Strategic Oil Stocks in the APEC Region[1]

Inja Paik,* Paul Leiby,** Donald Jones,** Keiichi Yokobori,* David Bowman**

*Asia Pacific Energy Research Centre
**Oak Ridge National Laboratory

April 6, 1999

Proceedings of the 22nd IAEE Annual International Conference,
International Association for Energy Economists

Rome, Italy, 9-12 June, 1999

Keywords: APEC, energy security, strategic oil stockpiling, macroeconomic costs of oil shocks.

1 We are grateful to the Strategic Petroleum Reserve Office of the U.S. Department of Energy for their financial support of this research, and also thank John Shages and Walter Chilman of that Office for their valuable insights.

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Introduction

In spite of ample oil supply and historic low world oil prices, security of oil supply is of concern to many APEC economies.[2] Oil has been a critical fuel for the decades of rapid economic growth in the Asia Pacific region. According to many studies, oil will remain a dominant fuel for the APEC region, comprising 40% of total primary energy consumption, at least until 2010. Further, a number of oil producing economies in the region either have recently become oil importers or will be importing oil from outside the region in the near future. As a result, by 2010, APEC will be importing 60% of oil supply from outside sources. Moreover, East Asia will import 75%, while East Asia without China will continue to import 100% of oil supply.[3]

The world oil market has endured at least 18 significant oil supply shocks since 1951. The most memorable of these, the 4 largest world oil shocks between 1973 and 1991, are now recognized to have cost the APEC economies hundreds of billions of dollars in the form of lower GDP and higher payments for oil imports. Even the oil exporting economies of APEC have suffered net economic losses due to oil shocks. Although it is not possible to avoid the macroeconomic costs of oil supply interruptions altogether, they could be limited through various emergency response measures, including emergency oil reserves. We find that emergency oil stocks can be a cost-effective way for APEC economies to mitigate potential future oil shocks.

This paper first reviews historical and projected oil market trends for APEC. It then presents empirical estimates of the costs of oil disruptions to APEC economies and engineering-economic estimates of the cost of building and maintaining strategic oil stocks. Finally, it combines these estimates to evaluate the net benefits of expanded APEC emergency oil stocks, using a stochastic simulation model.

Historical and Prospective APEC Oil Supply and Consumption

World oil consumption increased by 6.2 million bpd between 1990 and 1997, from 65.4 million to 71.6 million bpd. The fastest rate of demand growth by far was in the Asia Pacific region, where demand increased by 42%, or 5.8 million bpd. Despite the recent economic difficulties in some Asian economies, recovery is anticipated and the demand for oil in Asia is projected to grow at an average rate of around 4% per annum during the period of 1995-2020. Asian consumption is expected to be 19.4 million bpd in 2010, with net imports of about 13.1 million bpd, or 68%. (IEA 1998, APERC 1998).

Of particular concern to East Asia is that most of the additional oil required to meet the rising demand is likely to be imported from the politically unstable Middle East with a higher potential for supply disruptions. In turn, the Asia Pacific region is also important from the perspective of Middle East oil exporters. Asia Pacific imports account for about 60% of Middle East oil exports, up from 44% (7.6 million bpd) in 1990. While these trade patterns may cause concern among some APEC economies, the particular sources of imports for APEC are of themselves not the major problem, given the global nature of the world oil market, and the tendency of supply disruptions anywhere to lead to higher oil prices globally. Of more importance for APEC is its growing overall reliance on imported oil, which increases its vulnerability to oil shocks, and the growing dependence of the world as a whole to supply from OPEC,[4] whose instability raises the prospect of renewed oil supply disruptions.

Oil Security and Emergency Preparedness

Oil consuming economies, in particular, the Asian economies are likely to become increasingly vulnerable to oil supply disruptions in the coming decades for the following four reasons:

- A growing reliance on one region for oil supply, a region with a history of political instability;
- Diminished market "buffers" for offsetting supply losses: the decline in world spare oil production capacity, coupled with the oil industry's efforts to reduce operating inventories through improved management practices;
- The continued limited responsiveness (price elasticity) of oil demand in the short-run;
- Some erosion of the protection afforded by emergency oil reserves held among the members of the International Energy Agency in recent years.

The potential economic damages from oil supply interruptions could be limited through emergency preparedness and response measures, both long-term and short-term in nature. The long-term measures include diversification of oil import sources, improving oil efficiency, removing market impediments, investing in alternative energy technologies, and maintaining dialogue with oil producers. While the long-term measures such as these can reduce the likelihood or severity of oil supply interruptions, they are of limited help once oil supply is curtailed, prices skyrocket, people panic and begin hoarding oil, and canceling investments in the face of market uncertainty. The emergency response measures that could be implemented to alleviate short-run oil supply and demand imbalance situations include demand restraint, fuel switching, surge production, and emergency oil stocks.

Emergency oil stocks are a powerful and direct defense against oil disruptions. The most compelling reason for government oil stockpiling is that it can be used reliably, at the governments discretion, during an emergency to make up for the shortfall caused by interrupted oil supply. Moderating the oil price increase by releasing oil stocks can substantially limit the adverse macroeconomic impacts of oil supply disruptions, providing an external societal benefit that commercial stockholders would not consider. Compared to other response measures, increased oil supply could be more effective in calming the market and preventing panic buying. Once the panic subsides, stocks afford oil-consuming economies time to make necessary adjustments until more permanent solutions are found, or to use diplomatic routes to alleviate supply shortages. Finally, emergency oil stocks could serve as a deterrent to politically or economically motivated supply disruptions.

Existing APEC and Non-APEC Emergency Oil Stocks

Existing emergency stocks, including those currently held in Japan, Korea, Chinese Taipei[5], Europe and the U.S. provide an important cushion between a net oil supply shock (after supply offsets) and an oil price shock. APERC (1999) summarized the status and size of emergency oil stock programs in APEC countries. In identifying the level of emergency oil stocks, the following definition was used: emergency stocks are defined as government owned stocks *plus* government-mandated commercial stocks in excess of normal working stocks.[6] Using this definition, current emergency stocks total approximately 1258 million barrels, as itemized in Table 1.

These existing government-controlled emergency stocks of over 1.25 billion barrels are accounted for in the calculations of APEC reserve expansion benefits done here. We computed the *incremental* net benefits of additional APEC stocks. Current emergency stocks are assumed to be well coordinated with the incremental APEC reserve being evaluated. All emergency stocks are drawn down collectively to offset net supply shortfalls. Each country's stock is drawn in equal proportion, with the maximum drawdown rate equal to the six-month exhaustion rate.

Table 1
Total Existing Emergency Stocks

Region	Size
U.S.	563
Japan	315
Republic of Korea	43
Chinese Taipei	12
Europe	325
Total	1258

The Costs of Constructing Oil Storage Facilities

The engineering firm PB-KBB Inc. calculated the cost and performance characteristics of three oil storage technologies: in-ground trench, hard rock mine, and salt caverns. Table 2 below summarizes the PB-KBB (1998) report. The major cost categories are facility capital costs, and Operations and Maintenance (O&M) costs. O&M costs are given for standby operations (in $/BBL-yr) and fill and draw operations (in $/barrel).[7]

Table 2: Summary of Facility Cost Information from PB-KBB			
Technology	**In-Ground Trench**	**Hard Rock Mine**	**Salt Caverns**
Suitable Countries	China, Australia, South Korea, Thailand	China, Australia, South Korea, Thailand	China, Australia, Thailand
Capital Cost, US ($/BBL) – undiscounted sum	$15.68	$15.44	$5.51
Operation & Management Cost, US ($/BBL-yr)	$0.16	$0.09	$0.17
Fill/Refill Cost ($/BBL)	$0.05	$0.05	$0.09
Drawdown Cost ($/BBL)	$0.07	$0.07	$0.10
Facility Size, MMB	100	100	100
Maximum Drawdown Rate (MMBD)	1.17	1.17	1.17
Maximum Fill Rate (MMBD)	0.27	0.27	0.27
Development Time (years)	11	13	8

Although there are some differences among the three technologies in operating, filling, and drawing costs, the capital costs dominate by far. For all technologies, there is an initial 3-4 year period of modest costs, and then the bulk of capital costs occur around the middle of the development period. Completion of the facility will take 8 to 13 years. The discounted capital cost stream for salt caverns lies well below those of the other two technologies. Salt Cavern storage is available sooner and at lower cost. The Net Present Value (NPV) cost of salt caverns completed by 2008 is $4.03/BBL. In NPV costs per barrel, both the rock and trench technologies are almost exactly 3 times as expensive as salt caverns completed in the same year. Based on costs and operating characteristics alone, there is never a case in which trench or hard rock storage would be preferable, regardless of when it is built. For these reasons this analysis focuses attention on salt cavern storage.

Benefits of APEC Emergency Oil Stocks

The benefits of an emergency oil stock are the losses it can avoid, the principal element being avoided GDP loss. GDP losses from an oil price shock can be divided into two categories, a production frontier shrinkage following the resource scarcity imposed by higher prices, and adjustment losses imposed by the surprise element of the shock, price rigidities, and real costs of resource reallocations. Empirically the latter component is at least as large as the former. The sensitivity of GDP to oil price shocks is captured in statistically estimated oil price-GDP elasticities, to which considerable research has been dedicated over the past two decades.

These two impact components have imposed asymmetric effects on the macroeconomies of industrialized and industrializing nations (Hamilton 1983; Mork 1989). Positive oil price shocks, such as occurred in 1973-74, 1979-80, and 1990, both shrink the aggregate production possibilities frontier and cause costly reallocations of labor and capital. Both effects work in the same direction. Negative price shocks, such as the 1986 oil price collapse, expand the production frontier but still cause costly resource reallocations, but the effects work in opposite directions, at least partially canceling (Lilien 1982; Gilbert and

Mork 1986; Hamilton 1988).[8] Empirical research has found the responsiveness of GDP and unemployment to positive shocks, as captured in their respective elasticities, larger, and more commonly statistically significant, than the corresponding responses to negative shocks (Mork 1989; Mory 1993; Mork et al. 1994). Recent research on labor market behavior at the plant level reveals substantial gross destruction and creation of jobs by positive oil price shocks (Davis and Haltiwanger 1996); some of those labor market impacts last as long as a decade, requiring interstate migration to clear that market (Davis et al. 1996).

Table 3 presents asymmetrically-specified oil price-GDP elasticities for selected APEC economies, estimated with annual data and controlling for monetary policy (Bachman and Ingram 1999). The equations for the economies were estimated using seemingly unrelated regressions (more detail on the estimation is available in APERC 1999, Chapter 6). Sufficient time-series data were not available to obtain a satisfactory estimate for the People's Republic of China. Additionally, the Philippine elasticities estimated from annual data were of the theoretically incorrect sign and nonsignificant; re-estimation with quarterly data yielded correct signs but nonsignificant elasticities.

Table 3. Oil Price GDP Elasticities for Selected APEC Economies

	Oil price up		Oil price down	
	Oil price-GDP elasticity	t-statistic (ratio of elasticity to standard error)	Oil price-GDP elasticity	t-statistic (ratio of elasticity to standard error)
Hong Kong	-0.065	-1.51	n.s.[1]	
Indonesia	-0.043 (lag)-0.043	-2.07 (lag)-2.22	n.s.	
Japan	-0.058	-5.69	+0.021	+2.07
Malaysia	(lag)-0.056	-2.27	+0.086	+2.07
Philippines	-0.036[2]	n.s.	n.s.	
Singapore	-0.042	-1.80	n.s.	
South Korea	-0.087	-3.06	-0.067	-1.82
Taiwan	-0.084 (lag)-0.068	-3.41 (lag)-2.73	(lag)+0.041	(lag)+1.43
Thailand	-0.084	-4.91	n.s.	

[1]n.s. = not statistically significant.
[2]Annual average based on lagged quarterly estimates.

The APEC economies whose elasticities are shown in Table 3 demonstrate considerable sensitivity to positive oil price shocks (statistically non-significant elasticities for negative shocks are not presented). Oil exporters such as Indonesia and Malaysia, as well as highly import-dependent economies such as Japan and South Korea, reveal this vulnerability. Indonesia has a diversified and sophisticated manufacturing sector in addition to its oil production sector; when oil prices spike, the revenues coming accruing to the oil extraction sector increase but the other manufacturing sectors face the same shadow price of oil as all other manufacturers in the world and feel the contractionary effects of the positive shock. Its manufacturing sector is large enough relative to its oil sector to yield a substantial, net negative elasticity. The GDP-weighted aggregate of all the APEC economies' elasticities to positive oil price shocks is -0.063, corresponding to a 6.3% GDP loss for an oil price doubling.

Estimation of the Net Benefits of Expanding APEC Reserves[9]

Emergency oil stocks, by buffering supply losses and mitigating sudden major price shocks, are a direct and effective means for dealing with the risk to economies of persistent supply and price volatility. Private agents cannot justify holding large oil stocks for the long term as a contingency against unlikely but potentially dramatic market upheavals or geopolitical struggles. The private storage costs are too high, the planning time horizon too long, and the direct benefits to the private agents are too low.[10] Thus, it is appropriate for governments to store oil in the interest of their societies as a whole. Furthermore, it may be more efficient for the APEC economies to take collective action and establish joint emergency oil reserves. Large scale shared storage can lower storage costs and garner enough benefits for a large economy or combined economies for the costs to be worthwhile.

Expanding APEC emergency oil stocks will benefit all APEC economies, including the U.S. and other oil producing and exporting economies in the region. The analysis here addresses the specific question: is expanded stockpiling by APEC economies *other than the U.S.* worthwhile on the basis of benefits to those economies alone? (The issue of spillover benefits to other economies is not addressed.) The expected benefits of expanding APEC emergency oil stocks was determined using a Monte Carlo simulation of the world oil market, with and without additional APEC stocks. Each simulation was composed of thousands of samples, each sample being a randomized projection of the world oil market through the year 2030. For a given random outcome of the world market, if a disruption occurs, any available offsets such as world excess oil production capacity are used to alleviate it. If a net disruption remains (after available offsets) then the APEC reserve is used, in coordination with the existing IEA reserves. For every random realization of the future oil market, we compared the benefits provided by the current world emergency stocks with the benefits that would be offered by expanded stocks. In the event of a large disruption, an expanded reserve could easily be worth $50 billion or more in avoided shock costs. The expected net benefit calculation weights the magnitude of these large avoided shock costs by their relative frequency of occurrence over thousands of samples, and compares that expected benefit with the cost of the reserve. The study applied a probabilistic risk analysis to assess the uncertain implications of oil stockpiling. It followed and extended the basic logic of the model previously used in the 1990 DOE/Interagency

SPR Size Study [DOE 1990]. The model was adapted to the specific nature of the APEC economies.

The riskiness of the oil market is characterized by the frequency of supply disruptions, their duration and magnitude, and the availability of offsets to disruptions from various sources. The duration of interruptions was also random, from 1 to 6 months in length. In this study, the Base disruption probabilities for different disruption sizes were drawn from the 1990 DOE/Interagency Study, as one of the two explicit and careful analyses currently available.[11] A crucial aspect of the disruption probability distribution is the probability it assigns to large but unlikely disruptions, since those are the cases in which available slack production capacity and existing reserves might be inadequate, and additional emergency oil stocks would be beneficial. The frequency and size of gross disruptions were governed by a Weibull probability distribution, with the extreme event probabilities given in Table 4.

Table 4: DOE/Interagency 1990 Study Disruption Probabilities
Annual Probability of Gross Disruption, as Percentage of World Supply

Case	Disruption of 10% or More of Supply	Disruption of 15% or More of Supply
Lower Risk	1.5%	0.5%
Midcase	2.4%	1.0%
Higher Risk	3.1%	1.5%

Reserve Size Maximizing Expected Net Economic Benefit

The costs included are the costs of constructing and operating the facility and the net costs of buying and selling the oil itself. These costs are borne by the owners of the reserve. The benefits are the avoided disruption costs due to the reserve. These benefits are gained by all oil using and consuming economies. The costs and revenues are distributed over time, with most of the costs preceding the revenues.

Governmental entities are concerned not only with the costs of building and operating the reserve, but also with external benefits to the society as a whole. Included are avoided GDP losses to the entire economy due to ability of the reserve to dampen or eliminate potential oil price shocks. The magnitude of these avoided losses is roughly gauged through the use of the estimated GDP elasticity with respect to oil price shocks. The other public benefit is the terms of trade effect or avoided net oil import costs. Net import costs are be simply determined as price times import quantity. When an oil price shock occurs, price rises and demand falls.

By far the largest benefit of the reserve is the Avoided GDP losses. For the combined APEC economies excluding the U.S., the avoided GDP losses are about three times as large as the avoided import costs. This is an important insight: while APEC economies are rightly concerned about their growing levels of oil imports, the vulnerability of their economies to transitional losses during sudden price movements due to allocative dislocations appears to be an even larger concern. The first 100 million barrels provides an expected marginal GDP savings of about $1.75 billion, or $17.50/barrel. By 500 million barrels that marginal savings has declined to about $10/barrel, and it declines more rapidly thereafter.

Capital costs and net costs of reserve oil are comparable in magnitude to one another. Both of these components increase proportionally with the size of the reserve. The net cost of reserve oil is not its purchase price, but rather its purchase price plus transaction costs *minus* the expected, discounted sales price (either in a subsequent disruption or in the reserve "salvage" calculation for the end year 2030). We find that typically the expected NPV oil cost per barrel of stored is about $6.90 per barrel, slightly larger than the $5/bbl NPV capital cost of the salt cavern facility.

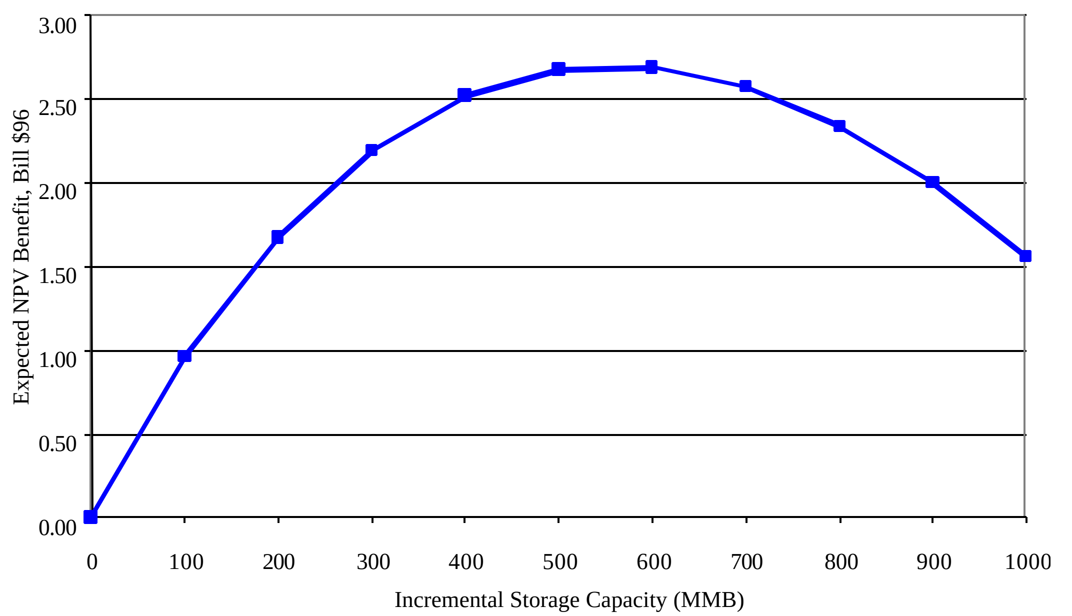

Figure 1: Base Case Results for the Benefits of Incremental Storage Capacity. (Mid Case inputs. For details, see Leiby and Bowman 1999.)

The Base Case (Figure 1) results indicate that a substantial incremental reserve could provide about $2.7 billion in discounted expected benefits, net of all costs. The peak benefits occur around a size of 600 million barrels, but benefits are roughly equivalent within ±100 million barrels of that size. The size is justified on the basis of collective net benefits to *all* APEC countries included in the analysis, a group with enormous projected GDP and substantial net oil imports. The size conclusion is also predicated on the use of the least expensive storage alternative (salt caverns), and the best available estimates of the sensitivity of APEC economy GDP to oil prices shocks.

Overall Conclusions Regarding APEC Reserve Size

The analysis presented here strongly supports the conclusion that expanding the APEC reserves by 200-500 Million barrels is justified on the basis of its expected net benefits to

APEC economies. Our evaluation considered the combined net benefit of expanded reserve sizes to all APEC economies other than the U.S..[12] It included the reserve's ability to reduce GDP losses and oil import costs during oil shocks, and subtracting the costs of building, filling, and operating the reserve. The conclusion that a substantial reserve expansion is justified holds true over a range of conditions, including more optimistic oil market assumptions that entail lower disruption risk over the next few decades. It also holds true for a range of variation in other key parameters such as the GDP elasticity with respect to oil price shocks, and for substantially higher storage costs than those of the least expensive alternative, underground salt caverns.

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[1] *Asia Pacific Energy Research Centre in Tokyo, Japan. **Oak Ridge National Laboratory, USA.
Keywords: APEC, energy security, strategic oil stockpiling, macroeconomic costs of oil shocks.

[2] The APEC (Asia Pacific Economic Cooperation) economies included in this study are: Australia; Brunei; Canada; Chile; China; Hong Kong, China; Indonesia; Japan; Malaysia; Mexico; New Zealand; Papua New Guinea; Philippines; Republic of Korea; Singapore; Thailand; and Chinese Taipei. The focus was on APEC economies other than the United States, that is, the U.S. was excluded from the benefit calculations.

[3] This number is based on APERC's *Energy Demand and Supply Outlook*, published March 1998. The outlook was updated in September 1998 to reflect protracted economic slowdown in the region showing lower oil consumption and import dependence of 53% for 2010. However, oil import dependence numbers for East Asia and Asia without China remain the same

[4] According to the "Annual Energy Outlook 1999," of the U.S. Energy Information Administration (EIA) world oil demand is expected to reach 114.7 million barrels a day in 2020. This projection relies heavily growth in production from the OPEC nations.

[5] Unlike the other countries Chinese Taipei has no official governmental reserve, rather a sizable private stockpiling mandate. Also unlike other countries whose private reserves could be considered working stocks, the Chinese Taipei reserves are sufficiently large (60 days of domestic consumption) that a portion (20 days or 1/3) is considered as emergency stocks available for drawdown.

[6] This definition of emergency stocks was applied to the data in the stockpile survey in APERC 1999, to produce the Table 7.2. Based on the discussion in that document, our operating definition of normal working stocks is 40 days of production or imports, whichever is larger.

[7] These costs are expected to vary slightly with the location of the site.

[8] The analysis of stockpiling benefits reported here only considers its potential usefulness in the event of oil price *increases*.

[9] For a more complete description of the estimation of APEC reserve net benefits, including detailed assumptions and sensitivity analyses, see Leiby and Bowman 1999.

[10] Since oil is traded globally, a major oil price increase soon spreads throughout the world, with disruptive effects on most energy-using economies. Within each economy, the shock costs are spread economy-wide. For this reason, oil-using firms and private consumers acting individually on their own behalf do not have sufficient motivation to take the actions necessary to adequately insure against the widespread costs of price shocks. Unless the government provides incentives for added storage, private oil inventories are principally "working stocks" . They are held to ensure reliable plant operations and process flows in the face of routine logistical delays, normal demand fluctuations, and modest short-term price variations.

[11] The only other published study with sufficient detail and justification is based on work of the Energy Modeling Forum: Huntington, Hillard, Antje Kann, John Weyant and Phil Beccue, 1997. *Quantifying Oil Disruption Risks Through Expert Judgment*, Energy Modeling Forum, EMF SR-7, April.

[12] The U.S. would also gain spillover benefits from expanded stockpiling by other APEC economies, just as they gain from the U.S. SPR. These benefits are not estimated here.