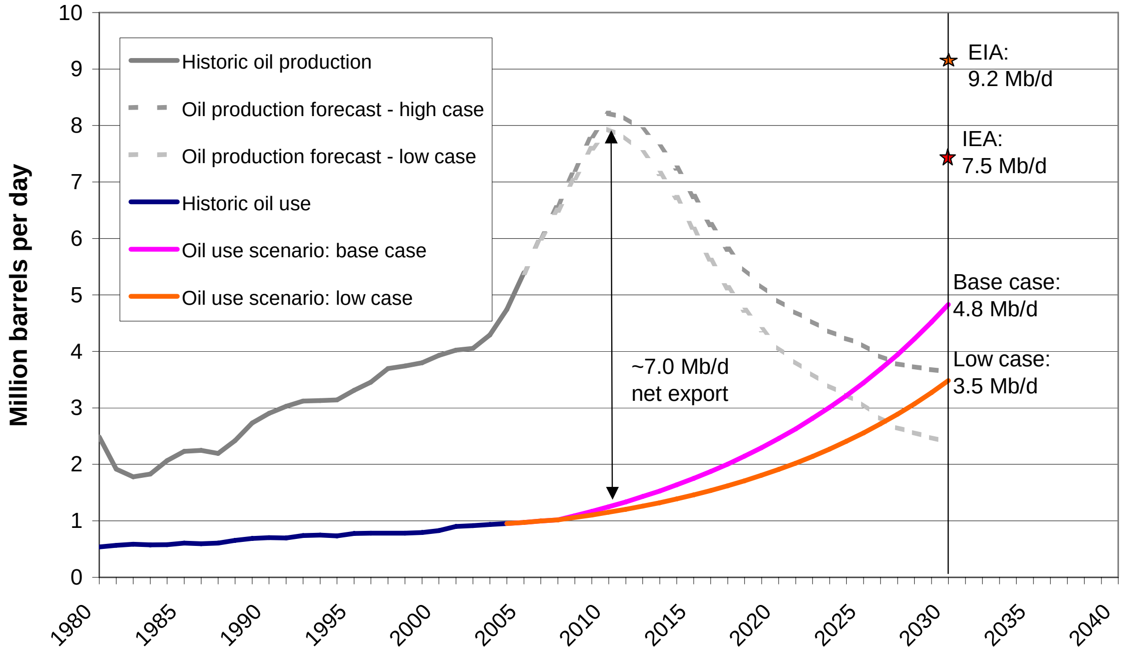

Figure 33. Scenarios of total oil use versus projected oil production in SSA.

3.4.4 Conclusions

The expectation that SSA will be able to sustain a large net export on the order of 7 Mb/d in the future, must rely both on arguably optimistic forecasts of future oil production and the assumption that the domestic consumption in SSA is kept lower than the most optimistic oil intensity scenario. If domestic consumption remains substantially lower than this scenario, it is unlikely that a 7% annual GDP growth will be feasible.

3.5 Discussion of Results

3.5.1 Major Findings

Here follows a list of the most important conclusions that can be drawn from this study:

- Economic activity must depend on the use of energy, since energy is the ability to do physical work.
- Oil is a strategically important energy source, not only by quantitative measures, but also because it is used in applications, primarily transport, where it is difficult to replace.
- Despite low absolute consumption, SSA is a region particularly dependent on oil as a commercial fuel due to its versatility and low infrastructure requirements.
- There are technical possibilities to eliminate some oil use, particularly in power utilities, which presently consume only about 10% of the oil.
- Oil use and development, both defined in terms of GDP and Human Development Index, are positively correlated across countries.
- In China and India, countries whose economic level in 1980 is comparable to the present situation in SSA, have increased their oil use substantially as their GDP has grown.
- Low oil intensity – oil use in relation to GDP – appears to be connected to low level of urbanization.
- India has attained the lowest oil intensity that appears reasonable to expect for any country in the process of economic development. The few cases of sustained economic growth within SSA give no reason to assume any lower realistic level of oil intensity for SSA.
- Not even OECD countries have hitherto managed to decrease their oil intensity below the level of India.
- 7% annual GDP (PPP) growth in SSA 2008-2030 would result in an oil consumption of 4.8 Mb/d in 2030 assuming unchanged oil intensity. If oil intensity could be decreased to the level of India, oil consumption in 2030 instead would be 3.5 Mb/d.
- Put in relation to the oil production scenarios, it is very unlikely that SSA will be able to simultaneously remain a large oil net exporter and achieve 7% GDP growth.

3.5.2 Limitations of the Methodology

Naturally this study is subject to the same limitation as any forecast, namely that it cannot be better than the assumptions it rests upon. In this case, the fundamental assumption is that historical experience provides a good basis for forecasting future oil intensity. Consequently, no presently unknown technological breakthroughs have been considered, or any other discontinuities that would radically diminish the need for oil. Given the slow replacement rates of vehicle fleets and other infrastructure, such an event appears to be unlikely. Of course it would be possible to challenge this assumption, but a challenger of historical experience must reasonably also accept the burden of proof.

3.5.3 African Development – A Global Issue

The literature on African developmental issues tends to focus on governance, corruption, institutions, markets and business climate. The selection of these particular topics is understandable in the light of the underlying assumption that the causes of African economic underdevelopment are to be found in internal political problems. When lack of access to energy and other physical resources is identified as an impediment to growth, it is almost exclusively described as an issue of lacking infrastructure. Certainly the infrastructure is necessary, but it would be of little use without physical resources to distribute. It appears to be taken for granted that if only the water pipes, power grids, roads and gas stations are present, water, electricity and liquid fuels would be available in ample supply at affordable prices. At least in the case of liquid fuels, this is a questionable assumption.

While lacking infrastructure in SSA can be viewed as yet another internal problem, the consumption of limited physical resources must by necessity be analyzed as a global issue. The country of resource extraction often does not coincide with the country of consumption. This is particularly true in the case of oil. The net flows of oil in the global market provides a vivid illustration, perhaps better than that of any other commodity, of how the wealth of certain countries is intertwined with the underdevelopment of others through established trade relations. If one accepts the premise that oil is at present a strategically important resource for economic development, and also accepts that it is a resource limited in supply, then the obvious conclusion must be that the large oil consumption of certain countries stands in direct conflict to economic development in SSA.

3.5.4 Possible Objections

- *It is still primarily the issues of bad governance and lack of infrastructure that are keeping African countries in poverty.*

Recognizing the role of oil in economic development is not the same thing as denying or downplaying the crucial importance of other factors. Corruption, weak infrastructure and other local impediments might very well be the *immediate* cause of the present underdevelopment in many countries of SSA. But even if these internal impediments are to be removed, as is proposed by the World Bank, the Commission for Africa and other organizations, the limitations set by physical resources such as oil will still remain, and will become more apparent.

- *Oil provides a substantial fraction of SSA's export income. Is it not good that other countries want to buy that oil at a fair market price, since SSA needs the money for economic development?*

This argument is commonly put forward, and therefore deserves some discussion. There is one principal objection against this reasoning. Money gained from oil exports is not useful in and of itself. Money is only made an instrument for material welfare when it is used to claim access to resources, be it energy in the form of fuels, or manufactures and services that require energy in their production. Thus, gaining money from oil exports does little to erase the need to consume oil domestically. However, there is a conflict of interest between the oil exporters and importers of SSA, since the exporters are favored by a high world market price that could be devastating to the importers. Still, the major oil exporters of SSA have hitherto not been very successful in transforming oil windfall revenues into general welfare. Instead, they have been plagued by corruption, economic mismanagement and internal conflicts. However, this 'resource curse' must not necessarily pertain in the future.

- *Is it not conceivable that SSA could eliminate the need for oil by exchanging it for other goods?*

If the main use of oil had been in manufacturing SSA would, in principle, be able to sell oil to countries with a more developed industrial capacity, and then buy the finished products for the oil revenues. However, only a small fraction of oil use in SSA is in manufacturing, while the bulk of the oil is used in transport. Naturally, the energy required for transport must be available where the transport work is done, that is, within the region.

3.5.5 Peak Oil and Global Equity

It is hardly controversial to state that the use of oil and other natural resources is very unevenly distributed across the world. Although this fact is sometimes discussed and criticized in terms of global equity, the present situation appears to have gained legitimacy from either of two assumptions:

(1) The need for natural resources such as oil will play an increasingly smaller role in the economy as knowledge and technology develops.
(2) A growing resource supply will ultimately allow all people to enjoy a high standard of living, without sacrifices on behalf of the presently well endowed.

As this study shows, there is no convincing empirical support for either of these notions. The first assumption can be questioned in the light of how oil intensity has developed historically. Oil intensities in OECD countries have indeed declined in the past, but they are still higher than in developing countries like India. The second assumption is challenged by the concept of 'Peak oil', which by definition means that oil, a strategic natural resource, will no longer be available in ever increasing amounts. Once the time of Peak oil is passed, which may happen in a few years or in the coming decades, any increase in oil consumption in one place, or even a maintained constant consumption, will be predicated upon a decrease in consumption somewhere else. The question is: will sub-Saharan Africa be that 'somewhere else' in the first round of oil demand destruction, or will the global community be able to manage the necessary reductions in an alternative way? In any case, even a radical reduction of oil demand in SSA will only have a very temporary impact on world oil prices, since SSA presently stands for only about 1.2% of world oil demand, comparable to the annual world demand increase.

3.5.6 Policy Implications and Future Prospects

Committing to a high GDP growth rate for SSA, without accounting for how the required energy in the form of oil is going to be made available, is arguably not a very realistic or viable policy. If the perceived solution is to maintain the global oil price at a level affordable to African countries, then the high oil consumption of OECD and rapidly developing countries must be put in focus, and become subject to measures. However, in the long-term it does not appear a good strategy to lead SSA further into the same development path dependent on fossil energy as China and India recently have entered.

Although this study has not examined possible alternatives to oil explicitly, a few of the conclusions might be relevant to consider also in that context. Regarding possible alternatives to gasoline and diesel in transport, other liquid fuels appear to be more viable than gases or electricity as a replacement, since they can be distributed and stored in much the same way as fossil liquid fuels. There are, however, some serious issues regarding the production of renewable liquid fuels that need further investigation:

(1) The cultivation of sugarcane, oil palm, jatropha or other plants for production of biofuels will require substantial amounts of land, which could potentially set fuel production in conflict with food production. Since food security is already a serious issue in some parts of SSA, this aspect must be seriously considered.

(2) Since parts of SSA have a more favorable climate for cultivation of energy crops than several developed countries, there is a risk that biofuels produced in SSA will turn into yet another export commodity like oil. Once again, a large net export capacity will require that the domestic consumption of biofuels within SSA remains low.

Conclusively, it is very hard to see how economic development in sub-Saharan Africa is going to be in ‘our common interest’ – as the title of the report from the Commission for Africa suggests – without substantial changes in the way that oil is presently used to fuel economic activities, both in Africa and in developed countries.

Appendices

Appendix 1

Conversion factors:

1 barrel = 159 liters = 0.159 m^3

Barrels per metric tonne:

Crude oil	7.3
Refinery gas	8
LPG & ethane	11.6
Motor gasoline	8.53
Aviation fuel	7.93
Kerosene	7.74
Gas / diesel oil	7.46
Heavy fuel oil	6.66
Naphta	8.5
Petroleum coke	5.5
Other products	7

Units of energy:
1 TJ = 947.8 MBtu
1 MBtu = $1.0551*10^{-3}$ TJ

Sources:
IEA, 2006c; IEA, 2006d

Appendix 2

Country	Country letter code
Angola	An
Benin	Be
Botswana	Bw
Burkina Faso	BF
Burundi	Bu
Cameroon	Ca
Cape Verde	CV
Central African Republic	CAR
Chad	Ch
Comoros	Co
Congo-Brazzaville	CB
Congo-Kinshasa	CK
Cote d'Ivoire	CI
Djibouti	Dj
Equatorial Guinea	EqG
Eritrea	Er
Ethiopia	Et
Gabon	Gn
Gambia, The	Gm
Ghana	Gh
Guinea	Gu
Guinea-Bissau	GB
Kenya	Ke
Lesotho	Ls
Liberia	Li
Madagascar	Mg
Malawi	Mw
Mali	Mali
Mauritania	Mn
Mauritius	Ms
Mozambique	Mz
Namibia	Na
Niger	Nr
Nigeria	Nia
Rwanda	Rw
Sao Tome and Principe	STP
Senegal	Sn
Seychelles	Sey
Sierra Leone	SL
Somalia	So
Sudan	Su
Swaziland	Sw
Tanzania	Tz
Togo	To
Uganda	Ug
Zambia	Za
Zimbabwe	Zw
Sub-Saharan Africa	SSA

References

Amadi, Stella & Germiso, Mekonnen & Henriksen, Asle (2006) *Statoil in Nigeria: Transparency and Local Content*, Oslo: Framtiden i våre hender

BBC (2002) "Sudan oil attacks 'to continue'", 26 March 2002, http://news.bbc.co.uk/2/hi/business/1894648.stm (accessed 2007-01-22)

Bozon, Ivo & Narayanswamy, Subbu & Woetzel, Jonathan R. (2006) "Meeting China's energy needs through liberalization", Mc Kinsey Quarterly, 2006 Special Edition

Broadman, Harry (2007) *Africa's Silk Road: China and India's New Economic Frontier*, Washington DC: World Bank

Buhanza, Victoria (2006) "Humørskifte i Tanzania", in *Oljespill: jakten på Afrikas svarte gull*, Oslo: Fellesrådet for Afrika & Solidaritet forlag

Cambridge Energy Research Associates (CERA) (2006) *Why the 'Peak Oil' Theory Falls Down: Myths, Legends, and the Future of Oil Resources*, http://www.relocalize.net/files/PeakCERAReport11-14-06.pdf (accessed 2007-01-29)

Campbell, Colin & Laherrère, Jean (1998) "The End of Cheap Oil", Scientific American, Vol. 278 (March 1998)

Campbell, Colin (2005) *Oil Crisis*, Brentwood: Multi-Science Publishing Co.

Cleveland, Cutler (2005) "Net energy from the extraction of oil and gas in the United States", Energy 30, 769-782

Coalition for International Justice (CIJ) (2006*) Soil and Oil: Dirty Business in Sudan*, Washington: CIJ

Commission for Africa (CFA) (2005) *Our Common Interest*, http://www.commissionforafrica.org/english/report/thereport/english/11-03-05_cr_report.pdf (accessed 2007-01-23)

Cummins, Chip (2006) "As Fuel Prices Soar, A Country Unravels" in Wall Street Journal, Nov. 18, 2006

Ebohon, Obas John (1996) "Energy, economic growth and causality in developing countries", Energy Policy, vol. 4, no. 5, 447-453

ECOSOC (2001) *Situation of human rights in the Sudan: Report of the Special Rapporteur, Gerhart Baum, submitted in accordance with Commission resolution 2001/18*, United Nations: E/CN.4/2002/46, 23 January 2002

Energy Bulletin (2004) "Full text of Dick Cheney's speech at the Institute of Petroleum

Autumn lunch, 1999", published 8 Jun 2004, http://www.energybulletin.net/559.html (accessed 2007-04-13)

Energy Information Administration (EIA) (2006a) *Nigeria Country Analysis Brief*, http://www.eia.doe.gov/emeu/cabs/Nigeria/pdf.pdf (accessed 2007-01-19)

Energy Information Administration (EIA) (2006b) *Angola Country Analysis Brief*, http://www.eia.doe.gov/emeu/cabs/Nigeria/pdf.pdf (accessed 2007-01-19)

Energy Information Administration (EIA) (2006c) *International Energy Annual 2004*, http://www.eia.doe.gov/iea/ (accessed 2007-02-04)

Energy Information Administration (EIA) (2006d) *International Petroleum Monthly, Dec 2006*, http://www.eia.doe.gov/ipm/ (accessed 2007-01-21)

Energy Information Administration (EIA) (2007) *Petroleum Navigator*, http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_m.htm (accessed 2007-02-08)

ESMAP/World Bank (2005) *The Vulnerability of African Countries to Oil Price Shocks: Major Factors and Policy Options*, Washington: World Bank

Ferguson, Ross & Wilkinson, William & Hill, Robert (2000) "Electricity use and economic development", Energy Policy 28, 923-934

Forum of Energy Ministers of Africa (FEMA) (2006) *Energy and the Millennium Development Goals in Africa*, http://www.esmap.org/filez/pubs/FEMAForPrintshop.pdf (accessed 2007-04-13)

Global Security (2006) "Cabinda", http://www.globalsecurity.org/military/world/war/cabinda.htm (accessed 2007-02-15)

Hayman, Andrew (2006) *Sub Saharan Africa - Massive Production Growth and Abundant Frontier Opportunities*, PowerPoint presentation, energy.ihs.com/NR/rdonlyres/FC1D08AA-FD7A-439D-B248-A4809EF4F2BC/0/IHS_AndrewHaymanSubSaharan.pdf (accessed 2007-02-05)

Hirsch, Robert & Bezdek, Roger & Wendling, Robert (2005) *Peaking of World Oil Production: Impacts, Mitigation & Risk Management*, http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf (accessed 2007-04-14)

Hodges, Tony (2004) *Angola: Anatomy of an Oil State*, Lysaker: Fridtjof Nansen Institute

Holmertz, Gert (2006) *Kampen hårdnar om Afrikas olja*, Stockholm: Utrikespolitiska Institutet

Human Rights Watch (HRW) (2003*) Sudan, Oil, and Human Rights*, http://www.hrw.org/reports/2003/sudan1103/sudanprint.pdf (accessed 2007-01-20)

Human Rights Watch (HRW) (2004) *Some Transparency, No Accountability*, http://hrw.org/reports/2004/angola0104/angola0104.pdf (accessed 2007-02-15)

Institute for Advanced Strategic & Political Studies (IASPS) (2002*) Proceedings of an Institute Symposium: 'African Oil: A Priority for U.S. National Security and African Development'*, http://www.israeleconomy.org/strategic/africatranscript.pdf (accessed 2007-01-11)

International Energy Agency (IEA) (2006a) *World Energy Outlook 2006*, Paris: IEA/OECD

International Energy Agency (IEA) (2006b) *Angola: Towards an Energy Strategy*, Paris: IEA/OECD

International Energy Agency (IEA) (2006c) Energy Statistics of Non-OECD Countries 2003/2004, Paris: IEA/OECD

International Energy Agency (IEA) (2006d) Energy Balances of Non-OECD Countries 2003/2004, Paris: IEA/OECD

IRIN (2003) "Border closed to curb banditry and smuggling", http://www.irinnews.org/report.asp?ReportID=35892&SelectRegion=West_Africa (accessed 2007-01-20)

Junger, Sebastian (2007) "Blood Oil", in Vanity Fair, February 2007, http://www.vanityfair.com/politics/features/2007/02/junger200702 (accessed 2007-02-14)

Karl, Terry Lynn (2005) "Understanding the Resource Curse" in *Covering Oil: A Reporter's Guide to Energy and Development* (eds. Svetlana Tsalik & Anya Schiffrin), Revenue Watch, Open Society Institute, Initiative for Policy Dialogue, http://www.soros.org/initiatives/cep/articles_publications/publications/covering_20050803/osicoveringoil_20050803.pdf (accessed 2007-01-19)

Klare, Michael & Volman, Daniel (2004) "Africa's Oil and American National Security", Current History 103(2004):673

Koppelaar, Rembrandt (2005) *World Oil Production and Peaking Outlook*, http://www.peakoil.nl/wp-content/uploads/2006/09/asponl_2005_report.pdf (accessed 2007-02-04)

Laherrère, Jean (2006) *Uncertainty on data and forecasts*, http://www.hubbertpeak.com/laherrere/ASPO2006-JL-long.pdf (accessed 2007-01-29)

Leffler, William L. & Pattarozzi, Richard & Sterling, Gordon (2003) *Deepwater Petroleum Exploration & Production: A Nontechnical Guide*, Tulsa: PennWell

Morrison, David & O'Rourke, Catriona (2006) *Angola's Oil & Gas Revenue: Past, Present & Future*, PowerPoint presentation, www.eitransparency.org/UserFiles/File/WoodMacDavidMorrisonAngolaOil%20GasRevenues.ppt (accessed 2007-02-05)

National Energy Policy Development Group (NEPDG) (2001) *National Energy Policy*, http://www.whitehouse.gov/energy/National-Energy-Policy.pdf (accessed 2007-01-15)

National Intelligence Council (NIC) (2000*) Global Trends 2015: A Dialogue About the Future With Nongovernment Experts*, http://www.dni.gov/nic/NIC_globaltrend2015.html#link8c (accessed 2007-02-08)

News Daily (2006) "Mass Burial for Nigerian Pipeline Victims", http://www.newsdaily.com/TopNews/UPI-1-20061228-12564700-bc-nigeria-pipeline.xml (accessed 2007-01-20)

Nigerian National Petroleum Corporation (NNPC) (2005) *2005 Annual Statistical Bulletin*

Obi, Cyril I. (2004) *The Oil Paradox: Reflections on the Violent Dynamics of Petro-Politics and (Mis)Governance in Nigeria's Niger Delta*, Leipzig: University of Leipzig Papers on Africa, Politics and Economics, No. 73

Offshore West Africa (2006) http://owa06.events.pennnet.com/ (accessed 2007-01-15)

Oil & Gas Journal (OGJ) (2006) "Special Report: Oil Production, Reserves Increase Slightly in 2006", vol. 104, issue 47, Dec 18, 2006

De Oliviera, Ricardo Soares (2006) "Kinas Oljesafari", in *Oljespill: jakten på Afrikas svarte gull*, Oslo: Fellesrådet for Afrika & Solidaritet forlag

Organization of Petroleum Exporting Countries (OPEC) (2007a) http://www.opec.org/home/quotas/ProductionLevels.pdf (accessed 2007-01-19)

Organization of Petroleum Exporting Countries (OPEC) (2007b) OPEC Bulletin, Jan 2007, http://www.opec.org/library/OPEC%20Bulletin/2007/pdf/OB012007.pdf (accessed 2007-01-20)

Pan, Esther (2007) "China, Africa and Oil", http://www.cfr.org/publication/9557/ (accessed 2007-02-08)

Robelius, Fredrik (2005) *Giant Oil Fields and Their Importance for Peak Oil*, Uppsala: Uppsala University

Robelius, Fredrik (2007a) *Giant Oil Fields – The Highway to Oil*, Uppsala: Acta Universitatis Upsaliensis (Uppsala Dissertations from the Faculty of Science and

Technology, no. 69)

Robelius, Fredrik (2007b) Personal communication during spring of 2007.

Skrebowski, Chris (2006a) "An Open Letter to CERA from Chris Skrebowski", http://www.globalpublicmedia.com/articles/825 (accessed 2007-01-22)

Skrebowski, Chris (2006b) *Peak Oil - The Emerging Reality*, http://www.aspoitalia.net/images/stories/aspo5presentations/Skrebowsky_ASPO5.pdf (accessed 2007-02-04)

Stark, Pete & Chew, Kenneth (2006) *The Exploration Dilemma in the Age of Energy Supply Anxiety*, PowerPoint presentation, http://energy.ihs.com/NR/rdonlyres/BAF57130-5BAE-43FE-82BD-957CE873F10B/0/Stark_Vail_v1.pdf (accessed 2007-02-05)

Svenska Petroleum Institutet (SPI) (2007) "Leveranser av oljeprodukter i Sverige, långtidsserie", http://www.spi.se/fprw/files/Leveranser%202006.xls (accessed 2007-03-31)

Söderbergh, Bengt & Robelius, Fredrik & Aleklett, Kjell (2007) "A crash programme scenario for the Canadian oil sands industry", Energy Policy 35 (2007)

Transparency International (TI) (2006) *Transparency International Corruption Perceptions Index 2006*, http://www.transparency.org/content/download/10825/92857/version/1/file/CPI_2006_presskit_eng.pdf (accessed 2007-01-22)

United Nations Development Programme (UNDP) (2006) *Human Development Report 2006*, New York: UNDP

United Nations Statistics Division (UNSD) (2006) *United Nations Statistics Division Common Database* (accessed 2006-11-28)

U.S. Geological Survey (USGS) (1997) *USGS Studies of Energy Resources in Sub-Saharan Africa*, Fact Sheet FS-053-97

U.S. Geological Survey (USGS) (2000) *World Petroleum Assessment 2000*, http://pubs.usgs.gov/dds/dds-060/ (accessed 2007-02-03)

White House (2007) "President Bush Creates a Department of Defense Unified Combatant Command for Africa", press release February 6, 2007, http://www.whitehouse.gov/news/releases/2007/02/20070206-3.html (accessed 2007-02-08)

Wolde-Rufael, Yemane (2006) "Electricity consumption and economic growth: a time series experience for 17 African countries", Energy Policy 34, 1106-1114

World Bank (1989) *Sub-Saharan Africa - From Crisis to Sustainable Growth*, Washington: World Bank

World Bank (2006) *World Development Indicators Database* (accessed 2006-12-04)

World Bank (2007a) "Enterprise Surveys Database", www.enterprisesurveys.org (accessed 2007-02-21)

World Bank (2007b) *Challenges of African Growth*, Washington: World Bank

Zarnikau, Jay & Guermouche, Sid & Schmidt, Philip (1996) "Can different energy resources be added or compared?", Energy 21, 483-491

Zweig, David & Jianhai, Bi (2005) "China's Global Hunt for Energy", Foreign Affairs, Sept./Oct. 2005, Vol. 84