U11A-0014 Problems Associated with Declining National Oil Production

James S. Jackson
Portland State University Portland, OR
jjackson@pdx.edu

1. Abstract

Forecasts of peak oil production have focussed on the global impacts of declining production. Meanwhile, national oil production has declined in 23 countries, leading to local problems that receive little comment outside of the effected regions. Two problems deserve wider recognition: declining state revenues and fuel substitution.

Most oil producing countries with large reserves adopted licensing practices that provide significant revenues to the host governments, such that oil revenues generate from 40 to 80 percent of total government funds. Typically these governments allocate a fraction of this revenue to their state oil companies, utilizing the remainder for other activities. As oil revenues decline with falling production, host governments face a dilemma: either to increase state oil company budgets in order to stem the decline, or to starve the state oil company while maintaining other government programs. The declining oil revenues in these states can significantly reduce the government's ability to address important national issues. Mexico, Indonesia, and Yemen illustrate this situation in its early phases.

Fuel substitution occurs whenever one fuel proves less expensive than another. The substitution of coal for wood in the eighteenth century and oil for coal in the twentieth century are classic examples. China and India appear to be at peak oil production, while their economies generate increasing demand for energy. Both countries are substituting coal and natural gas for oil with attendant environmental impacts. Coal-to-liquids projects are proposed in both China and India, which will require significant water resources if they are executed.

These examples suggest that forecasting the impact of peak oil at a regional level requires more than an assessment of proven-probable-possible reserves and a forecast of supply-demand scenarios. A range of government responses to declining oil income scenarios must also be considered, together with scenarios describing the range of environmental impacts. Forecasting the impact of national oil production declines is a multi-disciplinary activity requiring the skills of geologists, geophysicists, engineers, economists, and political scientists.

2. Global Peak Oil Forecasts

M. King Hubbert applied a logistic equation to forecast future Lower 48 US oil production while he was employed by Shell Oil Company. He subsequently revised his forecast while employed by the USGS. Figure 1 shows forecasts of US and world oil production presented by Hubbert to the US Congress in 1974. In subsequent years over two dozen forecasts of global oil production have been published (Figure 2). In most case Hubbert's logistic analysis has been applied using different assumptions.

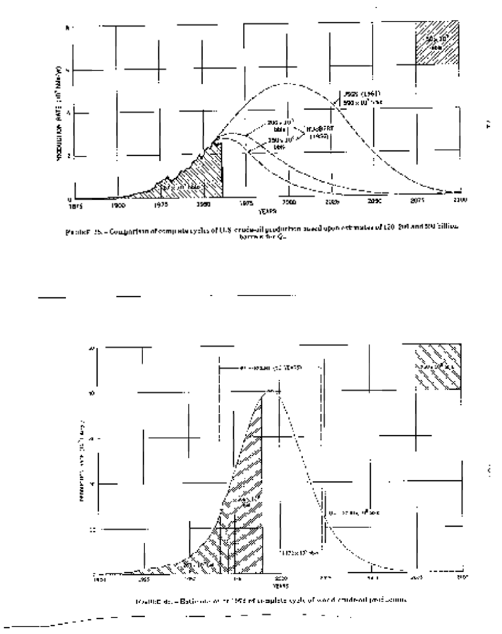


Figure 1. Peak Oil Forecasts (Hubbert 1974)

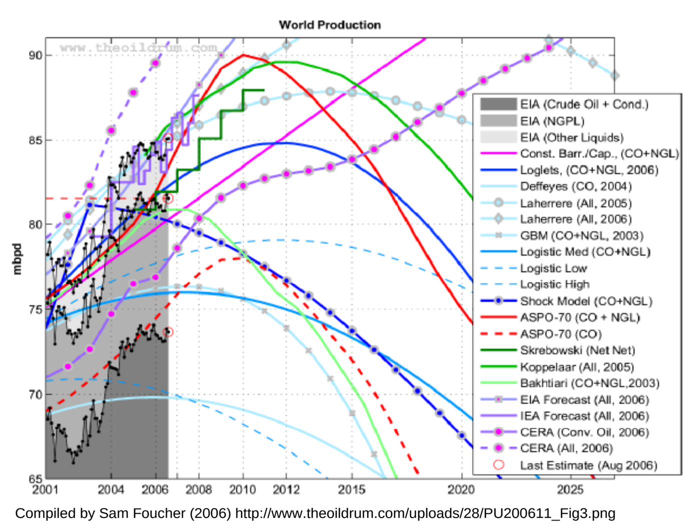


Figure 2. Recent Peak Oil Forecasts

Hubbert's method applies a technique used to forecast oil field production over the life of the field. It requires two assumptions: the volume to be produced and the initial production rate. To apply the technique to a country or the globe, four assumptions must be made (Figure 3).

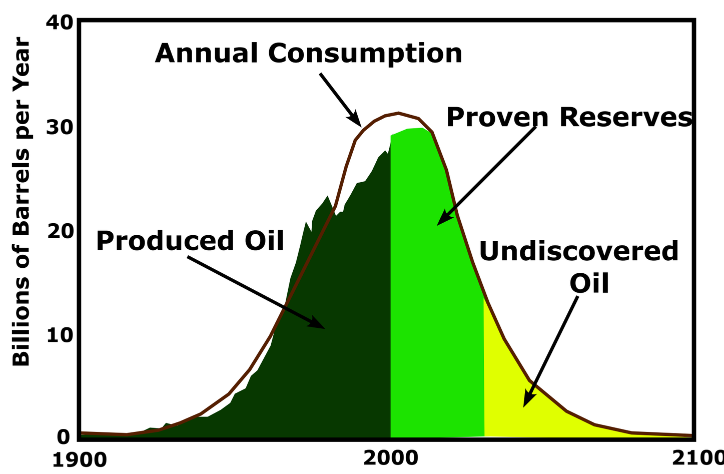


Figure 3. Components of an Oil Forecast

1. The volume of oil produced in the past.
2. The volume of oil discovered but not yet produced.
3. The volume of oil to be discovered.
4. The production profile from beginning to final depletion.

There is no significant dispute regarding (1), but there are disputes regarding (2-4). These lead to most of the differences among forecasts.

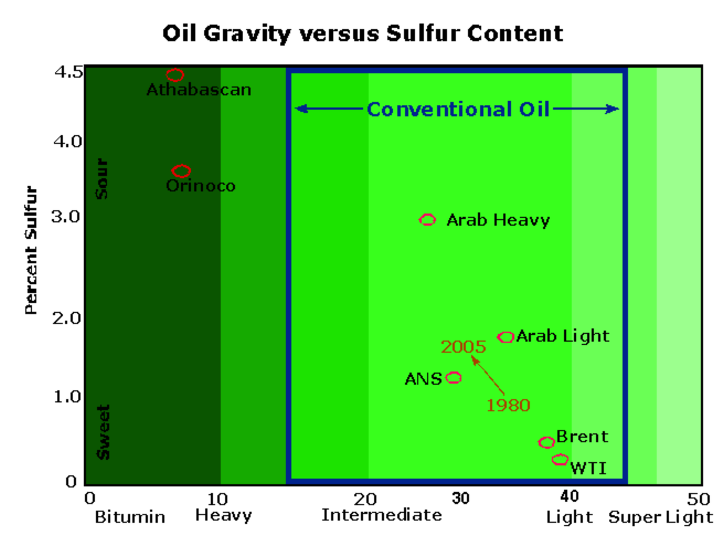


Figure 4. Composition of Selected Crude Oils

Among forecasts there are also differences regarding the type of oil under study. Refinery engineers identify as "conventional oil" that having an API Gravity less than 18°. A lower API oil is considered "heavy" or "unconventional". Some forecasts use an API of 18°, but the USGS uses an API of 15° in its assessments (Figure 4). Some forecasters do not distinguish conventional from "heavy" or "unconventional", lumping tar sands with lighter oils. Refinery engineers prefer to work with higher API oils, which yield a higher percentage of gasoline and other high value products than do low API or unconventional oils.

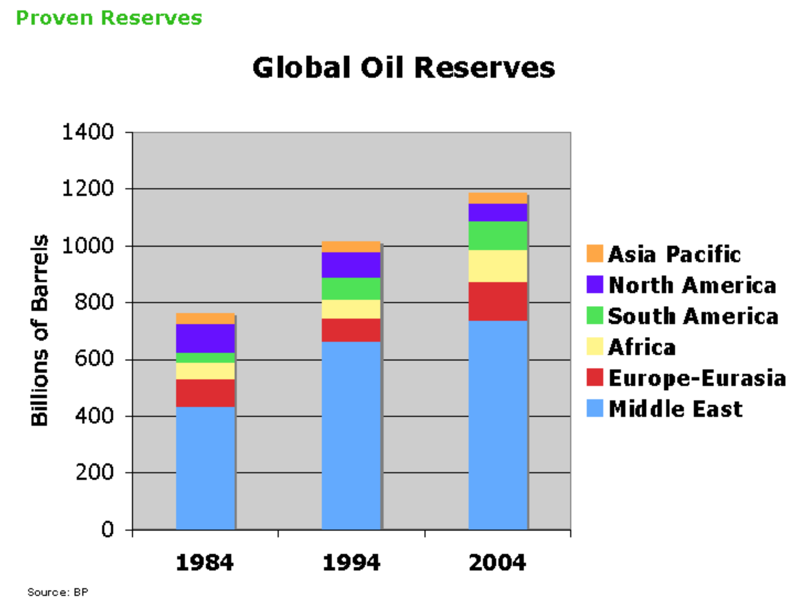


Figure 5. Global Oil Proven Reserves.

Proven reserves are subject to dispute by all global oil forecasters. In 1984 the price of oil collapsed by 50%. Members of OPEC responded by announcing new proven reserve estimates for their producing oil fields (Figure 5). These figures were not subject to an external audit, however, they were used to revise OPEC oil production quotas. Several analysts claim that Middle East proven reserves are over stated, and that a significant decline in production is imminent. Others claim the estimates are reliable. The treatment of these figures accounts a large portion of the forecast differences seen in Figure 2.

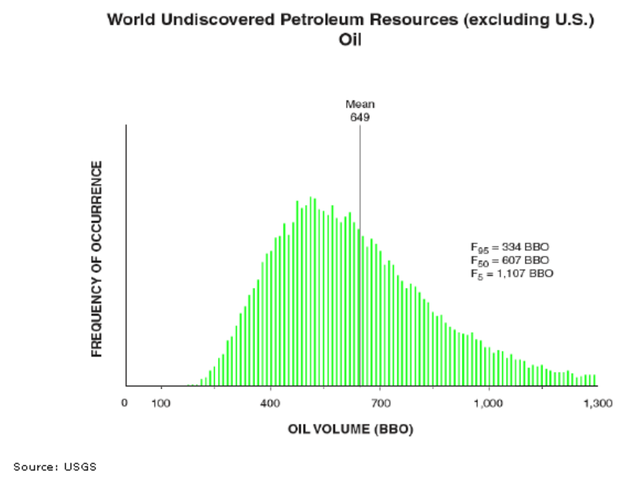
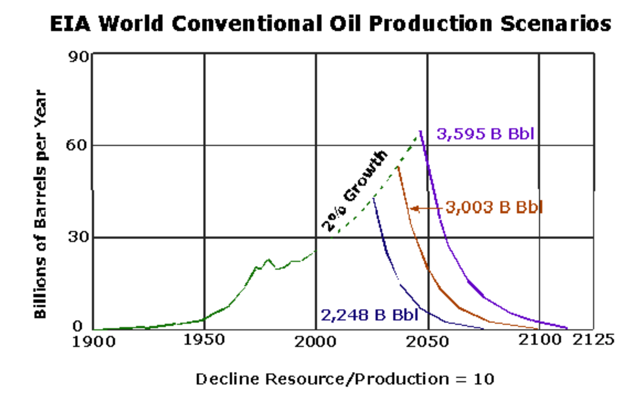


Figure 6. Undiscovered Oil Resources (USGS 2000)



Source: Wood et al 2004

Figure 7. Three Oil Production Scenarios

Most global oil production forecasts include undiscovered oil resources estimates made by the USGS, combining forecasts made for both US and non-US petroleum provinces (Figure 6). These estimates represent a range of possible future exploration outcomes, reflecting the uncertainty inherent in the exploration process. Some forecasts utilize the range of USGS estimate, thereby capturing some of the exploration uncertainty. Some also utilize more than one estimate of discovered, unproduced oil. Some forecasts choose a point within the USGS undiscovered oil estimate and a point within the range of discovered, unproduced oil to produce a single scenario that may be optimistic or pessimistic.

Less attention has been paid to the shape of the global oil production curve during or following "peak oil": many assume a symmetrical bell curve. The EIA has published scenarios that assume a different scenario (Figure 7). This topic deserves wider discussion outside of the economics literature.

A minority of forecasts use production data from producing fields to forecast likely field production profiles. These studies use forecasts of the 400 to 600 largest oil fields, which may account for 80 percent or more existing oil production. One such recent forecast (Figure 8) adds together the field forecasts to create a Fields in Production forecast (FIP), and then adds production forecasts for Fields Under Development (FUD), Fields Under Appraisal (FUA), and Fields Yet to Find (YTF).

These forecasts are well constrained by past field production data, but they rely on forecasts of declining field production which are subject to interpretation. These forecasts use proprietary oil field data bases whose quality varies from country to country, and from field to field.

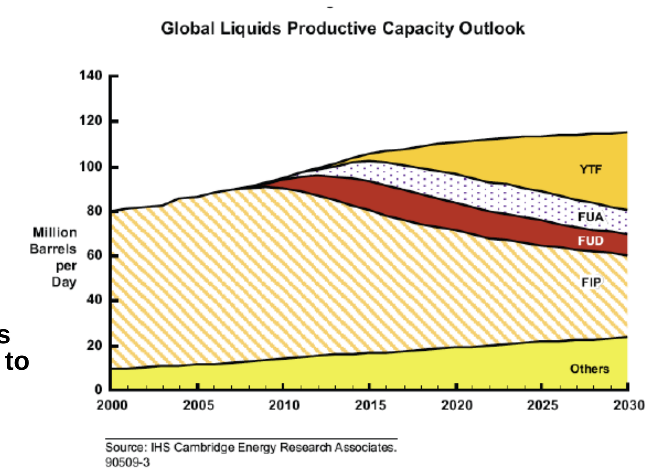


Figure 8. CERA 2009 Oil Production Forecast
http://www.cera.com/aspx/cda/client/report/report.aspx?KID=5&CID=10720

3. National Oil Production Forecasts

The wide range of global oil production forecasts does has not inspired a unified response from the oil industry or the political realm. Global peak oil forecasts provide no basis for policy responses, as there is no global agency charged to influence either global production or consumption. Oil is produced locally, and decisions effecting oil production are governed by national policy. Over 20 countries have a declining oil production profile (Figure 9).

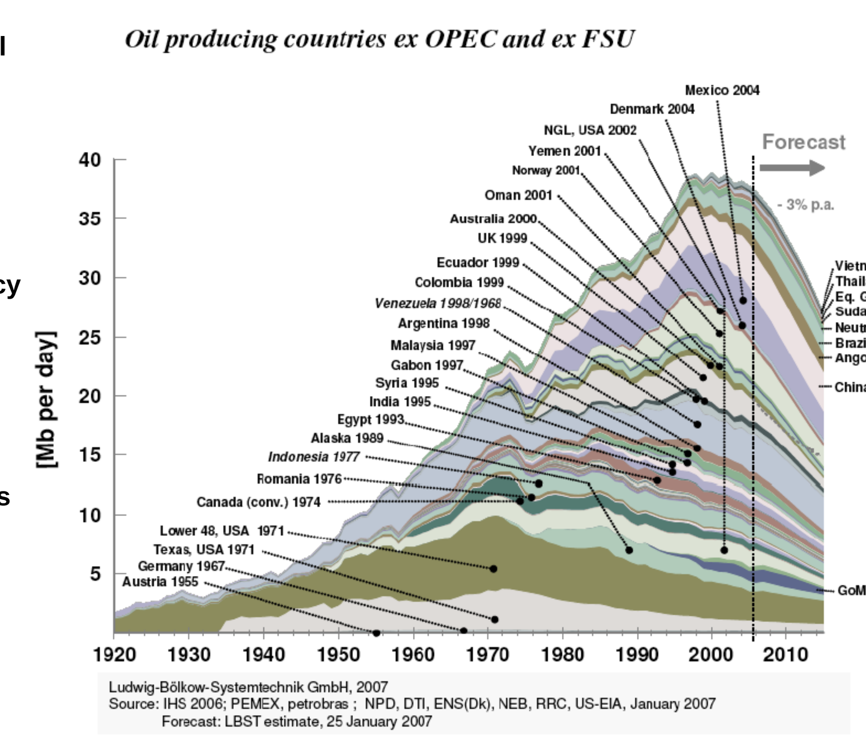


Figure 9. Oil Production Profiles by Country

4. Mexico

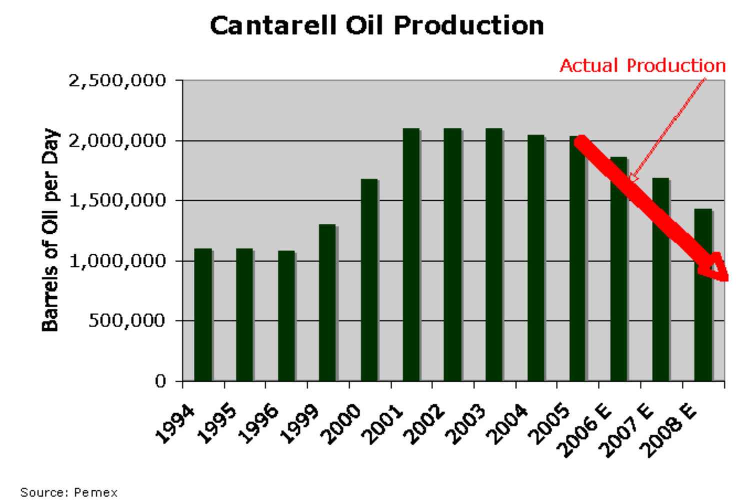


Figure 10. Cantarell Field Production.

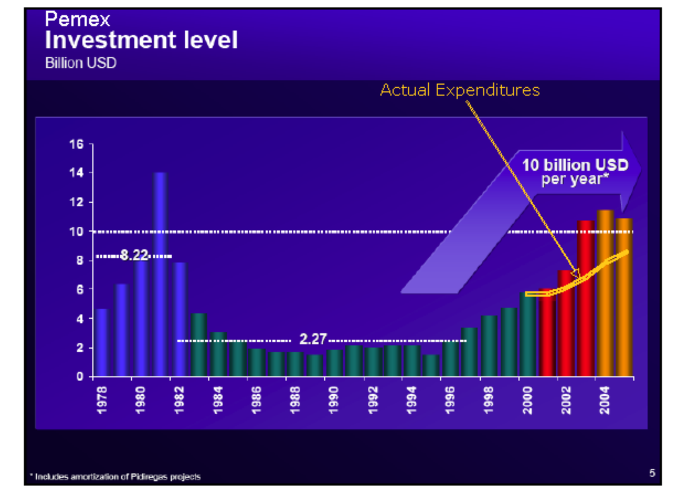


Figure 11. Pemex 2002 Capital Budget Forecast.

Oil exploration and production in most countries is controlled government organizations, such as national oil companies or departments of energy. Pemex is the state oil company of Mexico and it conducts both exploration and production throughout the country. Pemex is typical of state oil companies, in that revenues generated by oil production flow to the central government. In 2005 Pemex contributed 40% of the national government's revenue. Cantarell is the largest field in Mexico, contributing 57% of Pemex's revenue in 2005, and 24% of the national government's revenue that year. Production at Cantarell has fallen each year since 2005 at a faster rate than forecast by Pemex (Figure 10).

Each year Pemex receives a budget for exploration and production from the government (Figure 11). This is also the common practice at most national oil companies. Pemex proposes a capital budget to the national government as well as a long term capital expenditure plan. The national government allocates funds to Pemex based on a hierarchy of national funding priorities. Between 2002 and 2008 Pemex was given less funding than requested, resulting in less development and exploration well drilling. The rapid annual decline in production at Cantarell is in a part a result of these annual capital allocations to Pemex.

Declining oil production in Mexico will likely continue, reducing revenues for the national government. New taxes on other economic sectors will have to be found to offset the declining revenue stream. Without these, the government will be less able to provide services. This situation is typical of "petro-states" that obtain much of their government revenue from oil and gas production after that production goes into decline.

5. Indonesia

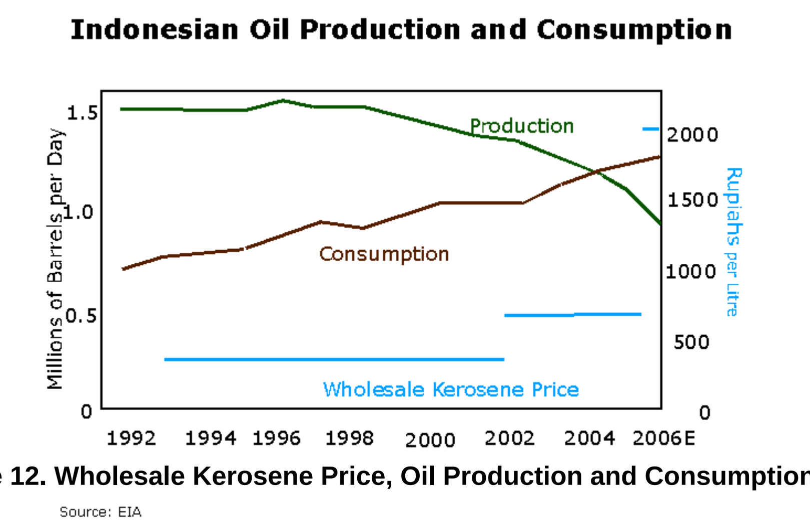


Figure 12. Wholesale Kerosene Price, Oil Production and Consumption

Indonesian oil production peaked in 1977 and began to decline in 1999 (Figure 12). As a member of OPEC during this period, Indonesia's production was subject to the OPEC quota system. Indonesia's oil consumption increased until it exceeded production in 2004, at which time Indonesia became an OPEC "observer member". Kerosene is the most widely consumed refined product in Indonesia. It's wholesale price is set by the national government. Between 1992 and 2002 the wholesale price of kerosene was only 10 percent of the world wholesale price. With declining crude production, the government doubled the wholesale price, touching off minor riots in 2002. In late 2005 the government raised the price kerosene again so that it was within ten percent of global wholesale price, this time provoking major riots throughout the country.

6. National Oil Production: Yemen

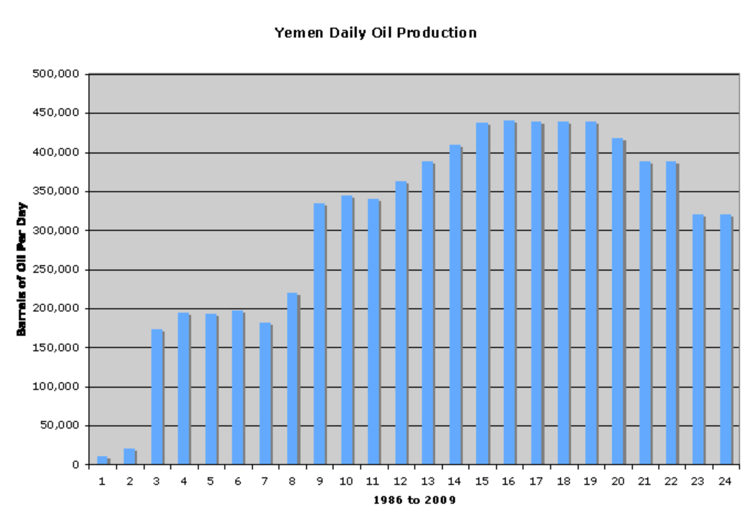


Figure 13. Daily Oil Production in Yemen 1985 to 2009

Oil was discovered in Yemen in 1984. A pipeline was built to the Red Sea coast in 1987, leading to a rapid increase Yemeni oil production (Figure 13). Production peaked in 1999 and began to decline in 2003. In 2005 oil revenues contributed 76% of total government revenue (Central Bank of Yemen 2005 Annual Report). In 2007 oil revenues contributed 69%, and 75% in 2008 when oil prices exceeded $100/barrel. The Central Bank of Yemen recently reported a 75% fall in oil revenues through July, 2009. At present the national government subsidizes fuel consumption, which accounts for one-third of government expenses. Most water is obtained from wells, and an estimated 90% of diesel fuel is used by water well pumps. The World Bank forecasts oil revenue will fall to zero in 2017.

7. Fuel Substitution: Coal to Liquids Projects in India and China

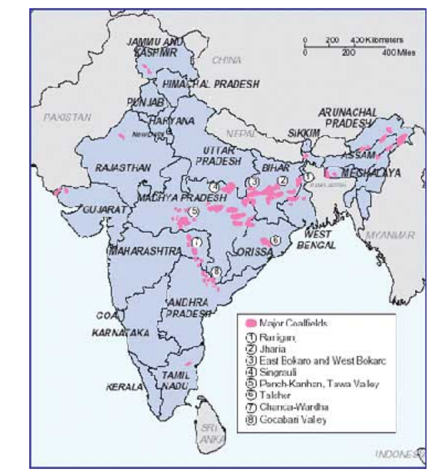


Figure 14. Coal Mining Districts of India

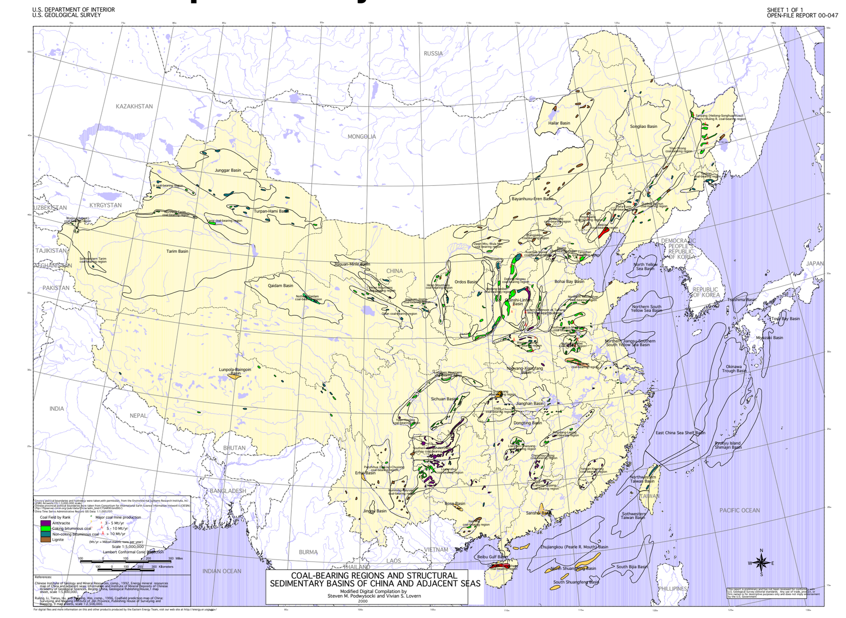


Figure 15. Coal Mining Districts of China

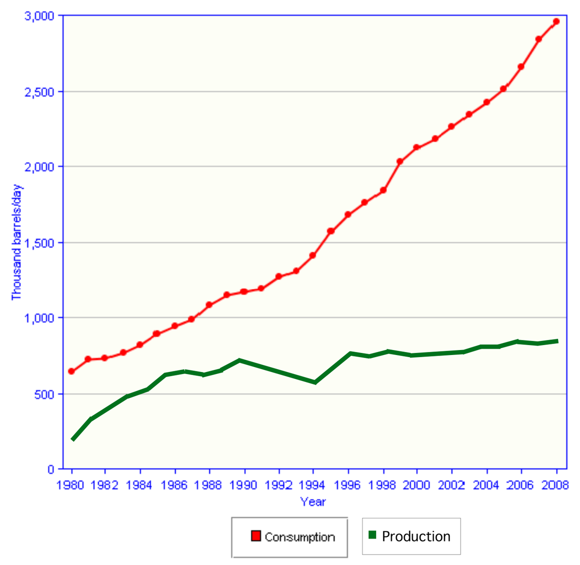


Figure 16. Oil Production and Consumption in India

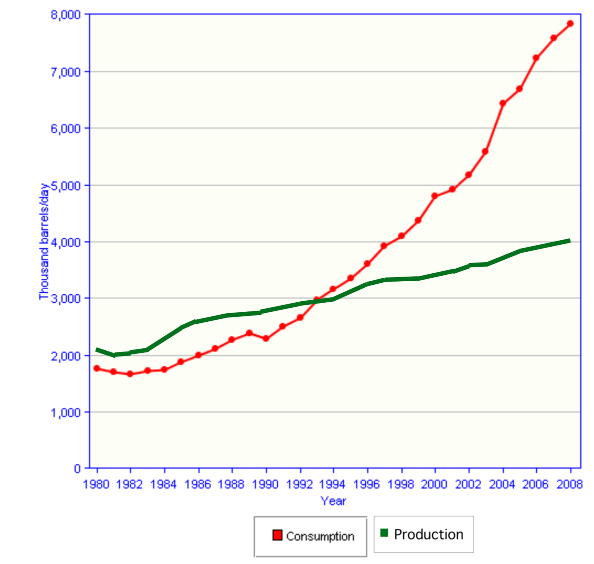


Figure 17. Oil Production and Consumption in China.

Commodity fuel substitution may occur when one fuel becomes less expensive than another. This may occur when new sources of a fuel are discovered, driving its price down, or when supplies of a fuel are nearly exhausted, driving its price up. The use of charcoal in iron smelting greatly reduced the supply of wood, first in Britain and later in North America. In both cases, coal was substituted for charcoal (Rich et al 1977) in the 18th century. Coal was adopted in shipping in the 19th century, only to be replaced by oil in the 20th century (Yergin 1991). With increasing oil prices in recent years, a return to coal as a transportation fuel has been proposed.

India and China possess substantial coal deposits (Figures 14 & 15). Neither country is able to meet increasing oil consumption with internal production (Figures 16 & 17). Coal-to-liquids projects have been proposed in both countries, including a new built pilot project at Shenzen. These projects appear to pose two environmental problems in addition to those due to coal mining.

Coal can be converted to a liquid fuel through three processes. Each has a somewhat different fuel yield (Bartis et al 2008) :

Fischer-Tropsch	~2.1 barrels per metric tonne of coal
Methanol-to-Gasoline	~2.2 barrels per metric tonne of coal
Direct Liquifaction	2.9 barrels per metric tonne of coal

Water requirements in these processes are poorly constrained for industrial scale projects. Estimates range from 5 to 10 barrels of water for 1 barrel of liquid fuel. Assuming an average of 2.5 bbl per tonne coal, a 1 million barrel per day coal-to-liquid fuel program woul use 146 million tonnes of coal and 28 to 56 million cubic feet of water per year. India consumed 238 million tonnes of coal in 2006 (IFP).

Carbon dioxide emissions are estimated to be 0.9 metric tonnes per barrel of fuel. A 1 million barrel per day coal-to-liquids program would emit 328 metric tons of carbon dioxide per year. In 2006 China emitted 6,018 metric tonnes of CO_2 while India emitted 1294 metric tonnes.

8. Discussion

Declining national oil production reduces oil-generated revenue in oil producing countries. Some "petro states" receive over 70% of their government revenue from oil production. As revenues fall, political difficulties arise when either fuel subsidies are reduced or taxes are imposed on other sectors of the national economy. Falling revenues can reduce the national government's ability to respond external stresses, such those resulting from climate change. Falling revenues may also lead to the failure of a petro state government. States with more robust economies may respond to declining oil production by substituting gas, coal, or fuels manufactured from gas. In addition to the environmental impacts due to coal mining, these activities also increase demand on fresh water, and produce additional CO_2 emissions. If the results of science are to influence these processes, then the political and economic components of the policy process must be explicitly recognized.

Acknowledgment
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