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**THE OIL PRICE SPIKE OF 2008:**

***THE RESULT OF SPECULATION OR AN EARLY INDICATOR  
OF A MAJOR AND GROWING FUTURE CHALLENGE TO THE  
AIRLINE INDUSTRY?***

by

Charles E. Schlumberger\*

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\* Doctoral candidate (DCL), Institute of Air and Space Law, McGill University. Lic. iur. (1986), University of Basle Law School, Switzerland. M.B.A. (1989), Harvard Business School, Boston MA. Principal Air Transport Specialist, The World Bank.

### ABSTRACT

*In July 2008, the price of crude oil reached an historical high level of US\$147 per barrel. However, as a consequence of falling demand over the following six months, the price declined by well over 60%. This article examines the causes behind the oil price spike, which has become a serious commercial threat to many airlines. While speculative forces may have been the primary driver, increased demand by emerging markets, decreasing inventories, as well as tight production played a significant role in this development.*

*The article subsequently expands its scope, and evaluates two of the possible future challenges in global oil production. The first concerns a peak in production due to inadequate past investments in upstream infrastructure. The second, a peak in global supply, is based on the fact that most oil producing countries have already reached their peak output and are in a permanent decline. Both scenarios would undoubtedly lead to very high fuel prices and they present a major risk to an industry in which there are presently no substitutes for fossil fuel based energy.*

*By outlining data concerning global oil production and the expected growth in demand, and by demonstrating that current reserves and future increases in production are based on many uncertain factors, the article concludes that the airline industry must address the issue of energy security in the interest of its own future. The article suggests that the industry should support and adopt measures to mitigate CO<sub>2</sub> emissions, which would also lead to a reduction in oil consumption, given the increased political pressure and public awareness with regard to climate change*

### RÉSUMÉ

*En juillet 2008, le prix du pétrole a atteint un pic de 147\$US le baril. Par contre, ce prix a ensuite baissé de plus de 60% à cause d'une chute de la demande. Cet article étudie la croissance du prix pendant la première moitié de 2008, croissance qui représentait à l'époque, une réelle menace pour les transporteurs aériens. Bien que la spéculation soit peut-être la première cause de cette croissance, il y avait également d'autres facteurs, tels que l'augmentation de la demande des marchés émergents, une diminution des inventaires, ainsi que le manque de marges dans la production.*

*L'auteur étudie ensuite deux futurs défis potentiels pour la production mondiale de pétrole. Le premier serait le pic pétrolier résultant d'un manque d'investissement dans l'infrastructure en amont. Le second serait la culmination de l'offre globale, la plupart des pays producteurs ayant déjà maximisé leurs extrants qui sont maintenant en recul permanent. Chacun de ces scénarios résulterait sans doute dans un prix de pétrole très élevé, ce qui est un risque important pour l'industrie aéronautique qui est entièrement dépendante d'énergie produite à partir de combustibles fossiles.*

*En soulignant les données de la production et de la demande globale et en démontrant que les réserves de pétrole existants et la future croissance de production sont loin d'être certains, cet article conclut que les compagnies aériennes devraient davantage se concentrer sur la problématique de l'énergie afin de défendre leurs propres avenir. L'article suggère que l'industrie devrait soutenir et adopter des mesures pour mitiger les émissions de dioxyde de carbone. Ceci entraînerait également une diminution de consommation de pétrole grâce à une pression politique accrue ainsi qu'une sensibilisation du public à propos du changement climatique.*

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## I. INTRODUCTION

On 11 July 2008, the price of crude oil reached an all time high of US \$147.27 a barrel at the New York Mercantile Exchange. By November 2008, this price had tumbled below US\$ 50 a barrel due to the global economic crisis.<sup>1</sup> Slower demand replaced high oil prices as the greatest menace to the airlines. On the supply side, after benefiting from the high oil price levels attained in early 2008, the Organization of Petroleum Exporting Countries (OPEC) announced in October 2008 that it was cutting oil production for the first time in almost two years to support prices.<sup>2</sup>

Pure investor speculation, driven by funds leaving the US real estate market is one popular theory for the oil price spike<sup>3</sup>, which is supported by the subsequent price collapse. On the other hand, others ascribe the situation to supply side conditions and warn that production and supply of oil may soon reach a worldwide peak, which would trigger a new and permanent spike in price.

The objective of this article is to examine the speculation and supply-constraint theories and to outline the consequences and perils for the airline industry if the issue of volatile oil prices is not addressed. Finally, the issue of climate change will be considered as a political platform from which to address problems pertaining to oil supply.

## II. THE PRICE OF OIL

### A. HISTORICAL DEVELOPMENT OF THE PRICE OF OIL AND THE ROLE OF SPECULATION

Aviation fuels fall into two basic groups. Jet fuel is the predominant energy source and is used in turbo-fan, turbo-jet, and turbo-prop engines. Aviation gasoline serves a much smaller market and is used in reciprocating or piston engines. For long periods, oil market prices have not been especially problematic for airlines since prices were largely stable. Jet fuel prices are tightly correlated to the price of crude oil. However a crack spread has been noted in recent years, whereby jet fuel prices have

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<sup>1</sup> Ayesha Daya & Fred Pals, OPEC Preparing Output Cut to Boost Prices After Slump, online: Bloomberg <2008.http://www.bloomberg.com/apps/news?pid=20601102&sid=acIbVy5J54Qo&refer=uk>.

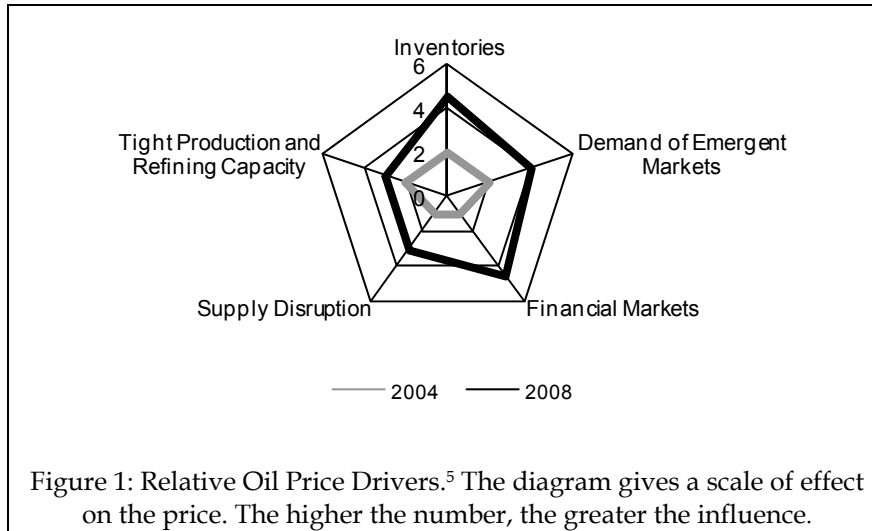
<sup>2</sup> *Ibid.*

<sup>3</sup> Some experts believe that as much as 60% of the cost of a gallon of gasoline, diesel fuel, or heating oil is the result of speculation and abusive trading practices. See online: Petroleum Marketers Association of America <http://www.stopoilspeculators.com>.

increased at a greater rate than the price of crude oil.

As demonstrated in Figure 1, oil prices are influenced by key drivers which include: (i) inventories; (ii) demand of emergent markets; (iii) financial markets; (iv) supply disruption; and, (v) tight production and refining capacity. Amongst these, the financial markets have taken on a significantly increased importance in the determination of price in the last five years.

In 2008, substantial investment funds were moved from traditional primary financial markets, such as pension funds, into commodity trading such as oil, thus representing the force of speculative interest.<sup>4</sup>



The entry of institutional investors into commodity trading created volatile trading conditions which, according to data supplied by the Air Transport Association of America, led to an increase in demand to a level approximately 13 times the actual oil requirements,<sup>6</sup> causing prices to reach unprecedented highs. Commercial traders also played a major role in the price increases by hedging their oil contracts.<sup>7</sup> It was subsequently

<sup>4</sup> Lord Meghnad Desai, "Act now to prick the oil price bubble" *Financial Times* (6 June 2008).

<sup>5</sup> Peter Griffiths, Implications for the Airline Industry of the Recent Increases in Oil Prices, (Paper presented at the Annual Meeting of the European Civil Aviation Conference (ECAC) Yerevan, Armenia, 2008 at 5.

<sup>6</sup> US Energy Information Administration and the Air Transport Association of America, *The correlation between the average monthly price of barrel of crude oil and of jet fuel, including evidence of a rising crack spread (CITE)* [EIA/ATAA Correlation]

<sup>7</sup> Commercial investors, such as airlines, are hedging their future purchases of oil based

recommended that better supervision be implemented especially on the commodity futures markets to detect and deter price manipulation.<sup>8</sup>

Inventory drops and supply disruptions also contributed to the 2008 oil price spike. Specific instances which affected supply were violence in Nigeria, disruptions in Mexico, and the Buncefield fuel farm fire in the UK. US inventory drops drove oil prices during most of the first half of 2008.<sup>9</sup> This effect was aggravated by the US government's decision to replenish its strategic oil reserves in early 2008, despite rising oil prices.<sup>10</sup>

In spite of the foregoing, the International Air Transport Association (IATA) has explicitly stated that the rise in oil price in 2008 was not caused by peaking oil supply. IATA estimates that, at current consumption rates, known reserves would last 44 years with no further discoveries.<sup>11</sup> IATA rather explained the increase as the effect of a "bubble" in the futures market for spot prices of Brent crude oil.<sup>12</sup> However, IATA also recognizes that the gradual rise in oil prices through 2007 could be explained by underlying changes including the increasing cost of oil exploration and production. IATA estimates the production cost per barrel of oil to be between US \$80 and US \$90.<sup>13</sup>

A 2006 US Senate study also indicated that oil prices were primarily driven by speculation. The study found that there was a significant rise in speculation in US energy commodity markets, due to the huge influx of speculative dollars, which contributed to increasing energy prices.<sup>14</sup>

The rapid oil price spike of 2008 was, thus, primarily driven by speculative forces. Other acknowledged factors included: rising demand

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commodities, such as jet fuel, against rising prices of crude oil. The number of commercial West Texas Intermediate (WTI) futures contracts at the New York Mercantile Exchange doubled between mid-2006 and early 2008.

<sup>8</sup> One measure would be daily access by the Commodity Futures Trading Commission (CFTC) to reports of large trades of energy commodities, without gaps such as the current exemption from reporting to the CFTC for London Intercontinental Exchange traders.

<sup>9</sup> Steve Hargreaves, "Oil kicks off year by hitting \$100" *CNN Money Online* (2 Jan. 2008) online: CNN

<<http://money.cnn.com/2008/01/02/markets/oil/index.htm?postversion=2008010212>>.

<sup>10</sup> *EIA/ATAA Correlation supra* note 6 at 5.

<sup>11</sup> IATA, *Economic Briefing: Medium Term Outlook for Oil and Jet Fuel Prices* (Geneva: IATA Publishing, 2008) [*IATA Economic Briefing*].

<sup>12</sup> *Ibid.*, at 2.

<sup>13</sup> *Ibid.*

<sup>14</sup> US Committee on Homeland Security and Governmental Affairs, *The Role of Market Speculation in Rising Oil and Gas Prices: A Need to put the Cop back on the Beat* (Washington DC: United States Senate, 2006) at 6 [*Role of Market Speculation*].

from China and India; a depreciation of the US dollar; and the danger of political and/or armed disruptions in oil supply.<sup>15</sup> While low inventories may also have contributed to the speculative bubble, no one has as yet ascribed the 2008 price increase to a long-term, supply-related problem.<sup>16</sup> The impact of speculation on the price of oil has been discussed widely with estimates of the real price impact of speculation varying greatly. On 23 June 2008, US Senator Byron Dorgan introduced the "End Oil Speculation Act of 2008"<sup>17</sup> seeking to end excessive speculation.

## B. THE EFFECTS OF HIGH OIL PRICES ON THE AIRLINE INDUSTRY

High oil prices have resulted in fuel cost rises since 2003. Traditionally fuel costs were less than 15% of airline operational costs; however this rose to around 35% in 2008 on an industry-wide basis, and exceeded 40% for carriers with lower labor costs.<sup>18</sup> Many airlines were not able to fully pass on the fuel costs to passengers, and their losses became substantial. In the first six months of 2008, 25 airlines went out of business, and the industry was expected to lose US\$ 6.1 billion globally.<sup>19</sup>

Previously, many air carriers successfully hedged the cost of jet fuel.<sup>20</sup> Good hedging strategy was critical to the profitability of some carriers. Southwest Airlines, for example, led the US domestic industry by hedging its jet fuel purchases by 82% in 2004, and by 60% in 2005, a period of steady price increases.<sup>21</sup> This helped Southwest to achieve minimal operating costs.<sup>22</sup> However, hedging jet fuel is expensive, and it only becomes important when oil markets are volatile, as in 2008. Some carriers who did not hedge their purchases in the past decided at or near the peak to hedge

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<sup>15</sup> Richard S. Eckhaus, *The Oil Price Really is a Speculative Bubble* (Cambridge, MA: Massachusetts Institute of Technology, 2008) [Eckhaus].

<sup>16</sup> *Ibid.*, at 7 where the author notes that oil reserves have been increasing at 2.5% per year since 2004, faster than the rate of increase in oil consumption. He concludes that the World is not running out of oil. The pressures on price are primarily of a speculative nature.

<sup>17</sup> *End Oil Speculation Act of 2008* US (Introduced in Senate), S 3183 IS, 110th Cong., Library of Congress.

<sup>18</sup> Brian Pearce, *Outlook for the Airline Industry - 2008 Q3 Update* (Geneva: IATA, 2008) at 15 [Pearce].

<sup>19</sup> Giovanni Bisignani, Director General of IATA stated on 20 August 2008, that a further 11/12 airlines were in danger of failing due to the high fuel cost.

<sup>20</sup> A fuel hedge contract commits a carrier to pay a pre-determined price for future purchases. Such contracts eliminate uncertainty and are beneficial when jet fuel prices rise, but if prices fall, airlines with hedged commitments will pay *supra* market prices.

<sup>21</sup> Richard Cobbs & Alex Wolf, *Jet Fuel Hedging Strategies* (Wharton School of Business) at 10 [Cobbs & Wolf].

<sup>22</sup> *Ibid.* Southwest Airlines was followed by Jet Blue and Delta, which hedged 40 and 32% of their 2004 purchases, but none in 2005. All other carriers hedged far less or not at all.

future purchases in anticipation that prices would continue to rise, however this backfired as prices fell rapidly.<sup>23</sup>

Fuel price was also a central theme at the June 2008 Annual General Meeting of IATA. Giovanni Bisignani, IATA Director General and Chief Executive Officer<sup>24</sup> noted that, in his opinion, the most pressing issue for the industry was that all combined savings and cost reductions achieved by airlines were insufficient to cope with increased fuel costs.<sup>25</sup> IATA's Annual Meeting resulted in the issuance of the "Istanbul Declaration", which called for a set of measures to help the airline industry cope with high fuel costs.<sup>26</sup>

The sharp decline in fuel prices in the second half of 2008 brought relief to those carriers which were not committed to higher fuel prices in hedging contracts, however the looming recession has resulted in reduced demand for cargo and passenger travel. The oil price spike, combined with the ensuing economic crisis, might prove fatal for many airlines, which otherwise would have been successful.

### III. SUPPLY AND PRODUCTION OF OIL

#### A. CONVENTIONAL OIL

##### 1. HISTORY OF OIL PRODUCTION, PRICE, AND GLOBAL OUTLOOK

Crude oil is formed through a lengthy geological process of compression and heating of ancient organic materials. Over time the organic matter mixes with mud and is buried under heavy layers of

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<sup>23</sup> Cathay Pacific issued a profit warning in November 2008, when it revealed that it faced unrealized losses of an estimated \$HK2.8billion (US\$510 million) in connection with fuel hedging engagement. Cathay hedged against rising fuel prices but jet fuel fell from a peak of US \$181.80 a barrel in July to US \$76.70 a barrel. Steve Creedy, "Fuel hedges squeeze Cathay as turmoil spreads", online: The Australian Business <<http://www.theaustralian.news.com.au/business/story/0,28124,24612219-23349,00.html>>.

<sup>24</sup> Giovanni Bisignani, "State of the Air Transport Industry", (Speech given at 64th IATA Annual General Meeting, Istanbul, June 2008).

<sup>25</sup> *Ibid.* the author notes that a spot price for oil of US \$135 per barrel compared with US \$73 per barrel in 2007 represented a US \$99 billion rise in fuel cost excluding the impact of hedging.

<sup>26</sup> *Ibid.* These measures should include government facilitation of cross-border restructuring of air carriers, the prevention of multiple and punitive fees and charges, the improvement of air transport infrastructure for the elimination of wasteful fuel consumption, the improvement of efficiency of monopoly service providers, labor unions refraining from making irresponsible claims, and "the enforcement of the integrity of the markets so that the cost of energy reflects its true value".

sediment exerting extreme heat and pressure, which leads to a change in the chemical composition of the organic matter. Initially, a waxy material known as kerogen is created. Later, through a process called catagenesis, more heat converts kerogen into liquid and gaseous hydrocarbons.<sup>27</sup>

Most hydrocarbons are lighter than rock or water, and thus migrate upward through rock layers to the surface or become trapped within porous rocks. Underground water flow also causes oil to migrate horizontally. Large quantities of oil eventually find their way to the surface of the earth as oil seeps. However, when hydrocarbons are trapped in large reservoirs, oil fields form from which the oil can be extracted by drilling and pumping.<sup>28</sup> Modern oil exploration focuses on discovering large oilfields. However, the rate of new discoveries has declined significantly over the past 30 years. As conventional oil production moves to smaller reservoirs to compensate for depleting large oil fields, production become increasingly complex and expensive.

Generally, crude oil is classified: by its place of origin (e.g. Brent); by its sulfur content; and, by its American Petroleum Institute (API) gravity.<sup>29</sup> Crude oil is grouped as "light" if it has low density and "heavy" if it has high density. It is described as "sweet" if it contains relatively little sulfur or "sour" if it contains large amounts. The place of production plays a significant role in pricing due to transportation cost between the field and the refinery. Light crude oil is more valuable than heavy oil as it produces higher gasoline yields, and sweet oil is usually more expensive than sour oil as there are fewer environmental challenges.

By an industrial process, crude oil is refined into various petroleum products, including gasoline, kerosene, and liquefied petroleum gas. These different hydrocarbons have distinct boiling points and are therefore separated by distillation. The lighter liquid elements are in great demand for use in internal combustion engines. Refineries therefore prefer to convert heavy hydrocarbons and lighter gaseous elements into these higher value products. Jet fuel, a mixture of a large number of different hydrocarbons, is an unleaded paraffin (kerosene) oil-based fuel.<sup>30</sup> The various petroleum fossil fuels (gasoline, kerosene, or diesel based) are used in ship, automobile, and aircraft engines. However, jet fuel, located between

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<sup>27</sup> See generally Kenneth S. Deffeyes, *Beyond Oil* (New York: Hill and Wang, 2005) [Deffeyes].

<sup>28</sup> *Ibid.*

<sup>29</sup> The American Petroleum Institute gravity, or API gravity, is a measure of how heavy or light petroleum liquid is compared to water.

<sup>30</sup> See Ozren Ocic, *Oil Refineries in the 21st Century* (Weinheim: Wiley-VCH, 2004) [Ocic].

diesel oil and gasoline products in the distillation process, has a smaller market when compared to global consumption of the other petroleum fossil fuels.

Oil production began in 1846 with the discovery of the process of refining kerosene from coal by Abraham Pineo Gesner. This process was improved by Ignacy Łukasiewicz leading to refinery of kerosene from more readily available "rock oil" ("petr-oleum") seeps in 1852. In 1854, Benjamin Silliman successfully fractionated petroleum by distillation. This method made news around the world, and in 1861, Meerzoeff built the first Russian refinery in the Baku oil fields. Baku quickly assumed production of about 90% of the world's oil.<sup>31</sup> The first oil well in North America was built in Oil Springs, Ontario, Canada in 1858. The US petroleum industry began with Edwin Drake drilling a 69-foot oil well in 1859 on Oil Creek near Titusville, Pennsylvania.<sup>32</sup> The industry grew rapidly through the 1800s, primarily driven by the demand for kerosene for oil lamps. However, the introduction of the internal combustion engine created demand for derivative oil products that have largely driven the industry to this day. Early producers were quickly outpaced by demand. This led to oil booms in Texas, Oklahoma, and California. Oil fields had also been discovered elsewhere by 1910. These included the Dutch East Indies (1885), Iran (1908), Peru, Venezuela, and Mexico.<sup>33</sup>

Oil production only started to accelerate significantly after the Second World War. Until the mid-1950s, coal was the world's dominant fuel, but thereafter oil took over. The US dominated world oil production until well into the second half of the 20th Century. In fact, for almost 30 years starting from the 1930s, US oil production had to be pro-rated among several producers in order to prevent oil prices from dropping too low.<sup>34</sup> US dominance in oil production reached its pinnacle in 1970 when production from the 48 continental States and the Gulf of Mexico peaked at 10 million barrels per day (mb/d). That year, as world production reached 66 million barrels, the main producers were the US, followed by Saudi Arabia and Iran, each at about 4 mb/d.

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<sup>31</sup> *Deffeyes, supra* note 27 at 17.

<sup>32</sup> Charles A. Warner, *Texas Oil & Gas Since 1543* (Fulton: Copano Bay Press, 2007) at 26 [Warner].

<sup>33</sup> For a complete review of the history of oil production see Leonardo Maugeri, *The Age of Oil: The Mythology, History, and Future of the World's Most Controversial Resource* (Westport: Greenwood Publishing Group, 2006) [Maugeri].

<sup>34</sup> Matthew R. Simmons, *Twilight in the Desert* (Hoboken: John Wiley & Sons Inc., 2005) at 44 [Simmons].

Oil producers in the Middle East and North Africa assumed greater importance in the early 1970s, when they collectively produced 20 mb/d, about one third of world production.<sup>35</sup> The influence of these countries became apparent during the 1973 oil crisis, when the Organization of Arab Petroleum Exporting Countries (OAPEC)<sup>36</sup> announced an oil embargo "in response to the U.S. decision to re-supply the Israeli military during the Yom Kippur war."<sup>37</sup> The targeted countries responded with policy measures aimed at limiting their dependency on OAPEC producers. A second oil crisis occurred in 1979, in the wake of the Iranian Revolution.<sup>38</sup> This was further aggravated in 1980 when Iraq invaded Iran, causing Iranian oil production to almost cease and Iraqi production was severely limited. These cuts represented the first significant decline in world oil production. Production recovered within a decade, and global oil production rose steadily to 84.4 million barrels per day in 2007.<sup>39</sup> Today, the most important oil producers are Saudi Arabia, the former Soviet Union, the United States, and Iran, which in 2007 collectively produced 40% of the world's oil supply.

Initially, oil prices were very high, nevertheless, by 1880 the price of a barrel of oil settled below US \$20 (in 2006 dollars) where it remained for nearly 100 years. Oil prices remained stable during both World Wars, the Great Depression, and all economic cycles. The domination of oil production by US, and later European multinational oil producing companies facilitated this stability. The rise in the oil production from OPEC countries, and the establishment of major national oil companies

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<sup>35</sup> International Energy Agency, *World Energy Outlook 2005* (Paris: IEA, 2005) at 138 [IEA WEO 2005].

<sup>36</sup> OAPEC is a multi-governmental organization headquartered in Kuwait which coordinates energy policies in Arab nations. It was originally intended to be a conservative Arab political organization which restriction membership to countries whose main export was oil and were not considered seen radical. The objective was to prevent that oil was used as a weapon, and focusing on economic development. It currently has eleven members: Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria, Tunisia and the United Arab Emirates.

<sup>37</sup> OAPEC declared it would no longer ship oil to the United States and other countries if they supported Israel in its conflict with Syria, Egypt and Iraq. At the same time, OPEC members agreed to use their leverage over the world price-setting mechanism for oil in order to raise world oil prices, after the failure of negotiations with the "Seven Sisters" earlier in the month. See *Simmons, supra* note 34 at 52.

<sup>38</sup> Following the Shah of Iran, Mohammad Reza Pahlavi's flight to exile in early 1979, and upon the succession of Ayatollah Khomeini, Iranian oil production became inconsistent and reduced, resulting in increased oil prices. Saudi Arabia and other OPEC nations increased production to offset this decline, and the overall loss in production was only about 4%. However, a global panic drove the price far higher than would have been expected. See *ibid.*, at 62.

<sup>39</sup> Total oil supply includes crude oil, natural gas plant liquids, other liquids, and refinery processing gain.

resulted in the decline of influence of the Western world on oil production and pricing.<sup>40</sup> In October 1973, ten Arab oil ministers decided to reduce their collective oil output by 5% per month until the Middle East conflict was resolved.<sup>41</sup> In addition, Saudi Arabia announced that it would cut production by 10%, and ban all petroleum shipments to the US and to the Netherlands. These announcements resulted in the first recorded oil shock. Despite the fact that a relatively small quantity of oil was withheld for delivery to Western consumers, the price rapidly rose to unprecedented levels.<sup>42</sup> In 1974 the price of a barrel of oil jumped from US \$3 to US \$12. During the second oil crisis in 1979, the price rose close to US \$40 per barrel. In 2006 dollars, the oil shocks resulted in a price spike of nearly US \$70 per barrel, a level only to be exceeded 27 years later. This indicated the sensitivity of oil prices to a perceived shortage. Nevertheless, the 2008 oil price spike was not driven primarily by fear of shortage; but rather by speculation. The dramatic fall in price to below US \$50 per barrel that occurred during the financial crisis of late 2008 is another example of how swiftly market forces react.

Following the 1980 spike, oil prices began a six-year decline that culminated with a 46% price drop by 1986. This was primarily due to reduced demand, occasioned by the implementation under the Reagan administration of a domestic US policy to end oil price controls and worldwide over-production. This resulted in OPEC losing its unity. During that period certain oil exporters such as Mexico, Nigeria, and Venezuela expanded production, whilst developments in Prudhoe Bay, Alaska, and

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<sup>40</sup> An illustrative example is the history of the oil company ARAMCO. Its history dates back to 29 May 1933, when the Government of Saudi Arabia signed a concessionary agreement with Standard Oil of California to explore Saudi Arabia for oil. Standard Oil of California passed its concession to a wholly-owned subsidiary called California-Arabian Standard Oil Co. In 1936, after the company had no success at finding oil, the Texas Oil Company purchased a 50% stake of the concession. The company changed its name in 1944 from California-Arabian Standard Oil Company to Arabian American Oil Company (ARAMCO). In 1948 Standard Oil of California and the Texas Oil Company were joined as investors by Standard Oil of New Jersey who purchased 30% of the company, and Socony Vacuum who acquired 10%. In 1950, King Abdul Aziz Ibn Saud threatened to nationalize his country's oil facilities. Subsequently ARAMCO had to agree to share its profits on oil sales on a 50/50 basis. In 1973 the Saudi Arabian government acquired a 25% share of ARAMCO, increased this to 60% by 1974, and finally acquired full control by 1980. In November 1988 the company changed its name from Arabian American Oil Company to Saudi Arabian Oil Company (or Saudi ARAMCO). Simmons, *Twilight in the Desert* at 25.

<sup>41</sup> The reaction of the Arab States against the United States was based on the fact that the US strongly supported Israel during the Yom Kippur War, which was fought from 6 to 26 October 1973 by a coalition of Arab states led by Egypt and Syria against Israel. *Ibid.*, at 53.

<sup>42</sup> The amount of oil actually withheld from Arab producers remains unclear to date. However, it is estimated that there was relatively little reduction, as Iran increased its production to stabilize the markets. *Ibid.*, at 54.

the North Sea increased American and European production. Oil prices remained low and very stable during the twenty years that followed and only began to rise again in 2003.

Between 2003 and 2007, global primary oil demand rose by 1.8% per annum. The IEA now estimates that this demand trend will flatten to 1% per year from 85 mb/d in 2007 to 94 mb/d in 2015 and to 106mb/d in 2030.<sup>43</sup> The prime driver of oil demand is economic activity. However, recent reductions in GDP levels of developed countries suggest a slightly lower rate of increase in demand in the coming years.<sup>44</sup> In addition, the recent spike in oil prices has prompted fuel efficiency policies in the United States and Europe and development and use of alternative fuels. However, emerging markets continue to increase their demand. Through 2030, the strongest growth is expected in India with 3.9%, followed by China with 3.5%.<sup>45</sup> Other emerging markets with rapid demand growth include several Middle Eastern countries accounting for 20% of the growth in oil demand. Nevertheless, in volumetric terms, China will be leading with 43% of total projected increase in oil demand.<sup>46</sup>

In non-OECD countries oil demand is rising as incomes rise and subsidies keep prices relatively low.<sup>47</sup> As a result, the IEA estimates that the weighted average crude oil price elasticity of total global oil demand is a relatively low -0.03 in the short-term, and -0.15 at the long-term. This makes oil demand quite insensitive to movements in crude oil prices.<sup>48</sup>

## 2. OPEC SUPPLY AND PRODUCTION

Global oil supply and production countries fall into two categories: Organization of Petroleum Exporting Countries (OPEC) members; and non-OPEC countries. OPEC is a cartel of 13 countries which seeks to ensure stable oil prices.<sup>49</sup> Since its creation, OPEC has enforced a quota system for

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<sup>43</sup> Growth between 2007 and 2015 will be 1.3%, and between 2015 and 2030 only 0.8%. International Energy Agency, *World Energy Outlook 2008* (Paris: IEA, 2008) at 92 [IEA WEO 2008].

<sup>44</sup> *Ibid.* In the past, each 1% per annum increase in GDP created a 0.3% increase in oil demand.

<sup>45</sup> IEA WEO 2008 *supra*, note 43 at 97.

<sup>46</sup> *Ibid.*

<sup>47</sup> See generally ESMAP, *Investing in oil in the Middle East and North Africa: institutions, incentives and the national oil companies* (Washington DC: The World Bank, 2007) [ESMAP].

<sup>48</sup> IEA WEO 2008 *supra*, note 43 at 97. Based on these new estimates, the IEA calculated that if oil prices had not risen since 2003, global demand would have risen 1.9% per year, compare to an actual annual increase of 1.8%.

<sup>49</sup> IEA WEO 2005 *supra* note 35.

oil production. OPEC member countries are mandated to respond to market fundamentals and forecast developments by co-ordinating their petroleum policies. To reach this objective, OPEC introduced production quotas in the late 1970s to stabilize the oil price. These quotas have decreased in significance as States have shifted towards producing oil at close to their capacity.<sup>50</sup>

One of the key concerns regarding long-term oil production relates to global conventional oil reserves and resources. At the end of 2007, worldwide estimates of remaining economically recoverable reserves of oil were between 1.120 and 1.322 billion barrels.<sup>51</sup> OPEC's cumulative share of this total was estimated at 934.7 billion barrels. Given OPEC's large oil reserves, its future production will play a key role in the global supply of fossil fuel based energy. However, OPEC's estimated reserves are not without doubt. According to BP, global proven unexploited reserves have almost doubled since 1980,<sup>52</sup> driven largely by large upward corrections put forward by OPEC countries between 1984 and 1988. Some experts believe that OPEC's reserves are in fact overstated by between 250 and 450 billion barrels, a very significant quantum.<sup>53</sup>

	UAE	Iran	Iraq	Kuwait	Saudi Arabia	Venezuela	Neutral Zone
1983	32.3	55.3	65.0	67.0	168.8	25.9	5.7
1984	32.5	58.9	65.0	92.7	171.7	28.0	5.6
1985	33.0	59.0	65.0	92.5	171.5	54.5	5.4
1986	97.2	92.9	72.0	94.5	169.7	55.5	5.4
1987	98.1	92.9	100.0	94.5	169.6	58.1	5.3
1988	98.1	92.9	100.0	94.5	255.0	58.5	5.2
1989	98.1	92.9	100.0	97.1	260.1	59.0	5.2
1990	98.1	92.9	100.0	97.0	260.3	60.1	5.0
1991	98.1	92.9	100.0	96.5	260.9	62.6	5.0
1992	98.1	92.9	100.0	96.5	251.2	63.3	5.0
1993	98.1	92.9	100.0	96.5	261.4	64.4	5.0
1994	98.1	94.3	100.0	96.5	261.4	64.9	5.0
1995	98.1	93.7	100.0	96.5	261.5	66.3	5.0
1996	97.8	92.6	112.0	96.5	261.4	72.7	5.0
<b>2005</b>	<b>97.8</b>	<b>136.3</b>	<b>115.0</b>	<b>101.5</b>	<b>264.2</b>	<b>80.0</b>	<b>5.0</b>

Figure 2 - Stated Oil Reserves of Selected OPEC Countries

Worldwide oil production reached 81.5 mb/d in 2007, OPEC's contribution being 35.2 mb/d or 43%.<sup>54</sup> Saudi Arabia, an OPEC member and

<sup>50</sup> Richard Heinberg, *The Oil Depletion Protocol* (Gabriola Island: New Society Publisher, 2006) at 128 [Heinberg].

<sup>51</sup> Six organizations plus oil companies have estimated global reserves with various methods. *IEA WEO 2008 supra* note 43 at 202.

<sup>52</sup> *Ibid.*, at 203.

<sup>53</sup> Phil Hart, *The 2008 IEA WEO - Oil Reserves and Resources*. Online: The Oil Drum <http://anz.theoil Drum.com/node/4775> [Hart].

<sup>54</sup> In fact, the peak of production was reached in 2006 with 81.6 mb/d. Production was

the world's leading oil producing country, had an output of 10.4 mb/d in 2007, down from its all-time high of 11.1 mb/d in 2005. The next ranking OPEC country is Iran with a production of 4.4 mb/d, followed by the United Arab Emirates (UAE) at 2.8 mb/d and Kuwait at 2.6 mb/d.<sup>55</sup> Saudi Arabia's is projected to remain the leading oil producer through 2030, by which time its output is estimated to be 15.6 mb/d.<sup>56</sup> However, some experts question Saudi Arabia's capacity to further increase production on a sustainable basis,<sup>57</sup> primarily because two oil fields, the Ghawar Field and Safaniya produce about 75% of Saudi Arabia's oil.<sup>58</sup> However, according to the IEA, five major oil field development projects in Saudi Arabia are in their final phase, and these are anticipated to produce 3 mb/d by 2015.<sup>59</sup>

The other major OPEC oil producing countries which are challenged to increase production are Iran and Iraq. Oil production in Iran is expected to fall to 4.1 mb/d by 2010. This is due to delays in implementing new projects. The IEA expects new projects to improve Iran's production, with an estimated output of 4.4 mb/d by 2015, and 5.4 mb/d in 2030.<sup>60</sup> The situation in Iraq is less certain. Due to the prevailing security situation, production remains at about 2 mb/d, far below its potential. Nevertheless, assuming that the security situation improves significantly, Iraq could increase production to 3mb/d by 2015 and to 6.5 mb/d by 2030.<sup>61</sup> The remaining OPEC countries have little potential to increase production. Kuwait and Venezuela are the only OPEC members to have projects which will modestly increase their production. Other OPEC members have insignificant or no potential to increase oil production in the future.<sup>62</sup> However, future increases in production from OPEC is very important, given that on present trends, just to replace the oil reserves that will be depleted and to meet the growth in demand, between 2008 and 2030, the world will require 64 mb/d of new oil-production.<sup>63</sup> Nevertheless, the IEA

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slightly lower in 2007. *IEA WEO 2008 supra* note 43.

<sup>55</sup> *Ibid.*

<sup>56</sup> *Ibid.*, at 40.

<sup>57</sup> *Simmons supra* note 34 where the author argues that production from Saudi Arabia, and especially from the world's largest oil field Ghawar, will peak in the near future if it has not done so already. Simmons bases his research on hundreds of internal documents from Saudi ARAMCO, professional journals, and on over 200 technical papers of the Society of Petroleum Engineers. Especially the latter provides a good overall picture of Saudi oil production since 1982, the year that OPEC discontinued providing field-by-field oil production data.

<sup>58</sup> *IEA WEO 2008 supra* note 43 at 41.

<sup>59</sup> *Ibid.*, at 274.

<sup>60</sup> *Ibid.*, at 275.

<sup>61</sup> *Ibid.*

<sup>62</sup> *Ibid.*, at 276.

<sup>63</sup> *Ibid.*, at 41.

recognizes OPEC's overall effort to further develop and advance its oil production to meet future demand.

### 3. NON-OPEC SUPPLY AND PRODUCTION

For analytical purposes, non-OPEC oil producing countries can be categorized into the following three groups, (i) North American producers, (ii) the former Soviet Union, and (iii) all other producers.

#### 3.1 North American Supply and Production

The proven recoverable reserves of conventional oil and natural gas liquids (NGL) in North America are assessed at about 69 billion barrels.<sup>64</sup> 29 billion barrels are located in the US, 28 billion in Canada, and 12 billion in Mexico.<sup>65</sup> The remaining recoverable resources in North America including remaining reserves, reserve growth, and undiscovered resources, are estimated at 185 billion barrels.<sup>66</sup> The proven reserves represent about seven years of North American consumption at the 2007 rate (25 million b/d), and the remaining reserves represent 20 years of consumption at 2007 rates. The leading consumer of oil is the US at 20 million b/d. Domestic production in the US represents about one third of its current consumption.<sup>67</sup>

The largest producer in North America is the US. For well over 100 years, the US was non-dependent on oil imports. However, in 1970 US oil production reached an all time high of 11.2 mb/d, and a decline started.<sup>68</sup> At the time of the decline, US oil production was almost entirely sourced from the 48 continental States. Production has since increased in Alaska, mainly in the North Slope's Prudhoe Bay, the richest oilfield in the United States. This temporarily stemmed the decline in production, but which did not return to its peak. By mid 1988, Alaskan oil production started to decline steeply.<sup>69</sup> However this was offset when in 2000, deep water exploration in the Gulf of Mexico produced some positive results. This

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<sup>64</sup> Natural gas liquids include propane, butane, pentane, hexane, and heptane, but not methane and ethane, since these hydrocarbons need refrigeration to be liquefied.

<sup>65</sup> British Petroleum (BP), *Statistical Review of World Energy 2008 Oil – Proved reserves* online: BP website <<http://www.bp.com/statisticalreview>> (Date accessed: 22 November 2008) at 6 [*BP Statistical Review 2008*].

<sup>66</sup> *IEA WEO 2008 supra* note 43 at 205.

<sup>67</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>68</sup> *Ibid.*

<sup>69</sup> Alaska Department of Revenue: Tax Division, *Production per Oil Field*. Online: Government of Alaska: <<http://www.tax.alaska.gov/programs/documentviewer/viewer.aspx?73>>.

boost is expected to be short-lived.<sup>70</sup> By 2007, the US was producing only 6.9 mb/d. In order to cope with declining domestic oil production, President Bush has called for increasing access to the US Outer Continental Shelf (OCS), where experts estimate recoverable reserves of about 18 billion barrels.<sup>71</sup> However, the US Energy Information Administration (EIA) estimates that access to the Pacific, Atlantic, and Eastern Gulf OCS will not have a significant impact on domestic crude oil and natural gas production or prices before 2030.<sup>72</sup>

Mexico is the second largest producer in North America, and the second source of oil imports for the United States. Mexico's oil production is dominated by one field, Cantarell, which used to account for over half of the country's oil production. However, in 2005 production from Cantarell started to decline. In spite of the efforts of Mexico's state-run oil company Petroleos Mexicanos aimed at improving and intensifying production, Cantarell's decline has continued and seems to be accelerating.<sup>73</sup> As a result, Mexico's oil production fell by 9% between 2006 and 2007, and is now under 3.5 mb/d.<sup>74</sup> It remains to be seen whether Mexico can restore its production. In 2007, Mexico's proven crude oil reserves were estimated at 12.2 billion barrels, less than half of the reserves held by the US or Canada. In addition, Mexico's consumption has been rising, now exceeding 2 mb/d, thus effectively reducing its exports to about 1.5 mb/d.<sup>75</sup> With further decline in oil production anticipated, Mexico may have to further reduce its exports.

Canada's crude oil production has been steadily rising over the past 40 years, and has reached a level of 3.3 mb/d. Most exploration and production is done in the province of Alberta, with a significant number of operations in British Columbia and in Saskatchewan. Canada's gigantic oil

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<sup>70</sup> *Heinberg supra* note 50 at 13.

<sup>71</sup> President George W. Bush warned during a speech at the White House on 18 June 2008 that "High oil prices are at the root of high gasoline prices. And behind those prices is the basic law of supply and demand. In recent years, the world's demand for oil has grown dramatically. Meanwhile, the supply of oil has grown much more slowly". While he acknowledged that in long run, the solution was to reduce demand for oil by promoting alternative energy technologies, he called for expanding American oil production by increasing access to the Outer Continental Shelf of the US, Office of the Press Secretary. *President Bush Discusses Energy* (Washington, DC: The White House; 2008) online: <<http://www.whitehouse.gov/news/releases/2008/06/20080618.html>> (Date accessed: 24 October 2008) [*Bush Discusses Energy*].

<sup>72</sup> Energy Information Administration, *Impacts of Increased Access to Oil and Natural Gas Resources in the Lower 48 Federal Outer Continental Shelf* online: EIA <<http://www.eia.doe.gov/oiaf/aeo/otheranalysis/ongr.html>>.

<sup>73</sup> David Luhnnow "Mexico's Oil Output Cools" *The Wall Street Journal* (27 January 2007),

<sup>74</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>75</sup> *Ibid.*

reserves are located in the Athabasca Oil Sands where there are an estimated 1.6 trillion barrels of reserves. However, the extraction of oil from oil sands is complex and extremely costly. Currently, about 1 mb/d are produced with this method; representing only about 1.2% of world consumption. Nonetheless, in 2002, oil sands from Alberta accounted for 33% of Canadian oil production.<sup>76</sup> Based on the presence of these oil sands, the IEA estimates that Alberta has 315 billion barrels of economically recoverable resources.<sup>77</sup> However, if only proven reserves of crude oil are taken into account, Canada has 27 billion barrels, which is slightly lower than the reserves held by the US. Canada's own domestic consumption of 2.3 mb/d makes it a net exporter with the potential to increase production and exports from oil sands extraction.

### 3.2 Production in the Former Soviet Union

The proven oil reserves of the former Soviet Union (FSU) are 128 billion barrels, about twice the entire reserves of North America.<sup>78</sup> The most important oil producing State of the FSU is the Russian Federation, followed by Kazakhstan.<sup>79</sup> In total, FSU countries produce 12.8 mb/d and consume 3.9 mb/d, which makes the FSU an important oil exporting region. Over 70% of Russian crude oil production is exported.<sup>80</sup> With exports of about 7 mb/d, Russia is the second largest single oil exporting country after Saudi Arabia, which exports about 9 mb/d.<sup>81</sup>

Russian oil production peaked at 12.5 mb/d in 1988 during the era of the Soviet Union, however this declined following the collapse of the Union to 6.1mb/d. This rapid decline was the result of the depletion of large oil fields due to production surges, and insufficient investment in, and maintenance of, existing infrastructure. The subsequent privatization of the Russian oil industry and rising oil prices resulted in increased production to almost 10 mb/d in 2007.<sup>82</sup> However, the IEA reported in April 2008 that

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<sup>76</sup> Deffeyes, *supra* note 27 at 104.

<sup>77</sup> IEA WEO 2008 *supra* note 43 at 215.

<sup>78</sup> States of the former Soviet Union are Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

<sup>79</sup> The IMF estimates that Kazakhstan has proven reserves of 30 billion barrels. However, taking into account new oil fields (10-15 billion barrels) and enhanced recovery (10-15 billion barrels) overall reserves are estimated between 50 and 60 billion barrels. International Monetary Fund *Republic of Kazakhstan: Selected Issues* (Washington DC: IMF, 2003) at 23 [*IMF Kazakhstan*].

<sup>80</sup> See online: EIA <<http://www.eia.doe.gov/emeu/cabs/Russia/Oil.html>>.

<sup>81</sup> *Ibid.*

<sup>82</sup> *Ibid.*

Russian oil production in the first quarter declined for the first time in a decade. According to Russian oil executives, this fall is indicative of a longer-term trend: the depletion of Siberia's older fields. Hoping that more investment might halt or reverse the decline, Russia plans to cut taxes in the oil sector. This, however, may not be enough, as Russia's oil industry needs about US \$1 trillion of investment over the next 20 years just to maintain production at 10 mb/d.<sup>83</sup> By November 2008, Russian oil firms were shipping only three quarters of their planned November exports as a government order to cut oil export duties had failed to make exports profitable again. Some experts are of the view that Russia's oil production has peaked and will soon decline further. General consensus ranges from the worst case: that Russian oil production and exports will peak very soon or have already done so; to the best case, that exports levels can be held stable until 2030. However, it seems unlikely that Russian oil production will ever increase more than 5-10% over present levels.<sup>84</sup>

Kazakhstan oil production reached an all time high of almost 1.5 mb/d in 2007, and the country has tripled its oil production in ten years.<sup>85</sup> With consumption of only 250,000 b/d, the country currently exports about 1.2 mb/d.<sup>86</sup> The surge in production was the result of massive foreign investments in oil exploration and international joint ventures and production sharing agreements with international oil companies. Further growth in production is expected as the country proceeds to develop its major oilfields.<sup>87</sup> According to the IMF, oil exploration from these oilfields and from new fields offshore from the North Caspian shelf could theoretically produce exports of up to 2.6 mb/d in 2015 and 3.3 mb/d by 2020. However, this will depend on massive investments in exploration and new infrastructure including the construction of considerable new export pipeline capacity.<sup>88</sup>

### 3.3 Production in the remaining non-OPEC Countries

Non-OPEC oil producing countries with a production above 1 mb/d are China, Norway, Brazil, and the United Kingdom (UK). All other producing countries have very low levels of production and mostly high

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<sup>83</sup> Guy Chazan & Neil King Jr., "Russian Oil Slump Stirs Supply Jitters" *The Wall Street Journal* (15 April 2008).

<sup>84</sup> See generally Aram Mälvierikko, *Russian Oil - a Depletion Rate Model Estimate of the Future Russian Oil Production and Export* (Thesis submitted to the Uppsala University, 2007) [unpublished].

<sup>85</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>86</sup> See online: EIA <http://www.eia.doe.gov/cabs/Kazakhstan/pdf.pdf>.

<sup>87</sup> *IMF Kazakhstan supra* note 79 at 23.

<sup>88</sup> *Ibid.*, at 25.

levels of domestic consumption. As such, no present or future export capacity is anticipated with respect to those countries.

China currently produces 3.7 billion barrels per year and has proven reserves of 15 billion barrels.<sup>89</sup> However its consumption which had risen to 7.8 billion barrels by 2007, China is a net importer of oil with growing demand.<sup>90</sup> The IEA expects China to import between 6.5 and 8.3 mb/d by 2015, rising to between 9.7 and 17.2 mb/d by 2030.<sup>91</sup> Most of China's oil production is onshore in a few oilfields, the most important of which, Daqing field, is already in decline. Overall, China's oil production has been increasing slowly over the past decade, but no major increase is foreseeable. While local Chinese exploration is conducted in cooperation with some international oil companies, China's national oil companies have acquired interests in exploration and production abroad.<sup>92</sup>

In 2007, Norway's oil productions was 2.5 mb/d, compared to a 2001 peak of 3.4 mb/d. Norway's oil reserves, located offshore on the Norwegian Continental Shelf, were estimated at 8.1 billion barrels in 2007.<sup>93</sup> Domestic consumption was only 221,000 b/d in 2007, thus Norway remains an important oil exporter; indeed, the fourth-largest behind Saudi Arabia, Russia, and the United Arab Emirates. However, its oil production is expected to decline further as new discoveries and further development of existing fields are expected to slow down.<sup>94</sup>

Brazil had proven oil reserves of 12.6 billion barrels as of 2007; the second-largest reserves in South America after Venezuela. Its oil production reached 1.8 mb/d in 2007.<sup>95</sup> However, Brazil is also the tenth largest energy consumer in the world and the third largest in the Western Hemisphere, behind the United States and Canada. In 2007, about half of Brazil's total energy consumption came from oil, including ethanol, and its oil consumption reached 2.2 mb/d, a figure which is only expected to grow

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<sup>89</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>90</sup> China has become the second-largest oil consumer in the world behind the United States, with net oil imports of 3.7 million b/d in 2007. See online: EIA <<http://www.eia.doe.gov/cabs/China/pdf.pdf>>.

<sup>91</sup> International Energy Agency, *World Energy Outlook 2007* (Paris: IEA, 2007) at 168 [*IEA WEO 2007*].

<sup>92</sup> In 2005 alone, China's national oil company, China National Petroleum Corporation, has invested US \$8 billion in Sudan's oil sector, has purchased PetroKazakhstan with 11 oilfields, and has purchased Encana's oil and gas assets in Ecuador and PetroCanada's oil and gas assets in Syria. *Supra* note 90 at 4.

<sup>93</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>94</sup> See online: EIA <<http://www.eia.doe.gov/emeu/cabs/Norway/pdf.pdf>>.

<sup>95</sup> *BP Statistical Review 2008 supra* note 65 at 8.

further.<sup>96</sup> This makes Brazil a net importer of oil. However, this is partially offset by domestic production of biofuels and other alternatives to traditional fossil fuel based products.<sup>97</sup> The EIA expects that Brazil's total oil production could reach 2.72 mb/d in 2009.<sup>98</sup>

Rio de Janeiro state produces over 80% of Brazil's oil. Most of Brazil's crude oil production is offshore in very deep water, and consists mainly of heavy grades. Nevertheless, Petrobras, Brazil's national oil company, announced in 2007 that it had discovered an estimated 5-8 billion barrels of recoverable reserves in the Tupi field, located in the Santos Basin,<sup>99</sup> in a subsalt zone at an average depth of 5,500 meters below the ocean's surface. Subsequently, numerous additional subsalt discoveries were announced, and industry analysts estimate the total amount of recoverable oil and natural gas reserves to be about 56 billion barrels of oil equivalent.<sup>100</sup> Nevertheless, production of oil from reserves at such an average depth presents a major technological challenge given the enormous water pressure and the infrastructure needed to reach the field. Before production from these sources begins (which may be a decade away), Brazil will most likely not be an oil exporting country.

The UK has remaining proven reserves of 3.6 billion barrels and a current production rate of 1.6 mb/d. However, its oil production peaked in 1999 at 2.9 mb/d.<sup>101</sup> Given its 2007 domestic oil consumption of 1.7 mb/d, the UK has become a net importer of oil. The UK's oil reserves are located mainly in the North Sea, with some smaller fields located in the North Atlantic Ocean. The UK also developed the largest onshore oil field in Europe, the Wytch Farm field. All UK oil fields have reached maturity, and oil companies are now focussing on increasing the productivity of existing fields and on developing smaller ones which were avoided during earlier stages of exploration.<sup>102</sup>

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<sup>96</sup> *Ibid.*, at 11.

<sup>97</sup> In 2007, Brazil produced 390,000 b/d of ethanol, up from 306,000, and EIA forecasts that Brazil's ethanol production will reach 440,000 b/d in 2008 and 530,000 b/d in 2009. See online: EIA <<http://www.eia.doe.gov/cabs/Brazil/Oil.html>>.

<sup>98</sup> *Ibid.*, at 3.

<sup>99</sup> *The Economist*, *A big oil discovery*, (12 February 2008).

<sup>100</sup> *Supra* note 97 at 4.

<sup>101</sup> *BP Statistical Review 2008 supra* note 65 at 8.

<sup>102</sup> See online: EIA <[http://www.eia.doe.gov/cabs/United\\_Kingdom/pdf.pdf](http://www.eia.doe.gov/cabs/United_Kingdom/pdf.pdf)>.

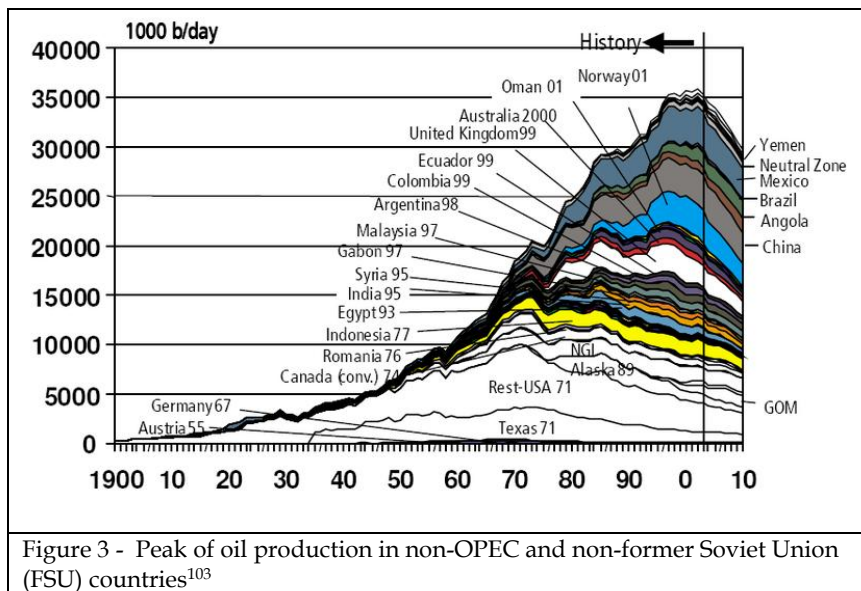


Figure 3 - Peak of oil production in non-OPEC and non-former Soviet Union (FSU) countries<sup>103</sup>

In summary, the main non-OPEC oil producing countries produced 34.9 mb/d in 2007, which represents 43% of world oil production. However, only five non-OPEC producers are net exporters. With the exception of Brazil and Canada, all non-OPEC and non-FSU countries have already reached peak oil production. As cumulative consumption of non-OPEC oil producing countries is 5mb/d higher than their production, these producers remain overall net importers of oil.

Country	Proven Reserves (b brls)	Production 2007 mb/d	Consumption 2007 mb/d	Net Exports mb/d	Trend of Production
USA	29.4	6.9	20.7	-13.8	Declining
Canada	27.7	3.3	2.3	1.0	Increasing
Mexico	12.2	3.5	2.0	1.5	Declining
Russia	79.4	10	2.7	7.3	Stable
Kazakhstan	39.8	1.5	0.2	1.3	Increasing
China	15.5	3.7	7.9	-4.2	Stable
Norway	8.2	2.6	0.2	2.4	Declining
Brazil	12.6	1.8	2.2	-0.4	Increasing
UK	3.6	1.6	1.7	-0.1	Declining
Total	228.4	34.9	39.9	-5.0	

Figure 4 - Main non-OPEC oil exporting countries

<sup>103</sup> Source: *Strategic Significance of America's Oil Shale Reserves* (Report prepared by the Office of the Deputy Assistant Secretary for Petroleum Reserves Washington DC: US Department of Energy, 2004) at 8.

#### 4. THEORIES OF PEAK PRODUCTION AND PEAK SUPPLY

##### 4.1 Peak of Production

In this article, the theory of peak of production refers to a potential levelling off in oil production due to the fact that investments in infrastructure for production have been inadequate, and production cannot be increased or even declines in some cases. The so called "oil supply crunch" in this case does not refer to below-ground resource constraints, but to inadequate investments by international oil companies (IOCs) and national oil companies (NOCs).<sup>104</sup> A peak in production, leading to an oil crunch, is the situation which occurs when demand for oil exceeds current supply of oil. As demand fluctuates, oil producing countries (mainly the members of OPEC) periodically adjust their production in order to meet demand and avoid situations in which an oversupply of oil drives the price of crude oil down. Low excess capacity has driven the price of oil up, as has been the experience in the past. However, so far, capacity has always matched demand (see Figure 3). If the equilibrium is disturbed, the price of oil will with no doubt climb dramatically, and could exceed US \$200 per barrel in 2008 dollars.<sup>105</sup>

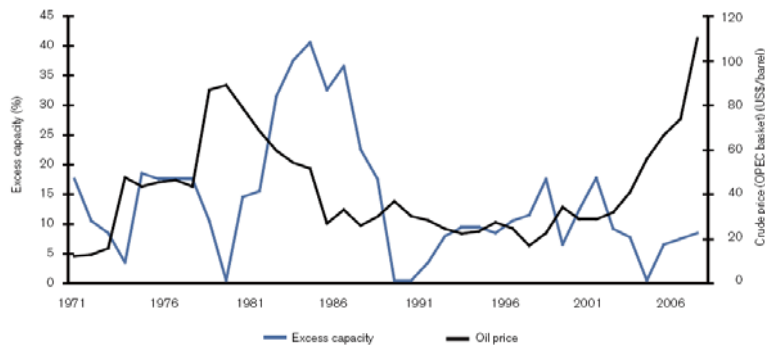


Figure 5 - Excess capacity and the price of oil<sup>106</sup>

According to Paul Stevens of Chatham House, there are grounds to believe that the world is headed towards an oil-supply crunch, unless there is a collapse in oil demand during the next five to ten years.<sup>107</sup> The

<sup>104</sup> *The Coming Oil Supply Crunch* by Paul Stevens (The Chatham House, London, 2008) at 9 [Stevens].

<sup>105</sup> *Ibid.*, at 8.

<sup>106</sup> Source: *ibid.*, at 6.

<sup>107</sup> Chatham House, formally known as the Royal Institute of International Affairs, is a non-profit, non-governmental organization based in London whose mission is to analyze and promote the understanding of major international issues and current affairs.

willingness of IOCs and NOCs to invest the funds required to maintain and develop oil production in the future has seriously diminished over the past decades. IOCs have developed a financial strategy derived from "value-based management", which hinges on the principle that if a company cannot perform better than its competitor in terms of shareholder value, it should return the money invested to the shareholders who can employ it more productively.<sup>108</sup> After the oil shocks of the 1970s, IOCs invested most of their large resulting surplus funds into exploration and development, which led to their relative strengthening as compared with OPEC production. However, in 2005 the six largest IOCs invested US \$54 billion in production, but only returned on average US \$71 to each of their shareholders.<sup>109</sup>

NOCs have a different motivation when it comes to investment in oil production. Their willingness to invest is primarily driven by the depletion policy of their country, which, in turn, takes several factors into account. The first consideration relates to the protection of national hydrocarbon resources, often calling for maximization of recovery. This is primarily a technical challenge to optimize production in view of natural depletion factors and recovery rates. The second factor concerns the hydrocarbon depletion policy of a country which addresses whether oil should be produced now or left for future generations. Several countries have limited production upon meeting certain objectives: Algeria cut production after eliminating its national debt; and Saudi Arabia has announced a production cap of 12.5 mb/d.

Availability of funds is also a pre-requisite to production. IOCs have difficulty accessing and developing low-cost oil reserves in the countries where oil production is cheapest. The reasons range from official government policy to exclude IOCs (Saudi Arabia), to security and legal constraints (Iraq), and to domestic resistance-based sanctions or growing nationalism (Iran and Kuwait).<sup>110</sup> Moreover, IOCs also face constraints in terms of managerial capacity which is again a consequence of value-based management and which has led to the reduction of manpower to maximize short-term returns for shareholders. Finally, there has been a serious capacity shortage with respect to service companies which undertake development and improvement of the infrastructure. As a result of the foregoing, the cost of developing new oil fields has doubled in the last four years.<sup>111</sup>

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<sup>108</sup> *Stevens supra* note 104 at 22.

<sup>109</sup> *Ibid.*

<sup>110</sup> *Ibid.*, at 24.

<sup>111</sup> Daniel Yergin, "Oil has reached a Turning Point" *Financial Times* (28 May 2008).

NOCs face three challenges which affect their ability to invest the necessary resources in the development and maintenance of oil production infrastructure. First is the so-called "principal-agent analysis", which concerns the behaviour of the agent (NOC management) and reaction of the principal (the controlling ministry). Principals view NOCs as high-cost and inefficient and thus withhold resources for investment, preventing NOCs from developing their production capacity.<sup>112</sup> A second obstacle is resource nationalism. Large development projects require complex coordination with various service companies, yet many NOCs do not have the skills to manage such projects. While IOCs could provide these skills, many NOCs rely on national human resources and this limits their effectiveness.<sup>113</sup> A third issue relates to general governance of the sector. The structure of the petroleum sector in many countries is deficient and this inhibits investments and efficient oil production.<sup>114</sup> This results in conflicting objectives: while NOCs aim to maximize their revenue from production and sale of oil, the government's focus is usually on increasing its fiscal revenue to serve non-oil purposes, or even to subsidize domestic energy prices. Finally, growing domestic consumption facilitated by government subsidies is another stumbling block preventing NOCs from maximizing oil production. Subsidies in the Middle East led to an average increase of consumption in the region led to of 3.9% between 1999 and 2007, whereas the growth rate in OECD countries was 0.4%.<sup>115</sup> The public funds absorbed by subsidies are not invested in NOCs, impeding them from making the required investments for long-term production.

The result of the lack of adequate investment in the development of oil production by both IOCs and NOCs is that, in the future, oil production may not meet demand. Paul Stevens projects that oil demand will exceed production between 2009 (in the high demand scenario) and 2014 (in the low demand scenario).<sup>116</sup>

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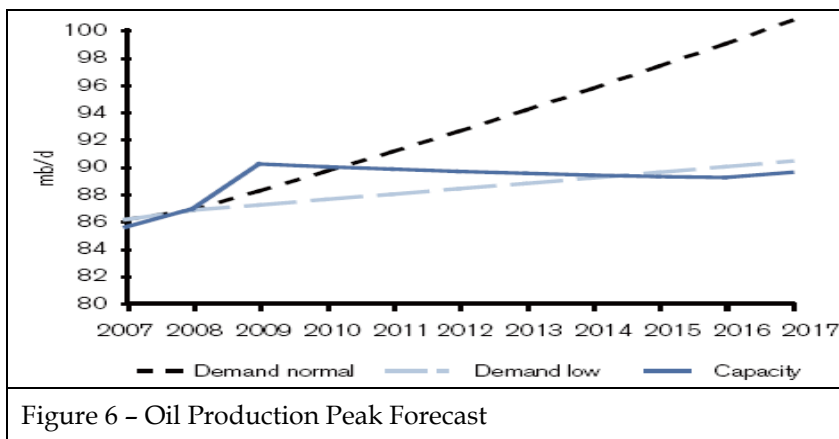
<sup>112</sup> *Stevens supra* note 104 at 25.

<sup>113</sup> *Ibid.*

<sup>114</sup> See generally ESMAP *supra* note 47.

<sup>115</sup> The Organization for Economic Co-operation and Development (OECD) is an international organization of thirty countries that accept the principles of representative democracy and free-market economy. There are currently thirty full members. For more details see online: OECD <[www.oecd.org](http://www.oecd.org)>.

<sup>116</sup> *Stevens supra* note 104 at 29.



In its World Energy Outlook 2008 (WEO 2008), the IEA outlines the massive amounts of investment needed to maintain and develop oil production to meet expected demand. The reference scenario of the IEA calls for investments exceeding US \$26 trillion (in 2007 dollars) between 2007 and 2030 in the energy sector worldwide, 48% of which are needed in the oil and gas sector alone.<sup>117</sup> Half of the global energy investments to be made between 2007 and 2030 are expected to be used for replacing ageing infrastructure in order to maintain current energy production levels. In addition, progressively mounting depletion rates of many oilfields will require higher investments in order to maintain production.

Upstream investment in oil and gas fields has been rising rapidly in recent years, and between 2000 and 2007, it tripled to US \$390 billion annually.<sup>118</sup> The IEA expects that these investment requirements will rise to over US \$600 billion in nominal terms by 2012, before levelling off. Overall, the IEA projects the need for cumulative investments in the upstream oil and gas sector to be around US \$350 billion per year (in 2007 dollars) between 2007 and 2030. However, the likelihood that a lack of investments will result in a production peak with rising demand is growing, given the current financial outlook, and that several investment projects in the oil and gas sector have already been delayed.<sup>119</sup>

<sup>117</sup> IEA WEO 2008 *supra* note 43 at 39.

<sup>118</sup> *Ibid.*, at 43.

<sup>119</sup> Total SA Chief Executive Officer Christophe de Margerie said in November 2008, that the drop in crude prices is threatening investment needed to boost global oil production. This, followed warnings by analysts that refinery projects around the world could be delayed as oil demand drops due to the economic downturn. See online: Bloomberg <<http://www.bloomberg.com/apps/news?pid=20601072&sid=aMXfdDC7FQ5A&refer=energy>>.

## 4.2 Peak of Supply

In this article, the theory of peak of supply refers to the fact that each oilfield, oil producing nation, and region will come to a point when its maximum rate of petroleum extraction has been reached, after which the rate of production will enter into a stage of terminal decline. The so called "Peak Oil" theory relates to the point in time when the maximum rate of global petroleum extraction is reached.<sup>120</sup>

The theory of peak oil was first developed by M. King Hubbert, a geologist and petroleum engineer for Shell.<sup>121</sup> According to the Hubbert model, the production rate of a limited resource will follow a roughly symmetrical bell-shaped curve, based on the limits of exploitability and market pressures. Based on the observed rate of discoveries and known reserves of a given region, a peak of production for that region (or the world) can be calculated, and quite accurately forecast in accordance with the model. Various enhanced versions of his original theory have been developed, but the central element of the theory that production stops rising, flattens and then declines, have remained unchanged. Relying on this theory in a 1956 presentation to the American Petroleum Institute, Hubbert accurately predicted that United States oil production would peak between 1965 and 1970.<sup>122</sup> When the model is applied to current oil production, different points of peak production are theorized. Most experts predict that the peak of conventional oil production will occur sometime between 2007 and 2020; while, on average, predictions indicate 2013 as the year of global peak oil.<sup>123</sup>

However, it is important to clearly distinguish between peak oil production of conventional oil on the one hand and non-conventional oil as well as gas liquids on the other. Critics of the peak oil theory point out that it hinges primarily on the peaking of known conventional oil resources, while ignoring the huge potential of non-conventional resources.<sup>124</sup> Other critics state that the underlying analytical model of the Hubbert method fails to incorporate the fact that recoverable reserve estimates evolve over

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<sup>120</sup> *Heinberg, supra* note 50 at 12.

<sup>121</sup> *Deffeyes, supra* note 27 at 29.

<sup>122</sup> M. King Hubbert *Nuclear Energy and the Fossil Fuels* (Houston: Shell Development Company, 1956) [Hubbert]

<sup>123</sup> See Alex Kuhlman "Peak Oil - Information and Strategies", online: Oil Decline <[www.oildecline.com](http://www.oildecline.com)>.

<sup>124</sup> Interview with Professor Paul Stevens, Senior Research Fellow (Energy) of the Chatham House and Professor Emeritus, Dundee University, Scotland, conducted by the author in Washington DC, 11 September 2008.

time as was the case during the peak of US oil production, which occurred within two years of Hubbert's predicted time, but at 600 million barrels higher than the predicted production peak.<sup>125</sup> Finally, a very small group of scientists claim that gas and oil have inorganic origins, implying that there are important resources in locations where oil and gas service companies do not usually explore.<sup>126</sup> Nevertheless, the majority of experts agree that both conventional and non-conventional oil supply will peak in the next twenty years.

In determining the point of peak oil supply, one key element is the balance between the depletion of existing oil fields and new discoveries. In its WEO 2008, the IEA analyzed over 798 existing oilfields, and observed a worldwide average production-weighted decline rate of 6.7% for fields beyond their production peak. The IEA expects this rate to increase to 8.6% in 2030.<sup>127</sup> When the 6.7% decline rate is applied to 2007 crude oil production, the annual loss of output would be 4.7 mb/d.<sup>128</sup> However, a 2007 report prepared by Peter Jackson of Cambridge Energy Research Associates (CERA) pointed out that only 41% of production comes from fields in the decline phase; the remaining 59% comes from fields in a build up or plateau phase. A significant proportion of plateau production comes from super giant OPEC fields. The general decline phase rate of oilfields varies from 6% for onshore fields to 18% for deep water, offshore fields. On the basis of this data, CERA concluded that the aggregate global decline rate was only 4.5%.<sup>129</sup>

The relatively high overall decline rate resulting in an annual output loss of close to 5 mb/d, and the expected annual increase in demand for oil of 1 mb/d, require that additional gross capacity comes on-stream.<sup>130</sup> Conventional crude oil sources output is expected to increase from 70.2

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<sup>125</sup> Cambridge Energy Research Associates (CERA), *Peak Oil Theory – "World Running Out of Oil Soon" – Is Faulty; Could Distort Policy & Energy Debate* (Cambridge: CERA, 2006) online: CERA website <[www.cera.com/asp/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=8444](http://www.cera.com/asp/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=8444)> [CERA *Peak Oil Theory* 2006].

<sup>126</sup> See generally J. F. Kennedy & al., "The Genesis of Hydrocarbons and the Origin of Petroleum" (2002) 99 *Proceedings of the National Academy of Sciences of the United States of America*.

<sup>127</sup> IEA WEO 2008 *supra* note 43 at 43.

<sup>128</sup> *Ibid.*, at 243.

<sup>129</sup> See generally Cambridge Energy Research Associates (CERA), *Finding the Critical Numbers: What Are the Real Decline Rates for Global Oil Production?* (Cambridge: CERA, 2007) online: CERA website <<http://www.cera.com/asp/cda/client/report/reportpreview.aspx?CID=8958&KID=>>> [CERA *Finding the Critical Numbers*].

<sup>130</sup> IEA WEO 2008 *supra* note 43 at 41.

mb/d in 2007 to 75.2 mb/d in 2030, while the remaining increase is expected to come from non-conventional oil and natural gas liquids. These expected increases underline the importance of both discovery and development of new oilfields as well as the improvement of oil production from alternative sources. However, the rate of discovery of new oilfields has declined since its peak in the 1960s; and the rate of oil production passed the rate of discovery in or about 1980. Recent discoveries of large oil fields are primarily deepwater-based resources, which require lengthy and costly development.<sup>131</sup>

Despite intentions to develop offshore oil production as for example in the US, it remains uncertain if anticipated conventional oil resources will be found and developed in time to counterbalance the depletion of existing oil fields.<sup>132</sup> The IEA acknowledges that the rate of decline at mature fields outweighs the rate of increase in production from new fields recently brought on-stream.<sup>133</sup> However, oil production from fields awaiting development and from fields yet to be discovered represents the larger share, and is projected to grow rapidly, especially after 2015. By 2030, 23 mb/d are expected to be produced from yet-to-be developed fields, and 19 mb/d from yet to be found fields.<sup>134</sup>

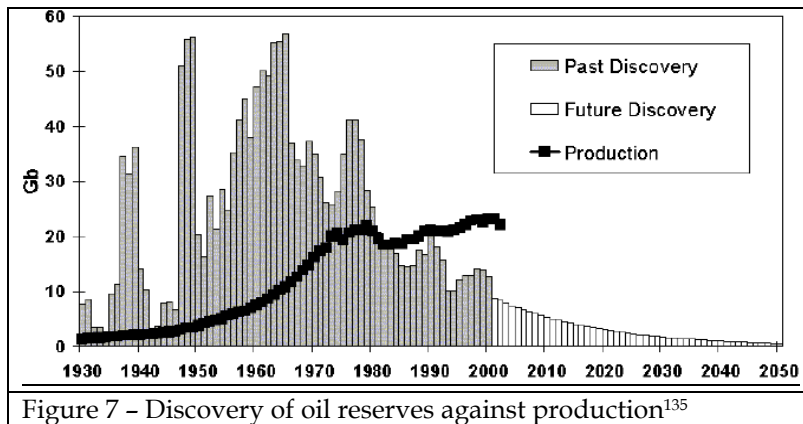


Figure 7 - Discovery of oil reserves against production<sup>135</sup>

OPEC's global oil production share is expected to grow from 44% in 2007 to 51% in 2030.<sup>136</sup> The lion's share of OPEC's production is expected to

<sup>131</sup> See the case of Brazil, *supra* note 97.

<sup>132</sup> *Bush Discusses Energy* *supra* note 71.

<sup>133</sup> *IEA WEO 2008* *supra* note 43 at 256.

<sup>134</sup> *Ibid.*, at 257.

<sup>135</sup> Source: Colin J. Campbell, "The Rimini Protocol - An Oil Depletion Protocol" (Paper presented at the Pio Manzu Conference Rimini, Italy 2003).

<sup>136</sup> *Ibid.*, at 251.

come from Saudi Arabia, which must increase its production from the current rate of 10.2 mb/d to 15.6 mb/d by 2030. Many experts worry that Saudi Arabia will not be able to meet this target production level, particularly since current output is dependent on two depleting fields.<sup>137</sup> Should Saudi fail to develop new fields, global production will not increase and the world would face an oil supply peak or plateau.

In addition to the development of new oil reserves, employing enhanced oil recovery methods (EOR) in existing oilfields could significantly increase recovery.<sup>138</sup> However, the IEA estimates that it will take two decades for the average recovery factor to be raised to 50% from the current 35%, and that, should this happen, it will boost world reserves by about 1.2 trillion barrels.<sup>139</sup> The incremental cost of applying EOR techniques, notably the injection of CO<sub>2</sub>, has also risen in recent years. Presently, it is estimated at between US \$20 and US \$70 per barrel, excluding the additional cost of offsetting the resulting CO<sub>2</sub> emissions.<sup>140</sup> When oil prices are high, CO<sub>2</sub> based EOR techniques might indeed be a valuable option, but several factors limit the usefulness of this technique. These include the characteristics of the oilfield and its state of depletion. EOR techniques would probably not be apt to respond to a country unexpectedly experiencing a peak of its current production.

Many notable petroleum industry experts, such as Kenneth S. Deffeyes and Matthew Simmons, believe that the dependence of most modern transportation, agricultural, and industrial systems on the relatively low cost and high availability of oil will cause post-peak production to decline rapidly. This will be followed by a steep increase in the price of oil, with severe implications for the global economy.<sup>141</sup> Given the price levels during the two previous oil spikes, in which supply did not drop significantly, it is very likely that upon peak supply, the price of oil will rise to unprecedented levels where it will oscillate due to continued supply shortages, speculation, and falling demand.

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<sup>137</sup> Simmons, *supra* note 34.

<sup>138</sup> There are several methods of EOR, such as thermal, nitrogen, carbon-dioxide, and chemical based technologies. The IEA expects that currently 2.5 mb/d are produced by EOR, and the worldwide potential for CO<sub>2</sub> EOR is between 160 and 300 billion barrels, representing 7 to 14% of current remaining conventional recoverable oil resources. IEA *WEO 2008 supra* note 43 at 213.

<sup>139</sup> *Ibid.*, at 212.

<sup>140</sup> *Ibid.*, at 214.

<sup>141</sup> See generally Simmons, *supra* note 34 and Deffeyes, *supra* note 27.

## B. NON-CONVENTIONAL SOURCES OF OIL AND ALTERNATIVE FUELS

### 1. NON-CONVENTIONAL SOURCES OF OIL

In its reference scenario for the WEO 2008, the IEA states that, while oil production from current producing fields will decline and production from fields to be yet found or developed will commence, oil production from non-conventional sources will become an important factor to fill the gap between conventional production and growing demand. Non-conventional sources of oil include heavy oil, extra-heavy oil, oil sands and bitumen, as well as oil from gas-to-liquids (GTL) and from coal-to-liquids (CTL). Of these non-conventional sources, oil sands and extra-heavy oil alone amount to about 9 to 13 trillion barrels, representing about 70% of the world's total oil resources.<sup>142</sup> However, exploitation of these resources for the same use as conventional oil is limited. Currently non-conventional oil production accounts for only 1.38 mb/d, or 1.6% of overall oil production, and this is expected to grow to 3.7 mb/d (3.9%) by 2015 and to 7.7 mb/d (7.2%) by 2030.<sup>143</sup>

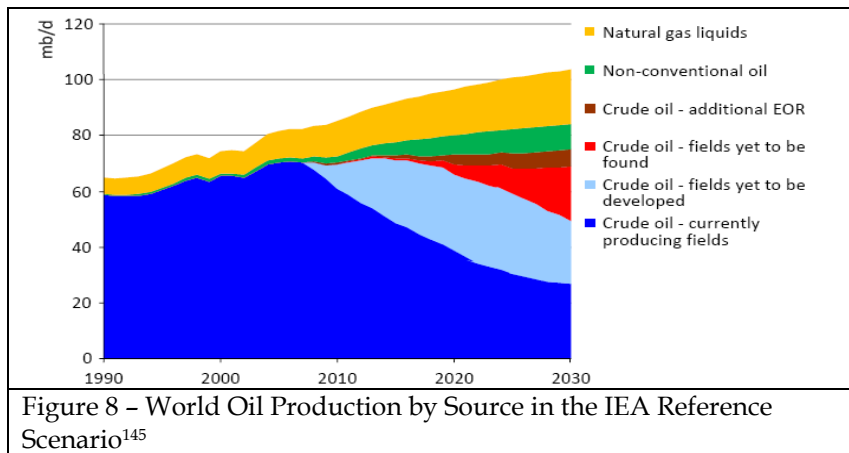
Oil sands, tar sands, and extra-heavy oil are forms of bitumen deposits. Oil sands are formed from the natural mixture of sand or clay, water and a very dense and viscous form of petroleum referred to as bitumen. Oil sands and extra heavy oil are found in large quantities in several countries, but the two main reserves are in Canada and Venezuela. To recover oil from oil sand, the sands must be extracted by strip mining or the oil can be induced to flow into wells by *in situ* techniques which reduce the viscosity of the oil by injecting steam, solvents, or hot air into the sands. This form of oil production requires large quantities of water and energy, which not only increase the cost of production significantly, but also induce environmental concerns.<sup>144</sup> Nevertheless, the IEA expects oil production from Canadian oil sands, currently pegged at 1.2 mb/d, to increase to 5.9 mb/d by 2030.

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<sup>142</sup> Schlumberger Ltd., *Highlighting Heavy Oil* (2006): *Summer 2006 Oilfield Review* at 35 [Schlumberger Ltd.].

<sup>143</sup> IEA WEO 2008 *supra* note 43 at 259.

<sup>144</sup> The government of Canada, pressured to be more environmentally conscious, announced in its 2007 budget that it will phase out some oil sands tax incentives over the coming years. Department of Finance, Canada, *Budget 2007 A Better Canada* at Chapter 3. See online: Government of Canada <[www.budget.gc.ca/2007/bp/bpc3e.html](http://www.budget.gc.ca/2007/bp/bpc3e.html)>.



Total proven oil-sands reserves are estimated to be 175 billion barrels.<sup>146</sup> However, as current mining techniques are economically feasible only if the depth of the oil sands does not exceed 75 meters. Large quantities of Canadian oil sands will probably never be mined. Production from extra-heavy oil sources in Venezuela is much smaller than oil extraction from Canadian oil sands, and the amounts are already included in the IEA's conventional oil figures.<sup>147</sup>

Another non-conventional source of oil is gas. The so called gas-to-liquids (GTL) process is a refinery method of converting natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons. As such, by applying the Fischer-Tropsch process, methane-rich gases are converted into liquid fuels by direct conversion or via an intermediate product called "syngas", which is a mixture of carbon monoxide and hydrogen.<sup>148</sup> These processes allow refineries to convert some of their gaseous waste products into more valuable fuel oils, which, currently, can only be sold as diesel fuel. Furthermore, the process may be useful for the extraction of gas deposits in locations where it is not economically feasible to build gas

<sup>145</sup> *Ibid.*, at 250.

<sup>146</sup> IEA WEO 2008 *supra* note 43 at 262.

<sup>147</sup> Production of Venezuelan heavy-oil reached 54,000 b/d in 1999 (about 10% of Canadian production), and is projected to eventually reach 500,000 b/d. See *Deffeyes, supra* note 27 at 107.

<sup>148</sup> The Fischer-Tropsch process (or Fischer-Tropsch Synthesis) is a catalyzed chemical reaction in which synthesis gas (syngas), a mixture of carbon monoxide and hydrogen, is converted into various forms of liquid hydrocarbons so as to produce a synthetic petroleum substitute, typically from coal, natural gas or biomass, for use as synthetic fuel or synthetic lubrication oil. The process was invented by Franz Fischer and Hans Tropsch, working at the Kaiser Wilhelm Institute in the 1920s. *Deffeyes, ibid.*, at 85.

pipelines. Currently, the GTL process is used at three locations.<sup>149</sup> Global GTL output has reached 50,000 b/d, but two additional plants in Qatar and Nigeria should increase this to about 200,000 b/d by 2012.<sup>150</sup>

The long-term outlook for oil produced by the GTL process depends primarily on cost. 8,000 to 10,000 cubic feet of gas is used to produce one barrel of oil which translates to a cost of between US \$40 and US \$90 per barrel. The process also releases a substantial amount of CO<sub>2</sub>, which may entail penalties in the future. Nevertheless, if several new GTL projects are brought on stream, the IEA estimates in its reference scenario that in 2030, worldwide GTL production could reach 650,000 b/d or 0.63% of oil production.<sup>151</sup> Despite its relatively small contribution when compared with traditional crude oil production, research indicates that GTL might become significant for transportation. The Dutch ferry *Dokter Wagemaker* became the first ship to be propelled by GTL diesel on 22 November 2007.<sup>152</sup> Aviation use of GTL was demonstrated on 1 February 2008, when an Airbus A380 became the first commercial airliner to fly with GTL-based fuel.<sup>153</sup>

Liquefaction of coal to liquid fuels such as gasoline and diesel is another well established, non-conventional method of oil production. The so called coal-to-liquids (CTL) process can be carried out by direct liquefaction (where the coal is hydrogenated or carbonized), or by first converting the coal into a gas and subsequently into a liquid, using the Fischer-Tropsch process.<sup>154</sup> The utility of the CTL process depends on the abundance of stable quality coal, and uses relatively high amounts of energy. While it is often seen as an opportunity for countries with large coal reserves, such as China or the US, CO<sub>2</sub> emissions are an important downside.<sup>155</sup> New carbon capture and storage (CCS) techniques have been

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<sup>149</sup> These are the Sasol Mossel plant in South Africa; the Shell Bintulu plant in Malaysia; and, the Oryx plant in Qatar.

<sup>150</sup> *IEA WEO 2008 supra* note 43 at 263.

<sup>151</sup> *Ibid.*

<sup>152</sup> The 'Dokter' Seeks Emissions Cure, online: The Maritime Journal, <[http://www.maritimejournal.com/archive101/2008/January/power\\_and\\_propulsion/the\\_dokter\\_seeks\\_emissions\\_cure](http://www.maritimejournal.com/archive101/2008/January/power_and_propulsion/the_dokter_seeks_emissions_cure)>.

<sup>153</sup> *Airbus A380 commences alternative fuel test flight programme*. Airbus Press Release, 1 February 2008.

Online:  
[www.airbus.com/en/presscentre/pressreleases/pressreleases\\_items/08\\_02\\_01\\_alternative\\_fuel.html](http://www.airbus.com/en/presscentre/pressreleases/pressreleases_items/08_02_01_alternative_fuel.html). Accessed: 29 November 2008,

<sup>154</sup> *Deffeyes, supra* note 27.

<sup>155</sup> One barrel of oil produced by CTL results in 0.5 to 0.7 tonnes of CO<sub>2</sub>, which would represent a potential penalty of US \$20 to US \$30 per barrel. *IEA WEO 2008 supra* note 43 at 264.

developed to address this issue.<sup>156</sup> Nevertheless, the identified drawbacks will continue to impede wide-scale development of this source of oil. Currently, only about 130,000 b/d of fuels are produced worldwide by the CTL process. The most important source of production is the South African Secunda plant, where the two-stage liquefaction process is applied. The energy-efficient direct liquefaction process is only used at one small commercial project at the Shenhua plant in inner Mongolia, with a daily output of 20,000 barrels. Cost of production varies regionally, and depends on the cost of coal, energy, capital expenditures, and CO<sub>2</sub> penalties.<sup>157</sup> While the fully allocated cost of producing a barrel of CTL oil in China lies between US \$40 and US \$60, this could reach US \$100 a barrel in the United States. The current rate of oil production from coal is only expected to reach 1.2 mb/d by 2030; representing about 1% of global oil production.

## 2. ALTERNATIVE FUELS

In this article, alternative fuels refer to fuels produced from biomass provided from living and recently dead biological material which can be used as fuel or for industrial production. Biomass can be grown from several plants including miscanthus, switchgrass, hemp, corn, poplar, willow, sugarcane, palm oil, and algae oil.<sup>158</sup> The production of fuel from biomass is commonly referred to as biofuel, and it is becoming increasingly relevant for the transportation sector.

There are several production methods for biofuel. The first method is to grow crops that are high in sugar (sugar cane, sugar beet, and sweet sorghum), or starch (corn or maize), and use yeast fermentation process to produce ethyl alcohol (ethanol). The second method involves growing plants that contain high amounts of vegetable oil, such as oil palm, soybean, algae, or jatropha. When the viscosity of the oil extracted from such plants is reduced by heat, the resulting product can be burned directly in a diesel engine, or chemically processed to produce fuels such as biodiesel. In addition, wood and its by-products can be converted into biofuels such as wood-gas, methanol or ethanol fuel; and cellulosic ethanol can be produced

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<sup>156</sup> Carbon capture and storage is a measure to mitigate global warming based on capturing carbon dioxide from large emitting sources and storing it deep underground instead of releasing it into the atmosphere. Long term storage of CO<sub>2</sub> is a relatively untried concept. The first experimental CCS power plant was completed in September 2008 in the German power plant Schwarze Pumpe, and is currently being evaluated for its technological feasibility and economic efficiency. International Energy Agency, *Energy Technology Perspectives* (Paris: IEA, 2008) at 268 [IEA, *Energy Technology Perspectives*].

<sup>157</sup> IEA WEO 2008 *supra* note 43 at 264.

<sup>158</sup> Energy Information Administration, *Renewable and Alternate Fuels: Biomass*, see online: EIA <[www.eia.doe.gov/cneaf/solar.renewables/page/biomass/biomass.html](http://www.eia.doe.gov/cneaf/solar.renewables/page/biomass/biomass.html)>.

from non-edible plant parts. Production of biofuels remains well below 1% of global fossil fuel production.

1.5% of total road transport fuel demand globally is supplied with biofuels. North America is the largest biofuel consumer. The IEA expects that current demand, representing only 800,000 b/d of equivalent fossil fuels, will grow to 3.2 mb/d by 2030, representing 5% of road-transport fuel demand or 3% of total oil consumption.<sup>159</sup> Biofuels have the prime advantages of having both a low net fossil-energy requirement and a low level of life-cycle greenhouse gas emissions.

Several challenges need to be addressed before biofuels can assume a major role in the transportation sector including: food security and land competition, impact of biofuels on water resources, and biodiversity.<sup>160</sup> First generation biofuels are based on feedstock which includes grains (wheat, maize), sugarcane, oil seeds (oilseed rape, soybean), and palm oil. However, the successful development of next generation biofuels hinges on using non-food feedstock, such as cellulose ("second generation" biofuels), or algae ("third generation" biofuels).

Not all biofuels are suitable for aviation. Methanol contains only 75% of the energy found in the same quantity of gasoline. Weight sensitivity dictates that biofuel must contain at least the same energy content as jet fuel to be a suitable substitute for aviation. The most promising biofuels for aviation are algae based. IATA recognizes the potential use of algae based biofuel, but calculates the required capital investment to switch from jet fuel to biofuel to be between US \$74 billion and US \$2.5 trillion.<sup>161</sup>

In summary, non-conventional sources of oil and alternative fuels will play a role in future energy supply. These sources will contribute about 5% of world oil production in 2015, and 10% by 2030. No research however indicates that these resources could compensate for an unexpected, major drop in production or supply of conventional oil.

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<sup>159</sup> IEA WEO 2008 *supra* note 43 at 171.

<sup>160</sup> IEA, *Energy Technology Perspectives*, *supra* note 156 at 332.

<sup>161</sup> International Air Transport Association (IATA), *IATA Report on Alternative Fuels* (Montreal/Geneva: IATA, 2007) at 33.

Source	2007 (mb/d)	% global oil production	2015 (mb/d)	% global oil production	2030 (mb/d)	% global oil production
Oil Sands	1.20	1.4%	3.20	3.4%	5.90	5.5%
GTL	0.05	0.1%	0.20	0.2%	0.60	0.6%
CTL	0.13	0.2%	0.30	0.3%	1.20	1.1%
Biofuel	0.60	0.7%	1.32	1.4%	3.20	3.0%
<b>TOTAL</b>	<b>1.98</b>	<b>2.3%</b>	<b>5.02</b>	<b>5.3%</b>	<b>10.90</b>	<b>10.2%</b>

Figure 9 - Oil production from non-conventional and alternative sources

#### IV. THE NEED FOR A GLOBAL PLAN TO AVOID A POTENTIAL ENERGY CRISIS

The world is faced with challenging realities when it comes to the global outlook of energy. Global trends in energy supply and consumption are on a dangerous unsustainable path, underpinned by dependence on fossil fuels. The rising demand from emergent markets on the one hand, and a decreasing number of oil producing countries on the other hand, increases the risk of supply disruptions. Furthermore future output will be increasingly dependent on a few OPEC countries which do not have accurate estimates of unexploited reserves.

The oil price spike of 2008 highlighted the sensitivity of the price of oil to both tight supply and decreasing demand. The fact that the price of oil rose steeply until July 2008 points to the potentially devastating effect on price should global oil production ever fall short of demand. This could result temporarily from a production peak; or permanently from a supply peak. The short period within which the price of oil doubled to reach a peak in 2008, and the subsequent rapid decline suggest that world energy production would not be able to transition quickly enough into other sources if supply of conventional oil were unable to match demand. Such a shortage would also induce an economic slowdown possibly combined with major geopolitical changes or incidents.

Aviation is highly sensitive to oil prices. The 2008 oil price spike increased operating costs as fuel costs reached 40% of total operating costs.<sup>162</sup> A permanent increase in the cost of jet fuel would increase the cost of air travel significantly, and this would cause certain segments of the markets such as leisure travel, to shrink dramatically. Indirect operating costs would also rise as many related services depend on oil and oil related products. Finally, the resulting economic slowdown would result in severely contracted demand for aviation services.

<sup>162</sup> Pearce, *supra* note 18.

Over the years, the air transport industry has continuously strived to lower fuel consumption. Technological improvements, better utilisation of aircraft, procedural measures, and direct operational changes have generated extensive fuel efficiencies. However, the typical service life of an aircraft is 30 to 40 years.<sup>163</sup> As such, fleet renewal aimed at introducing more efficient aircraft will take several years. Alternative fuels such as gas-to-liquids based jet fuel and the application of biofuels have also been tested in aviation.<sup>164</sup> However, technological challenges need to be addressed especially with respect to biofuel usage, and lengthy certification processes will then follow. In addition, it is also likely that the use of alternative fuels will be given priority in surface transportation given that gasoline and diesel represents a much larger proportion of the market as compared to jet fuel. The aviation sector will therefore continue to depend on fossil fuels, while many other sectors have the potential to more quickly adopt other sources of energy.

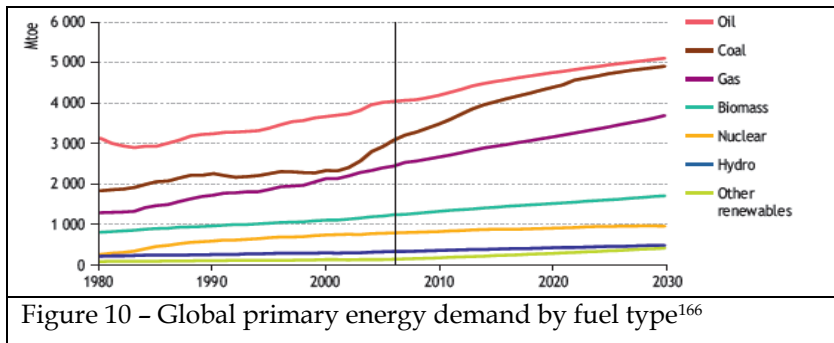
Transportation will almost certainly remain the principal consumer of oil.<sup>165</sup> It has been forecast that other types of fuel, especially coal, will increase in significance, but oil will remain the principal energy source. It is thus vital that the possibility of oil supply shortages is addressed before a global energy crisis occurs. The first urgent anticipatory measure must be a full and transparent assessment of OPEC's oil reserves, alongside an independent feasibility evaluation of the anticipated production increases, especially in Saudi Arabia. The key long-term measures are to reduce dependency on oil and to reduce consumption through efficiency gains.

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<sup>163</sup> *Supra* note 190 at 216.

<sup>164</sup> A Boeing 747-400 of the UK carrier Virgin Atlantic flew from London to Amsterdam in February 2008, carrying in one of its four fuel tanks a 20-percent mix of biofuel derived from coconut and babassu oil. Boeing, News Release, "Boeing, Virgin Atlantic and GE Aviation to Fly First Commercial Jet on Biofuel" (24 February 2008), online: Boeing <[http://www.boeing.com/news/releases/2008/q1/080225c\\_nr.html](http://www.boeing.com/news/releases/2008/q1/080225c_nr.html)>.

<sup>165</sup> In the United States about two-thirds of oil is used in the transportation sector. Worldwide the share of transportation is lower, at about 55%, but the difference is narrowing as developing countries are expanding their transportation sector. Robert L. Hirsch *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management* (Washington D.C.: publisher, date) at 25.



Various experts have recently addressed how to reduce oil consumption. In 2003 Colin J. Campbell, a geologist, proposed the Rimini Protocol (later also called Uppsala Protocol) which contains a mechanism for stabilizing oil prices and minimizing the effects of peak oil. To achieve this, producing countries would not produce oil in excess of their depletion rate, thus the oil burnt, expended or exported must be equal to the oil produced or imported. Importing nations, in turn, would stabilize their imports at existing levels. The objective is to keep global oil prices reasonably correlated to production costs and to allow developing countries to import oil at affordable prices.<sup>167</sup> A similar approach was suggested by Robert L. Hirsch in a study commissioned by the US Department of Energy in 2005.<sup>168</sup> Hirsch concluded that the peaking of world oil production is inevitable, but the effects can be mitigated if addressed early. He examined the possible scenarios of (i) not initiating any action before peaking of oil occurs, (ii) initiating action 10 years before peaking, and (iii) initiating action 20 years before peaking. Hirsch concludes that the peaking of oil will create a severe liquid fuels problem, particularly for transportation, with its biggest impact being felt in developing countries. Mitigation of the impact would require, at least a decade of intense and expensive efforts, and would have to commence at least twenty years before the peak to avoid a shortfall.

Despite the growing number of indicators that global oil production and supply might not be secure in the foreseeable future, significant measures have neither been developed nor discussed by the international community to address this risk. To avoid an energy crisis, a global plan is needed to reduce global dependency on oil. This can be achieved by

<sup>166</sup> In million tons of oil equivalent. See *IEA WEO 2008 supra* note 43 at 78.

<sup>167</sup> Campbell, *supra* note 135; described in detail in *Heinberg, supra* note 50.

<sup>168</sup> Robert L. Hirsch, *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management* (Report prepared by Science Applications International Corporation for the US Department of Energy, Washington DC, 2005).

increasing energy efficiency in all sectors of high oil consumption, such as surface transportation; as well as by moving certain sectors to other energy sources. Coal could play a major role given the fact that it is cheap, versatile, and plentiful in many countries. Electric power generating, for example, could move from natural gas and oil to coal. In turn, natural gas could increasingly be used for automobiles and trucks, while aviation would continue to depend on oil for the foreseeable future.<sup>169</sup> However, the transition would require substantial investments with regard to environmental factors.<sup>170</sup>

Currently, the climate change polemic coupled with the drive to reduce global CO<sub>2</sub> emissions presents the best platform from which to address the issue of potentially peaking oil production or supply.<sup>171</sup> In 2006, the transportation sector accounted for 23% of global energy-related CO<sub>2</sub> emissions, with aviation contributing 11% to this share.<sup>172</sup> The European Union (EU) has begun implementing policies to attain its Kyoto Protocol target of 8% CO<sub>2</sub> reductions by 2012.<sup>173</sup> The EU has initiated the European Climate Change Programme which includes an emissions trading scheme (ETS), and has prepared legislation to include aviation in its ETS.<sup>174</sup> The aviation sector should support globally agreed emission charges for air travel as it is the sector with the longest path to reduce or discontinue oil as its primary energy source. However, the aviation sector should also condition its support upon the implementation of measures in other sectors which can more quickly lower CO<sub>2</sub> emissions by reducing consumption of fossil fuels. The survival of aviation in an environment of scarce oil supplies

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<sup>169</sup> *Deffeyes, supra* note 27 at 98.

<sup>170</sup> See description of Carbon Capture and Storage (CCS) mechanisms above.

<sup>171</sup> In its Fourth Assessment Report (AR4), published in 2007, the Intergovernmental Panel on Climate Change (IPCC) projects that, without further action to reduce greenhouse gas emissions, the global average surface temperature will rise by 1.8 - 4.0°C this century, and this could even reach 6.4°C in the worst case scenario. The projected global warming will trigger serious consequences for mankind and other life forms, including a rise in sea levels of between 18 and 59 cm endangering coastal areas and small islands, and more frequent and extreme weather events. Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report*, online: IPPC <[http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf)>.

<sup>172</sup> *IEA WEO 2008 supra* note 43 at 393.

<sup>173</sup> The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change, an international environmental treaty concluded at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, from 3-14 June 1992. The treaty intends to achieve a "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." See *Protocol to the United Nations Framework on Climate Change*, 11 December 1997, 1869 U.N.T.S. 299 (entered into force 16 February 2005) [*Kyoto Protocol*].

<sup>174</sup> See generally European Union, *Aviation and Climate Change*, online: EU <[http://ec.europa.eu/environment/climat/aviation\\_en.htm](http://ec.europa.eu/environment/climat/aviation_en.htm)>.

will largely depend on the reduction of oil consumption by other sectors.

## V. CONCLUSION

It has not been the objective of this article to predict if and when global oil production might reach a temporary or permanent peak but rather to outline critical aspects of global energy supply, especially the outlook of production and supply of fossil fuel based products, which are critical to the aviation sector.

The most significant conclusion of the foregoing is that there is a real possibility that global oil production and supply might indeed reach an untimely peak. Such a peak would be devastating, especially for aviation. Timely mitigation measures, namely reducing consumption and shifting to other sources of energy, could reduce the impact. However, initiatives proposed so far have not been implemented, and the current economic slowdown coupled with the fall of the price of oil has shifted the focus away to currently more pressing challenges.

Nevertheless, public sensitivity about climate change and global warming presents an excellent opportunity and platform to address some of the necessary mitigation steps. In applying the principles of good airmanship, the airline industry could seize this opportunity and become an active advocate of both oil and climate-change issues. This would not only restore the industry's reputation as an environmentally conscious player but would also extinguish a potential threat.

