THE FUTURE OF OIL IN MEXICO

/ EL FUTURO DEL SECTOR PETROLERO EN MÉXICO



Scenarios for Oil Supply, Demand and Net Exports for Mexico

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JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
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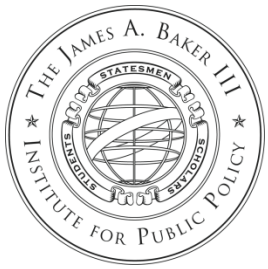

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Scenarios for Oil Supply, Demand and Net Exports for Mexico

By

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About the Study: The Future of Oil in Mexico/ El futuro del sector petrolero en México

The energy industry plays an important role in the Mexican economy, and energy trade is a major component to the U.S.-Mexico relationship. The Mexican government relies on the oil industry for 35 percent of total government revenues, including taxes and direct payments from Petróleos Mexicanos (Pemex), the state oil company. Mexico is the third-largest foreign crude oil supplier to the United States. However, with declining production and rising demand, Mexico could become a net oil importer in the coming decade. President Calderón pushed for energy sector reform in Mexico, but more reforms will be needed for Mexico to reverse its current path toward importer status. This study identifies the dynamics of the political trends in Mexico that will impact future energy policy. The aim of this study is to promote a better understanding of the challenges facing Mexico's oil sector and to enhance the debate among policymakers, the media and industry on these important issues.

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Since its establishment in 2002, Oxford's Mexican Studies Programme has conducted research and promoted graduate teaching in Mexico's external relations; democratization and the functioning of democratic institutions in Mexico; and on various Mexican public policy issues, including economic and energy policies.

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Medlock's research covers a variety of topics in energy economics, including domestic and international natural gas markets; energy commodity price relationships; transportation; modeling national oil company behavior; economic development and energy demand; and energy use and the environment. Medlock is member of the International Association for Energy Economics (IAEE), the American Economic Association and the Association of Environmental and Resource Economists. In 2001, he won (joint with Ron Soligo) the IAEE's "The Energy Journal" Campbell Watkins Best Paper Award.

Medlock served as an adviser to the U.S. Department of Energy and the California Energy Commission in their respective energy modeling efforts. He also was the lead modeler of the modeling subgroup of the 2003 National Petroleum Council (NPC) study of long-term natural gas markets in North America, and was a contributing author to the California Energy Commission and Western Interstate Energy Board's "Western Natural Gas Assessment" in 2005. He also contributed to the 2007 NPC study "Facing the Hard Truths" and is involved in the ongoing NPC study, "North American Resource Development."

Previously, Medlock held the Baker Institute's M.D. Anderson Fellowship and was a corporate consultant at El Paso Energy Corporation. He received his Ph.D. in economics from Rice.

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I. Introduction[1]

Oil has been important for Mexican economic development, but has been both a boon and a curse. While the heady days of the oil bonanza are relatively recent, dating to the mid-1970s, the Mexican oil industry dates back to the early days of the 20th century. Spurred by World War I demand, Mexico became a major producer and exporter with production peaking at 25% of world output in 1921.[2] Mexico continued to be a major exporter until the onset of the Great Depression when oil prices collapsed along with demand, and Venezuela emerged as a significant producer and exporter.

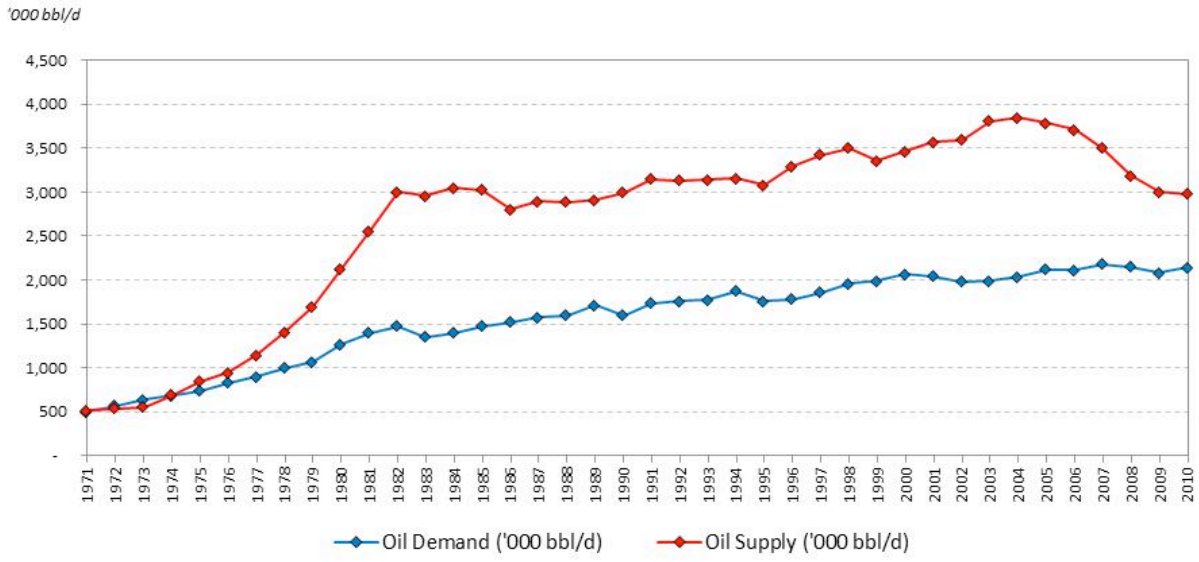
The Mexican oil industry was sustained by a recovery of domestic oil demand during the 1940s, but the country became a net importer in the mid-1950s. Eventually, the discovery of the super-giant Cantarell oil field in the mid-1970s dramatically changed the scale and nature of the Mexican oil industry. Once again, Mexico became a major exporter of oil.

Following the massive discoveries in the late 1970s, Mexican oil production surged from roughly 500,000 barrels per day (b/d) to just over 3 million b/d in 1982. Production hovered around that level until the mid-1990s when there was an additional increase in output. Production peaked at approximately 3.9 million b/d in 2004. Since 2005, Mexico's output has fallen by more than 25%, to 2.98 million b/d in 2010.[3]

At the same time, domestic demand for oil has grown from 500,000 b/d in 1971 to roughly 2.15 million b/d in 2010, with some fluctuations along the way reflecting the changing fortunes of the economy.[4] At present, Mexico is a net oil exporter, with total net exports in 2009 running at just under 1 million b/d.

[1] The authors would like to thank Esther Rios and Sam Hile for their research assistance.
[2] Tim L. Merrill and Ramón Miró, eds., *Mexico: A Country Study* (Washington, DC: GPO for the Library of Congress, 1996). http://countrystudies.us/mexico/78.htm.
[3] Data on total oil supply is from the U.S. Energy Information Administration.
[4] Demand includes both the direct demand for oil by end users in Mexico as well as the indirect demand for oil embodied in imports of refined petroleum products.

Figure 1. Mexican Oil Supply and Demand, 1971-2010



Unfortunately, heavy borrowing and economic mismanagement prevented Mexico's rise as a major oil producer in the 1970s and 1980s from producing strong economic growth. Over the past two decades, the country has pursued economic reforms, including the privatization of many state-owned companies and a general opening of the economy to international markets. The production and export structure of the Mexican economy was restructured to diversify earnings and, thus, it is no longer dependent on oil exports for the overwhelming share of export earnings. Still, oil exports are important, accounting for 15% of total export earnings in 2009. Moreover, oil remains a major source of revenue for the federal government, contributing some 40% to total government revenues.[5]

Given the important role oil export earnings play in the country's federal budgeting process, the decline in oil output that began in 2005 is of considerable concern. National debate has ensued about what Mexico needs to do to stave off continued declines in oil output rates. Outside observers are not optimistic about Mexico's chances to reverse its rapid production decline. For example, the Energy Information Agency (EIA) forecasts that Mexico's liquids production will drop to around 1–1.4 million barrels per day by 2025—depending on the assumption regarding

[5] U.S. Energy Information Administration, Mexico–country analysis, http://www.eia.doe.gov/countries/cab.cfm?fips=MX.

oil prices. Such a continued drop in production levels would mean that Mexico would inevitably become a net oil importer. With per capita growth remaining anemic—averaging only 1.1% between 1985 and 2008[6]—it remains unclear how Mexico would adjust to an anticipated drop in oil export earnings.

Recent increases in spending have meant that Pemex has been able to slow the decline rate at the Cantarell field, at least temporarily. Pemex has also increased investments in the Ku-Maloob-Zaap (KMZ) and the onshore Chicontepec fields. Production at KMZ has increased but not in sufficient quantities to offset declines at Cantarell. Chicontepec has thus far proven to be a very large disappointment because of its complex geology. Despite spending more than US$4.9 billion on the field, production is forecast to be only 70,000 b/d in 2011.[7]

It is believed that Mexico has substantial resources in the deepwater areas of the Gulf of Mexico. The U.S. Geological Survey (USGS) puts the mean estimate of those resources at 10 billion barrels. However, Pemex does not currently possess the know-how and technology to develop these resources, and the recent spill in the U.S. Gulf of Mexico may, in any case, further delay development. Even if new reforms would allow Pemex to partner with private firms to give it access to needed technology, the required lead times to undertake seismic and development work, including the necessary infrastructure to handle production, suggests that oil from deepwater areas will be not be produced for many years.[8] In the meantime, Mexico will have to depend on its shallow water and onshore resources. Nevertheless, deepwater development may be necessary to ensure long-term export capability and revenue generation.

In this paper, we model Mexican oil demand and supply to examine some possible scenarios for the future of Mexican oil exports. We find that under reasonable, average assumptions about Mexican economic and population trends, Mexico could become a net importer of oil within the

[6] Gordon H. Hansen, "Why Isn't Mexico Rich?" *Journal of Economic Literature* XLVIII, no. 4 (December 2010): 987-1004.
[7] Carlos Manuel Rodriguez, "Pemex Increases Chincontepec Output Estimate for 2011," *Bloomberg Businessweek,* October 29, 2010. http://www.businessweek.com/news/2010-10-29/pemex-increases-chicontepec-output-estimate-for-2011.html.
[8] Manik Talwani, "Oil and Gas in Mexico: Geology, Production Rates and Reserves," James A. Baker III Institute for Public Policy, April 29, 2011 (paper from the study "The Future of Oil in Mexico/El futuro del sector petroléro en México").

next 10 years if it fails to sufficiently invest in upstream activities utilizing advanced technologies. Investment in oil field development has accelerated during the last two years but the results so far do not point to a reversal of the downward trend, given technical and geological barriers.[9] Thus, without major changes, Mexico may be heading for yet another crisis in both its balance of payments and federal budget accounts.

II. Scenarios for Mexican Oil Demand

Our approach to determining net Mexican oil exports over the next decades is based on a model consisting of two parts—one for the demand, the other for supply.

Demand for oil is projected by a broadly defined end-use sector (residential and commercial, transportation, industrial, and other). The demand in each sector is a function of:

- Per capita income (measured in real Purchasing Power Parity (PPP) dollars)
- Population
- Oil price
- The share of oil in the production of electricity (to capture the substitution of gas and renewables for oil in the generation of electricity)

The model is an extension of the work by Medlock and Soligo[10] in which panel data for 28 countries was used to generate end-use energy demand for each of the three sectors defined.

In the Medlock-Soligo demand model, we utilize forecasts for both economic and population growth. For the latter, we rely on population projections from the United Nations. For economic growth, we develop a model based on the notion of conditional convergence. Countries are assumed to converge to a reference growth rate, which is modeled as a per capita income-dependent path using a spline knot regression of the per capita income growth rate of the United States on per capita income since 1840. Each country is then modeled as converging to this

[9] Talwani, "Oil and Gas."
[10] Kenneth Medlock and Ronald Soligo, "Economic Development and End-Use Energy Demand" *Energy Journal* 22, no. 2 (April 2001).

fitted long-run path where the rate of convergence is estimated using panel data for 78 countries. Countries converge to the long-run growth path at a rate estimated by using an unbalanced panel across all countries spanning multiple years.

For this exercise projecting Mexican demand, we have considered various scenarios involving the four variables in the demand equation. These scenarios are given in Table 1.

Table 1. Assumptions Used for the Demand Scenarios

	Growth in Per Capita Income	Population Growth Rate	Oil Price US$ Per Barrel	Oil Share in Power Generation
High	3.0 %	1.1 %	95	36.7 %
Median	1.5 %	0.6 %	75	20.0 %
Low	0.5 %	0.2 %	55	1.0 %

The scenarios for overall gross domestic product (GDP) growth (which is the sum of per capita growth rate and the population growth rate) range from 4.1% to 0.7%. These growth rates are expressed in real PPP dollars. (These are highly correlated with GDP expressed in dollars converted at official exchange rates, but are considered to be a better measure of economic development.)

Our "high" scenario per capita income growth of 3% is chosen somewhat arbitrarily but is certainly considered an average growth rate within reach of the Mexican economy. The "median" scenario of 1.5% growth is the historical average growth rate from 1971 to 2007.

Table 2 shows how domestic oil demand varies for different assumptions about per capita income growth and the price of oil. In all of these cases, we have assumed the median population growth rate (0.6% per annum) and that oil would account for 20% of the fuel used in the generation of electricity.

The difference in oil demand between the high (3%) and low (0.5%) per capita growth rates is not extremely large over the next decade. Under the high growth scenario, Mexican oil demand would rise from 2.141 million b/d in 2010 to 2.419 million b/d by 2015 and 3.016 million b/d by 2025 (see Table 2). Under the low growth scenario, Mexican oil demand is predicted to be 2.264 million b/d by 2015 and 2.469 million b/d by 2025. The difference in demand between the high to the low case is about 150,000 b/d in 2015, and increases to 450,000 b/d by 2025.

The effect of the different price assumptions is smaller. The difference in demand under US$95 and US$55 scenarios is only 55,000 b/d by 2015, reaching just over 300,000 b/d in 2025. Of note here is the fact that, in comparison to supply-side influences, the assumptions regarding GDP growth and oil price are not large determinants of the export potential in Mexico in the near term.

Table 2. Domestic Oil Demand Under Different Assumptions ('000 barrels per day)

	Oil Price = US$75			*Per Capita GDP growth = 1.5%*		
Year	Per Capita GDP Growth 3.0%	Per Capita GDP Growth 1.5%	Per Capita GDP Growth 0.5%	Oil Price US$55	Oil Price US$75	Oil Price US$95
2010	2,141			2,141		
2015	2,419	2,326	2,264	2,357	2,326	2,302
2020	2,695	2,495	2,362	2,590	2,495	2,424
2025	3,016	2,684	2,469	2,867	2,684	2,553
2030	3,373	2,890	2,581	3,182	2,890	2,686
2035	3,764	3,111	2,700	3,535	3,111	2,824

Using our median per capita growth rate of 1.5% and the median price forecast, oil demand is projected to reach 2.326 million b/d by 2015 and 2.684 million b/d by 2025.

III. Scenarios for Mexican Oil Supply

In our model, the supply of oil is a function of:

- The reserve-production ratio, which inversely identifies the rate at which reserves are drawn down within a period
- The rate of reserve additions, where reserves are added as a result of growth in existing fields through the course of development and through upstream investment in new plays
- The technically recoverable resource base, which defines the extent to which proved reserves can expand with continued investment (estimates are from the USGS)

The depletion rate is determined by the difference between reserve additions and production; the critical determinants of future supply are replacement rate and the total resource base.

Our projected supply estimates are based on the four scenarios shown in Table 3.

Table 3. Assumptions Used for the Supply Scenarios

	Annual Reserve Replacement (billion bbls)	Recoverable Resource Base (billion bbls)	Additional Deepwater Resource (billion bbls)
High	2.2	61.81	18
Median	1.2	29.83	10
Low	0.00	7.18	0
Five Year Average (2005-2009)	0.220	NA	NA

Reserve replacements are given in absolute magnitudes based on several alternative assumptions. The “high” scenario of 2.2 billion barrels each year represents a very optimistic outcome. This corresponds to high levels of upstream investment that bring large-scale fields online. The “median” scenario for the rate of reserve replacement (1.2 billion barrels per year) is

based on U.S. experience over the last 10 years, adjusted for the relative resource base in the United States and Mexico. The "average" replacement of 0.275 refers to the actual average reserve replacement in Mexico during the last five years. The "low" level assumes no new replacements. The use of high and low scenarios is useful to determine the sensitivity of our results to various assumptions. Our analysis below is based primarily on the "median" and "five-year-average" scenarios. The level of reserve replacement is ultimately determined by the level of investment in oil field development; but rather than explicitly model the investment process and probability of exploration success, we choose to examine scenarios that cover the range of outcomes that could be realized in Mexico.

The resource base data refer to USGS estimates that reflect the probability distribution associated with estimates of technically recoverable resources. The "high" estimate refers to the P-5 estimate, or the quantity identified to exist with a 5% degree of certainty. Similarly, the "low" resource base estimate is the P-95 estimate, and the median number refers to the P-50 estimate. The production forecast is modeled such that it cannot exceed the total resource base. However, our supply forecasts are not sensitive to the resource base assumption over the period considered.

The deepwater Gulf of Mexico resource estimates are shown separately. We assume that these resources are not available until 2020, reflecting an optimistic assumption regarding the pace of exploration and development in this untapped frontier, especially given the lead times associated with production infrastructure development. Nevertheless, once the resource is available, the reserves may be booked and production may commence.

Table 4 shows the effect of different assumptions regarding the replacement rate on oil production. Abstracting from the surge in output that might occur after 2020 when deepwater fields are developed, the difference between business as usual (continuing reserve replacement at the average rate over the last five years) and a U.S.-type replacement is quite large. By 2015, the difference in production is more than 600,000 b/d.

Beyond 2020, production of deepwater resources is a material factor in comparing production forecasts. For example, in 2025, the difference between an average recovery rate scenario and a U.S. recovery rate scenario is 2 million b/d, when deepwater resources are not pursued. But under a scenario where deepwater resources are exploited, the difference between the five-year recovery rate scenario and the U.S. recovery rate scenario is only 900,000 b/d. This occurs because the exploitation of deepwater Gulf of Mexico (GoM) resources results in a very large increase in forecast production under the scenario with the lower reserve replacement rate.

Table 4. Domestic Oil Supply Under Different Assumptions ('000 barrels per day)

	No Deepwater Resources		Deepwater Resources Included	
Year	Median Reserve Replacement	Last 5 Years Reserve Replacement	Median Reserve Replacement	Last 5 Years Reserve Replacement
	Reserves (billion bls)			
2010	10.404			
2015	10.749	6.401	10.749	6.401
2020	11.015	3.714	21.015	13.714
2025	11.219	2.197	19.876	9.558
2030	11.378	1.583	18.698	5.801
2035	11.501	1.355	17.640	3.348
	Production ('000 b/d)			
2010	2,983			
2015	3,118	2,506	3,118	2,506
2020	3,157	1,798	3,157	1,798
2025	3,187	1,189	3,970	3,088
2030	3,209	820	3,907	2,369
2035	3,226	683	3,841	1,679

The combined conclusion from Tables 2 and 4 is that variations in factors that impact the supply side will be the most critical factor in determining Mexico's future export potential. We turn to this point in the next section.

IV. Forecasts for Mexico's Net Oil Exports

Figure 2 shows domestic production and demand to 2040 under the "median" scenario for both supply and demand, and Figure 3 shows net exports from 2010-2040 under this scenario. Thus, per capita GDP growth is set to 1.5%, population growth is assumed to be 0.6%, reserve replacement is assumed to be 1.2 billion barrels per year, the resource base is assumed to be 29.8 billion barrels, and the additional deepwater resource of 10 billion barrels is also available for exploitation beginning in 2020. Figure 3 reveals that net exports decline steadily until 2020 when deepwater resources are brought online. Then, there is a resultant short-term boost in exports, but declines resume with net imports occurring after 2040. If the deepwater resources are much lower than expected or their development is delayed, the downward trend seen in the period up to 2020 will continue.

Figure 2. Mexican Oil Production and Demand (1971-2040) Under Median Scenario

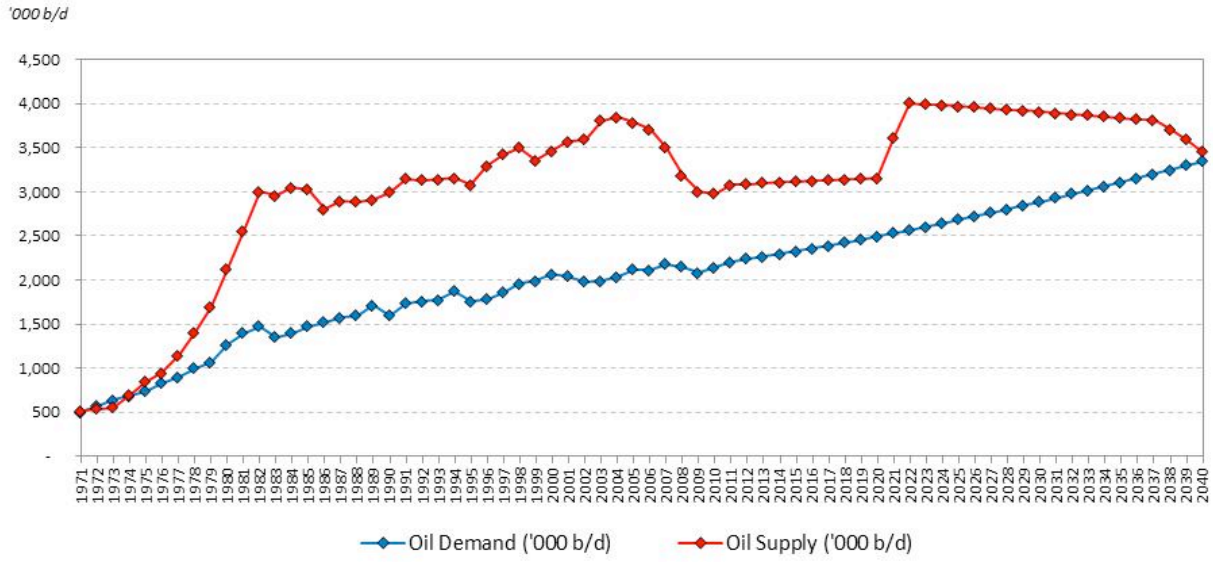


Figure 4 shows net exports under a scenario of median growth in per capita income (1.5% per year) and population (0.6% per year) but reserve replacement is assumed to be equal to the five-year average experienced in the period 2005-09. The median resource base (29.8 billion barrels) and median deepwater resource (10 billion barrels) are also assumed. Thus, this scenario

represents a case in which upstream investment is not as large as in the scenario depicted in Figures 2 and 3.

Figure 3. Mexican Net Oil Exports (1971-2040) Under Median Scenario

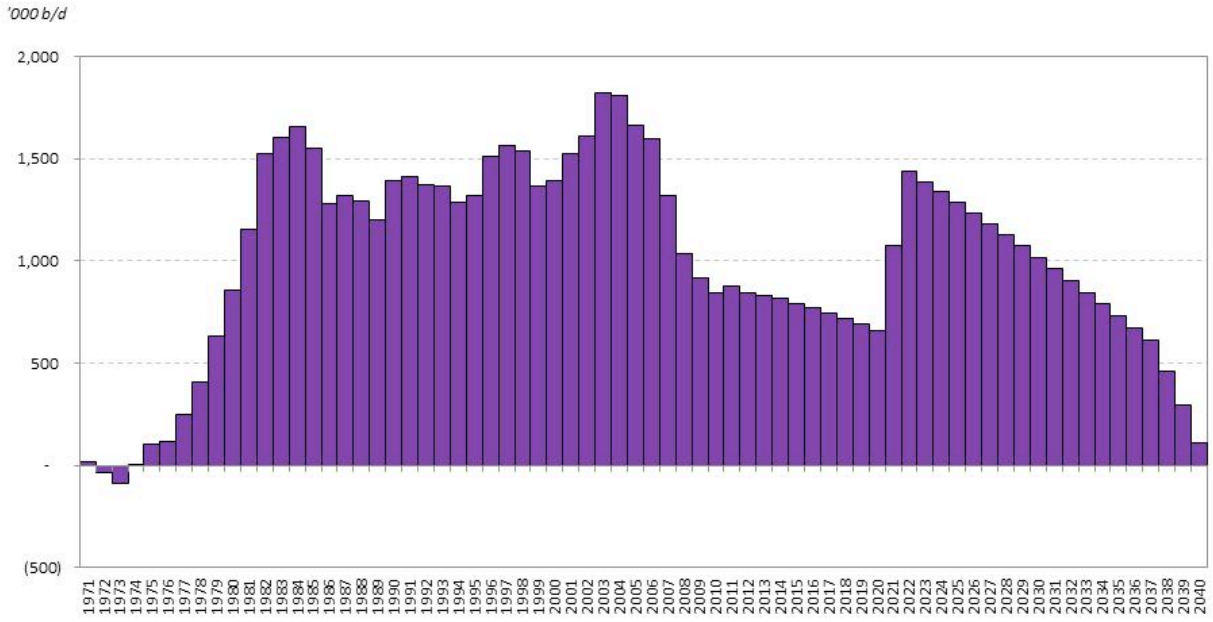
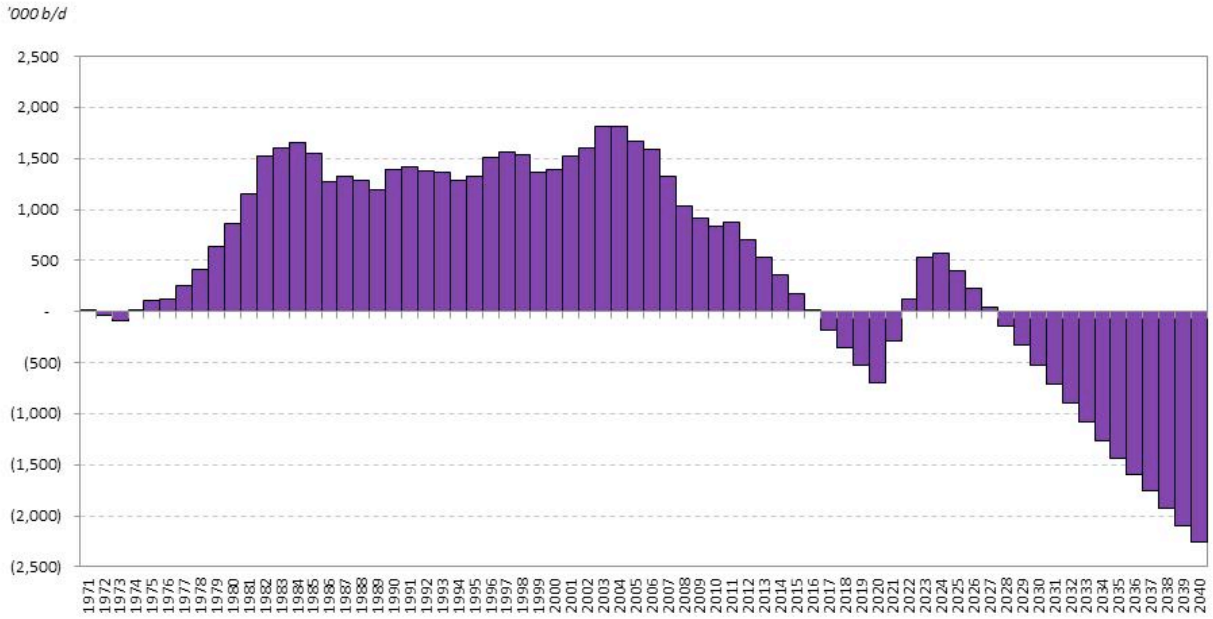


Figure 4. Mexican Net Exports (1971-2040) Under Less Aggressive Investment Scenario



Under this assumption, Mexico becomes a net importer of oil in 2016 and imports will continue to increase until deepwater resources come online in 2020. If the development of deepwater resources is delayed, or simply does not occur, then the level of oil imports will continue to increase as production declines continue.

Although differences in the growth rate of income and the price of oil can have appreciable impacts on demand, these differences are relatively small over the next few years and, hence, exert only a minor effect on net exports for the decade. Clearly the higher the growth in per capita income and the lower the price of oil, the greater will be demand growth and the earlier will net exports reach the zero position. But even with a 3% per capita growth rate and US$55 oil, the year when net exports reach zero is advanced by only one year (not pictured).

It is the supply side that is critical in determining net exports over the immediate time period. The experience over the past five years in terms of reserve replacement indicates that exports cannot be sustained and that net exports are on a path toward zero within a decade. On the other hand, if Pemex can increase the rate of reserve replacement in relation to its overall resource base to something like what is seen in the United States, the export crisis could be avoided for many years to come. As Figure 3 shows, net exports can be sustained for another 30 years. Moreover, this conclusion holds even if deepwater resource development is deferred indefinitely. Figure 5 shows that in the median supply and demand case, exports in the 2020s and beyond would be lower than in the case where deepwater is developed, but net exports remain positive through the mid-2030s.

The most optimistic case for supply development coupled with the median forecast for oil price, economic growth, and population growth is pictured in Figure 6. Here, we have assumed the "high" cases for the resource base, additional deepwater resources, and reserve replacements, equal to the U.S. experience. The export picture under this scenario remains quite robust through 2040. Importantly, for this scenario to come to pass, dramatic changes are required for upstream development in Mexico.

Figure 5. Mexican Net Oil Exports in the Median Supply and Demand Case without Deepwater Development

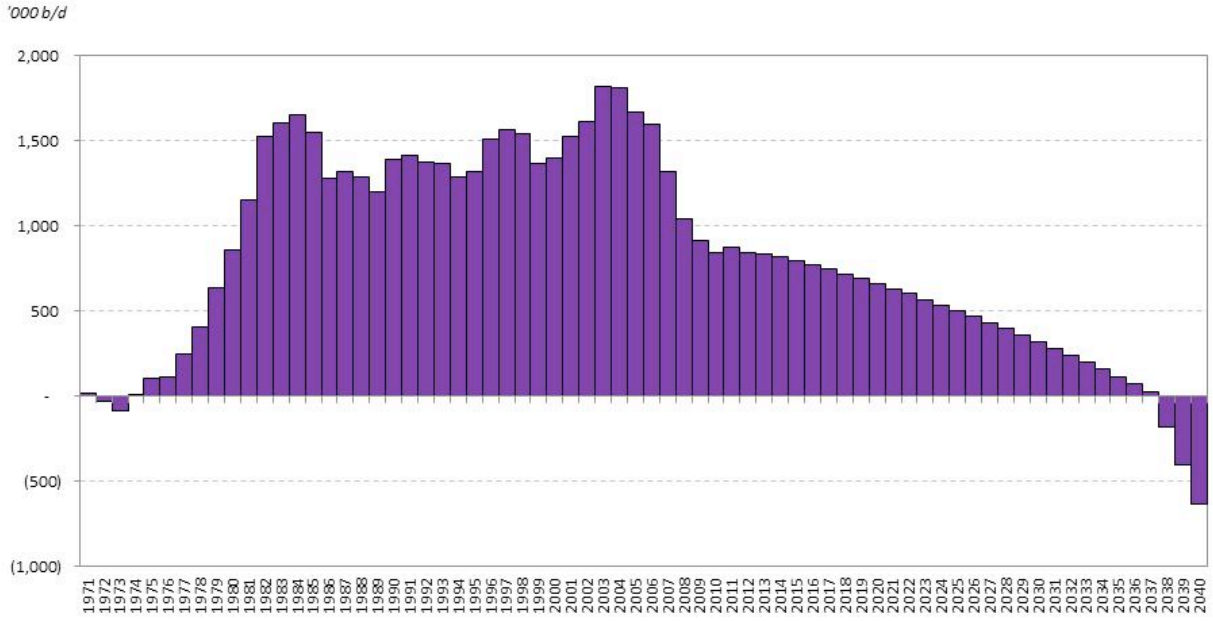
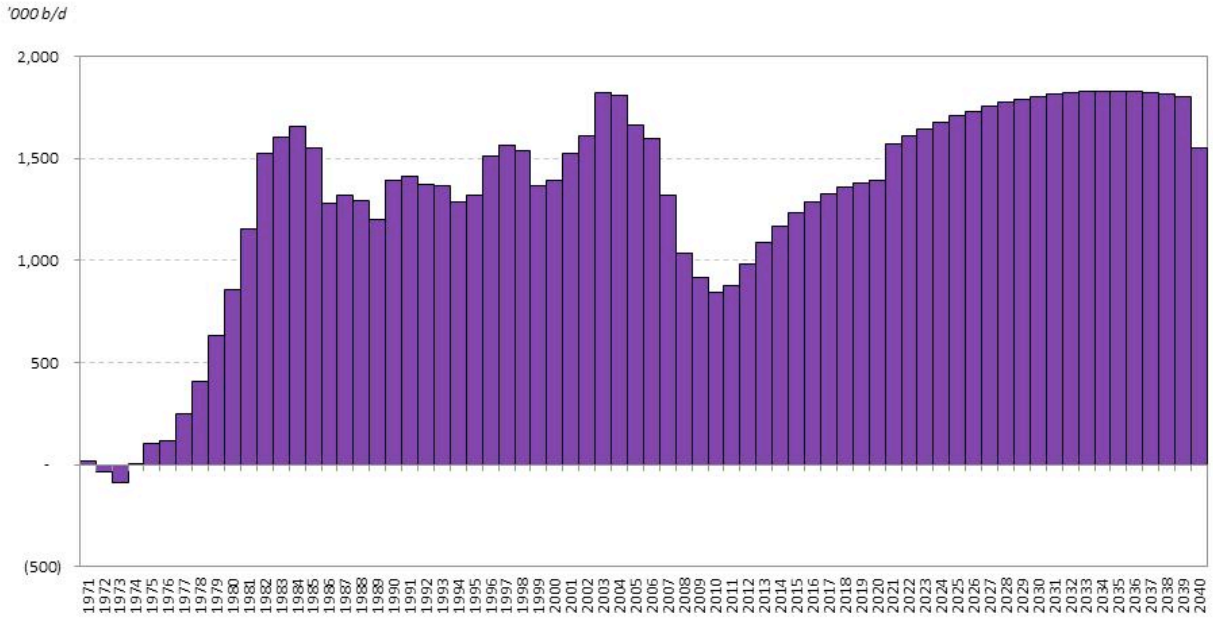


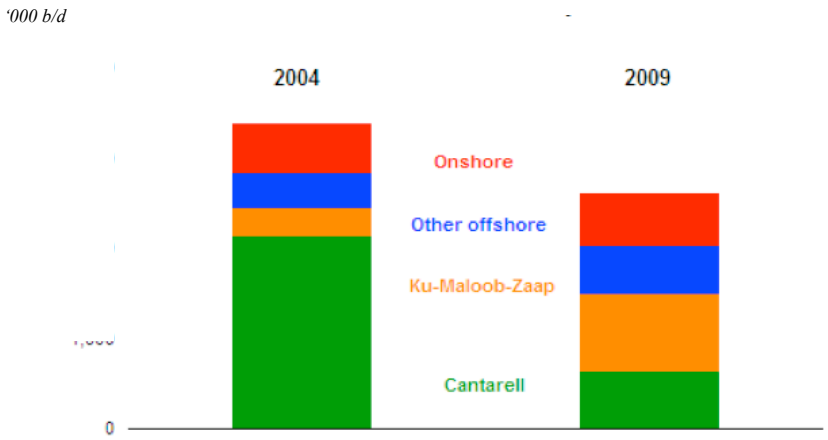
Figure 6. Mexican Net Oil Exports in the Median Demand Case with High Resource Base and Reserve Replacement Assumptions



V. Production and Investment in Oil Fields

Mexico's most productive hydrocarbon areas are divided into four zones. The Northeast Marin region, which historically has been the most productive of all, includes the Cantarell and Ku-Maloob-Zaap (KMZ) projects. The second most prolific area is the Southeast Marin Region, producing less than half the hydrocarbons of the Northeast; it includes projects like Abkatún-Pol Chuc and Litoral Tabasco. Third in importance is the South Region, comprised of projects such as Cinco Presidentes, Bellota-Jujo, Macuspana, Muspac, and Samaria-Luna. Last is the North Region, which is home to the Burgos, Poza Rica-Altamira, Aceite Terciario del Golfo (formerly Chicontepec), and Veracruz projects. The largest fields have been the super-giant Cantarell and KMZ. Figure 7 shows how the composition of production by area has changed in the period between 2004 and 2009. Total output is down, with increases in KMZ output partially offsetting the rapid decline in the share of total output coming from Cantarell.

Figure 7. Changing Composition of Mexican Production



Source: Energy Information Administration, http://www.eia.doe.gov/countries/cab.cfm?fips=MX

Cantarell production declined precipitously from a peak of 2.136 million b/d in 2004 to only 685,000 b/d in 2009 and 558,000 b/d in 2010.[11] Pemex has said that it has slowed the rate of decline at Cantarell, but it is not clear whether this is a short-term respite or a long period of

[11] Secretería de Energía, Sistema de Información Energética, http://sie.energia.gob.mx/sie/bdiController.

more sustained rehabilitation that will give Pemex time to develop alternative areas. Output at the KMZ field was 808,000 b/d in 2009, about 500,000 b/d higher than its 2004 level.

Pemex had hoped that production at Chicontepec would offset some of the declines from Cantarell, and has invested billions of dollars in this field. Yet despite these large investments, production there has been disappointing and is only forecast to be about 70,000 b/d in 2011.[12] Chicontepec produced 40,000 b/d in 2010.

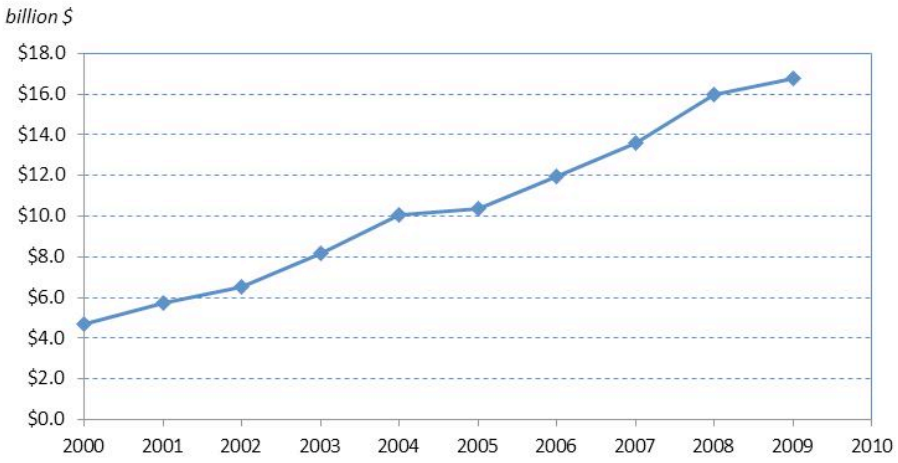
Pemex has contracted with foreign companies that have the technology to deal with geologically complex fields and has plans to enter into additional contracts. Despite suggestions from the National Hydrocarbons Commission (CNH) that it reallocate investment resources to other fields, Pemex has insisted on continuing its aggressive investment program at Cantarell, with investment plans for the 2007-2012 period (subject to budgetary approval) of US$10.5-14.5 billion.[13] CNH has no mechanism to enforce its recommendations.

In the meantime, resources and foreign contracts are focused on boosting production from marginal wells along the onshore Gulf Coast. Investments are also being made in the Tsimin and Ayatsil discoveries in the shallow offshore. Carlos Morales, Pemex chief of exploration and production, has said that with these investments—along with more success at Chicontepec—Pemex can achieve its production target of 2.8 million b/d by 2013.

Pemex has rapidly increased its investments in the last few years, as shown in Figure 8. Investments in exploration alone rose from 14.7 billion pesos in 2005 to 30.4 billion pesos in 2009—essentially a doubling in just four years—and production and total investments have been increasing at similar rates.[14]

[12] Rodriguez, "Pemex Increases."
[13] "Pemex: Situation and Prospects in a Changing Environment," (presented at the Offshore Technology Conference awards luncheon, Houston, Texas, May 2008). http://www.pemex.com/files/content/Pres_jrhotc_may08.pdf.
[14] Pemex, "Operating Summary," Pemex Annual Report 2009. http://www.ri.pemex.com/files/content/Key data_Annual Report 2009.pdf.

Figure 8. Pemex Investment in Exploration and Production, 2000-2009



Sources: Pemex Annual Report, http://www.ri.pemex.com/files/content/7spemex%20anuario%20estadistico.pdf
Exchange Rates from U.S. Federal Reserve Bank

In lieu of direct federal investments, Pemex is increasingly financing projects with third-party funds; investors are then paid with revenues generated by the project. These Deferred Expenditure Impact Projects (*pidiregas*) now account for 95% of total Pemex investments. This policy, established in 1990, is designed to free Pemex's investment plans from the federal government's budgetary situation. However, the loans must be invested wisely since projects must pay for themselves.

It would appear that the days of easy oil are over for Pemex and that future production will have to come from more complex fields that require greater technical expertise and higher development costs. Whether those fields can be developed in time to avert further drastic declines in exports is a major challenge for Pemex and for Mexico. While nature's endowment of generous oil resources has not been reflected in the economic performance of the economy, oil exports still remain a significant source of foreign exchange earnings and government revenue.

If higher levels of spending do not allow Pemex to replace reserves at rates higher than those in the past five years, we find that Mexico could become a net oil importer as soon as 2016. This would be a major challenge for the Mexican government—one that could be avoided through changes in Mexico's upstream oil investment policies and strategies.

Appendix A

Sensitivity of Demand Scenarios

Figures A1 and A2, below, show how domestic oil demand varies for different assumptions about per capita income growth and the price of oil, respectively. In the cases indicated, we have assumed the median population growth rate (0.6% per annum) and oil share will converge to 20% of the fuel used in the generation of electricity.

Figure A3 indicates combinations of different assumptions that are meant to reveal the highest and lowest possible demand cases among the scenarios considered. The spread in oil demand by 2040 rises to over 3.5 million b/d.

Figure A1. Effect of Different GDP Growth Rates

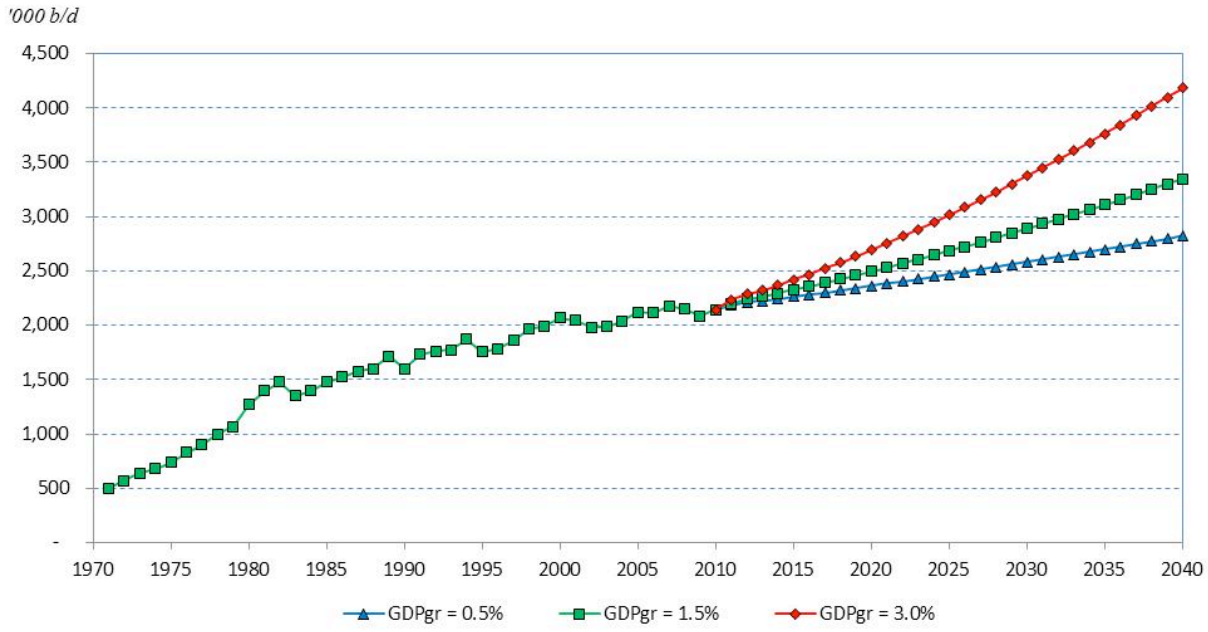


Figure A2. Effect of Different Oil Prices

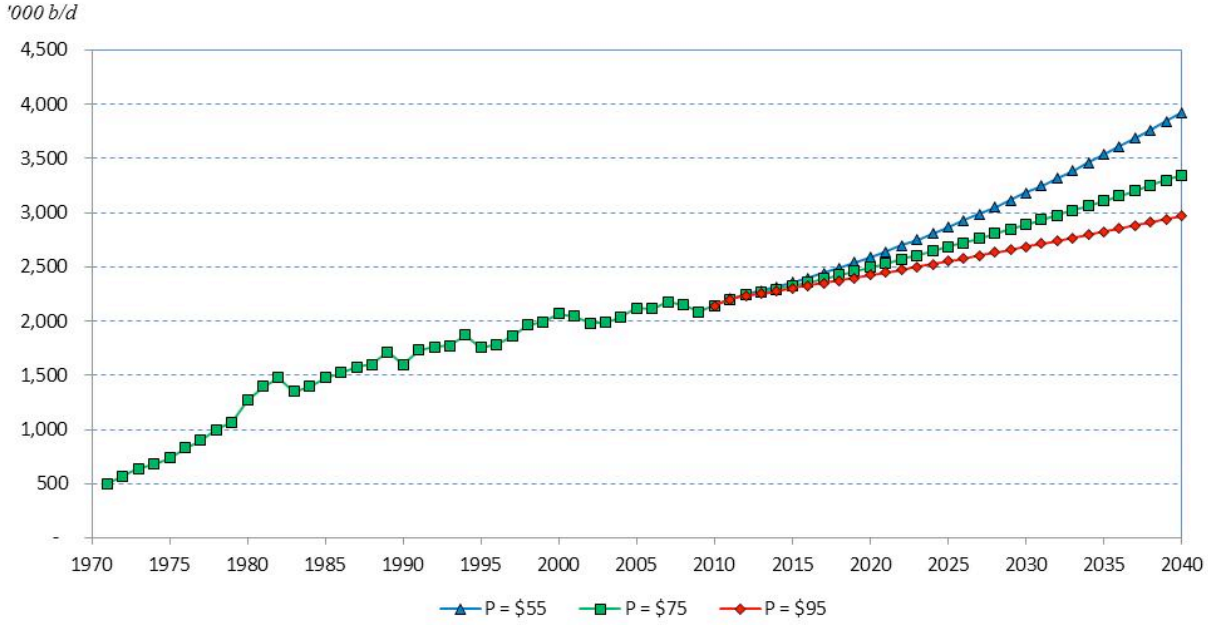
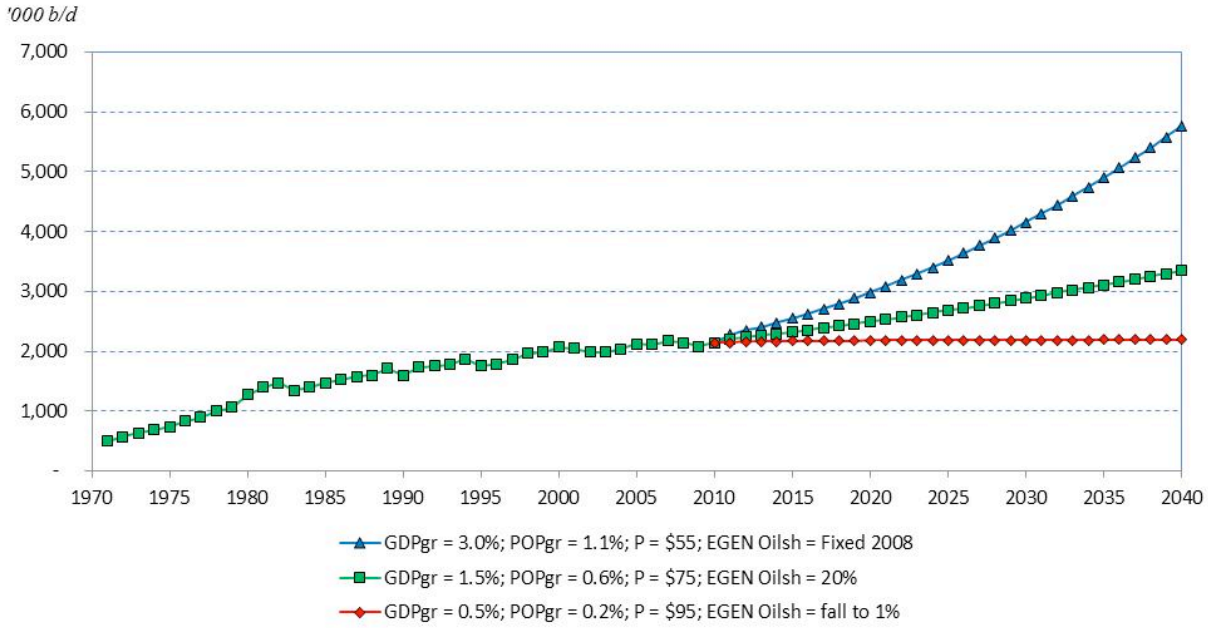


Figure A3. Extreme Demand Scenarios



Appendix B

Figure B1 shows the effect of different assumptions regarding the reserve replacement rate on oil production. As is evidenced by the figure, by moving from the low reserve replacement rate to the high among the cases considered, we see a substantial difference in production outcomes. This indicates the potential impact that different upstream investment policies could have on production. The scenarios assume resource constraints are not present, so the high USGS resource base is assumed.

Figure B1. Effect of Different Reserve Replacement Rates on Production