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Costs, Benefits and Financing of Holding Emergency Oil Stocks

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Executive Summary

Oil is traded in a market where uncertainty, price volatility, and sudden supply disruptions are common characteristics. Natural disasters, political disagreements and wars can seriously affect supply and demand, and consequently economic activity. One particularly powerful tool of IEA member countries to respond to such disruptions is emergency oil stocks. In its history the IEA released stocks on three occasions, reducing supply shortfalls and the associated economic damage.

This paper is expected to provide a general guide to the existing emergency stockholding system for countries who are considering the introduction of new stockholding systems or changes to their existing emergency stocks. It highlights the overall gains associated with emergency stocks and outlines important considerations for the establishment of stocks.

In order to assess the economic benefits derived from holding emergency stocks this paper proceeds in four steps. First, it quantifies the costs involved in holding emergency stocks. Second, it assesses the benefits associated with holding emergency stocks. Third, cost and benefits are compared in order to assess the net-benefits associated with the emergency stocks. Forth, the paper outlines different ways of financing emergency stocks based on IEA countries' practices.

To quantify costs and benefits associated with holding emergency stocks the results of this paper are based on two fundamental assumptions. First, for the purposes of this paper, stockholding costs refer to public oil stocks held exclusively for emergency situations. Second, this paper focuses on global crude oil disruptions to assess the benefits of emergency stocks. Though it discusses additional benefits such as protection in the event of a domestic disruption or during a product supply disruption, these contingencies could not be taken into account in the final results. Costs and benefits indicate only a rough order of magnitude of the actual figures for any specific country.

Stockholding cost figures are based on size and type of storage facilities (above-ground tanks and underground caverns) as well as composition of stocks (crude/product). Total yearly costs range from USD 7-10 per barrel, reflecting the fact that holding emergency stocks in underground caverns is about 30% cheaper holding oil in above-ground facilities. The acquisition of stocks represents at least 50% and up to 85% of the overall costs, based on recent oil price levels. The expenditures for building the storage facilities and the related infrastructure amount up to one fifth of yearly costs. The share of expenses for operating and maintenance of the storage sites vary considerably between storage options, amounting to as little as 5% for caverns and as much as one quarter for above-ground facilities. Refreshment of oil products and land costs both represent a marginal proportion of overall costs.

Economic benefits consist of reduced GDP losses and reduced import costs. These are derived primarily from offsetting supply losses and thereby reducing significant oil price increases. A computer model simulated thousands of individual scenarios over a time-horizon of 30 years to quantify these benefits. The simulation results show that the use of IEA stocks equals about USD 3.5 trillion of avoided costs to IEA and non-IEA net importing countries. On a yearly basis these benefits amount to about USD 50 per barrel. This value represents an average payoff from the "insurance" provided by stocks. While the results are relatively robust with regard to global crude oil disruptions, the simulation did not attempt to account for benefits derived from the use of stocks in the event of a domestic disruption in or in case of a product supply disruption.

Yearly net benefits amount to some USD 40 per barrel. Major non-IEA consumer countries have long recognised the enormous global benefits provided by emergency stocks. China and India have started to set up emergency stocks of their own during the last decade.

Finally, the paper outlines the different ways of financing the acquisition and maintenance of emergency stocks as reflected in the distinct practices adopted by IEA countries. Financing mechanisms can generally be divided into two categories: financing of public stocks and financing of obligated industry stocks. These different approaches highlight the flexibility in financing emergency stocks and reflect efforts to keep the burden on state budget, industry and final consumers at a minimum. In many countries, the cost for the final consumer amounts to less than one cent per litre, a comparative modest amount compared to the considerable macroeconomic damage that can result from supply disruptions.

1. Costs of Holding Emergency Oil Stocks

This chapter assesses the different costs involved in holding emergency oil stocks. For the purposes of this paper, stockholding costs refer to costs of holding public oil stocks exclusively for emergency situations.

Calculating the costs of holding emergency oil stocks in IEA member countries on a comparable basis poses certain challenges. Difficulties arise from the lack of sufficient data for some countries, the use of different accounting methods, varying coverage of costs (e.g. inclusion or exclusion of costs of land acquisition, oil acquisition), differences in the size of storage facilities, currency fluctuations, inflation, technological factors, local scarcity of labour or steel and so forth. As a result of these uncertainties, the cost figures presented in this paper are expressed in ranges. The averages of these cost ranges indicate merely an approximation to the actual costs in any specific country.

The cost assessment does not include historical costs, as many of the facilities in IEA member countries were constructed and filled at times when prices were (very) different from today. For countries interested in an estimate of current cost levels, historical numbers would lack relevance since they are largely outdated. Moreover, such a calculation might actually add little insight when compared with stockholding benefits based on today's circumstances. Therefore, the cost assessment focuses on the costs of oil stored in newly-built facilities.

The costs considered in this chapter consist of four principal sets of expenses involved in holding emergency stocks:

- set-up costs of the storage facilities: the capital costs and associated amortisation for construction of the storage facility and the purchase of the oil stocks, including material costs (storage tanks, pipelines, pumps and any discharge/loading terminal or equipment) and labour costs;
- operating and maintenance costs, including labour costs, utility costs, and insurance;
- refreshment costs for maintaining quality specifications of petroleum products; and
- land costs for renting or buying the needed terrain

These costs are based on size and type of storage facilities (above-ground tanks and underground caverns) as well as composition of stocks (crude/product).

This chapter also discusses a range of additional factors that have an influence on cost levels, such as the effect of land rental costs and soil conditions as well as the effect of jetty costs and the complexity of the terminal infrastructure. It is also assessed how costs differ across distinct world regions. The final cost figures are broken down into yearly costs and compared with current market rates for renting comparable facilities on a longer term basis.

The cost information in this paper is generally provided in USD per barrel.[1] Although storage tanks and the related infrastructure are usually measured in cubic meters, oil stocks are generally counted in barrels by the IEA Secretariat. In addition, the economic benefits drawn from oil stocks are also expressed on a per barrel basis. Therefore, for reasons of consistency and comparability, original cubic meter measurements of storage infrastructure have been converted into barrels.

[1] The exchange rate used for this purpose equals USD 1.28/EUR. This amount is in accordance with the average of 2012 daily exchange rates as published by the European Central Bank and the US Federal Reserve.

Set-up and construction costs

In order to assess the costs of holding emergency oil stocks four storage options are considered: above-ground stand-alone facilities, add-on facilities to existing tank farms or refineries, salt caverns, and rock caverns. The effect of the facility size, individual tank capacities and the difference between crude oil and product stocks on costs is discussed for all four kinds of storage options.

For the purpose of this paper the term "set-up costs" refers to the expenditures for building the storage facilities and the related infrastructure, as well as the expenses to purchase the stocks. "Construction costs" are a component of set-up costs; the term exclusively refers to the expenses necessary to build the physical storage facilities and the necessary infrastructure. It does not include the costs for purchasing the oil stocks.

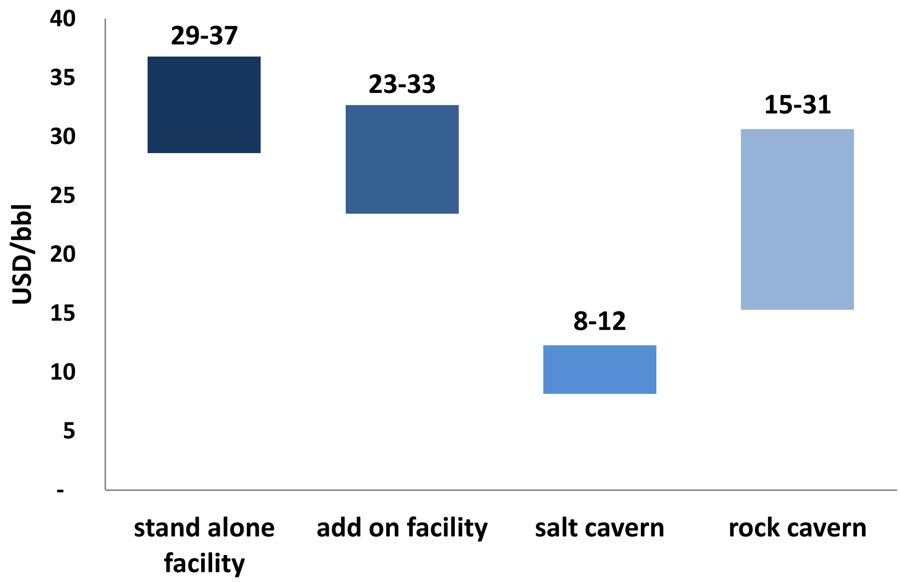
Not included in the cost assessment are any costs related to dismantling the storage facility.

Overall construction costs of storage facilities

Construction costs for above-ground storage facilities range from USD 29-37/bbl (EUR 140-180/m^3) for stand-alone facilities and from USD 23-33/bbl (EUR 115-160/m^3) for add-on facilities.

Above-ground storage facilities generally consist of three main elements: the tank farm, the jetty, and the truck/railcar loading facilities. The minimal optimal size for an above-ground facility is about 500 000 m^3, or about 3.1 million barrels. Tank farms with a smaller capacity result in higher costs per storage unit, while a larger capacity does not significantly reduce the construction costs on a per cubic meter basis.

Figure 1 • Construction costs (excluding jetty costs)



Source: Downstream B.V.

Construction costs for underground storage facilities amount to USD 8-12/bbl (EUR 40-60/m^3) for salt caverns and to about USD 15-31/bbl (EUR 75-150/m^3) for rock caverns. Construction costs of underground caverns are considerably lower than the construction costs of above-ground facilities, if these caverns are of sufficient size (at least 1.5 million m^3). Storage in caverns is however not possible in every country because of underground limitations.

Brine disposal has a significant influence on the construction costs of salt caverns. Legislation on this issue differs considerable among IEA member countries. For instance, while brine can be disposed into the sea in Germany, French law requires a brine pond to be built, which is more expensive. A third option is to use an aquifer for brine disposal. However, a suitable aquifer is not always located in close proximity to the caverns.

The construction costs for rock caverns are higher compared to salt caverns due to more complex excavation operations. The large variation in construction costs of rock caverns is a result of the high content of labour costs which can differ considerably between different regions.

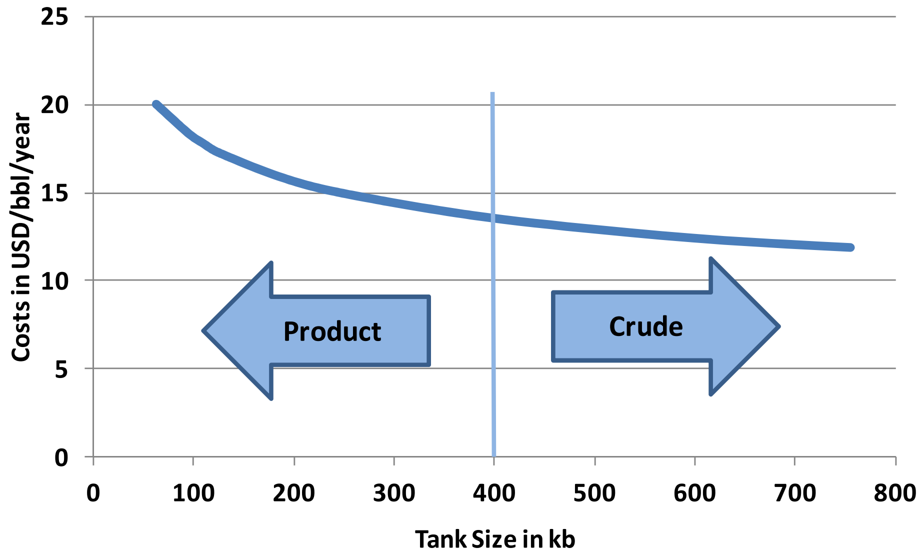
Principal elements construction costs

Storage tanks

The construction costs of the storage tanks often represent less than half of the overall construction costs of the storage facility. The costs for constructing the tanks differ according to the type of hydrocarbon to be stored as well as the size of the tank. Construction costs for low flash product tanks (e.g. gasoline) are about 15-20% higher on a cubic meter basis than the costs for crude oil and middle distillate tanks. Several factors are responsible for this difference, such as tank size, roof design, fire fighting systems and vapour recovery systems.

First, crude oil tanks – and to a lesser extent middle distillate tanks – benefit from economies of scale due to their larger size compared to low flash product tanks. For logistical reasons optimal tank sizes lie between 500-750 thousand barrels (80-120 thousand m^3) for crude oil and 250-375 thousand barrels (40-60 thousand m^3) for products (Figure 2). Second, the design of low flash product tanks is generally more sophisticated than crude oil and middle distillate tanks. Contrary to crude oil tanks, gasoline tanks require a fixed roof (with an inner float) instead of a floating roof, which makes construction more expensive. Furthermore, due to their low ignition propensity low flash products require a more sophisticated fire fighting system. Lastly, contrary to crude oil or middle distillates, low flash product storage requires vapour avoidance and vapour recovery systems.

Figure 2 • Construction costs of storage tanks for different tank sizes



Source: Downstream B.V.

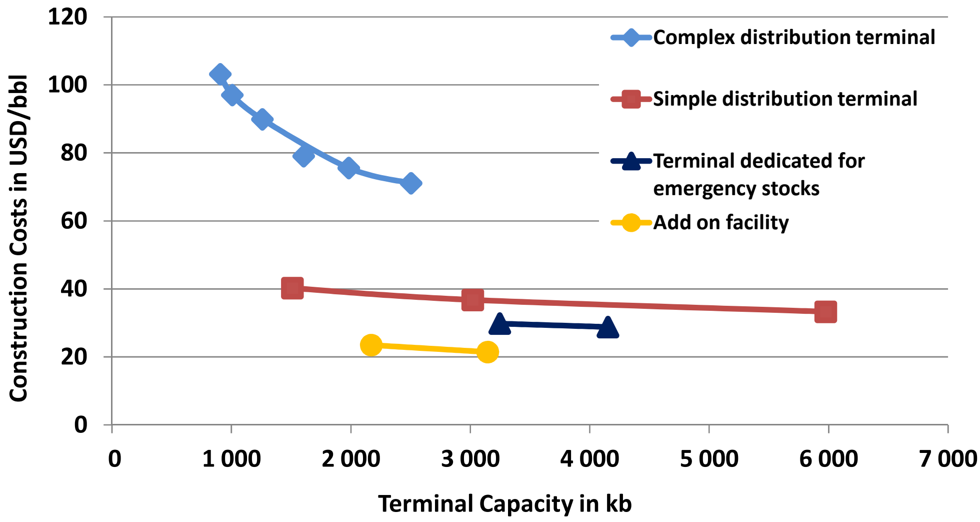
In case that tank foundations have to be piled as a result of insufficient subsoil conditions, tank construction costs would increase by about 10-15%. Costs for piling can amount to up to USD 18/m^2 (EUR 14/m^2).

For the purpose of this paper it is assumed that soil conditions are suitable and no piling is required for tank foundations. It is further assumed that tanks are of cost efficient sizes.

Infrastructure and jetties

The expenses for building the necessary infrastructure (loading platforms, piping) and the jetty – if needed – can amount to almost two thirds of the overall construction costs of a storage facility. Therefore, an important assumption for the cost figures presented in this paper is that storage operations are limited and relatively simple, handling only emergency stocks. Operations at a storage site for commercial purposes (e.g. a refinery) require more sophisticated jetties and involve more complex operations; consequently, the necessary infrastructure is more expensive (Figure 3).

Figure 3 • Construction costs of different terminal types (including related infrastructure)



Source: Downstream B.V.

When comparing newly built tank farms to adding tanks to an already existing facility ("add-on facilities"), the construction costs for the latter option are about 10-15% lower. Building additional tanks at an existing facility reduces the need for expenditures for loading and offloading facilities as well as the related infrastructure. The principal requirement for building an add-on facility is the availability of suitable land in close proximity to an existing site. Additionally, existing jetties and the infrastructure in place have to have sufficient slack to accommodate the movement of emergency stocks.

Despite the limited sophistication of the jetties needed for holding emergency stocks, they represent a major proportion of the overall construction costs. Jetties increase the construction costs of a tank farm by 10-40% on a per barrel basis (Table 1). The costs for constructing a jetty able to accommodate very-large crude carriers (VLCC), of about 200–320 thousand deadweight tonnage, amount to almost USD 40 million (EUR 30 million). Constructing a jetty for smaller Panamax product tankers, of about 60–80 thousand deadweight tonnage, comes at a cost of about USD 25 million (EUR 20 million).

Table 1 • Additional construction costs per cubic meter due to jetties

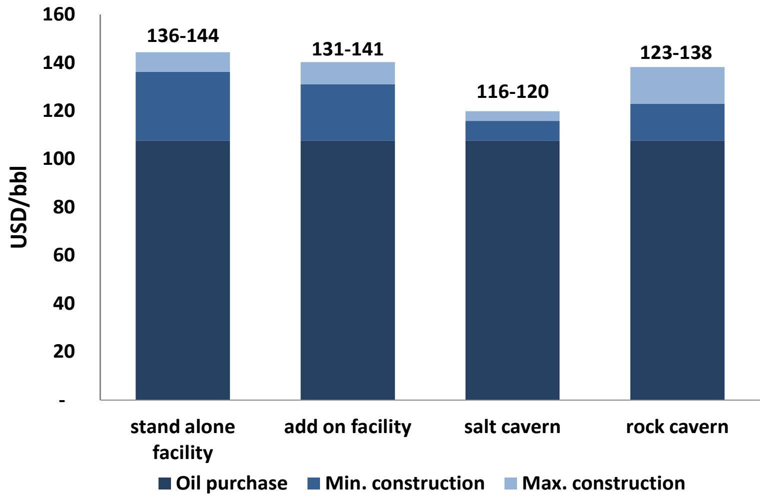
Jetty Size	For VLCC (USD 40 million)	For Panamax (USD 25 million)
	cost without jetty USD 28.60/bbl (EUR 140/m³)	cost without jetty USD 32.70/bbl (EUR 160/m³)
3.1 million barrels (0.5 million m³)	+ USD 12.30/bbl (or + EUR 60/m³)	+USD 8.20/bbl (or +EUR 40/m³)
6.2 million barrels (1 million m³)	+ USD 6.10/bbl (or +EUR 30/m³)	+ USD 4.10/bbl (or +EUR 20/m³)
9.4 million barrels (1.5 million m³)	+ USD 4.10/bbl (or +EUR 20/m³)	+ USD 2.70/bbl (or +EUR 13/m³)

Oil stocks

When accounting for the purchase of the stocks, the costs to buy the crude oil and/or petroleum products represent 75% to 80% of the set-up costs (excluding jetty costs) for above-ground facilities at 2011 oil price levels. For underground caverns the share of buying stocks can amount to as much as 90% of total set-up costs (excluding jetty costs). For the purpose of this paper, the price for purchasing the stocks is set at USD 107.61/bbl. This figure is based on the average crude oil import costs for across all IEA countries in 2011.[2] Accordingly, purchasing costs of petroleum products would be higher.

One of the assumptions that had to be made in order to quantify the benefits of holding emergency oil stocks was that these stocks would consist exclusively of crude oil. For reasons of consistency and comparability the figures presented in this section also focus on the costs associated with holding crude oil stocks.

Figure 4 • Set-up costs (excluding jetty costs)



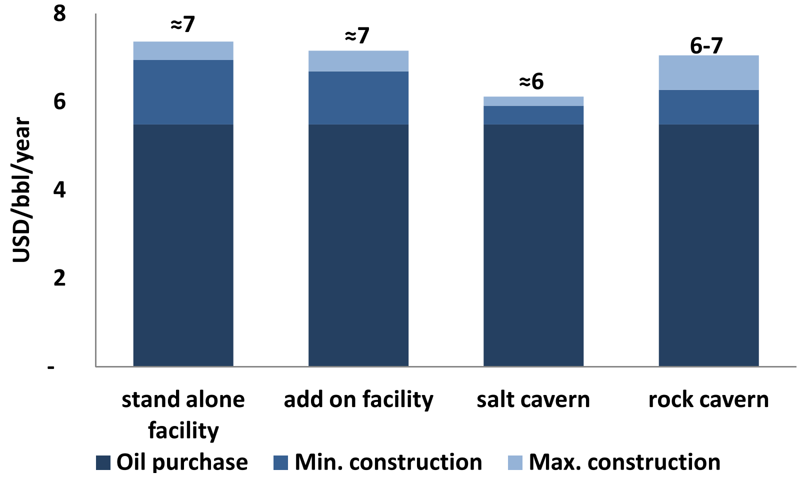
Source: Downstream B.V.

[2] Import costs include the crude oil price, insurance and freight but exclude import duties. Of note, average 2011 crude oil import prices in IEA Asia Pacific and IEA Europe were higher than the overall IEA average with USD 109.45/bbl and USD 110.54/bbl, respectively. Crude oil import prices in IEA North America were lower for the same period, amounting to USD 103.05/bbl on average. Since this report focuses on costs and benefits across IEA countries and regions, average total IEA crude oil import costs are used in order to allow for consistency in the methodology. Differences in costs across distinct world regions are discussed in a later section.

Annualised set-up costs

The set-up costs can be broken down into yearly figures. For this purpose a project life span of 30 years and a yearly interest rate of 3% are assumed.

Figure 5 • Annualised set-up costs (3% interest rate)

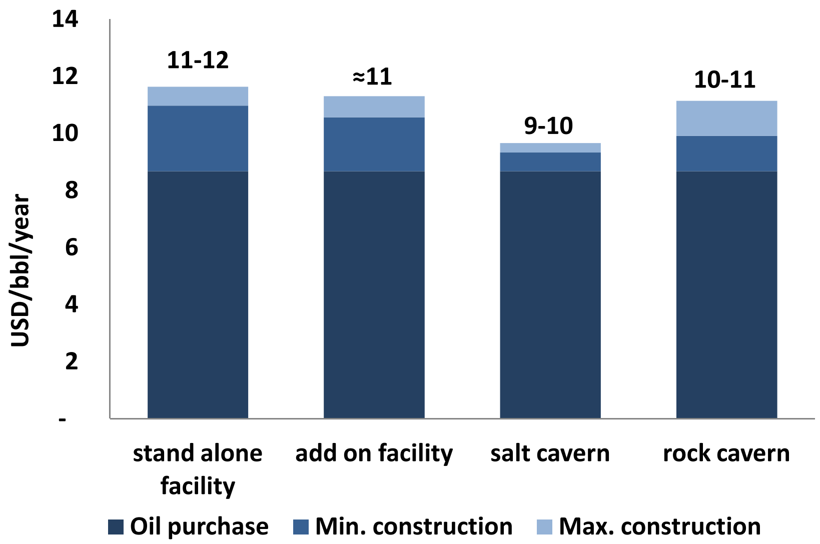


Source: Downstream B.V.

Annualised costs for constructing different storage options amount to USD 0.50-2.00/bbl (EUR 2-9/m^3). Construction costs for above-ground facilities amount to USD 1.20-2.00/bbl (EUR 6-9/m^3) while annualised costs for building underground storage facilities amount to roughly half that figure with USD 0.50-1.50/bbl (EUR 2-8/m^3). As before, these figures do not include the costs for jetties that might have to be built. The annualised cost for purchasing the necessary crude oil stands at about USD 5.5/bbl.

The interest rate has a considerable impact on the yearly cost figures. When assuming an interest rate of 7%, instead of 3%, the annualised set-up costs outlined above increase by about 60%.

Figure 6 • Annualised set-up costs (7% interest rate)



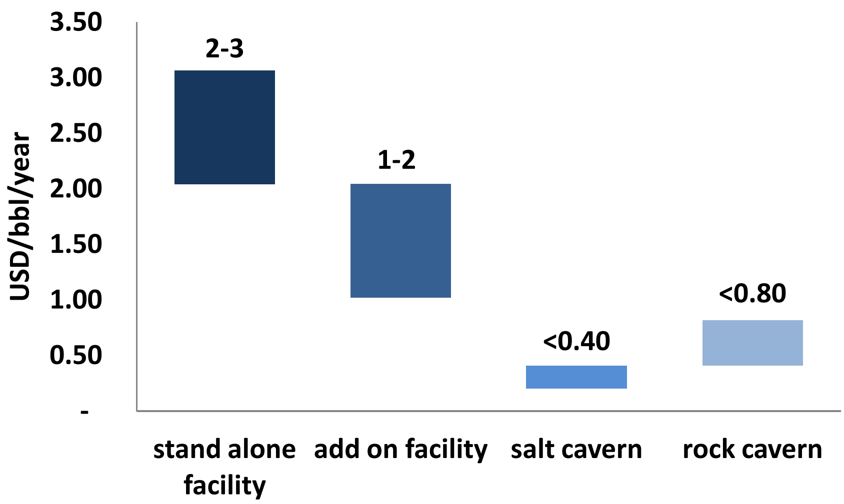
Source: Downstream B.V.

A strong argument can be made for assuming a 3% interest rate. This paper mainly focuses on public (government-controlled) oil stocks held exclusively for emergency situations. In most IEA countries which dispose of public stocks the initial set-up costs for those stocks were financed either directly from government budget or by government-backed loans. In addition, while the private sector pays higher interest rates, public stockholding entities are granted the same credit ratings as their host nation governments. Though recognising that some IEA member countries have to pay interest rates higher than 3%, the interest rate for government bonds of the large majority of IEA countries lies around or below 3%.

Operating and maintenance costs

Operating and maintenance costs principally consist of labour, utility and insurance costs. Annual operating and maintenance for different storage options range from as much as USD 3/bbl (EUR 15/m^3) for newly built above-ground facilities to less than USD 0.40/bbl (EUR 2/m^3) for underground caverns (Figure 7).

Figure 7 • Operating and maintenance costs



Source: Downstream B.V.

Operating and maintenance costs for underground caverns are generally very low when compared to above-ground facilities. Underground storage sites benefit from much lower insurance costs than above-ground facilities. Furthermore, expenses for personnel and maintenance for caverns are lower in comparison to tank farms.

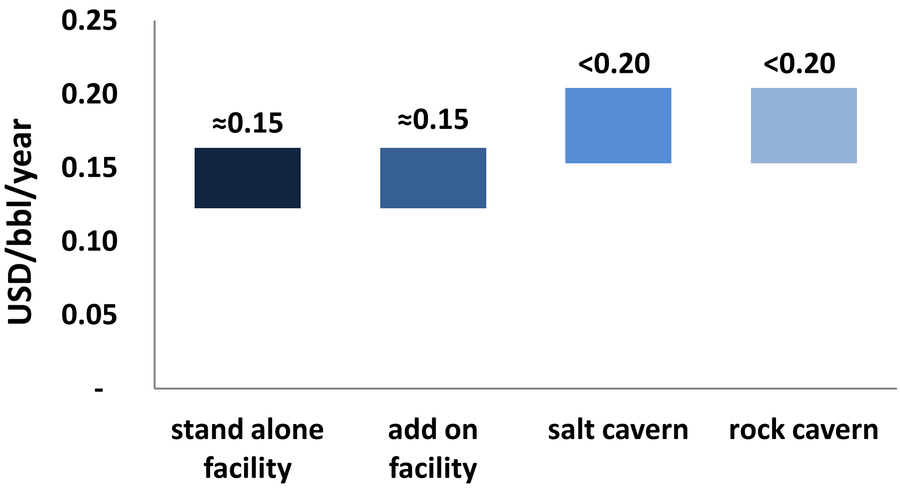
Operating costs for add-on above-ground facilities are about 30-50% lower than the operational costs for newly built tank farms. Add-on facilities allow for operations and maintenance to be integrated into an existing organisation.

Operational costs can differ across different world regions depending on local labour costs. However, since the share of operational costs in the overall expenses is low, even large differences in labour costs have little effect on the overall yearly costs.

Refreshment costs

Compared to other costs involved in holding emergency oil stocks refreshment costs account for a marginal proportion (Figure 8). The term "refreshment" refers to the regular renewal of petroleum product stocks in order to maintain quality specifications.

Figure 8 • Refreshment costs



Source: Downstream B.V.

Refreshment costs depend on a variety of factors. First, refreshment costs depend on the composition of emergency stocks, i.e. the share of finished products in the overall stocks. While crude oil can be stored without any refreshment over long periods, products need to be exchanged due to quality loss as an effect of ageing. Therefore, the higher the share of petroleum products in overall emergency stocks the larger the expenses for refreshment.

Second, the costs also depend on the frequency by which refreshments are undertaken. According to several IEA stockholding agencies, the rotation of oil products does usually not occur more often than once every six years. Refreshment periods in individual countries may be shorter due to changes in quality standards or changes in stockholding regulations.[3]

Third, refreshment costs depend on the price of the newly purchased oil products. In many cases, products to be refreshed are sold at a discount in connection with ageing while the new products have to be purchased at market prices.

Forth, temporary alternative stocks are needed to maintain compliance with stockholding requirements during a refreshing period. These temporary stocks can be held physically by the stockholding entity or in the form of tickets on reserved stocks physically held by other parties. Both options come at a cost. Fifth, the refreshment of oil stocks usually involves handling costs in terminals as well as shipping fees. Sixth, refreshment costs involve interest costs that have to be covered.

Generally, refreshment costs for above-ground storage facilities are slightly lower than for underground caverns. Refreshment costs for caverns are higher because the individual storage units are bigger; while the maximum size for product tanks is generally about 400 000 barrels (60 000 m^3), a single cavern can have a volume of more than 3 million barrels (500 000 m^3). Therefore, the amount of temporary stocks needed during the refreshment is much higher for

[3] The final cost figures used in this paper are based on a six year frequency according to agency experience of best practice.

caverns. Additionally, the refreshment process for products stored in caverns generally takes longer since pumping rates in caverns are lower. Finally, caverns need access to an above-ground reception tank during the process for collecting the product before its delivery to the market.

Refreshment costs for add-on facilities might be entirely avoided in cases where emergency stocks are comingled with commercial stocks.

Land costs

For the purpose of this paper, land costs are only considered relevant for above-ground storage facilities. In European IEA countries it is common practice among stockholding entities to rent the land on which storage facilities are built. In other world regions it is more common to purchase the respective terrain. However, when comparing the two practices, the cost involved in purchasing the necessary land is does not differ substantially from rental costs over time.

Annual leases of waterfront acreage suitable for tank farms range between USD 5-12/m^2 (EUR 4-10/m^2). Taking into account security perimeters, tank farms permit 19-25 barrels (3-4 m^3) of storage per square meter of available land on average. Based on this proportion the annual rental costs translate into a cost of less than USD 1 per barrel (EUR 1-3/m^3). If suitable land is not available in close proximity to a waterfront the costs for infrastructure increase since pipelines will have to be built in order to connect the storage site to an import terminal or a distribution hub.

Cost differences across world regions

Cost differences between different world regions are principally the result of varying labour costs. Particularly in the case of rock caverns, costs can diverge due to the high labour content in the construction costs. Under the conditions laid out above, construction costs for above-ground tank farms and salt caverns do generally not differ considerably across distinct world regions.

Discrepancies between costs experienced by individual IEA member countries and the cost figures outlined in this paper can result from a number of factors: one assumption for the cost calculations in this paper is that the most cost efficient tank sizes are used in a tank farm. These range from 500-750 thousand barrels for crude oil tanks and 250-375 thousand barrels for product tanks. The utilisation of smaller tanks can increase construction costs on a per barrel basis considerably.

The design of the storage facility also has a significant impact on construction costs. Generally, a terminal for the sole purpose of holding emergency stocks is as basic as possible while a full fledged, general purpose terminal (e.g. in case of a refinery) is more sophisticated and therefore more expensive. In order to insure comparability, construction costs for jetties have been excluded in most of the cost figures. The inclusion of jetty costs leads to a 10-40% increase in construction costs. The rise is even higher if a more sophisticated jetty is built.

The construction of long pipelines, the need to pile the soil on which tanks are built as well as extensive security measures for a highly guarded facility can further increase construction costs as well as operating and maintenance costs. A cost estimate for an above-ground storage facility in the inland of the United States is one example for considerably higher construction costs than those presented in this paper. Extensive pipelines and security measures as well as a contingency budget of 30% for unforeseen engineering costs led to an estimate for construction costs equivalent to USD 50-60/bbl (EUR 250-300/m^3), almost double compared to the cost figure of USD 29-37/bbl (EUR 140-180/m^3) in this paper.

In this paper, the expenses to purchase the stocks are based on 2011 crude import costs across all IEA countries (USD 107.61/bbl). Import costs in IEA Asia Pacific (USD 109.45/bbl) and IEA Europe (USD 110.54/bbl) are above this average, while they are lower in IEA North America (USD 103.05/bbl). In addition, since these are regional averages individual countries might experience higher import costs. Due to the large share represented by the purchase of stocks, differences in import costs can have a significant impact on the level of total costs.

The interest rate has a considerable impact on yearly cost figures. Annualised costs are based on an interest rate of 3%. Higher interest rates lead to higher yearly expenses.

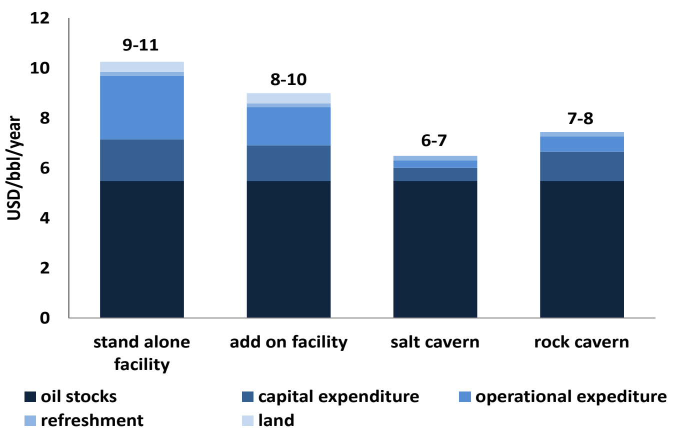
Australia is one example of higher stockholding costs due to a combination of the reasons outlined above. First, the local steel price is about 20% higher than the steel price on the world market. Second, labour costs in the Australian construction sector are twice as high as in comparable IEA countries while productivity in the sector is about 10-15% lower. Third, 2011 import prices for Australia were more than USD 8/bbl above the average IEA price level. Taken together these effects increase stockholding costs in Australia by about 20% compared to the total costs outlined in this paper.

Cost results and conclusions

Holding emergency stocks in underground caverns comes at a clear cost advantage when compared to above-ground tank farms. Overall yearly expenses for holding stocks in caverns are about 30% lower than the costs for holding oil in above-ground facilities.

At current oil prices the purchase of the necessary oil stocks represents about 50-60% of the overall yearly costs in the case of above-ground storage facilities and as much as 85% for underground caverns. The expenditures for building the storage facilities and the related infrastructure (excluding jetties) amounts to nearly one fifth of total yearly costs for above-ground tank farms and rock caverns while accounting for less than 10% of yearly costs for salt caverns.

Figure 9 • Breakdown of total yearly costs (3% interest rate)

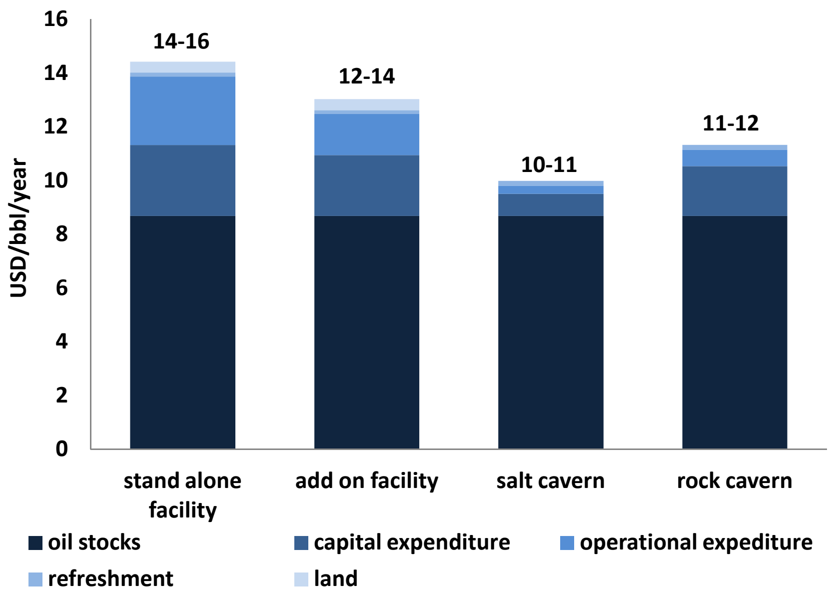


Source: Downstream B.V.

Expenses for operating and maintenance of the storage sites represent up to one quarter of total yearly costs for above-ground facilities and about 5-10% for caverns. Refreshment costs represent a very low proportion in overall costs generally amounting to less than 3%. About 5% of the total yearly costs result from leasing or purchasing the necessary terrain in the case of above-ground storage.

The interest rate has a considerable impact on the yearly cost figures (Figure 10). When assuming an interest rate of 7%, instead of the 3% base case, annualised total costs for above-ground storage facilities increase by about 40%, while the yearly costs for underground caverns would augment by more than 50% due to a higher share of set-up costs in the overall expenses.

Figure 10 • Breakdown of total yearly costs (7% interest rate)



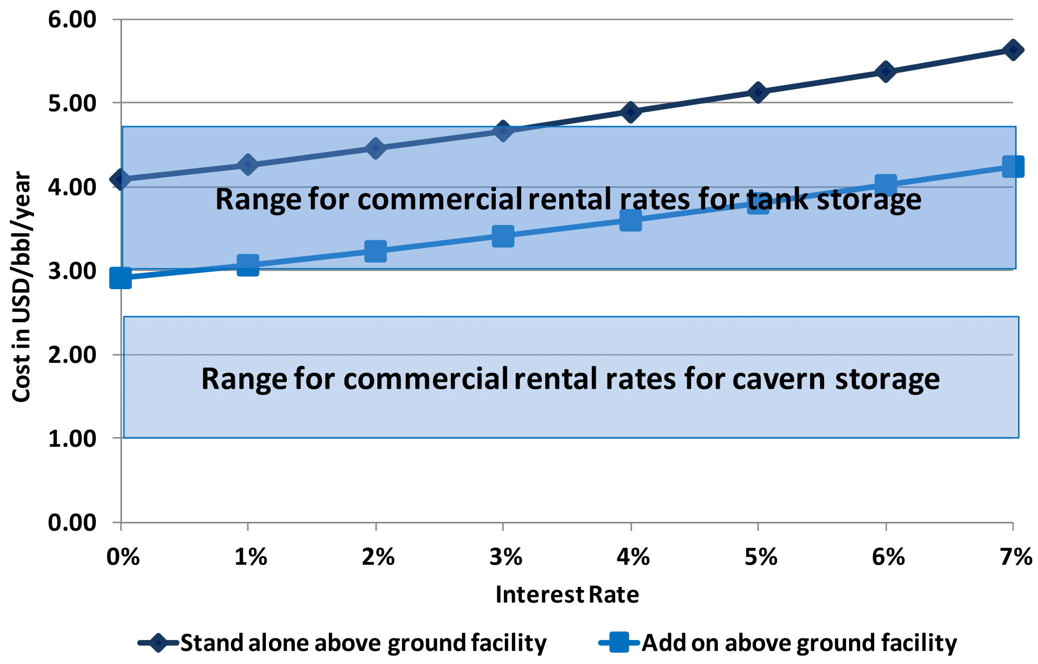
Source: Downstream B.V.

This paper discusses the costs and benefits involved in holding public emergency stocks. Since public stockholding entities are granted the same credit ratings as their host nations, costs figures reflecting a 3% interest rate are considered a realistic assumption.

As a sensitivity test, the sum of annualised construction costs (excluding jetties), operational costs and land costs is compared to rental rates for different storage facilities. Rental rates for underground storage space range from USD 1.00-2.50/bbl (EUR 5-13/m^3), while rates for above-ground facilities fall between roughly USD 3-5/bbl (EUR 15-23/m^3).[4]

[4] These ranges are the result of interviews the consultant conducted with commercial storage companies.

Figure 11 • Annualised construction, operating and land costs versus renting costs



Source: Downstream B.V.

The yearly stockholding costs outlined in this paper fit reasonably well into the ranges for rental rates. The annualised cost figures for add-on above-ground facilities, at a 3% interest rate, fall comfortably within the range of rental charges. Annualised costs for newly built above-ground storage facilities, at a 3% interest rate, coincide with the upper ceiling of rental charges.

For public stockholding entities that face an interest rate higher than 3%, renting storage facilities to hold emergency oil stocks appears to be a cost efficient alternative to constructing their own facilities, provided that sufficient commercial storage space is available.

2. Benefits of Holding Emergency Oil Stocks

The following chapter outlines how the economic benefits derived from IEA emergency stocks were calculated with the help of a computer model (Figure 12, *ORNL Computer Simulation*). It presents the principal results of the simulation and discusses important assumptions on which these results are based. Finally, the benefits are compared to the costs.

Benefits refer to collective economic benefits of existing IEA stocks for all net importing countries – IEA and non-IEA. The study does not attempt to quantify benefits at a country level since these benefits depend to a large extent on a country's specific economic characteristics such as energy intensity of GDP, the share of oil in total primary energy supply, the share of oil net-imports, and per capita GDP. Global economic benefits are calculated as the reduction in economic damage caused by a disruption due to the use of stocks compared to a situation where no stocks are made available. The benefits are derived from a large series of individual simulations over a 30-year horizon.

For the purpose of this paper, IEA emergency stocks are comprised of public stocks and all industry stocks held under an obligation, amounting to about 2.3 billion barrels of oil.[5] This is considerably lower than the more than 4 billion barrel of total IEA stocks. The stricter definition of what is counted as emergency stocks in this paper excludes all commercial stocks that are held outside of an obligation, since it is unclear if and how these stocks could be used in the event of a supply disruption. The amount of industry stocks held under obligation, referred in this paper, also excludes potential amount of Minimum Operating Requirements (MoR).

The benefits analysis treats total IEA emergency stocks as crude oil. Although a considerable amount of IEA stocks consists of oil products, the lack of sufficient data on the economic impact of a product disruption prevents this aspect from being taken into account.

Due to the inherent simplifications of the simulation model, the results can only represent an approximation to the actual benefits that oil importing countries collectively receive from holding emergency stocks. As noted above, benefits for individual countries vary depending on their circumstances.

Quantifying economic benefits

Simulating supply disruptions

Oil is a vital commodity for the global economy and oil supply disruptions have the potential to cause economic damage. Due to very low short-term demand elasticities, the oil price increase in the wake of a sudden supply disruption can be very large. Such an abrupt increase in prices has a severe impact on the world economy through multiple channels, such as inflationary pressures, reductions in capacity utilisation rates, and dislocations in labour markets. All of these effects ultimately translate into a reduction of GDP of net importing countries and an increase in import costs.

Over the next decades, the world will continue to be exposed to the serious risk of severe oil supply disruptions as the result of natural disasters, strikes and social unrest as well as war. Holding emergency oil stocks provides an effective insurance to mitigate the economic damage caused by any such disruption.

[5] IEA emergency stocks are subject to change as net import figures and in consequence stockholding obligations vary. It is, however, considered in this paper that on average these stocks amount to about 2.3 billion barrels over the 30-year horizon.

However, the specific magnitude, timing and impact of any future disruption are uncertain. To account for this uncertainty, the benefits of emergency stocks were examined by a randomised model that simulates the global economic benefits of IEA emergency oil stocks over thousands of possible disruption scenarios and market outcomes. The model estimated changes in oil price, gross domestic product and net import costs with and without the use of IEA emergency stocks. Each individual outcome was weighted by its assessed likelihood allowing for the establishment of mean (expected) values and confidence intervals.[6]

The economic benefits of emergency stocks are derived primarily from offsetting supply losses and thereby reducing potentially significant oil price increases.[7] The two principal types of benefits are reduced GDP losses and reduced import costs. Over the course of the 30-year horizon of the simulation, the use of IEA stocks results in some USD 3.5 trillion of avoided costs to net importing countries.

The six key inputs for assessing the benefits of holding emergency stocks (pp. 30 ff, Leiby et al., 2012) are:

- reference market conditions;
- spare oil production capacity;
- IEA emergency oil stock capabilities;
- non-IEA emergency oil stock capabilities;
- oil supply disruption probabilities; and
- market responsiveness (price elasticities of supply and demand) and macroeconomic sensitivity to shocks (GDP elasticities towards the oil price)

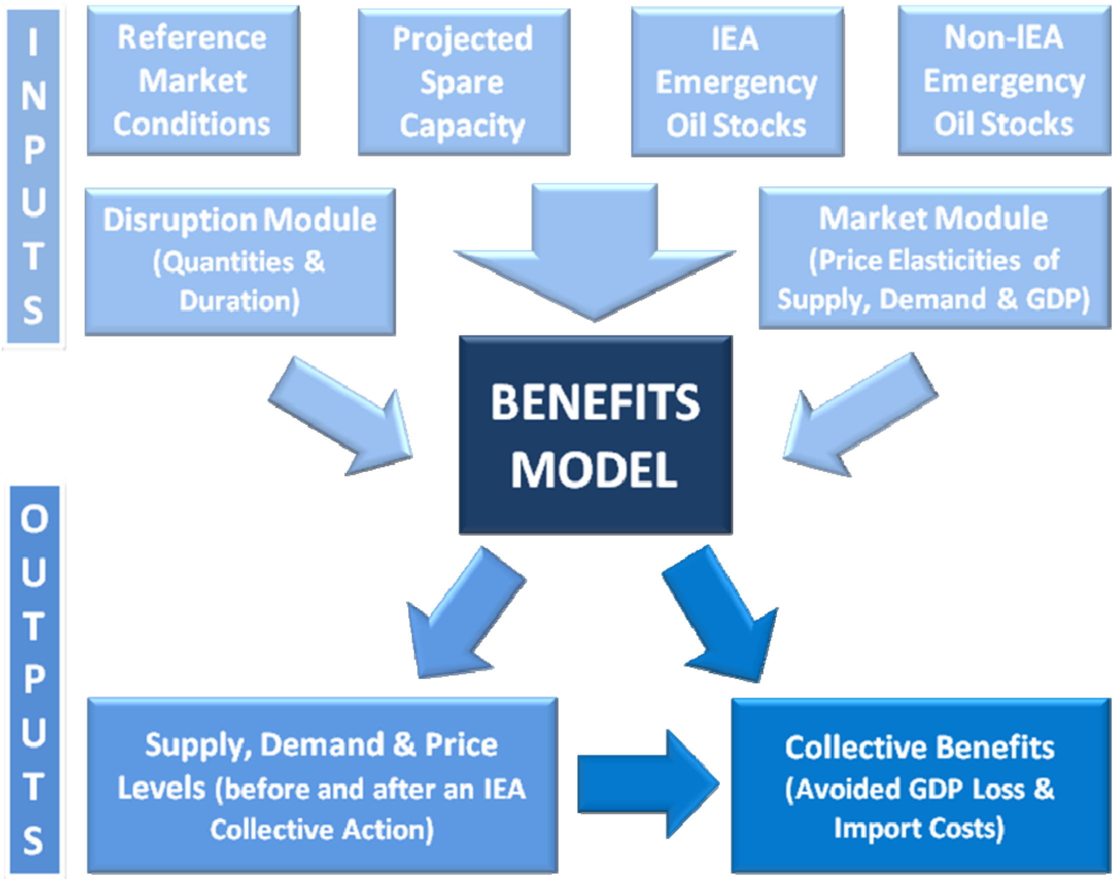
The model simulates the benefits of emergency stocks in response to a wide range of possible disruptions over the 30-year period using randomly generated future time paths for oil supply and oil price. It characterises emergency stocks in terms of stock sizes, draw down rates, fill rates and refill rates. The model also produces estimates of the expected frequency of disruptions and use of emergency stocks, the probability of stock exhaustions, and the probability distribution of economic benefits. These distributions are generated using thousands of sample iterations (p. 5, Leiby et al., 2012).

Simulations were run for a base case and several alternative scenarios accounting for variations in key parameters such as price elasticities of oil demand, the amount and use of spare capacity, the disruption size at which an IEA Collective Action is triggered and the availability of obligated industry stocks. This allowed testing the robustness of the results for different sensitivities.

[6] Specific disruption risk probabilities for different oil producing regions are based on an assessment by the U.S. 2005 Energy Modelling Forum (EMF). For more details on the assessment see Leiby et al. (2012) and Beccue & Huntington (2005).

[7] Prices with IEA drawdown are slightly higher than the reference price despite the shortfall being fully offset. This reflects the assumption of a risk premium in oil prices.

Figure 12 • Schematic of the ORNL Computer Simulation



Source: ORNL (Leiby et al., 2012)

Base case – assumptions and results

The following paragraphs present the assumptions and results of the benefit simulation for the base case. Sensitivity cases are discussed in the subsequent section.

The base case rests on the following assumptions:

- Reference forecasts for oil demand, supply and price are based on the 2011 IEA World Energy Outlook.
- Gross oil supply disruptions are directly offset by two exogenously specified sources: spare production capacity and short-run demand switching; the latter generally being very small. If the net disruption (after these offsets) is greater than the specified drawdown threshold level, it was assumed that emergency stocks are used in a coordinated fashion. The base case uses an assumed drawdown threshold of 2 mb/d.
- It is assumed that obligated industry stocks, which are referred here in the model, are 100% available.
- The drawdown strategy is assumed to follow the subsequent pattern: a prompt coordinated draw at the maximum draw rate necessary to fully offset the net supply disruption for the first three months. After three months, drawdown slows to a sustainable rate for the expected length of disruption.

- The full offset of the net shortfall does not completely restore the market to its state before the supply. Among others this is assumed to be the result of a risk premium or speculative behaviour.
- A discount rate of 3% based on government borrowing rates instead of private sector interest rates is assumed in order to guarantee consistency and comparability throughout the paper.8 In many IEA countries the initial set-up costs of emergency stocks were financed either directly from government budget or by government-backed loans. The interest rate for government bonds of the large majority of IEA countries lies around or below 3%. In addition, the cost assessment of holding emergency stocks refers to public oil stocks held exclusively for emergency situations.

Under the above-mentioned assumptions the total net benefits accumulated over the 30-year horizon of the simulation add up to more than USD 3.5 trillion (Table 2). This figure is an average payoff from the insurance provided by stocks.

Table 2 • Benefits – Mean and 90% Confidence Range (Base Case)

90% Confidence Range	Low	Mean	High
Accumulated global benefits over 30 years (in USD)	622 billion	3 546 billion	6 806 billion
Annual global benefits in USD/bbl (0% discount)	18.14	85.08	161.81
Annual global benefits in USD/bbl (3% discount)	8.88	50.68	97.27

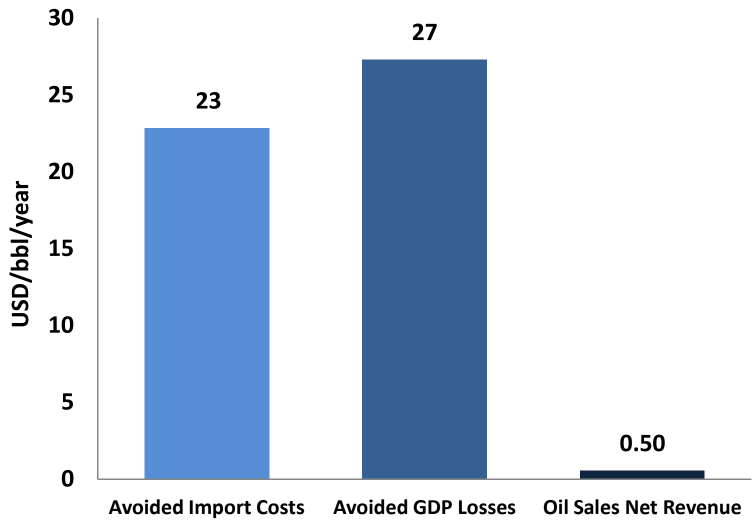
Source: ORNL (Leiby et al., 2012)

The accumulated benefits can be broken down into an annual average per barrel of stocks. This annual figure amounts to nearly USD 51/bbl (Table 2). It represents the average benefit over 30 years reflecting a large number of possible sequences of market outcomes. This USD 51/bbl/y reflects an average payoff from the insurance provided by emergency stocks while the actual benefits could be smaller or much larger depending on the size and duration of disruptions during the 30-year horizon. The 90% confidence interval for benefits reflects this uncertainty and therefore encompasses a wide range from USD 8.88 to 97.27/bbl/y. Such a wide distribution would be expected when looking at rare but high-impact events such as global oil supply disruptions.

The benefits consist of two principal components of roughly equal sizes: avoided oil import costs and avoided GDP losses (Figure 13). While for a given country the relative contribution of these two components depends on that country's level of imports and macroeconomic sensitivity to oil supply disruptions, on a global scale the two components are comparable in size. For the base case avoided oil import costs amount to nearly USD 23/bbl/y while avoided GDP losses equal roughly USD 27/bbl/y. In addition, a modest net revenue is derived from stock sales during a supply disruption (minus the cost for refilling).

[8] Discounting adjusts future benefits to account for the time-value of money, i.e. the greater value of USD 1 now than one year from now. Unless otherwise specified, annualised or total (net present value) benefits are computed by adjusting the benefits over time with a 3% annual discount rate. Because of the long planning horizon, all of the benefit figures are much larger when considered in undiscounted terms, as Table 2 indicates.

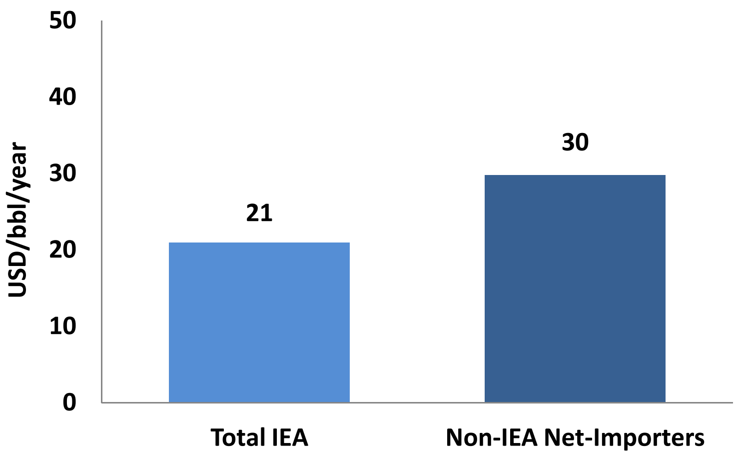
Figure 13 • Annual benefits of IEA stocks by component (Base case)



Source: ORNL (Leiby et al., 2012)

It is necessary to distinguish between GDP losses and higher import costs as the result of an oil supply disruption. While GDP losses reflect a drop in a country's economic output, higher import costs reflect a transfer of wealth (GDP that has been generated). Therefore, the two are additive.[9]

Figure 14 • Annual benefits of IEA stocks by world region



Source: ORNL (Leiby et al., 2012)

[9] It is widely recognised that GDP is an accounting measure that provides only an incomplete measure even of economic welfare. Leiby et al. (Leiby et al., 1997) argue that domestic absorption (how much of its Gross National Product (GNP) a national economy gets to keep) is a better measure of a country's welfare than gross output (how much a national economy produces). Macroeconomic adjustment costs from shocks are a temporary (several years) excess loss of GNP that is suffered in addition to the loss of potential GNP due to the increased economic scarcity of oil. Huntington and Eschbach (Huntington and Eschbach, 1987; p.200) also emphasise that excess wealth transfers from increased import costs and the losses of real GNP due to oil price shocks measured by macroeconomic models are additive. The increased payment for oil imports is not a reduction in potential GNP, but an increased claim by foreign interests on a national economy's output/GNP. Their argument that macroeconomic models ignore the oil wealth loss arises from the way GNP is measured and is essentially an accounting problem. (See also Toman, 1993)

The global benefits derived from IEA emergency stocks can be broken down between benefits for IEA countries and benefits for non-IEA net oil importing countries. The benefits enjoyed by non-IEA countries are of comparable size to the benefits IEA countries draw from their stocks (Figure 14).

There are two principal reasons for this outcome. First, non-IEA oil consumption and GDP are projected to grow significantly over the 30-year horizon of the simulation, eventually exceeding collective consumption and GDP of IEA member countries. The high share in oil consumption and GDP is reflected in a high share of the benefits derived from stocks during a supply disruption. Second, on average GDP sensitivity to oil supply disruptions is relatively high in non-IEA countries, second only to that of the U.S. The higher sensitivity translates into a proportional increase in the benefits these countries derive from emergency stocks.

Major non-IEA consumer countries such as China and India have recognised their potential vulnerability to oil supply disruptions and started to build emergency stocks of their own. Benefits per barrel of incremental stocks are expected to be smaller than the benefit per barrel of the existing stocks.[10] However, the value of any additional emergency stocks depends on future IEA policy and whether the IEA continues to completely offset any supply loss on a global scale. To the extent that IEA emergency stocks are only used to cover for a certain share of the disruption, the benefits derived from additional stocks increase accordingly.

Sensitivity of results to assumptions

The results of the benefit assessment depend on a variety of underlying assumptions. The following paragraphs provide a sensitivity analysis concerning several of the key assumption and discuss the impact of altering these assumptions. The key assumptions under scrutiny are:

- short-run elasticities of oil demand and supply;
- GDP sensitivity to oil price shocks;
- spare oil production capacity;
- availability of industry-obligated stocks;
- drawdown threshold; and
- risk premiums during a supply disruption.

Figure 15 illustrates the results for each sensitivity case in which one of the key base assumptions was altered. It indicates the mean value for each sensitivity case, with a 90% confidence interval. The benefits are reported in average dollars per barrel per year.

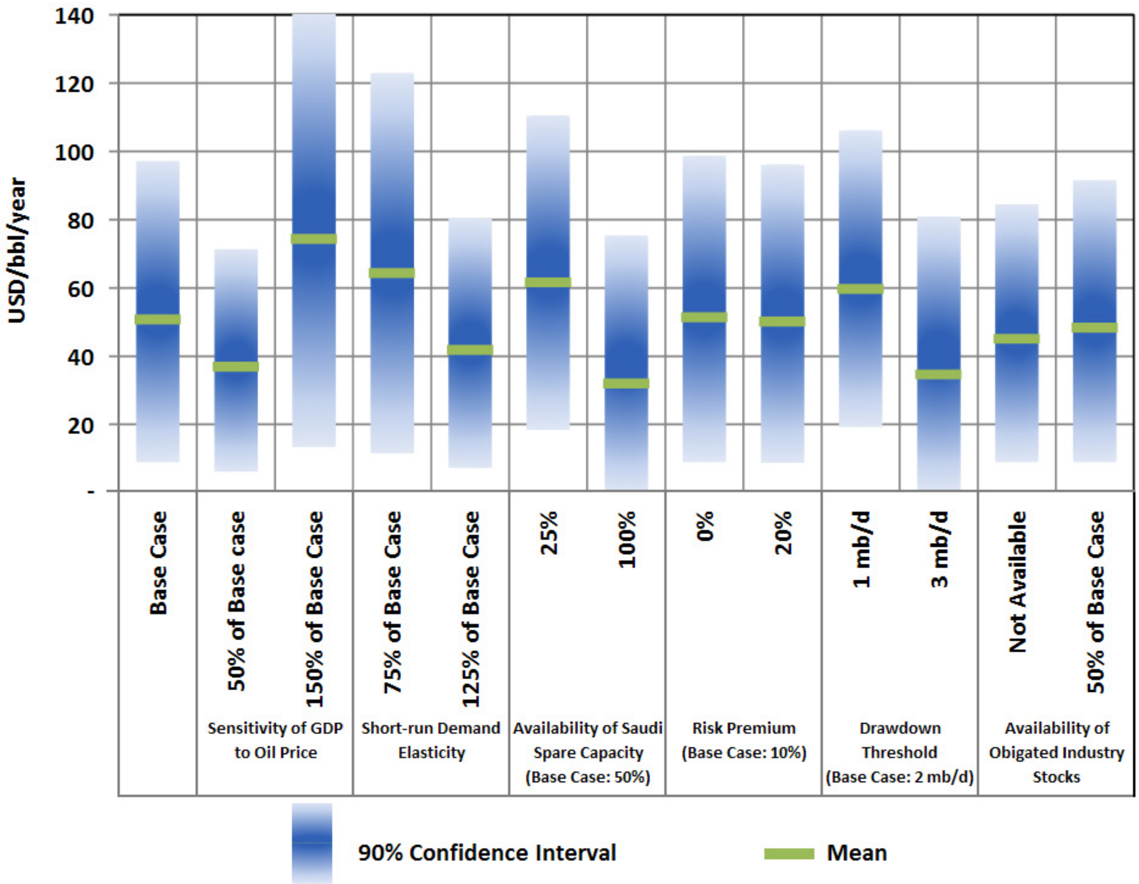
The benefit results obtained under the base case appear to be robust. Under the different sensitivities benefits generated from the release of IEA stocks amounted to at least USD 32/bbl/y (USD 2.2 trillion in net present value), and went as high as USD 74/bbl/y (USD 5.2 trillion).

The sensitivity analysis also highlighted that the assumptions with the largest impact on the final results are: (1) the sensitivity of GDP to oil price increases, (2) the sensitivity of demand to oil prices, and (3) the amount of available Saudi Arabian spare capacity. Particularly global demand flexibility and global GDP sensitivity are depended on the level of oil consumption. With the ongoing trend of increased use of oil in emerging and developing economies global demand flexibility is likely to decrease while global sensitivity to oil price shocks is likely to increase. This

[10] The model assumes that additional stocks only provide benefits in cases where the existing stocks would be insufficient to offset the global supply loss.

would raise the costs associated with a severe supply disruption and increase the benefits derived from emergency stocks.

Figure 15 • Sensitivity cases



Source: ORNL (Leiby et al., 2012)

Principal sensitivity cases

Short-run flexibility of demand

Variations in the short-run flexibility (price-elasticity) of demand have a high impact on the benefits associated with holding emergency stocks. In the event of a supply disruption, the market impact depends on the extent to which global demand adjusts to rising oil prices in the short run. This short-term flexibility is represented by the elasticity of global net oil demand. A smaller elasticity (lower flexibility) of demand requires higher price levels to rebalance supply and demand, given the same supply disruption.

Global demand elasticity is generally quite small in the short term. It is generally lower in some sectors (e.g. transportation) and world regions (e.g. emerging economies). Any global trends toward decreased flexibility of oil demand would increase the impact of a supply disruption and make emergency stocks more valuable. Two developments could cause such a decrease in demand elasticity: (1) the continued expansion of emerging economies' share in global oil demand and (2) a continued trend of concentration of global oil consumption in the transport sector.

There is an almost symmetric correlation between demand elasticity and economic benefits derived from oil stocks. If the future elasticity of demand is 25% lower than assumed in the base case, yearly benefits increase from USD 51/bbl to about USD 64/bbl, whereas they decline to about USD 42/bbl/y if the elasticity increases by 25%.

Sensitivity of GDP to oil price

The economic damage caused by supply disruptions is dependent on the sensitivity of the economy to sudden oil price increases (price shocks). This relationship is reflected in the oil price-GDP elasticity. This elasticity depends on several factors such as the energy intensity of GDP, the share of oil in a country's total primary energy supply, the share of oil net-imports, and per capita GDP.

Benefits derived from emergency stocks are almost directly proportional to changes in the oil price-GDP elasticity. A 50% reduction in the elasticity leads to a decrease in benefits from USD 51/bbl/y to about USD 37/bbl/y, whereas a 50% elasticity increase causes benefits to rise to almost USD 75/bbl/y.

Many IEA countries have reduced oil demand through vehicle efficiency and fuel diversification over the last decades. This had the effect of reducing the sensitivity of their economies to oil supply disruptions. In contrast to this trend, rapid economic growth in emerging markets has led to increases in consumption and dependence on imported oil as well as to a higher energy intensity of their national economies. All of those trends are making them more vulnerable to global oil supply disruptions.

Spare capacity

The IEA defines spare capacity as "the capacity levels that can be reached within 30 days and sustained for at least 90 days". Spare capacity has fluctuated over the past decades, driven by alternating periods of rapid macroeconomic growth and recessions. Current and future spare capacity is projected to be rather low compared to historical numbers. It is also concentrated in a single exporter, namely Saudi Arabia.[11]

Availability and use of spare capacity from alternative producers reduces the need for the IEA to initiate a stock draw during a supply disruption. Therefore, variations in spare capacity have a considerable impact of the benefits associated with holding emergency stocks.

The base case of the simulation assumes that on average, 50% of Saudi spare capacity would be available and used during a supply disruption. This average is based on an assessment of historical use of Saudi spare capacity in the event of a supply disruption. The actual use of spare capacity depends on the situation at the time.

Sensitivity analysis shows that a reduction of spare capacity use to 25% of the existing capacity increases the benefits of IEA stocks to about USD 62/bbl/y, whereas assuming the use of 100% of existing spare capacity reduces the benefits to about USD 32/bbl/y.

Disruption price premium

The base case assumes that after the initiation of an IEA Collective Action in response to a supply disruption the oil price is somewhat higher than the level determined by the global supply-demand balance. During a disruption, market dislocation, speculative behaviour, or concerns

[11] For the purpose of this paper (and the results of the computer simulation on which this paper is based), current and projected OPEC spare capacity is based on 2011 data.

about risk are assumed to elevate prices even though the physical disruption has been fully offset by the use of emergency stocks. In Figure 15 this effect is labelled "risk premium".

In the base case the risk premium was set at 10% (assuming the price is 10% above the level incurred by the disruption alone). Sensitivity analyses raising that risk premium to 20%, or reducing it to zero, do not have a significant effect on benefits, since the premium occurs, and remains, with or without the use of stocks.

Drawdown threshold

IEA oil stocks are reserved for emergencies where unmitigated oil supply disruptions would cause significant economic damages. Thus, in deciding when to drawdown stocks the IEA would seek to exclude supply disruptions that can be effectively resolved by market resilience. A drawdown decision for a supply disruption depends on market conditions, and is difficult to determine in advance. In this study, as an approximation, the base case established that the net supply loss (after spare production capacity has been utilised) has to be above 2 mb/d in order to trigger an IEA stock release. Two sensitivity cases examined the impact of drawdown thresholds of 1 mb/d and 3 mb/d. Lowering the drawdown threshold to 1 mb/d increased yearly benefits to about USD 60/bbl whereas a higher drawdown threshold of 3 mb/d reduced benefits to about USD 35/bbl/y.

Availability of obligated industry stocks

Like IEA public stocks, the release of obligated industry stocks reduces the supply gap during a disruption. The base case assumes that obligated IEA industry stocks are fully available. However, it is possible that during a supply disruption the availability of obligated industry stocks may be constrained. Therefore, sensitivity cases examine a reduced availability of those stocks. Assuming that obligated industry stocks are completely unavailable reduces total benefits to about USD 45/bbl/y. A reduced availability of 50% would decrease benefits to USD 48/bbl/y.

Additional benefits

The tangible economic benefits of holding emergency oil stocks to respond to global supply disruptions are substantial. However, the preceding quantitative economic analysis includes only a subset of benefits for a certain kind of events, i.e. global crude oil supply disruptions.

The benefits derived from emergency oil stocks go well beyond such events. There are at least two specific contingencies were additional benefits can be identified. First, emergency stocks can be used in response to domestic disruptions (e.g. caused natural disasters to infrastructure outages) that may affect local markets without triggering an IEA Collective Action. Second, emergency stocks provide protection against product supply disruptions.

There are two principal reasons for why these additional benefits were not part of the preceding assessment. First, there is a severe lack of data concerning the economic impact of product supply disruptions. The limited amount of data does not allow for a robust simulation to quantify the benefits drawn from product stocks. Second, benefits under both contingencies are difficult to quantify because they are highly country-specific and depend to an even higher degree than global crude oil disruptions on the local and regional context. Although several IEA countries have experienced local (product) supply disruptions and used emergency stocks in response,[12] the benefits obtained during those events do not only depend on the size and duration of the

[12] Prominent examples are the Czech Republic, Japan, Switzerland and the United States.

disruption, but also on where stocks are held. Therefore, it is at the country or regional level that these additional benefits would best be evaluated.

The principal conclusion is that when the additional benefits identified above are taken into account, the total benefits associated with holding emergency oil stocks are likely higher than the figures presented in the preceding section. This adds further robustness of the results obtained from comparing cost and benefits in the following section.

The mere presence of emergency stocks may have prevented certain potential supply disruptions although some benefits would be impossible to quantify.

3. Comparing Costs and Benefits

Under the base case total gross benefits of about USD 51/bbl/y have to be compared to a yearly cost of USD 7-10/bbl. That leaves a yearly net benefit of at least USD 41/bbl/y even for the most expensive storage option (i.e. newly built above-ground facility).

Considering the results of the sensitivity cases and the fact that benefits in the event of domestic and/or product supply disruption could not be captured in the numbers above, the actual net benefits are likely larger. Even under most unfavourable circumstances there remain considerable global net benefits of USD 20-25/bbl/y (Table 3).

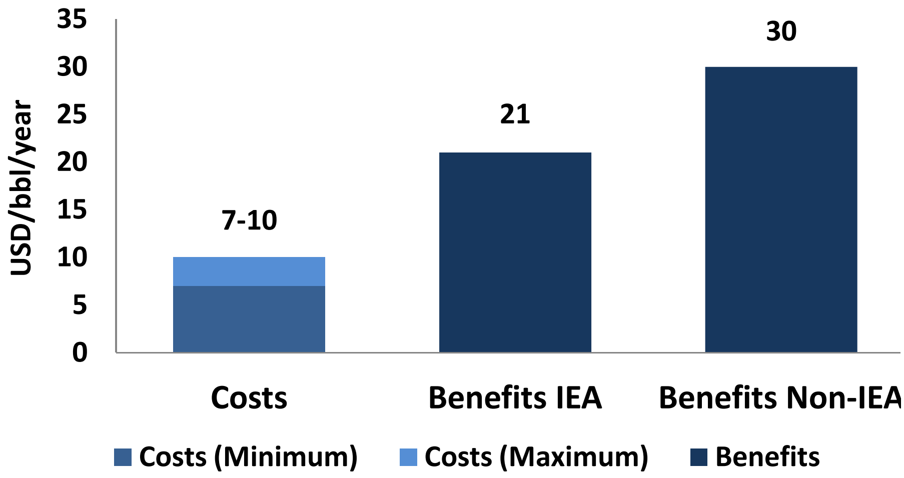
Table 3 • Benefits versus costs for a variety of sensitivity cases (in USD/bbl/y)

Sensitivity Test	Base Case	Price Elasticity of Demand		Use of Saudi Arabia Spare Capacity (Base Case: 50%)		Drawdown Threshold (Base Case : 2 mb/d)		Availability of Obligated Industry Stocks (Base Case: 100%)	
Variation Compared to Base Case	Base Case	Lower Elasticity (75% of Base Case)	Higher Elasticity (125% of Base Case)	Lower Use (25%)	Higher Use (100%)	Lower Threshold (1 mb/d)	Higher Threshold (3 mb/d)	None Available (0%)	Lower Availability (50%)
Gross Benefits									
Total IEA	21	27	17	26	14	25	15	19	20
Non-IEA Net-Importers	30	38	25	36	18	35	20	26	28
Total Gross Benefits	51	64	42	62	32	60	35	45	48
Costs									
Newly Built Above Ground	10	10	10	10	10	10	10	10	10
Add on Above Ground	9	9	9	9	9	9	9	9	9
Salt Cavern	8	8	8	8	8	8	8	8	8
Rock Cavern	7	7	7	7	7	7	7	7	7
Net Benefits									
Total IEA	11-14	17-20	7-11	16-20	4-7	15-19	5-8	9-12	10-13
Non-IEA Net-Importers	30	38	25	36	18	35	20	26	28
Total Net Benefits	41-44	55-58	32-36	52-55	22-25	40-47	25-28	35-36	38-41

Source: ORNL (Leiby et al., 2012)

The overall picture does not change when dividing the global benefits between IEA member and non-member countries (Figure 16). Although smaller, net benefits for IEA countries alone remain considerable. Net-importing countries outside the IEA have long recognised the enormous benefits derived from emergency stocks. Major non-IEA consumers such as China and India have embarked on programmes to set up emergency stocks of their own during the last decade. In addition, in the light of the growing share of non-IEA countries in global oil consumption, the IEA has engaged in closer co-operation with non-member countries, exploring the possibility of acting in unison during future supply disruptions.

Figure 16 • Costs compared to gross benefits



Source: ORNL (Leiby et al., 2012)

In this context it is important to note that incremental stocks – in addition to existing IEA stocks – provide considerable net benefits, even accounting for the high cost of oil acquisition. The global benefits derived from additional stocks increase to the extent that IEA stocks are only used to cover for a certain share of the disruption.[13]

[13] Benefits from incremental stocks are expected to increase due to growing global demand outside the OECD and the diminishing cover provided by existing IEA stocks. Those stocks are likely to be held in areas of demand growth.

4. Financing Emergency Oil Stocks

In practice, there are two different stockholding systems in IEA member countries: government/agency stocks[14] (public stocks) and obligated industry stocks (industry stocks). This difference is reflected in the way stockholding schemes are financed.

First, this chapter presents the different ways of financing government and agency stocks adopted by IEA member countries. It will differentiate between financing the initial set-up costs and financing the running costs. Second, the different practices of financing compulsory industry stocks will be presented. Third, the use of ticket contracts will be discussed as a way for governments, companies and stockholding agencies to comply with stockholding obligations.

Financing government/agency stocks

Initial set-up costs

The 18 IEA member countries with public stocks used a variety of methods to cover the initial set-up costs of their stockholding regimes.[15] The two most common practices are: (1) recourse to direct central government funding either directly taken from the budget or through a government loan, and (2) reliance on private creditors in the form of bank loans or bonds. For the latter, the provision of government loan guarantees as backup for the creation of independent stockholding agencies can play an important role for the financing.

Government budget

In seven countries (the Czech Republic, Finland, Japan, the Republic of Korea, Poland, the Slovak Republic, and the United States) the initial set-up costs for stocks were financed from the central government budget.

Particularities have to be mentioned for three of these countries. First, in the Czech Republic as well as in the Slovak Republic, the offices which oversee the state's emergency oil reserves[16] are not only mandated to cover the countries' entire oil stockholding obligation but they are also required to hold reserves which include agricultural goods, metals and industrial materials. In both countries, parts of the government's oil stocks have been purchased by gradually selling stocks of non-oil goods.

Second, in Korea, a small percentage of the expenses to purchase the oil for public stocks were financed by revenues from the Korean National Oil Company, a state-owned company which is responsible for holding the country's public emergency stocks.

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[14] There are two types of stockholding agencies across IEA countries; those set up by governments and those set up by industry. This difference has an impact on the financing of emergency stockholding.

[15] These are Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Japan, Korea, the Netherlands, New Zealand, Poland, Portugal, the Slovak Republic, Spain, and the United States. While the stocks held by the Austrian stockholding agency (ELG) fall under the IEA definition of "public stocks", these amounts are currently included under "industry stocks" as Austrian data reporting to the IEA does not separate ELG stocks from industry held stocks. However, since ELG is an official licensed stockholding entity the company's stocks are classified as agency stocks in this report.

[16] In both countries the so-called Administration of the State Material Reserves is mandated to cover the entire oil stockholding obligation.

Bank loans or bonds

In ten IEA member countries (Austria, Belgium, Denmark, France, Germany, Hungary, Ireland, the Netherlands, Portugal and Spain) the set-up of emergency reserves was financed by bank loans or in the form of bonds issued by the stockholding agency. In general, the assets held by the agency, i.e. the oil stocks themselves as well as the infrastructure owned by the agency, serve as a security to back these loans. The agencies' assets are usually booked at their acquisition value and are not exposed to price fluctuations in the oil market.

In the specific case of Portugal, a small share of the initial set-up costs (EUR 250 000) was financed directly from the central government budget. However, most of the investments in storage facilities and the purchase of stocks were covered by bank loans and bonds.

Besides taking bank loans several stockholding agencies also issue bonds as an instrument of financing. Often the aim is to diversify the funding sources which allows for lower interest rates and provides a larger spread of risk. In general, a stockholding agency's credit rating is similar to that of its host country's central government. The duration of bonds differs among countries. For example, while France and Germany issue a mixture of short-term commercial papers and longer-term bonds, Spain and Portugal rely exclusively on long-term bonds of 10 and 20 years, respectively.

The provision of government loan guarantees as backup for the creation of independent stockholding agencies can play an important role for the financing. These guarantees require the government to assume the agency's debt obligation if the latter defaults. The initial set-up costs for agency stocks were backed by government loan guarantees in four IEA member countries, namely Austria, Germany, Hungary and the Netherlands. Government loan guarantees generally allow stockholding agencies to borrow at lower interest rates on financial markets.

Austria's and Germany's stockholding agency (ELG and EBV) are both backed by federal loan guarantees. While the Hungarian government initially backed the set-up of agency stocks, it later withdrew its assistance. Since 2002 the Hungarian oil stocks themselves have been working as the only guarantee behind the bank loans.

As for the Netherlands, the initial set-up costs were funded by private bank loans backed by government loan guarantees. Since 2003 all loans of the country's stockholding agency (COVA) have been financed by loans provided by the Dutch Ministry of Finance. This access to government financing tools has allowed the agency to minimise its financing costs by obtaining even more favourable interest rates.

Table 4 • Financing of Government/Agency Stocks

Country	Initial Set-up Costs			Running Costs		
	Government budget	Government backed loan	Bank loans/ bonds	Government budget	Levy on Industry	Tax
Austria		X			X	
Belgium			X		X	
Czech Republic	X			X		
Denmark*			X			
Finland	X					X
France			X		X	
Germany		X			X	
Hungary		X			X	
Ireland			X		X	
Japan	X			X		
Korea	X			X		
Netherlands**		X				X
New Zealand***				X		
Poland	X			X		
Portugal			X		X	
Slovak Republic	X			X		
Spain			X		X	
United States	X			X		

Note: *In Denmark running costs are covered by the financial surplus the Danish stockholding agency built in the early 1990s in the wake of falling demand and rising indigenous output, together with the amortisation of storage facilities.

**In the Netherlands running costs are covered by a levy on final consumers.

***New Zealand has not built a physical reserve for emergencies. The difference between operating industry stocks and the IEA obligation is entirely covered by stockholding tickets. Therefore, there have been no set up costs.

Government backing does not necessarily have to be in the form of loan guarantees. Instead it can also become important in the event of a stock release. Across IEA countries, stock releases are generally done in two different ways; either through loans of a certain quantity of oil or through a tender process. In a tender process the stockholding agency could endure a financial loss even if the selling price was lower than the acquisition cost of the stocks. Several IEA countries have laws in place to prevent such a loss. For example, laws in France protect the country's stockholding agency (CPSSP/SAGESS) from any financial loss in a situation where CPSSP/SAGESS has to sell a certain amount of its stocks following a government request. The agency would be compensated for any financial loss by additional contributions from its member companies.

Running costs

As with the initial set-up costs, the individual practices of covering the running costs of public stockholding vary considerably among IEA member countries. There are three principal methods of financing running costs: (1) from the central government budget, (2) through a levy paid by market operators, or (3) through a tax paid by final consumers.

Denmark represents an exception. The country's stockholding agency is able to cover running costs from a considerable financial surplus built up previously.

Government budget

In seven IEA-member countries (the Czech Republic, Japan, Korea, New Zealand, Poland, the Slovak Republic, and the United States) the running costs of public stocks are financed from the central government's budget. As was the case for the initial set-up costs, part of the running costs in Korea are covered by revenues from the country's National Oil Company.

In the Slovak Republic, the fee on industry based on import volumes has been introduced since 2011. The fee collected from the industry goes to the state budget account, and then it is reallocated to the administration for bearing the costs of holding emergency stocks.

Levy or tax

The main difference between an industry levy and a tax is whether the industry/stockholding agency or the central government is responsible for collecting the money needed to cover the running costs. In case of a levy, market operators pay their respective fee directly to the stockholding agency with the expectation of recovering this cost in the market place via retail prices. In case of a tax, the money is collected by the central government as a direct charge on final consumers and passed on to the stockholding entity.

In general, the levy is charged on market operators[17] according to the volume of product sales and deliveries into the domestic market (Belgium, Germany, Ireland, Portugal and Spain), on crude/product import volumes (Hungary, Portugal), or on the volume to be stored (Austria). In either of these cases, the costs covered by the fee would be expected to be borne by final consumer via retail prices.

In Finland and the Netherlands a tax is charged on specific products. It is collected by the countries' tax authorities and passed on the stockholding agencies.

In most countries the stockholding levy/tax is charged on gasoline, middle distillates, and fuel oils. While some member countries exclude certain products from the charge (e.g. jet kerosene in Ireland and residual fuel oil in the Netherlands), other countries collect a toll for additional fuels, such as natural gas and coal (e.g. Finland). In most cases, the specific amount of the fee is based on the product category, with charges on gasoline and diesel generally being higher than fees on fuel oil. Deliveries to marine bunkers and to foreign military forces stationed on national territory are generally excluded from the stockholding obligation.

In Austria, France and Spain, stockholding agencies recoup their running costs through a storage fee proportional to the amount of crude oil and product delegated to the agency.[18]

[17] Market operators generally include refiners, importers and producers. In addition, stockholding laws in Ireland and Spain explicitly mention that large consumers have an obligation to pay fees.

[18] In all three countries, a company's stockholding obligation is calculated based on the volume of domestic deliveries or net imports. In France and Spain, companies are required to delegate a certain share of the mandatory stocks to the respective stockholding agency. In France, operators are required to hold an equivalent of 29.5% of the volume of oil products (as defined under the three EU categories as well as jet kerosene) brought to the domestic market during the previous calendar year. Companies can decide whether they hold 10% or 44% of this obligation. The remained is delegated to CPSSP/SAGESS. In Spain, companies (including large consumers) have to hold 92 days of deliveries to the domestic market or consumption in the precedent 12-month period. Companies have to delegate stocks equivalent to 42 days have to CORES. Operators can request CORES to hold an additional 35 days of stocks on their behalf. In the case of Austria companies are obliged to hold stocks equivalent to 27.5% of their previous year's net imports. There is no obligation on how much of these stocks have to be held by ELG. However, ELG currently holds about 98% of the obligated stocks.

Table 5 • Industry levies/consumer taxes for financing emergency stocks in IEA member countries

Country	Levy/Tax	Amount
Austria	Industry levy on storage of crude oil, gasoline and bio gasoline, middle distillates and bio diesel, and fuel oil	Crude oil: EUR 42.25/crude oil equivalent tonne(tcoe) Gasoline and bio gasoline: EUR 49.50/tcoe Middle distillates and bio diesel: EUR 49.00/tcoe Fuel oil: EUR 38.00/tcoe*
Belgium	Industry levy on domestic deliveries of products under the three EU categories**	EU Category I: EUR 11.43/m^3 EU Category II: EUR 12.18/m^3 EU Category III: EUR 10.00/t
Finland	Tax collected by the Finnish Customs and directly passed on to NESA	Low sulphur fuel oil: EUR 2.86/t Gasoline: EUR 6.73/m^3 Light fuel oil and diesel oil: EUR 3.53/m^3 Heavy fuel oil: EUR 2.86/m^3
France	Industry levy on storage of crude oil and products under the three EU categories**	~EUR 23,00/t
Germany	Industry levy on products imported or manufactured in Germany	Gasoline: EUR 3.56/t (EUR 2.70/m^3) Diesel and light heating oil: EUR 3.56/t (EUR 3.00/m^3) Jet fuel: EUR 3.56/t (EUR 2.85/m^3)
Hungary	Industry levy	Gasoline: EUR 11.41/m^3 (3 300 HUF/m^3) Gas oils: EUR 11.08/m^3 (3 205 HUF/m^3) Kerosene: EUR 10.55/m^3 (3 052 HUF/m^3) Fuel oil: EUR 10.63/m^3 (3 075 HUF/m^3)
Ireland	Levy on domestic deliveries of products	Gasoline, kerosene, gas oil, diesel oil and fuel oils: EUR 20/m^3
Netherlands	Stockholding levy on domestic deliveries of products passed on to COVA	Gasoline, diesel and heating gas oil: EUR 8/m^3
Portugal	Industry levy on domestic deliveries	Gasoline: EUR 7.3/t Middle distillates: EUR 4.59/t Fuel oil: EUR 5.41/t LPG: EUR 2.15/t
Spain	Industry levy on storage of products under the three EU categories**	EU Category I: EUR 0.0962/m^3/day EU Category II: EUR 0.0962/m^3/day EU Category III: EUR 0.0928/t/day LPG: EUR 0.08/t/day

Note: * The actual amount companies have to pay can be considerably lower than the indicated amounts due to a system of discounts provided by the Austrian stockholding agency (ELG).

** Category I: Motor spirit and aviation fuel of gasoline type; Category II: gasoil, diesel, kerosene and jet fuel; and Category III: fuel oil.

Until 1992, the Danish stockholding agency (FDO) was financed by charging a fee on companies for its coverage of their obligations. With the reduction in the country's stockholding obligation due to falling demand and rising indigenous output as well as the amortisation of storage facilities, FDO found itself with a considerable financial surplus. It has since used this surplus to finance its running costs. However, FDO can still charge the companies for such fee to cover its costs.

Financing obligated industry stocks

In 17 of the 19 IEA member countries that impose all or part of their stockholding obligations on market operators, the associated costs are initially imposed on companies though economic theory suggests they are ultimately borne by the final consumers.[19]

Most countries distribute the stockholding obligation and the associated financial costs in proportion to a company's oil import share or its share of sales in the domestic market. One exception is that several countries impose a higher stockholding obligation on refineries (Italy, Turkey, and the United Kingdom), due to their high level of operating stocks.

Among the 19 IEA member countries with a stockholding obligation on industry only the governments of Japan and Switzerland provide financial support to market operators. Moreover, while the Greek government does not provide any financial support to companies that fall under the stockholding obligation, it may on occasion decide to set a ceiling for fees charged by storage companies to operators lacking sufficient storage capacity.

Through the Japan Oil, Gas and Metals National Corporation (JOGMEC) the Japanese government provides low-interest loans to companies to fund 80% of the volumes needed to account for the difference between minimum operating stocks (defined as 45 days of stock) and the 70-day stockholding obligation imposed by the government. For LPG, the low-interest loans cover 90% of the additional volumes needed to account for the difference between minimum operating stock levels (10 days of stock) and the government's 50-day obligation. This loan scheme works reduces the financial costs of holding obligatory stocks.

In Switzerland, the purchase of obligated stocks by market operators can be financed through bank loans backed by guarantees provided by the Swiss government, allowing for lower interest rates than usual commercial loans. However, compared to other countries which rely on an industry obligation, the Swiss stockholding system itself stands apart. While an industry-based organisation (CARBURA) coordinates the implementation of the stockholding obligation, stocks themselves are held by market operators. CARBURA collects a special levy on product imports for the so-called guarantee fund. This fund aims to cover operating costs as well as to ensure that stockholders make no loss by stockholding, i.e. the guarantee fund carries the price risk and pays compensations covering the costs of stockholding on market operators.

Oil stock ticket contracts

Many IEA member countries allow oil companies or stockholding agencies to meet their stockholding obligations for certain amounts through leasing agreements, referred to as tickets. Tickets are stockholding arrangements under which the seller agrees to hold or reserve an amount of oil on behalf of the buyer, in return for an agreed fee. Ticketing is a flexible way for companies or agencies with insufficient stocks to avoid breaching stockholding obligations. It essentially provides an alternative to acquiring oil stocks directly and building or renting additional storage capacity.[20]

[19] These are Austria, Belgium, Denmark, Finland, France, Greece, Italy, Korea, Luxemburg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Turkey, and the United Kingdom.

[20] The IEA does not collect detailed information about the percentage of stocks that is held under domestic ticket arrangements in individual member countries. This information is only collected for stocks held abroad.

Countries that permit ticket arrangements generally impose a limit on the share of stocks that can be held in the form of tickets. Other countries explicitly prohibit ticket arrangements, such as Austria, Greece, Hungary, Switzerland, and Turkey.

Table 6 • Provision and usage of ticket stockholding

Country	Domestic tickets		Tickets abroad	
	Allowances	Usage	Allowances	Usage
Australia	Not applicable		Not applicable	
Austria	Not allowed		Not allowed	
Belgium	Allowed	Yes	30% of public stocks	Yes
Canada	Not applicable		Not applicable	
Czech Republic	Not allowed		Not allowed	
Denmark	Allowed	Yes	30% of obligated industry stocks and 5% for FDO	Yes
Finland	Allowed	*	20% of obligated industry stocks	No
France	Allowed	Yes	Allowed	No
Germany	10% of EBV's stockholding obligation maximum	Yes	10% of EBV's stockholding obligation maximum	No
Greece	Not allowed		Not allowed	
Hungary	Not allowed		Not allowed	
Ireland	Allowed	No	Allowed	Yes
Italy	Allowed	Yes	Allowed	Yes
Japan	Not allowed		Not allowed	
Korea	Not allowed		Not allowed	
Luxembourg	Allowed	No	Allowed	Yes
Netherlands	Allowed	Yes	Allowed	Yes
New Zealand	Allowed	No	Allowed	Yes
Norway	Not allowed		Not allowed	
Poland	Allowed	*	5% of obligated industry stocks, not allowed for ARM	No
Portugal	Allowed	*	Allowed	No
Slovak Republic	Not allowed		Not allowed	
Spain	Allowed	Yes	Allowed	No
Sweden	Allowed	Yes	20% of obligated industry stocks	Yes
Switzerland	Not allowed		Not allowed	
Turkey	Not allowed		Not allowed	
United Kingdom	Allowed	Yes	Allowed	Yes
United States	Not applicable		Not applicable	

Note: * Information on the use of domestic tickets in Finland, Poland and Portugal was not available at the time this paper was drafted.

In practice, the proportion of stocks held abroad in the form of tickets is small for the IEA as a whole, amounting to just above 1% of the total stocks held by member countries. However, tickets can represent a significant portion of stock cover for some countries. For example, tickets play an important role in New Zealand. Since the country places no minimum stockholding obligation on industry, rising import dependency over the past decade resulted in the country being temporarily non-compliant with regard to the IEA obligation. In response, the New Zealand government has acquired stocks in other IEA member countries, in the form of ticket reservations.

As a result of the common market, the use of bilateral tickets is relatively common among European IEA member countries. However, the prominence of such ticket arrangements differs among countries. While bilateral tickets accounted for a share of merely 3% of total European stocks in 2011, they account for a much higher share in countries like Belgium, Ireland, Italy, and Luxemburg. Luxembourg represents an extreme example. Since decades, over 80% of Luxembourg's obligation is met with stocks held outside the country, for the most part in the form of short-term ticket agreements. On the contrary, abundant storage capacity in the Netherlands often serves for the benefit of other countries under bilateral agreements.

Summary of financing emergency oil stocks

There are considerable differences in the way IEA member countries finance their stockholding systems. First, the most fundamental difference results from whether compulsory stocks are held as government/agency stocks or under an obligation on industry. Second, financing has to cover two principal sets of costs; the costs involved in setting up emergency stocks and the expenses for administering and maintaining these stocks.

Among the 18 IEA member countries with government or agency stocks, the initial set-up costs are either financed from the central government budget (seven countries) or in the form of bank loans and bonds (ten countries) sometimes with the support of government loan guarantees (four of the ten countries). In 17 of 19 IEA member countries that impose all or part of the stockholding obligation on market operators, the initial set-up costs of those stocks are initially imposed on companies though economic theory suggests they are ultimately borne by final consumers via retail prices. In two countries, companies were provided with financial assistance from central governments to set up emergency stocks.

There are three principal methods to finance the running costs of public stocks among IEA member countries. First, in seven countries these costs are covered directly from the central government budget. Second, in eight countries the running costs are recouped through a levy paid by market operators. Third, two countries impose a special tax on final consumers which is passed on to the stockholding agencies. Under an industry stockholding obligation the running costs for emergency stocks are directly borne by the companies. Economic theory suggests that costs imposed on companies are ultimately borne by the final consumers.

In many IEA member countries, leasing agreements on oil stocks in the form of so-called tickets represent an alternative to acquiring oil stocks directly and building or renting necessary storage capacity. While the IEA Secretariat has very limited information on the domestic use of tickets, the proportion of stocks held in the form of tickets under a bilateral agreement is small for the IEA as a whole.

5. Conclusions

Holding emergency oil stocks provides significant economic benefits. Benefits were estimated at a global level using a randomised computer model to simulate tens of thousands of possible oil supply disruption scenarios and market outcomes. The simulation analysis showed that global net benefits derived from existing emergency stocks amount to USD 41 per barrel per year. This figure equals some USD 3.5 trillion over the 30-year time horizon considered in this paper. Emergency oil stocks primarily function like an "insurance" against oil supply disruptions. The benefits provided by those stocks are derived primarily from offsetting oil supply losses and thereby reducing potentially significant oil price increases. They consist of reduced GDP losses and reduced import costs.

Benefits vary by country and cannot always be quantified. Benefits of USD 41 are likely to represent a conservative estimate since this figure does not include any benefits derived from mitigating domestic or product supply disruptions. Benefits associated with such disruptions are more difficult to quantify because they are highly country-specific and depend to a large extend on the local context. For example, the benefits obtained during domestic disruptions do not only depend on the size and duration of the disruption, but also on the location of emergency stocks. The fact that benefits vary by country also makes it difficult to quantify the benefits of any incremental stocks. Those stocks are likely to be held in world regions experiencing demand growth. Therefore, the associated benefits are expected to increase due to growing global demand outside the OECD with the incremental stocks offsetting diminishing cover provided by existing IEA stocks.

Acquisition costs of oil represent the largest share in overall costs associated with holding emergency stocks. At current oil prices the purchase of the necessary oil stocks represents about 50-60% of the overall yearly costs in the case of above-ground storage facilities and as much as 85% for underground caverns.

The financing of emergency oil stocks is highly flexible. There are different ways of financing the acquisition and maintenance of emergency stocks as reflected in the distinct practices adopted by IEA countries. Financing mechanisms can generally be divided into two categories: financing of public stocks and financing of obligated industry stocks. The different approaches highlight the flexibility in financing emergency stocks and reflect efforts to keep the burden on state budget, industry and final consumers at a minimum. In many countries, the cost to the final consumer amounts to less than one cent per litre.

Acronyms, abbreviations and units of measure

Acronyms and abbreviations

ARM	Polish stockholding agency
CARBURA	Swiss industry-based stockholding organisation
CORES	Spanish stockholding agency
CPSSP/SAGESS	French stockholding agency
COVA	Dutch stockholding agency
EBV	German stockholding agency
ELG	Austrian stockholding agency
FDO	Danish stockholding agency
MoR	Minimum Operating Requirements
ORNL	Oak Ridge National Laboratory
VLCC	very-large crude carrier

Units of measure

bbl	barrel
mb/d	million barrel per day
m^2	square metre
m^3	cubic metre
tcoe	tonne of crude oil equivalent
USD	United States Dollars
EUR	European Euros

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