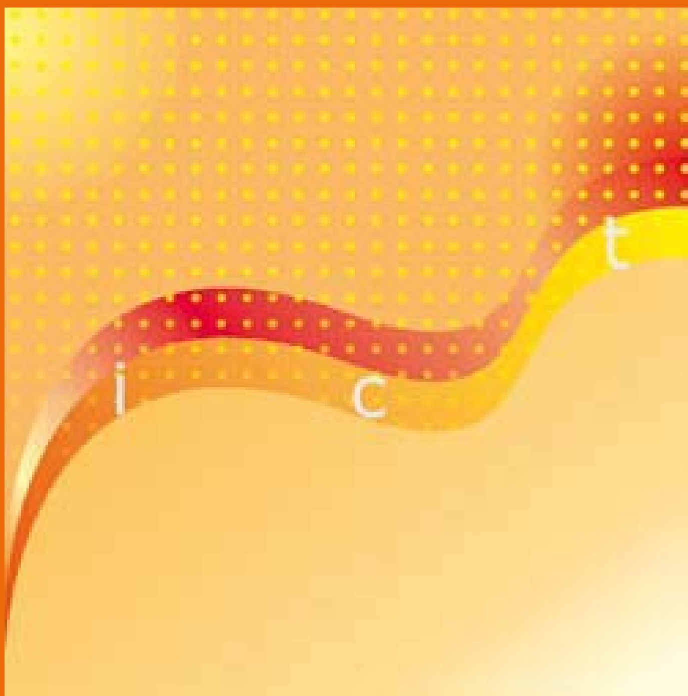
EMBARGO
The contents of this Report must not be quoted or summarized in the print, broadcast or electronic media before
16 November 2006, 17:00 hours GMT

United Nations Conference on Trade and Development

INFORMATION ECONOMY REPORT 2006

The Development Perspective



United Nations

Chapter 4

ICTs IN THE OIL SECTOR: IMPLICATIONS FOR DEVELOPING ECONOMIES

A. Introduction

Oil is the main non-renewable source of energy that is currently "fuelling" the world economy. In spite of many efforts to develop renewable energy sources, which have been further stimulated by major increases in international crude oil prices during last few years, the share of such sources in global energy consumption is still marginal. Conventional wisdom suggests that the world economy will continue to be highly dependent on oil and gas: while in coming decades the share of gas might increase considerably and eventually surpass that of oil, the latter will still play a major role in the world energy balance.

Increased oil prices, together with global warming, are considered to be a change of first order for the world economy. In particular, the oil industry itself has an impact on the use of information and communication technologies (ICTs) in the global economy. Higher oil prices increase the risk of squeezing information technology (IT) budgets in oil-using industries. In particular, they can affect oil-importing developing countries with regard to their increased consumption and their often limited capacity to respond to oil price shocks. On the other hand, increased revenues of energy producers give oil-producing countries an opportunity to increase their investments in IT. At the same time they will increase support for high-tech energy conservation efforts and for the production of alternative renewable energy sources (Bartels, 2006).

ICTs play a major role in increasing productivity and cutting costs in many sectors of the economy (UNCTAD, 2003a). And given the expectation of high oil prices for long periods of time, the question arises as to whether more efficient production and more equitable distribution of this valuable energy resource are possible, inter alia, through the active use of modern ICTs. To what extent can ICTs help increase efficiencies in the production and allocation of crude oil and its products?

This is in particular pertinent to developing and transition countries whether they are oil exporters, or major or low-income oil importers. Oil exporters are interested in maximizing the benefits of using ICTs. Oil importers, as they further increase their oil consumption, particularly China and India, are interested in being able to buy petroleum[1] at better prices and use it effectively. Reducing price volatility is especially important for developing countries' importers, from low-income economies, as they have more difficulties in coping with oil price shocks. Thus, determining the role of ICTs in the oil sector could be crucial for better assessing the economic development perspectives of developing countries in the coming decades.

ICTs and modern petroleum technologies (which are also becoming information - intensive technologies) provide new opportunities to improve economic performance at all stages of the oil supply chain. These technologies influence both upstream operations (exploration and production of crude oil) and downstream operations (transportation, refining of crude oil and distribution of oil products). For example, in upstream operations, ICTs and related technologies may provide possibilities for expanding proven crude oil reserves, improving the rate of crude oil extraction from existing wells, and providing further means to discover new wells, and so forth.

Understanding to what extent new ICTs and related technologies might help to extend the lifespan of proven oil reserves and help to find new ones will provide more predictability about future oil supply; it could also be a stabilizing factor helping to allay investors and consumers' fears, and could contribute to putting downward pressure on oil prices.

The use of ICTs in the oil industry is not only relevant for international oil companies (IOCs) in their competitive drive to stay in the forefront of technological progress, but also has also direct implications for national oil companies (NOCs) in OPEC and other oil-exporting countries. Unlike in the 1970's, the major national oil companies in the OPEC region as well as in other countries have matured, accumulated considerable financial resources and know-how, and are ambitious to compete with IOCs also in the use of ICTs. However, they still have to address issues such as the lack of skilled human resources, and the need for increased knowledge of cutting-edge technologies, and business processes. The NOCs in some developing countries face the challenge of keeping up with new technologies, including ICTs. But to upgrade technologies they need first to put in place basic infrastructure and earmark enough financial resources to upgrade their technological capabilities.

Oil trading in spot markets started in the early 1980s, creating modern futures markets and becoming the dominant mode of trading of oil. It is hard to overstate the role of ICTs in oil spot and futures markets and in the changes that occurred. The number of participants in the physical oil supply chain is limited, but the emerging e-marketplaces are generating further competition within the oil industry. In addition to oil and its derivatives, oil equipment and technology are increasingly offered for sale online. E-marketplaces might still provide increased efficiencies in the distribution and marketing of oil products and related equipment. ICTs are helping in the exchange of information and better interaction among oil companies and between them and their equipment, technologies and services suppliers.

The chapter starts by reviewing the state of play in the international petroleum market. Section C identifies ICT-driven efficiency gains in both upstream and downstream stages of the global petroleum industry, drawing on the experience and concerns of developing countries. Section D reviews the electronic trading methods of major oil exchanges and emerging oil and related-product e-marketplaces. Section E identifies the means of increasing the effectiveness of the petroleum industry and opportunities for its further diversification in oil-exporting developing and transition economies, as well as possibilities to improve the production and distribution of oil products in oil-importing countries. To conclude, the chapter provides some policy recommendations.

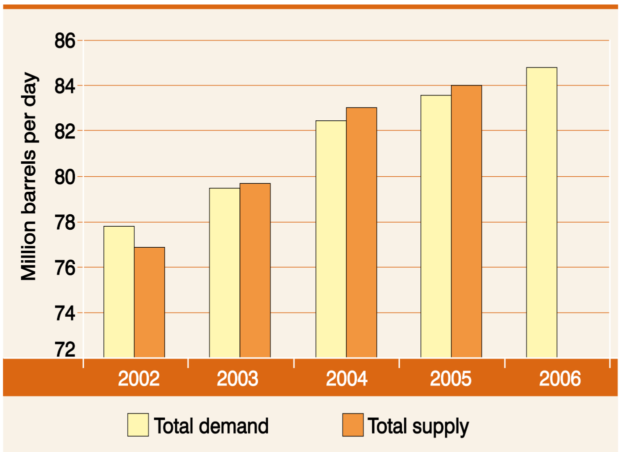
B. International petroleum market: The state of play

In spite of serious energy conservation measures taken primarily by OECD countries, resulting in nearly halving the energy intensity of their per capita incomes, the world economy continues to witness an increase in demand for oil. One of the driving forces here is the demand from major developing economies, primarily China and India, where energy and, in particular, oil consumption is increasing in both absolute and relative terms. Thus, China imports 3 mb/d (million barrels per day) of crude oil, which represent half of its domestic consumption. While China's share in the global oil market is still 8 per cent, since 2000 it has captured 30 per cent of the growth in global oil demand. As a result of such growth in China, India and other Asian countries, Asia, which in the 1970s consumed only half of the amount consumed by the North American market, surpassed North America as the principal oil-consuming region of the world. However, the United States' per capita oil consumption is still twice as much as in Europe and several times higher than in Asia, and its imports of around 12 mb/d are approximately equal to the crude oil production of all former USSR countries (CERA, 2006; Yergin, 2006).

As chart 1 shows, world oil demand may rise from 77.7 mb/d in 2002 to nearly 85 mb/d in 2006 and that in spite of more than tripling of prices since 2002 from around $20 to around $70 per barrel of crude oil.[2] According to the International Energy Agency (IEA) as well as similar forecasts of the Organization of the Petroleum Exporting Countries (OPEC), by 2030 oil demand might reach 120 mb/d, with the transportation sector as the main user of its products (IEA 2002, 2005a; OPEC, 2006).

The recent decline in stocks of oil in importing countries highlights a situation of nearly full capacity utilization in the oil industry and exerts upward

Chart 4.1
Global oil supply and demand



Source: IEA, Oil Market Report, 12 May 2006.

pressure on oil prices in the spot and futures market. More importantly, the political climate in respect of the Islamic Republic of Iran and shortfalls in production of crude oil in Nigeria, Venezuela and Iraq, as well as the impact of Hurricane Katrina on the US Gulf coast, also add upward pressure on oil prices. On the other hand, the recovery of Russian oil production is notable, representing almost 40 per cent of the global crude oil production increase since 2000. However, various internal policy problems and insufficient investment limit the production of Russian crude oil (Hill, 2004).

Current tight supply and demand conditions that increase the prices of oil products are also due to a mismatch between global petroleum refining capacities and their product mix, and an actual demand for oil products. As a result of underinvestment during the period of low oil prices (1980s–1990s), there is a shortage of capacities to convert heavier crudes into highly demanded middle distillates such as diesel, jet fuel and heating oil (Franssen, 2005). That in turn increases the premium paid for lighter grades of crude oil. The profitability margins (that is, the price difference between the crude oil input and the oil products) of the main refining centres has dramatically increased in 2005–2006.[3] Meantime, the spare capacities in the global oil refining industry are still at the unprecedented low level of 3mb/d.[4]

The volatility of oil prices in spot and futures oil markets is also a result of the heightened reactions by speculators who recently switched part of their hedge funds investment from financial to commodity derivatives, thus creating a liquidity overhang in commodity exchanges.[5]

OPEC countries[6] produce around 40 per cent of the world crude oil and other related liquids (that is, 3 mb/d) and they dominate in the world demand for oil.[7] Additionally, by coordinating their production and export strategies through production quotas (28 mb/d in 2005), OPEC countries dominate the oil trade flows. Another major oil exporter is the Russian Federation, and the rest of non-OPEC oil exporters (including from the former USSR, Latin America and Africa) still play a marginal role (see table 4.1).

Given the fact that all spare capacities of 1.8 mb/d, that is less than 2 per cent of global supply, are located in Saudi Arabia (see table 4.2), OPEC countries have additional power to balance demand needs if

Table 4.1

Geography of crude oil and oil products trade in 2005 (mb/d)

	Crude imports	Product imports	Crude exports	Products exports
United States	10 055	3 470	38	1 091
Canada	934	276	1 643	558
Mexico		328	1 956	109
S & Central America	657	399	2 201	1 327
Europe	10 537	2 724	765	1 384
Former USSR		92	5 374	1 702
Middle East	205	134	17 329	2 492
North Africa	179	169	2 462	608
West Africa	58	186	4 191	167
East and Southern Africa	548	117	249	17
Australasia	488	234	145	77
China	2 552	832	135	293
Japan	4 225	999		107
Other Asia-Pacific	7 420	2 086	930	1 388
Unidentified			442	727
Total world	37 859	12 047	37 859	12 047

Source: BP Statistical Review of World Energy, June 2006

Table 4.2

OPEC vis-a-vis the rest of world supply (mb/d)

	7 January 2005	May 2006		
	OPEC 10 quota	Production	Capacity	Surplus capacity
Algeria	894	1 380	1 380	0
Indonesia	1 451	900	900	0
Iran (Islamic Rep. of)	4 110	3 800	3 800	0
Kuwait	2 247	2 525	2 525	0
Libyan Arab Jamahiriya	1 500	1 680	1 680	0
Nigeria	2 306	2 150	2 150	0
Qatar	726	800	800	0
Saudi Arabia	9 099	9 200	10 500–1 000	1 300–1 800
United Arab Emirates	2 444	2 500	2 500	0
Venezuela	3 223	2 500	2 500	0
OPEC 10	28 000	27 435	28 735–29 235	1 300–1 800
Iraq		1 900	1 900	0
Crude oil total		29 335	30 635–31 135	1 300–1 800
Other liquids		3 998		
Total OPEC supply		33 333		

Sources: IEA and OPEC

marginal and unexpected increases occur.[8] It is also important to remember that after nationalization of the oil fields by OPEC in the 1970s the lion's share of the world's proven reserves is on the balance sheets of the NOCs of such key OPEC members as Saudi Arabia, the Islamic Republic of Iran, Iraq, Kuwait and Abu Dhabi.

At the same time the higher oil prices are playing their classic role: on the supply side they bring into the stream crude oil from more expensive oil fields and its derivatives from tar sands and other fossil fuels, as well as stimulating production from alternative energy sources, while on the demand side they further squeeze purchasing power and encourage energy conservation measures. Thus, on the basis of the current level of prices, the potential increase in the international petroleum industry's productive capacity in the coming decade is estimated at between 20 and 25 per cent (Yergin, 2006). The annualized cost of crude oil for the buyers may have already surpassed $2 trillion. In the principal consuming regions the crude oil price represents less than half of the cost that the end users are paying for oil products (the rest going to refining, distribution, marketing and taxes). This suggests that these elements are also crucial for the efficient use and allocation of oil.

The recent major increases in oil prices are reminiscent of the oil price increases during the famous first and second oil crises of 1973–1974 and 1979–1980. However, unlike in the 1970s, this terms-of-trade shock represents a smaller share of GDP, financial markets and international trade. As a result, the global economy shows greater resilience and is still characterized by dynamic growth rates coupled with relatively low inflation and interest rates (IMF, 2006b). The fact that increased oil bills for consuming industries and households do not translate so far into lower demand reflects also the low short-term price elasticity of oil consumption. At the same time, in spite of a longer-term relative decrease in demand for oil in developed countries, its steady increase in selected developing and transition economies might create possibilities for further energy crises and price increases.

Ensuring that supply will keep pace with demand involves a massive scale of investment in primarily exploration and production of oil, representing around 80 per cent of the capital costs of the oil supply chain. According to the IEA (2003), to meet the demand, investments in crude oil and its products supply chain should be close to $1 trillion during the current decade, and for supply to exceed demand they would have to increase further in the next two decades.

So far, the recent decreases in reserve replacement rates to less than 100 per cent in some major IOCs mean that the latter were pumping more oil than they were able to add to their proven reserves. While IOCs are trying to improve the proven reserve profiles of their existing oil fields by increasing their oil recovery rate through the use of new technologies, including ICTs, they are not equally successful in finding new oil, especially outside existing major oil-producing areas. Attempts by some IOCs to improve on reserve replacement rates by buying companies or participating in the ownership of oil wells in-oil producing developing countries help to improve the position of a given company vis-a-vis its competitors and the value of its shares, but not overall proven crude oil reserves.[9]

Already in the 1970s the higher oil prices triggered supply–side competition and, as a result, expansion in the exploitation of more costly and difficult oilfields through the use of newer technologies (Indjikian, 1983). Currently, ICTs are introducing major changes in the oil supply chain. They represent a larger part of the capital structure of the oil industry and are also embedded in oil-related technologies. Moreover, moving from the exploration of conventional oil to its extraction from tar sands, or its conversion from gas and coal, increases the technological intensity of the oil-manufacturing process. Oil derived from those sources and especially heavy oil, mainly contained in tar sands, might dramatically increase the volume of global recoverable oil reserves. And here the question relates not only to the oil price that would make those projects viable, but also to the application of new more powerful technologies such as a sophisticated steam injection process, making it possible to increase the heavy oil recovery rate from 6 to 40 per cent.[10]

As was the case in the 1970s, the oil-exporting countries are experiencing a considerable increase in their export revenues owing to the increased oil prices. That will open up new investment opportunities to upgrade the capital stock in both upstream and downstream oil sectors of those countries. The increase in prices will also trigger more oil production by non-OPEC exporters competing with low-cost OPEC oil for the market share. As a result, oil fields in countries such as Angola and VietNam or Azerbaijan and Kazakhstan will become more attractive for further exploration and exploitation. As the following sections will show, the development of modern oil technologies, coupled with more intensive use of ICTs, allows the exploitation of more difficult oil fields, including offshore and deepwater ones, which is particularly interesting for developing countries such as those mentioned above.

The current high level and volatility of oil prices further increase the possibility of financial crises. Low-income oil-importing developing countries that are not major exporters of other commodities or dynamic exporters of manufactures and services particularly face the burden of further balance-of-payments difficulties and increased current account and fiscal deficits as a result of such terms-of-trade shocks. The IMF and other multilateral and bilateral donors are called on to protect low-income countries from sharply increased oil import bills. The introduction of the newly proposed Exogenous Shocks Facility as a part of IMF emergency lending could be used to cover oil price shocks as well as other external shocks such as natural disasters and armed conflicts (Bunte, 2005). This facility would have a conditionality similar to that of Poverty Reduction and Growth Facility (PGRF), and thus be more concessional than other mechanisms such as the IMF Compensatory Financial Facility (IMF, 2006a).

Nevertheless, this chapter, rather than exploring how to overcome financial constraints, will focus on how developing countries can make better use of technologies, and, in particular, ICTs, in order to make the distribution of oil products more efficient and hence less costly for end users.

C. ICTs and their impact on the oil supply chain

The capital-intensive and labour-saving nature of the oil industry helps to explain the very high levels of company revenues per employee. In the case of leading oil companies this indicator can reach several million dollars. The information revolution further increases the role of automation, computation, modelling and other analysis methods, and has scaled up the use of ICTs in the petroleum industry, both upstream and downstream. Although all major IOCs and NOCs were vertically integrated companies and were trying to optimize resource flows and investments and integrate operations from exploration to distribution of oil products, they lacked the necessary instruments to achieve that objective. ICTs, through modern software and their capacities to find optimal solutions for complex systems containing multiple inputs and variables, might increase efficiency in the petroleum industry.

Given the capital-intensive nature of the oil sector, the main part of investment goes to oil-specific technologies, with ICTs still in the process of gaining relative importance in technology related investment. In this regard, it is important to make a distinction between the use of basic ICTs such as e-mail and the Internet and the use of more sophisticated ICT solutions such as integrated data networks or censor devices measuring the drilling and extraction processes. The basic ICT solutions are increasingly standardized and are used extensively by IOCs as well as NOCs in developing countries. The more sophisticated ICT solutions have so far been fully installed only in leading IOCs but are becoming more and more important within the oil sector. Thus, it is estimated that the oil majors, including BP, Conoco-Phillips, Chevron, Exxon-Mobil, Shell, that is the five descendants of the famous seven sisters (Sampson, 1975), as well as ENI and Total, spend over $10 billion a year on ICTs in all their oil and gas operations, including upstream, downstream and petrochemicals.

When implementing ICT solutions in the oil sector there are several conditions that need to be fulfilled. The first concerns the ability to have sufficient capital to invest in new technologies including ICTs. Second, the human and logistical infrastructure has to be in place so that it is possible to apply and work with the new technology. The third condition is the functionality and adequacy of the technology that one would like to apply. Linking the second and third elements is essential as these technologies cannot stand on their own, and sufficient expertise and ability to adjust business processes need to be within the reach of organizations. For example, employees need to be able to easily interpret data flowing in from control systems, integrate and transform those data into knowledge and share and mix different bits of the knowledge of various experts in order to take quick collective decisions on the optimization of business processes.

An indicator showing the increased adoption of ICTs by oil companies is the amount of hardware and software per employee. The better performance of new oil equipment, as far as its measuring and computing features are concerned, also indicates the growing information-intensive nature of the equipment and its integration with ICTs within more holistic business architectures and processes. Increased efficiency in using ICTs might contribute to the extension of proven reserves beyond existing levels, and increase the rate of extraction of crude oil from existing wells and products from crude oil. Competitive pressures from producers of alternative energy sources might also drive technological advances, implying the increased use of ICTs.

While IOCs have a vertically integrated structures that manages all upstream and downstream operations, there are oil companies specializing in parts of those operations or just oil trading. Among vertically integrated or specialized oil or transportation companies there are both private and public companies. The presence of both types of proprietary systems in the international petroleum industry reflects the policies of various Governments regarding natural monopolies and the role of oil in the national economy. In that respect, identifying the impact of ICTs' use in the oil-sector of oil exporting developing countries might be of particular importance.

The advent of modern Internet-based ICTs in the 1990s increased the interest of oil-sector players in assessing the impact of ICTs on the industry and the prospects for competitive benefits that their extensive use might bring about. Apart from analysis undertaken within major IOCs, a number of private consultants (Accenture, Aupec, Compass, Gartner, Forrester, Hackett), as well as technology vendors (Halliburton, IBM, Schlumberger, EDS, Siemens), are systematically exploring the possibilities for more extensive use of ICTs and related new technologies in the oil sector. The responsive attitude of oil companies to surveys conducted by specialized consultants is driven by their desire to keep pace with their peers. With the aid of confidentiality agreements to preserve their anonymity and competitive advantages, they share information willingly with specialized oil consultants to trace the use of ICTs within different peer groups in the oil industry. These studies also permit them to compare the performance indicators of oil or oil-product producers operating in different regions and countries.

Major NOCs from leading developing oil exporters are equally interested in improving production methods and increasing their market shares in downstream operations and are becoming more open in participating in peer reviews and thus learning more from the best practices not only of IOCs but also of other NOCs. That was one of the conclusions of recent major research by the United Kingdom's Royal Institute of International Affairs, analysing the activities and performance of five major NOCs, namely Saudi Arabia's Aramco, the Kuwait Oil Company (KOC), the Abu Dhabi National Oil Company (ADNOC), the National Iranian Oil Company (NIOC) and Algeria's Sonatrach (Marcel and Mitchell, 2006).

Specialized energy consultants normally provide confidential benchmarking services to IOCs and to some NOCs to assess the efficiency of ICTs in particular business functions[11] or for specific aspects of ICT services.[12] The data supplied are then analysed statistically to determine the best explanatory variables for measuring efficiency and other management decision indicators. On the basis of such data, various key performance indicators or metrics are constructed using normalizing or explanatory measures.

For ICT services as a whole a key cost driver is the number of access points, measured as the total number of desktops, including PCs, laptops and technical workstations. The common ICT performance indicator is the total ICT operating cost divided by the total number of desktops. The senior management of IOCs are often more concerned about the effectiveness of their ICT services. When that is the objective of measurement, the normalizing measures are likely to be oil production, sales volume, asset value or profitability. The numerators (or top line date) for many of the key financial performance indicators are usually total ICT spending or costs and its components, operating expenses and investment spending. To understand the ICT intensity of operations at the level of the whole company a measure computing the percentage of total company expenditure devoted to ICTs is used. As a result of such surveys, a participating oil company has a better idea regarding the use of ICTs, on the basis of comparison with its peers and with companies in other regions. This information helps in the decision-making process regarding future resource commitments to ICTs (Rose, 2002).

ICTs are increasingly considered to be a commodity for the production of goods or services (such as electricity). While previously analysis of the use of ICTs and its impact on economic performance consisted mainly in comparing peers in a single industry, linking ICTs to commodities now makes it possible to compare the oil industry with other industries. Comparing the oil industry with, for example, the organization of business by financial service providers might encourage the use of ICTs in the former. Such an approach might be complicated by the uniqueness of applications and related hardware to carry out technological operations in a given industry. For example, the geophysics applications are technology-specific to the oil industry.

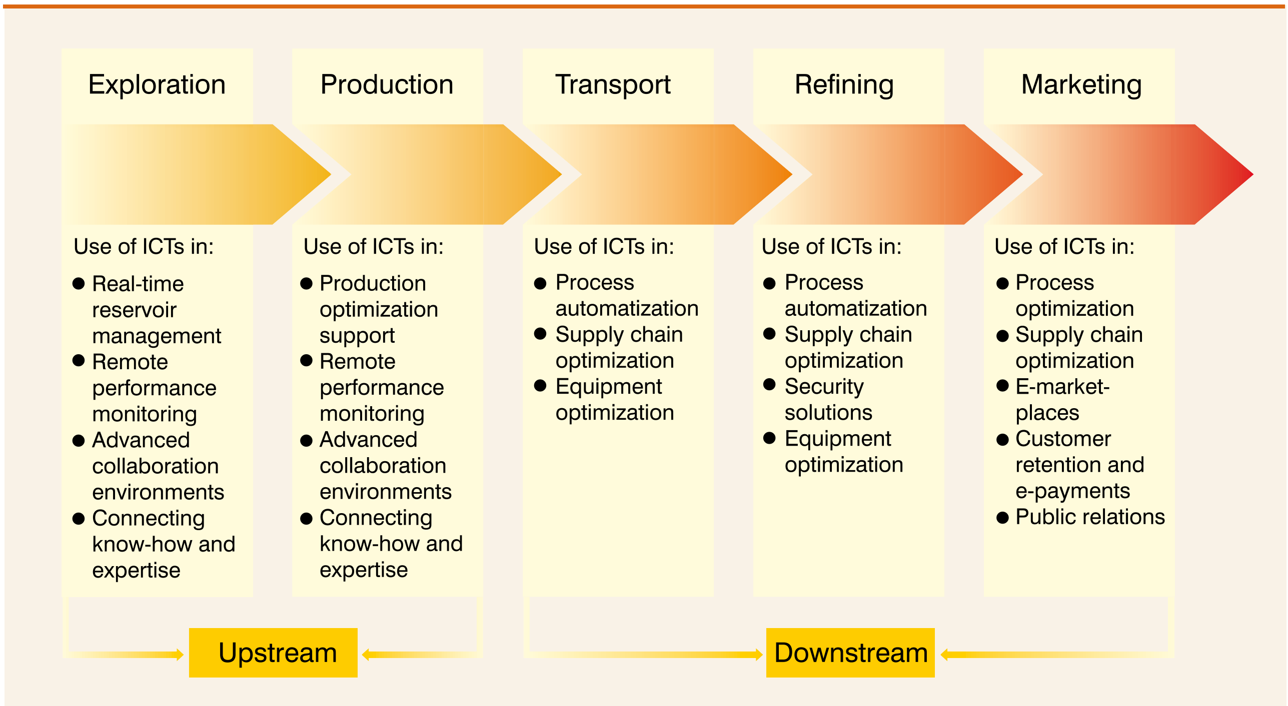
The following subsections will explore in more detail the use of ICTs in upstream and downstream operations, which is schematically presented in chart 4.2.

1. ICTs and upstream operations

The main challenge of upstream operations that include exploration and production (E&P) of crude oil is to extend the life of this depleting resource.

Chart 4.2

ICTs in the oil value chain



ICTs are becoming more and more important for the upstream operations of the oil industry. Because of the increasing demand for oil and the difficulties in keeping up with this demand from the supply side, the sector is facing the challenge of increasing production and improving oil recovery rates. This situation has caused the oil sector to invest more and more in research and development, and as a result, improved drilling and extraction technologies have been introduced. These new technologies can be divided into two categories. The first one is purely mechanical, focusing on better drilling and extraction instruments such as "horizontal drilling", a drilling process where the pipes are horizontally inserted into the oilfield. This makes it possible to cover a broader area than with vertical drilling. The second category of technologies is based on providing information during the processes. This is done by using monitoring devices in drilling and extraction processes in order to steer them in such a way that maximum productivity and oil recovery are achieved. These new technologies are becoming indispensable as the share of easy oil from the Middle East is decreasing and difficult oil such as offshore oilfields in deep water is replacing it to keep up with demand. The increasing importance of difficult oil has led to the emergence of a new kind of oilfield that is highly digitalized.

Apart from going for new oilfields, a key challenge is to get more oil out of existing fields through the use of more sophisticated technologies that make it possible to "visualize" the oil wells and recover more oil than the current techniques permit. ICTs' role here is hard to overstate as they make it possible to collect massive amounts of data concerning oilfields, with consecutive transfer and manipulation of those data in sophisticated models that in their turn support decision-making as far as the optimal oil recovery methods are concerned. Oilfields are increasingly becoming a part of an ICT network at company level, as all of them are increasingly connected through the Internet and monitored in a quasi-real-time regime. All elements of oilfields, including the oil wells, pumps, pipelines, rigs, production platforms and compression facilities, are interlinked, each having its own IP address. The greatest computing needs for interpreting elements of oil-well-related data derive from so-called 3D/4D seismic search methods that by using downhole sensors make it possible to visualize subsurface fluid flow in three or four dimensions, time being the fourth such dimension. At the same time, major IOCs continue to work on improvements in those methods, trying to acquire seismic data in substantially higher resolution.

The US petroleum industry is one of the largest users of the computing capacity provided by major IT companies such as IBM. They provide capacity to geoservice companies or similar departments of IOCs to manipulate data of prospective and existing wells using the 3D seismic technology which makes it possible to monitor changes in oil fields and to provide

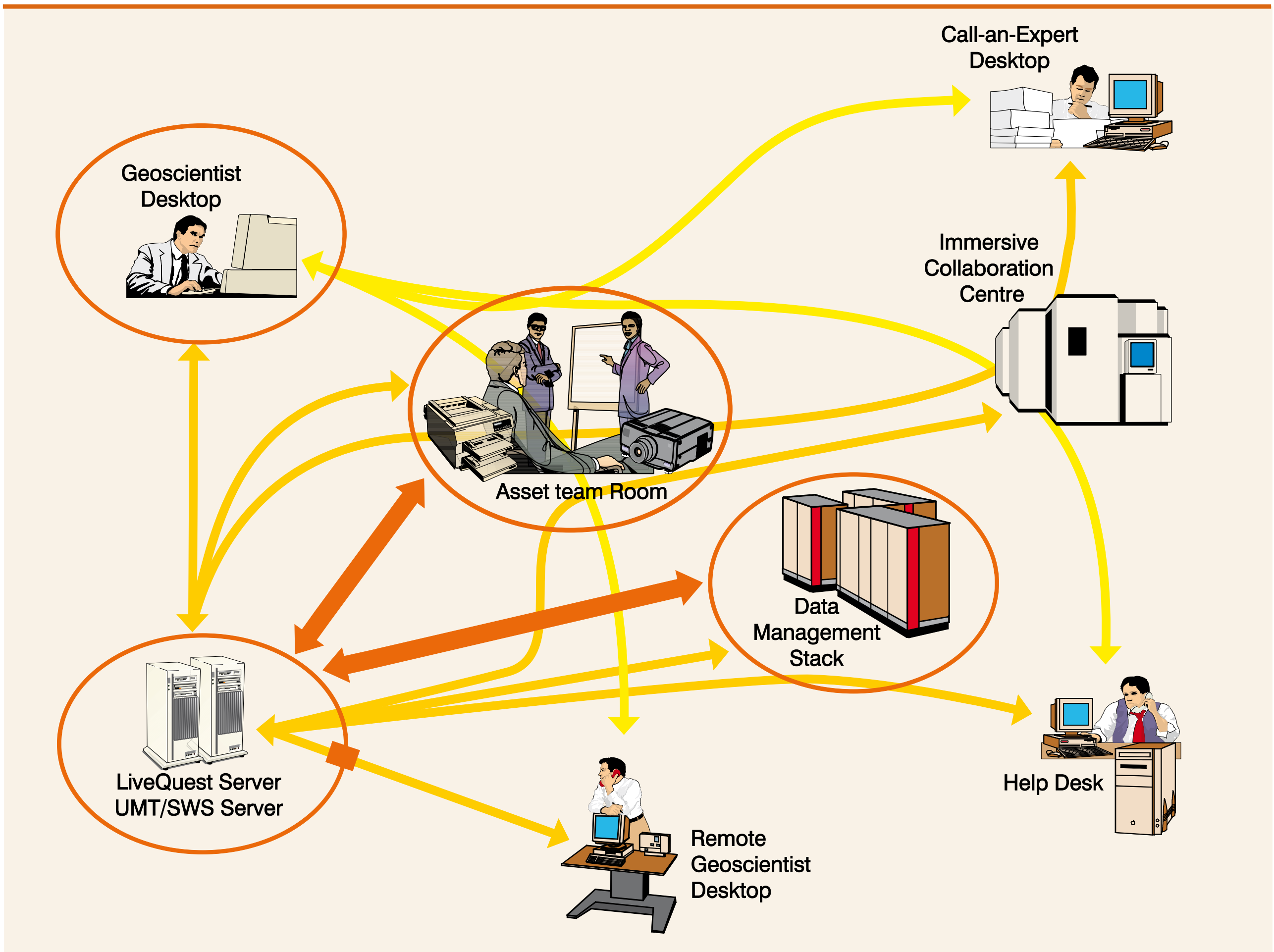
Box 4.1

Managing oilfields electronically

Managing oilfields electronically from remote centres is not only about improved use of technology or introduction of more IT, but also changes the way in which the processes of oil exploration and production are carried out. A typical digital field implies remote control and operation of oil wells on a constant basis using the interpretation of near real-time data captured by sensors that are installed within oil wells and obtaining information about various physical and chemical parameters of the oil well. Computer-based models capture data not only from sensors but also from logging equipment and flow-rate measuring equipment. In the event of a problem with, say, a well production log, the oil company calls in the logging company (such as Schlumberger) to help interpret the log. All these different streams of data are integrated into a model that helps geologists, engineers, physicists and other company experts to work as a team to find solutions to ensure the well's optimal "behaviour". A computer model can suggest an optimal decision after trying out thousands of different possibilities. To get a value from all oilfields and their wells in an optimal way, an oil company will need to model their behaviour during their complete life cycle (i.e. from the beginning). In that case, the model will determine the initial control setting, based on the design and expected yield of the well. At the same time the model provides for modifications based on the actual flow of oil from a given well. If an experienced technologist disagrees with the model's suggestions, he or she can alter the decision and then feed the modified decision back into the model. The latter will incorporate such a change while proposing future solutions. Combining logical solutions provided by computers with the human ability to interpret is the synergy required to run a digital field.

Source: Digital Energy Journal, issue 1, April 2006, and issue 2, June 2006.

Chart 4.3
An ICT-based collaborative environment in oil upstream



Source: Society of Petroleum engineers, Paper 99482.

data for further manipulation services to their clients. Such a large amount of quasi-real-time information creates a problem regarding its assimilation and the timely taking of complex decisions on the optimization of oil extraction.

There is a major need to manipulate data, especially in the case of horizontal drilling in hostile environments of difficult wells. By using logging while drilling, the data from the wells are transmitted to the experts, who then judge and take action to ensure the best drilling strategies and oil recovery methods. One such method consists in lowering a "logging tool" on the end of a wire line into a well, which makes it possible to visualize and monitor the actual drilling process, record rock and fluid properties and identify hydrocarbon zones in geological formations sometimes below the earth's crust. An interpretation of these measurements then makes it possible to locate and quantify potential depth zones intervals containing oil. Logging tools developed over time measure the electrical, acoustic, radioactive, electromagnetic and other properties of the rocks and the fluids contained in them. Well logging is performed at various intervals during the drilling of the well as well as when the total depth of the well, which could be from 300 m to 8000 m, is drilled. Traditionally, logging was performed as the drilling tools were pulled out of the hole. Now ICTs enable data to be read using sensors in the drill-string. This saves time and money. The data, called a "Well Log", on the basis of which a decision is made are normally transmitted digitally and almost in real time to the main offices.

The departments of major oil companies responsible for the search for oil and optimization of exploration and production processes are now increasingly responsible for running so-called digital or smart or electronic fields. For example, Shell developed the "Smart Fields" program. Here smartness implies a technology-driven improvement in the business process that enables an appropriate level of intelligence to be applied to that process.[13] The idea is to build up integrated operations that bring together offshore and onshore work teams across companies to carry out operations and rework strategies.

Fields using ICTs and related modern oil technologies are also operated by IOCs in several oil-exporting developing countries.

- Shell's South Furious field in Malaysia has four remotely operated wells providing 350,000 pieces of data daily. Other "Smart Fields" projects have been developed in Brunei Darussalam and the Gulf of Mexico. The "smart" method enabled Shell to halve its costs in the Gulf of Mexico through bundling six relatively small oil wells in a single project by putting sensor and control equipment in each of them and then "plumbing" them.[14]

- Collaborative workflows to upgrade capabilities and processes have been developed by a joint Shell–Schlumberger project in deepwater oilfields in the Gulf of Mexico known as Mars. By defining the most probable scenarios of oilfield development and related risks, the team in charge of those fields tried to identify the optimal use of resources. It used software solutions to evaluate scenarios and options, support decisions and provide architecture for collaboration. It also introduced business model improvements in hydrocarbon development and integrated-reservoir-modelling (IRM) processes. Chart 4.3 provides an example of such a collaborative workflow._

The smart collaborative environment in chart 4.3 includes a smart workflow system, an uncertainty management tool and other new collaborative work processes that also function in this environment. The central part is the asset team, which is based in a central, mainly onshore location and receives data through servers in near real-time that enable the situation in oilfields to be assessed. To take a decision, the team needs to collaborate with the remote desktops of geoscientists and call-in experts, and with a helpdesk (see thinner arrows). The so-called immersive collaboration centre reviews the process and gives feedback at a higher company-wide level (Langley, 2006).

Following are two examples of the way in which oil companies from developing and transition economies use ICTs to improve efficiency (box 4.2 and 4.3).

Box 4.2

ICT use by the Saudi Arabian national oil company

A striking example of the use of the most advanced IT systems to manage the oil upstream process is the Saudi Arabian NOC, Aramco. It is sitting on the largest oil reserve in the world and is also the world's largest producer and exporter of oil. It disposes of the recent models of CRAY, one of the largest computer systems in the world. Aramco uses them to manipulate enormous masses of data on oilfields' performance and reservoir characteristics in order to '"see into" the reservoirs in three dimensions, thus managing to achieve an optimal level for oil fields' production performance. It has also developed in-house so-called fractal deconvolution, an algorithm enabling improved resolution of seismic pictures. Other software, called DETECT, makes it possible to map out subsurface channels and see the thinnest and thickest parts of oil reservoirs. The company has installed a major integrated SAP software solution, to which 51,000 users in company locations worldwide have access. It supports about 80 per cent of Aramco's key business processes and has managed to absorb more than 250 legacy programs without compromising or disrupting company operations. Employees in remote areas are linked to each other through wireless local area networks (LANs). Access to wireless LANs also allows service and utility organizations to access company SAP applications, e-mail and the Internet. Since 2001, Aramco has also been using VSAT (very small aperture terminal) satellite technology to provide network connectivity for mobile field operations and remote company facilities. VSAT provides inter alia disaster recovery capabilities and back-up communications services to remote areas. The satellite communications enable timely use of information from rigs, field crews and marine vessels. They are available on all rigs, feeding advanced 3D visualization centres and thus enabling remote geo-steering systems for drilling operations through real-time drilling, data collection and monitoring. More sophisticated IT solutions that are feature-rich, real-time and multimedia-based are increasingly making inroads into company practices. According to its Chief Geophysicist, in the next five years Aramco is planning to quadruple its investment in oil exploration.[1] The company invests on a continuous basis in developing and enhancing the IT knowledge of the workforce so that it can adapt better to technological change. The company's ICT-related sophistication has been reflected in the several international awards that its website has received during the last few years.[2]

[1] "Saudi Aramco commits to technology automation" *Digital Energy Journal,* 16 May 2006
[2] See: www.saudiaramco.com

Box 4.3

ICT use by Russian oil companies

Another large oil producer is the Russian Federation, where oil is produced by a mix of government-controlled and private companies. Among the major Russian oil producers are Rosneft in which the Government is a majority shareholder, and other privately owned companies such as Lukoil, TNK-BP and Surgutneftegaz. Rosneft is using actively technologies to improve the flow rates of existing wells, as well as exploiting proven but as yet untapped reserves through development drilling with quite low levels of operating and capital expenditures. By using traditional well and modern well and reservoir management techniques, including artificial lift, hydrofracturing and waterflooding techniques the company achieves higher recovery rates from existing wells. Integrated production management software based on geological and simulation models using 2D and 3D seismic data of the key fields, makes it possible to identify those wells with the greatest potential and to allocate drilling, hydrofracturing and lifting resources to maximize the net present value of production in each field. At the same time Surgutneftegaz has designed a method for drilling horizontal wells that makes it possible to increase four or five times the rate of crude oil flow in comparison with wells drilled through the application of conventional technologies. All those technologies are monitored by ICTs related to those processes.[1] Other oil producers in the Russian Federation also use similar methods. At the same time the local oil-related technology and ICT producers are facing tough competition from international service companies and are having difficulty in winning contracts from Russian major oil companies.

[1] See www.rosneft.com; www.surgutneftegas.ru.

Many leading IT and process automation service providers are involved in helping IOCs and NOCs to make upstream operations an ICT-intensive process. While service operators and technology vendors propose various technological solutions, the oil companies are striving to design a single IT architecture for their upstream operations permitting them to operate like an integrated system. As a result, they request the help of service providers in achieving such a solution rather than selling their pieces of ICT equipment or applications. Within oil companies, while business units create and own data it is the responsibility of IT departments to manage those data in the most effective ways. The latter implies ensuring the security of data and its standardization across the company.

Aupec studies analyse the use of ICTs in upstream operations in a representative group of both IOCs and NOCs.[15] The average share of IT spending in total expenditures (including operating capital and project expenditures) was 7 per cent for 2004 and 8 per cent for 2005. These numbers compare well with the share of ICT expenditures in the GDP of the most developed economies. While more than two thirds of the IT budget goes to operating expenditure for running and maintaining the IT infrastructure, investments are also increasing. Also, one fifth of the operating expenses to maintain software applications are devoted to ERP support. While all employees have desktops and many of them have laptops, there is a tendency towards use of high-end PCs and workstations. Equally, companies use predominantly new servers (less than three years old), with Unix servers having a dominant position. Linux use is increasing in the technical computing segment.[16]

From a developing and transition economy perspective, the adoption of ICTs and investment in them in the oil sector need to take into account a number of considerations.

First, ICTs are becoming extremely important to the oil industry. While pipes, rigs, pumps and large platforms are thought to be made up of low-tech bits and pieces, in reality they are monitored by ICTs and interact by relying on massive amounts of high-tech inputs – from exploration to drilling, development and production – using data management and manipulation, computer-aided design (CAD), supervisory control and data acquisition (SCADA), and so forth. The above elements represent parts of increasingly integrated operations in the oil industry networked by ICTs that make it possible to communicate, monitor, compute, model and take decisions at the various levels of the upstream.

Second, given the remoteness of many oil-fields and their location outside the main telecommunications networks, access to sufficient bandwidth is of prime importance for IOCs and NOCs. This helps them maintain operations in a holistic way. Some of them use the services of satellite telecom providers to set up intra-company satellite telecommunication networks to link all their oilfields and manage them from the head or strategic regional offices. Companies operating in developing and transition oil-producing countries need to spend more on ICT infrastructure than is the case for North America and Europe, as they frequently need to build up their own infrastructures and cannot rely on local support.

Third, the diverging interests of various players and competition between different standards and programs sometimes limit the possibility of extending integrated operations throughout the industry. These difficulties become apparent when undertaking restructuring, standardization and simplification of installations and programs. Adapting to technological change also requires changing old working habits and labour composition and location. This is often done by moving control and measurement activities from offshore platforms to onshore locations, where virtual control and decision-making are increasingly taking place (Wahlen et al., 2005).

In order to maximize the impact of ICTs on oil upstream operations, developing and transition economies must continuously invest in ICTs and other technologies, and consider the additional barriers, such as limited local expertise, and the need for additional investment in infrastructure.

2. ICTs and downstream operations

ICTs are also actively used in the downstream part of the oil supply chain, namely transportation and refining of crude oil as well as marketing and distribution of its products. As in upstream, here also the share of ICT expenditures in overall costs, including operational and capital expenditure, tends to be around 8 per cent.[17] Downstream operations constitute an information-intensive process that deals with different pieces of data on purchasing and delivery of crude, further refining and distribution of products. Those data include crude prices, inventory, storage and transport capacity, delivery costs, sourcing options and prices, oil products throughput and mix, and delivery to wholesale and retail points of sale. Similar logistical and data assimilation and decision-making problems arise in the case of petrochemicals production and distribution.

The main regulatory requirements that induce oil companies to use next-generation oil technologies more actively are those that impose a large-scale reduction of harmful emissions. As a result, the producers of oil products are constantly searching for products with the lowest possible CO_2 and other polluting emissions. Since vehicles and other means of transportation are the main users of oil products, the possibilities of supplementing oil products with bio fuels or, synthetic fuels or combining combustion engines with electrical motors are among the possibilities to explore. "Fuel cell" is an emerging method for the production of clean energy from fossil fuel. It is an electrochemical device which combines hydrogen and oxygen to produce electricity. It does not require recharging and its only by-products are water and heat. Compared with combustion, this process is several times more efficient and less polluting. However, in spite of the introduction of new technologies and fuels, oil products remain unchallenged and their global consumption shows an upward trend.

Meanwhile the use of ICTs in refineries helps to improve technological processes and increases yields of lighter oil products with less harmful emissions. In transportation and distribution, ICTs make it possible to avoid losses and help to optimize the stocking and further delivery of oil products to users.

Given expectations of a high oil product demand, the world is not short of projects for building new refineries. However, according to Wood Mackenzie[18], most announced refinery projects in 2006 (500, of which 66 are for new refineries) will probably not be realized. As a result, capacity utilization in the industry will remain high and any additional supply capacity will be most probably absorbed by the increasing demand. At the same time the structure of demand will generate further investment in additional refining capacity and more upgrading of existing capacities. The main region that is expected to construct new refineries of a capacity of 1.5 mb/d and expand existing refineries by 2 mb/d is the Asia-Pacific region. Surprisingly, the North American region will concentrate on new projects of more than 1 mb/d, while the Middle East will concentrate on extension of existing refineries by 1.5 mb/d, adding a meagre 0.4 mb/d as new refineries. Another surprise is the fact that while Africa might expand its existing capacities by some 0.4 mb/d, even lower growth is expected in Latin America, Europe and the Russian Federation (Jamieson, 2006). At the same time, given the outdated nature of the technologies used in Russian refineries, which are biased towards heavy oil products, many companies are starting to invest to upgrade the refineries product mix towards lighter products and middle distillates.[19]

Efforts to increase refinery utilization were made in the period of low oil prices in the second half of the 1980s and 1990s, with a view to improving operating efficiencies and thus meeting the challenges of fall a in revenues and profits. Thus, between 1982 and 2002 the US refining industry increased its capacity utilization from 85 per cent to 93 per cent. It also managed to raise by 75 per cent the yield of light products from heavy crudes, considerably reduce crude and product inventories and double the average throughput per retail station. Such efficiency gains were due mostly to progress in using ICT tools. While the 1980s were characterized by the use of linear programming and modelling, which enabled economic processes to be assessed and plant operations to be optimized, the 1990s brought advances in distributed controls, in-line blending, maintenance management, logistics management and introduction of software systems of enterprise resource planning (ERP). Later on, the scale-up of electronic communications and transactions, as well as a wave of consolidations in the industry, added to the increase in operating efficiencies. However, the efficiency gains of that period did not result in increased net margins for the refineries, as the benefits were competed away and passed to customers (Miller et al., 2003).

At the same time, the mergers and acquisitions of the 1990s also increased the operational complexity of running large enterprises. Meanwhile competition and new methods of tracing inventories brought about a trend of decreasing inventories with related risks in supply shortfalls in the event of unexpected contraction of supply from crude oil producers. As mentioned above, modern refineries have also to face the clean fuel requirements and an increasing number of product specifications. Finding the optimal balance between those complexities and efficient and effective production of oil products is a major challenge and requires capital investment not only in modern deep oil cracking equipment, related storing and distribution facilities, but also in integrated downstream operations and management solutions based on the recent web - based ICT programmes. The challenge here is to move out from IT silos based on the priorities of individual departments or parts of the downstream value chain to a global functional model controlling in an integrated manner the work processes, information flows and performance indicators (Moore, 2005).

In other words, further expansion of refining capacities in various parts of the world should take place on the basis of modern information-intensive business processes characterized by intensive use of IT systems that manage transportation of crude, technologically advanced refining processes and further flow of oil products in the paradigm of optimized IT solutions for all stages of the downstream. Linkages between information systems of various oil companies may also create possibilities to switch from competition to cooperation between oil product suppliers, especially if there are tight demand conditions and very high-capacity utilization.

As will be shown in following sections, the downstream operations are important for developing countries. Many oil exporters diversify their petroleum industry by investing in refinery and distribution not only in their own countries but also in countries importing their crude oil. Some oil-importing developing countries also have refineries. All of them should be concerned with improvement in oil products distribution systems. ICTs are becoming increasingly present in all those operations.

D. ICT contribution to increased efficiency in oil trading

1. Oil spot and futures markets

In the aftermath of the crises of the 1970s the oil market was the first to introduce on a large scale the spot and futures market as a method of trading, risk management and price discovery. The first oil futures contract using West Texan Intermediate (WTI) as a benchmark was launched in 1983.[20] As a result, in the early 1980s, the prices set previously by oil exporters were replaced by spot prices determined in the London and New York exchanges by both supply and demand. To cover the risks of price fluctuations and defaults on payments, the oil exchanges started to introduce derivative financial instruments such as futures and options. Soon the derivatives market became a major business, which greatly exceeded the volume of the physical market. Increased reliance on futures markets became the main method of determining the market price and managing risks related to price and exchange rate fluctuations. Eventually, the derivatives also determined the prices for oil products and petrochemicals.

Futures trading as a concept has been used since the late Middle Ages, when agricultural producers were managing the risk of price falls by setting contract prices in advance with their potential buyers. However, only the means provided by ICTs permitted futures trading to really take off. The use of electronic means made the price discovery process nearly instantaneous, making it possible to factor in market fundamentals, as well as positive and negative news, for setting current and expected prices of a commodity. However, it was only after the second oil crisis in the early 1980s that pricing started to move out from the so-called posted prices (set by OPEC members) to prices quoted in derivatives exchanges by spot and futures contracts. This oil trading mainly takes place in two principal energy exchanges – the New York Merchantile Exchange (NYMEX) and the International Commodity Exchange (ICE) of London[21]. Those exchanges had concentrated the highest levels of liquidity, which permits the efficient setting of oil futures and options. Operations here are regulated by exchange clearing houses which act as counterparts to every transaction and ensure that brokers honour their commitments. The exchanges cover themselves against the risk of default by pooling brokers' deposits in the clearing house. For example, in NYMEX, which is the largest energy futures exchange, the clearing-house safety net pooled a guarantee fund of $135 million and a default insurance fund of $ 100 million.[22]

Even if energy represents only 2 per cent of the global derivatives markets with financial products,[23] the traded values are growing at an impressive rate. Thus, during the first two months of 2006, 11.1 million oil futures contracts were traded in NYMEX. This represented an impressive 32.1 per cent increase in comparison with the same period in 2005. During the same period, the number of Brent futures contracts in ICE increased by 63.3 per cent to reach 6.4 million. New types of contracts also experienced rapid growth. For example, NYMEX recently launched the electronic mini crude oil contracts. From 2005 to 2006 their volume increased by 488.4 per cent to reach 1.6 million contracts. Interesting was also the dramatic growth of fuel oil contracts in the Shanghai Futures Exchange. Those contracts were launched in August 2004 and reached the impressive level of 2.2 million contracts in January–February 2006, with an 887.6 per cent increase on a yearly basis. There are derivatives exchanges also operating in developing and transition economies, including India, China, Mexico, Brazil and Taiwan Province of China. They are in full expansion and already trade several hundreds of millions of various contracts a year. One of the largest derivatives exchanges in the world is the Korea Exchange. [24]

Analysing the nuts and bolts of futures trading is not the aim of this chapter. However, a short description of its ICT use is provided. Oil futures markets are similar to stock exchanges where brokers agree on futures contracts through open outcry. The positions of the many bidders are then digitalized and communicated to the counterparts and the exchange clearing house. However, to make trade happen, the broker needs to be physically present in the exchange.

This traditional type of futures market still exists in NYMEX, but no longer in ICE, which became an entirely electronic trading floor. Traders in ICE communicate with each other silently through Internet connection and ICE could therefore give up the trading floor in central London. In fact the fully electronic trading floor has a shorter transaction time. The increase in the speed and volume of transactions brought about a dramatic increase in the membership of ICE, streamlining access to a larger pool of buyers and sellers and a market with more liquidity. Also, ICE developed a service called ICE Data, which delivers online to more than 20,000 subscriber's data on the energy market, including prices, real-time quotes, trades, tick data, historical time series and technical analysis.[25] ICE's departure from the open outcry method induced NYMEX Europe to follow up by opening similar e-floors, first in Dublin and then in London.

At the same time, in June 2006, NYMEX agreed with the Chicago Merchantile Exchange (CME) to start trading energy futures on the CME Globex electronic trading platform.[26] This is one of the largest financial exchanges, with derivative instruments not only for commodities but also for segments of stock equity indexes, interest rates and individual equity. The new element of commodities futures in Globex was the addition of the energy and crude oil segment to the more traditional soft commodities traded in CME.

According to critics, the fully electronic market is more anonymous[27] and more rigid than the open outcry one. They also claim that, in order to be efficient, brokers need to have multiple screens to compensate for the flexibility of the open outcry.[28] The organizers of fully electronic exchanges are aware of this and equip brokers with all necessary ICT tools to ensure that electronic brokerage meets fully the requirements of clients.

Finally, it is known that the benchmarks[29] used in the main US and UK exchange markets refer to the local crude oil types such as WTI and Brent, which are lighter crudes. The only heavy crude that is used as a benchmark is the Dubai from the United Arab Emirates, which has lost importance with time. While world crude oil production shifts towards heavy or sour types of oil with higher sulphur content, the oil product mix demand faces stricter environmental regulations and therefore favours lighter products with very low sulphur content. As a result, it is increasingly difficult to ensure that the price discovery for heavy oils compares well with that of light oil benchmarks traded in NYMEX and ICE. As the Middle East and the Russian Federation are not only the main suppliers of oil but also the centres of heavy oil production, the rationale of focusing oil trading on light benchmarks is questionable. With increasing expertise in the functioning of derivative exchanges and with adequate financial resources, selected oil-exporting developing and transition economies could become new centres of spot and futures trading for energy and primarily crude oil. These new centres would introduce new benchmarks based on the main heavy crude types such as Urals and Dubai. That in turn may increase the ICT-related sophistication of oil-traders based in the main oil-producing regions.

2. Other oil-related e-marketplaces

There are other major oil-trading platforms with Internet-based techniques for transacting mainly oil products, petrochemicals and also some crudes. However, such oil-related e-marketplaces are less visible than e-trading of, say, electricity. Analysis of their structure, business models and sources of financing make it possible to describe the role of Internet-and of Intranet-based e-marketplaces in the oil sector. There is also online trading of oil equipment, spare parts and the like(Geyer, 2003).

E-marketplaces for commodities have been well known for quite some time.[30] Here also buyers and sellers leverage information to make the exchange of products more efficient. However, after the first Internet boom many online trading initiatives in the oil sector were abandoned and the high expectations for e-marketplaces' performance could not be met. Over-investment, together with weak financial management, caused the failure of many of these e-marketplaces. The investments needed were larger than the expected cost reductions. However, some companies such as Intercontinental Exchange and Trade-Ranger continued operating in the market by betting on the long-term benefits of e-business and were ready to invest until the potential of e-marketplaces had been fully developed (Jones, 2003).

The participants in oil e-marketplaces include suppliers,[31] buyers,[32] traders, brokers, distributors, and industrial and private end-users. The varying needs and interests of the different actors, the increasing competitiveness in the sector and the complexity of the oil supply chain itself have led to the emergence of various e-marketplaces.

The first type, the Power Exchanges, function like stock exchanges. This leads to an environment in which every participant can decide whether to sell or buy its commodity. Thanks to the electronic environment facilities, searching time can be reduced and efficiency gains can be achieved. Because of the nature of the oil market, orders have to be scheduled. This process of scheduling is accompanied by procedures for coping with potential imbalances in supply and demand. These e-exchanges also permit online financial settlements.

The second type, the e-procurement operations, can be regarded as the purchasing of commodities online. Services are designed to deal with the difficulties of complex supply chains, as can be seen in the oil sector. This is being achieved by fully automating the procurement process in a rule-based environment that is supposed to be beneficial to both buyers and sellers. The efficiency gains generated in these procurement e-marketplaces derive from the latter's ability to create sufficient liquidity, deals flow and collaboration arrangements, leading to cost reduction in the supply chain process. The procurement e-marketplace might be compared to a reverse auction process where buyers can place offers and make sellers compete. This leads to an environment in which every supplier can decide where to set its commodities price to get the order. Buyers, on the other hand, can decide what to buy taking into account the prices and amounts offered by suppliers. Meanwhile, given the limited number of players in the oil market, the IOCs are not yet considering e-marketplaces as important playing fields and as a result the emerging e-marketplaces do not yet have the financial backing of IOCs.

At the same time e-procurement and online trading of oil-related equipment are becoming increasingly popular. In many cases these e-marketplaces are a part of multifunctional platforms that also provide other services to customers in the oil industry. One of such platform, called Rigzone.com, together with a marketplace for various type of equipment, also provides information, directories, analysis and so forth.[33]

Selling and buying oil products and oil equipment in e-marketplaces could create competition and thus play a beneficial role, especially for oil-importing developing countries, which would be able to use such marketplaces as to benefit from better prices. For this, adequate ICT infrastructure and financial mechanisms need to be in place.

E. The development perspective

Developing and transition economies will probably not be in a position to use oil in the same way as industrialized countries for at least two reasons: the natural oil resources are limited and environmental concerns impose the use of sustainable development models. To both problems ICTs can provide solutions that go beyond the mere improved efficiency and productivity of the oil industry.

To effectively use ICTs in the petroleum industry and related sectors oil-exporting and oil-importing countries need to improve employees' knowledge and skills. The local oil companies are increasingly aware of this issue and engage more often in technology and human capital investments. They also need to learn to combine local R&D with technology transfer so as to make the most efficient use of both.

1. Oil-exporting developing and transition economies

Thanks to increased demand for oil and high oil prices, emerging oil-exporting developing countries currently can have access to sufficient financial resources for their oil projects. However, they encounter many other challenges, including technical ones. The use of state-of-the-art ICT technologies in the oil sector is becoming more and more widespread. Developing countries are now facing the challenge of keeping up with technological developments in order to be able to derive maximum benefit from their oil reserves. As shown before, they need to meet several preconditions in order to do so. While IOCs are already working on integrating their ICTs with business processes and are adapting their human skills to carry out that task, NOCs and independent companies in developing countries are still struggling to get their infrastructure right and to improve access to modern ICTs. Larger NOCs from the Middle East and the Russian Federation are better positioned than the NOCs from other countries as they have enough financial resources to secure access to recent technologies and acquire the requisite experience and skills.

To secure access to new ICTs, the NOCs have basically two possibilities. They can either buy access to new technologies from service operators or they can cooperate with IOCs in exploiting their oilfields. They might acquire more experience and technology by working on pilot projects and other cooperative arrangements with IOCs and to a lesser extent with NOCs from countries such as China, Malaysia, the Russian Federation and Saudi Arabia. Cooperative arrangements with IOCs have another advantage compared with working with service operators. Clauses for technology transfers and training of NOCs' staff can be inserted in the contracts on the terms of participation of IOCs in the oil production process. As a result, these new agreements are creating a solid legal base for acquiring and adapting the new technologies used by IOCs while the IOCs get access to new oilfields. IOCs can provide developing country NOCs with valuable experience regarding how to re-engineer processes and implement new technologies in an effective way. Including adequate training programme requirements in agreements with IOCs is equally important for creating a skilled workforce to drive NOCs towards new technologies and ICTs.

Another of the major problems that developing countries have to resolve in their drive for more value-added activities is development of human capital and skilled labour. In the oil industry those categories include qualified engineers and IT experts. The new work processes based on the use of new technology, including ICTs, need skills that are not easy to find in those countries. One way of addressing this issue would be for local companies to hire specialized skilled labour and consultants from abroad to train the local workforce while backing up local operations. Another way would be to leverage on the technology transfer clause in the contracts with foreign oil companies to ensure the transfer of technology and training and education of local staff. So far, NOCs have requested from IOCs more technology transfer than training for local personnel. Probably many prefer to use specialized independent consultants to train local staff without interference from their potential competitors.

Perceiving oil-exporting countries as a high political risk in terms of their reliability as oil suppliers has often more to do with geopolitical calculations than with economic analysis. The track record of oil-exporting countries shows the contrary. Unlike in the pre-OPEC times of concessions, today oil-exporting countries are fully exercising ownership rights to underground reserves. At the same time, they work in close cooperation and are parties to E&P agreements with IOCs. Those agreements may take the form of production sharing agreements (PSA), service contracts, buy-back deals and so forth. Moreover, many oil-exporting countries, through their national oil companies, play a leading role in new discoveries and capital investment in E&P. For example, of the

$8.6 billion expected to be invested in E&P in Algeria during 2006–2010, more than 70 per cent will be invested by Sonatrach, the national oil company, while the rest will come from foreign partners. Sonatrach itself made six out of eight discoveries in 2005.[34] If it had not had the technological and financial capacity, Sonatrach would have been unable to take the lead in searching for oil. Moreover, being less constrained by the short-term reporting of results to shareholders, well-organized and modern national oil companies are able to cope with more risky investments in E&P and are reinvesting the resulting profits to improve the proven reserves/production ratios.

After the nationalization of oilfields by OPEC countries in the mid-1970s, the largest part of global oil reserves is under the control of NOCs. In recent decades the NOCs have accumulated not only financial resources but also know-how and diversification strategies by incorporating downstream and upstream operations both locally and internationally. At the same time, the NOCs with access to conventional technologies are increasingly aware of the need to introduce more actively the latest technologies, including ICTs. The latter are at the disposal of technology vendors and major IOCs. To produce oil in more complex and unconventional environments the NOCs will need to work within new IT-intensive collaborative processes and be able to better leverage new technologies.

According to comprehensive research on leading NOCs, the latter prefer to go for independent ways of building up modern business processes and technological capabilities For example, ADNOC, Saudi Aramco and Sonatrach are eager to participate in R&D of new technologies in order to gain an edge in the industry. As was mentioned in the section on ICTs and upstream operations, Saudi Aramco tries to build up its core competencies by addressing fundamental pillars such as technological excellence, people and processes. Looking into the future of the oil market, Aramco is also trying to innovate by developing for example, fossil-fuel-driven fuel cell technology. The emerging collaboration between NOCs to develop clean oil technology is also a part of their technological drive (Marcel and Mitchell, 2006).

An example of active use of ICTs is the National Iranian Oil Company (NIOC), a subsidiary of the Ministry of Petroleum (MOP). It is providing IT services to MOP and its other subsidiaries within the oil sector. The aim is to equip all operational and service units with modern ICTs permitting them to be competitive both in the Islamic Republic of Iran and abroad. NIOC plays the role of an ICP (with a plans to become an ASP) for all MOP subsidiaries in order to provide secure communications for all oil industry units. With more than 150 IT engineers and with a network centre connected to more than 300 access points in various parts of the country, it tries to run enterprise applications which improve communications and procedures within and between the various units in the upstream and downstream operations. It also plays the role of a consultant and provides management with information necessary for taking decisions. The ERP, e-commerce and other web-enabled applications are the elements of online activities of the producers of the Iranian crude oil, as well as of those of oil products and petrochemicals and their users.[35]

There is also an increasing South–South dimension in the oil companies' search for new oil. Sonatrach has been active in prospecting for oil in other developing countries such as Yemen. Being a major oil exporter, the Russian Federation actively encourages its companies to invest in upstream and downstream operations in other transition and developing economies. Major oil-importing developing countries such as China and India are increasingly participating in the search for oil in Africa. This is another dimension of South–South investments in the oil sector (see section on oil importers). All those national companies are competing quite actively with IOCs, proposing to host countries modern technological solutions on more competitive terms.

Finally, the benefits of a more effective use of ICTs in the oil sector should also spill over to other sectors of the economy in order to avoid the "Dutch disease" or, in other words, to avoid making other exports (especially manufactured goods) less competitive as a result of the windfall profits from the oil export sector and the appreciation of the national currency, which could hold back the diversification of the economy and even cause its de-industrialization. One way of countering the "Dutch disease" could be the dissemination in oil-exporting countries of the ICT-enabled efficiency gains, in particular improved corporate governance and organization, to the oil servicing sectors as well as other parts of the economy and especially to less competitive export and non-traded goods sectors. Such a spill over effect, together with flexible foreign exchange and monetary policies, could also keep prices and hence national currencies at competitive levels. It may also inter alia allow local oil services companies to be competitive while participating in bids and auctions of oil-producing companies seeking equipment, goods and services for their activities.

2. Oil-importing developing and transition economies

While major emerging economies can sustain the financial shock due to the increase in oil prices, thanks to their flexibility and quite diversified exports base, the majority of middle and small oil-importing countries are facing major terms-of-trade losses and related multiple economic challenges. In 2005, while net official development assistance (ODA) stood at $106 billion, the outflow from the developing countries on the account of higher oil prices increased by $130 billion. Already in the year 2000, at the time of a much lower oil price increase, UNCTAD proposed that IFIs activate compensatory financing facilities in order to smooth the terms-of-trade shock for oil-importing developing countries.[36] The magnitude of the external shock this time was much greater. Thus, between 2003 and 2005, owing to the increase in oil prices, real incomes in oil-importing countries contracted by 3.6 per cent, while for some low-income countries the loss was much greater, totalling up to 10 per cent of their income (World Bank, 2006).

Major developing net oil importers

As indicated at the beginning of chapter two major developing oil importers–China and India–are considered to be major competitors in the international oil markets and are thought to be among the driving forces behind the higher plateau of crude oil prices. Currently, around 60 per cent of Middle Eastern oil is flowing to Asia, including Japan, which is second to China in terms of absolute level of oil consumption (OPEC, 2004). In fact, China and India also have local oil production and their NOCs are moving fast up the ladder, catching up with IOCs as far as their corporate organization, technological sophistication and working methods are concerned.

The main Chinese NOC is the China Petroleum & Chemical Corporation, more than 50 per cent of whose shares are controlled by the Government. It showed an extremely impressive expansion of overall sales, both upstream and downstream, from around RMB 350 billion in 2002 to RMB 830 billion in 2005 (Sinopec Corp. 2005, p. 9). Its parent company, Sinopec Group, has developed major South–South oil investment projects including those in West and North Africa. It has been taking economic and political risks in acquiring international equity capital in crude oil production in various regions, and it is expected that the oil produced from those sources will increase quite soon from 3 million tons to 10 million tons yearly. As soon as the issue of economic and political risks has become a matter of less concern, these assets will be transferred to Sinopec Corp.

With regard to using the local and imported crude oil in an efficient way, Sinopec Corp. stressed the use of ICTs as crucial in the development of resource and supply chain optimization systems, especially in downstream operations. Thus, it established an integrated optimization model at headquarters, followed by a single refinery and multi-period enterprise model, a crude spots procurement optimization model, a process mechanism model, and an integrated refinery and chemical enterprise model. The company IT infrastructure is constructed around a major ERP system covering key information-intensive elements such as supply chain, electronic commerce, seismic data processing, oil reservoir description, production scheduling optimization, advances process control and, IC refuelling card. By the end of 2005, 41 branches of Sinopec Corp. were using the ERP.[37]

In India the two major NOCs, the Oil and Natural Gas Corporation Ltd (ONGC) and Oil India Ltd (OIL), dominate the county's oil sector. While the Government is the main shareholder in both, they are also strategic partners through cross-ownership – that is, they own a part of each other's shares. While OIL is the downstream giant of India, ONGC is the largest Indian player in upstream and transportation (pipelines). Through its subsidiary, Indian Oil Technologies Limited (ITL), and its R&D Centre, OIL is trying to pioneer oil technology development in India. It has upgraded such technologies and technical expertise in the refining and lubricant sector as fluid catalytic cracking (FCC), hydro processing, catalysis, residue upgradation, distillation, simulation and modelling, lube processing, crude oil evaluation, process optimization, material failure analysis and remaining life assessment.[38] At the same time ONGC has one of the main virtual reality interpretation facilities and also one of the largest ERP implementation facilities.[39]

Other oil importers

The small and medium-sized oil-importing developing countries have fewer possibilities to compensate for the increase in their oil bills through a corresponding increase in exports of goods and services, or accelerated economic growth, and are facing formidable challenges in adapting to the world of expensive oil. These countries include the overwhelming majority of least developed countries (LDCs). While the combined GDP of the 50 LDCs was around $260 billion in 2004 and could be a little higher for 2005 and 2006, the increased profits of oil majors or the-so-called five sisters represented around half of the overall value added produced by those countries.[40]

The main challenge for these oil importers is to find internal and external financial resources to finance the greatly inflated oil imports bill. They also face the need to improve the management of trading, transportation and distribution of oil products to consumers. Increased costs of acquisition of oil and oil products are in themselves a major deterrent and do not allow complacency about the costs related to oil distribution networks in those countries. However, to cut costs or diminish waste they also need upfront investments to replace the outdated technologies and storage capacities.

One of the main challenges for oil importers, and especially for small and medium-sized countries, is the development of a system of joint stockpiling and emergency sharing of oil. Stocks representing 30 days of imports are considered to be optimal. While in some countries Governments and the private sector stock only crude oil, in other countries it is a mix of crude oil and oil products. Moving oil storage from national to regional level makes the management of stocks a more complex task and by definition requires better organization of this framework. Since the regional framework represents a type of network, ICTs are the technologies that can ensure its efficient functioning provided that the established rules of the game do not face the risk of unilateral changes by individual members. Among developing countries this question has been discussed particularly in various Asian organizations and forums. However, the Asian countries are still at the stage of pledging to institute such an arrangement and have not yet started it (Shin, 2005).

Another major problem is the outdated nature of refining in many oil-importing developing countries. In the majority of cases the refining capacities are not using the modern cracking technologies, and the yield of light oil products out of imported crude oil is much lower than similar indicators for modern US and European refineries. While improving the existing oil products distribution network requires relatively incremental investments in ICTs to enable resource flow to be better tracked and losses to be diminished, the technological changes needed in refining and acquiring related modern ICTs would require considerably larger investments.

Meanwhile many oil-importing developing countries are trying to use imported crude oil and oil products more effectively and are building up stocks. In trying to meet such targets as better organization of purchasing, inbound logistics and distribution of oil products many of them are endeavouring to improve the capacity to manage such processes with more active use of ICTs. In countries with relatively well-organized oil trading companies the latter are in a position to rely on local or international vendors of hardware and software and relative simple variants of ERP to organize streamlined versions of purchasing, transportation and distribution of oil products.

However, the financial resources at the disposal of oil-importing developing countries are further diminished by the increase in oil prices, and the financial assistance provided by international financial organizations, bilateral donors and oil-exporting countries is lagging far behind the actual need of those countries. At the same time, awareness of the need to help developing oil importers to face the challenges of streamlining their oil distribution networks, inter alia through the more efficient use of ICTs, is increasing among various groups of donors as well as the oil companies that are trying to sell oil products to those countries.

F. Conclusions and policy recommendations

Traditional crude oil will probably continue to play a crucial role in the future world energy balance for at least several decades. In the more distant future crude oil will derive not only from traditional oilfields but also from other oil-containing energy sources. Also, oil products will be increasingly used in conjunction with biofuels and electricity. That presents policy-makers as well as industry participants and consumer groups with the major task of ensuring a secure supply and efficient use of oil in the paradigm of sustainable development models. In that respect, a key question that should be addressed primarily by the international petroleum industry is how to ensure optimal ways of supplying oil and its products, in particular by using the possibilities provided by ICTs.

Better use of ICTs and related technologies in the oil sector might provide an approach to addressing the current difficult situation regarding oil supply in world energy markets and to achieving a more efficient use of existing oil resources. While ICTs and related technologies should help to locate new oil-fields, with greater accuracy and hence more effective capital expenditure, the issue of more efficient oil extraction from existing fields is no less important. Consequently, the main stakeholders, including the shareholders of IOCs, should espouse a longer-term strategic approach, including increased R&D efforts in the oil sector and reinvesting larger revenues from hydrocarbons in better production modes and reserve indicators.

Avoiding potential deterioration and supply shocks can be achieved only within the framework of well-defined and coordinated policies and practices that include the use of ICTs as a tool for integrating and optimizing business processes in both upstream and downstream operations. The benefits of such an approach are especially apparent for those countries that are lagging behind in the use of technologies as a means of improving their energy situation. The most vulnerable group in that respect are the oil-importing developing countries that have no means of compensating for the increases in the cost of oil by switching to alternative energy sources or by introducing effective conservation measures. Thus, it is equally apparent that well-designed international energy cooperation efforts should clearly include financial and technological support measures for those countries.

To improve the use of ICTs and new technologies the NOCs of the main oil-exporting developing countries should continue investing in ICT related know-how and business processes. Inserting technology transfer clauses in production sharing or other arrangements with IOCs could also be a part of their strategies. At the same time the technology transfer clauses in various types of contracts with IOCs could be the main way of acquiring oil technologies, including those related to ICTs, especially in the case of the new wave of non-OPEC oil exporters from developing and transition economies. Another way to make sure that the IOCs use state-of-art ICTs and other technologies while exploiting oil-fields and developing related infrastructure is to include such requirements in the national oil regulatory framework and ensure that oil operators are fulfilling them. As a result, foreign operators will make the necessary investments in new ICTs and other oil-related technologies while extracting oil in those countries.

Another approach, which is quite well utilized by NOCs from mainly OPEC countries, is based on closer relations with oil service companies and oil technology and ICT-related vendors, and on closer ties with other oil industry consultants and experts. That makes it possible to set up competitive and integrated technology and ICT architecture within NOCs using means that are relatively independent of IOCs. The problem here is to compensate for the gaps in experience and adequate business processes within NOCs by more actively involving service and technology providers in following up the functioning of newly installed ICT and related technologies. At the same time more active cooperative arrangements for R&D with leading international companies and the involvement of experienced and in many cases retired oil engineers, technicians and corporate executives to help to use better those technologies could also be among the means of achieving a state of excellence in technology, business processes and human resources development.

At the same time oil-exporting countries' Governments may find that the reason for lagging behind is because NOCs, exploiting their special status, are not paying enough attention to the introduction of modern ICTs as a means of improving their corporate performance. To avoid such a situation, adequate regulatory and incentives mechanisms encouraging NOCs to participate more actively in, say downstream might be envisaged. For example, while Governments in many oil-exporting countries are the owners of oil wells, private capital investment, and hence competition, can be further promoted in downstream operations.

Similarly, possibilities for competition in purchasing and supplying oil products in both oil-exporting and oil-importing countries might lead local oil trading and distribution companies to streamline their corporate structures and use ICT more effectively. The issue of efficient use of transportation, storage and distribution networks in all countries, as well as refining in countries that do have such capacities, is becoming a major issue in improving the efficiency of the global oil supply chain. Further diversification of the oil sector in developing countries should take into account the most recent technological solutions in the oil-refining and petrochemicals industry which make it possible to enter as competitive participants in the higher-value-added levels of downstream operations both domestically and internationally.

Oil-importing developing countries that face severe financial problems in buying oil products need to receive financial and technical assistance in purchasing oil products and ensuring that they are transported, stored and distributed efficiently. To make that happen, there is an urgent need to change the focus from traditional IMF compensatory financing mechanisms to special new funds, for example to an enlarged Exogenous Shock Facility with active participation by various groups and types of donors. OPEC and other oil-exporting countries, as well as major oil companies, are in a position to provide considerable funding for such mechanisms. They should also consider playing a proactive role in defining the conditions attached to such a facility. Thus, better use of technologies, and especially ICTs, to streamline the distribution of oil and its products could be one of the recommendations while providing such a facility. In other words, one of the requirements while rendering financial assistance might be the use of part of that assistance to upgrade the ICT capabilities of oil refining and oil products distribution networks in oil-importing developing countries in order to achieve tangible results with regard to more efficient ways of supplying oil and its products to end users.

Such an approach should also be a part of national policies encouraging policy-makers and company executives in those countries to pay due attention to introducing corporate governance criteria that take into consideration the efficient use of ICTs in the distribution of oil products. However, this cannot be achieved unless international financing arrangements helping the most affected oil-importing countries are put in place. Considering better options for financing and using oil and its products should be an important responsibility of public and private decision makers in oil-importing countries. It should be also an important point for consideration by oil exporters, IFIs and the donor community at large.

References and bibliography

Ait Laoussine Nordine and Gault John (2004). Foreign investment and public goals. Paper presented at the 9th International Energy Forum 2004, 22-24 May, Amsterdam, Netherlands.

Bartels Andrew (2006). Trends 2006: Six economic shifts affecting IT. Forrester, March 15.

Bunte Jonas (2005). Analysis of the new IMF Exogenous Shocks Facility (ESF). Paper for erlassjahr.de dated 5 December.

http://www.erlassjahr.de/content/publikationen/dokumente/20051205_esf_analysis.pdf

CERA (2005). The oil industry growth challenge: Expanding production capacity. Testimony by Robert Esser to the US House of Representatives, 12 December.

CERA (2006). The Global Context. Testimony by Daniel Yergin to the US House of Representatives Committee on Energy and Commerce, 4 May.

EIA (2006). *International Energy Outlook 2006*.

Shin Eui-Soon (2005) Joint stockpiling and emerging sharing of oil: Update on the situations in the ROK and on arrangements for regional cooperation in Northeast Asia. Presentation at the Asian Energy Security Workshop, Sampson 13-16 May.

Franssen Herman (2005). The end of cheap oil: Cyclical or structural change in the global oil market? *Middle East Economic Survey,* 7 February.

Geyer Gerda (2003). E-marketplaces in the Energy Sector. Norwegian Trade Council.

Hill Fiona (2004). Oil, gas and Russia's revival. Foreign Policy Centre, London, September.

IEA (2000). India-a growing international oil and gas player, March, Paris.

IEA (2002). *World Energy Outlook 2002*, Paris.

IEA (2003). *World Energy Investment Outlook 2003*. Insights. Paris.

IEA (2005a). *World Energy Outlook 2005*. Paris.

IEA (2005b). Energy technologies at the cutting edge. Paris.

IMF (2004). Review of the compensatory financing facility. Prepared by the Policy Development and Review Department, 18 February.

IMF (2006a). Guidance note on the Exogenous Shocks Facility. Prepared by Policy Development and Review Department, 27 January.

IMF (2006b). Oil prices and global imbalances, Chapter II, *World Economic Outlook,* April.

Indjikian Rouben (1983). OPEC in the world capitalist economy, monograph (in Russian), International Relations Publishers, Moscow.

Jamieson Aileen (2006). Refiners to see strong returns near-term despite looming capacity build-up. *Oil and Gas Journal*, 13 March, pp. 52–56.

Jones Matthew (2003). E-business: The second generation. World Petroleum Congress 2nd Regional Meeting and Exhibition, held December 8-11, 2003 in Doha, Qatar.

http://www.world-petroleum.org/isc2004/File%20014/089-93.pdf

Langley Diane (2006). Shaping the industry's approach to intelligent energy. *Journal of Petroleum Technology,* Society of Petroleum Engineers, March.

Marcel Valérie and Mitchell John V (2006). "Oil titans: National oil companies in the Middle East", monograph, Chatham House/Brookings.

Miller William J, Sakaguchi Jeffrey B and Gess Mark A (2003). Transforming the petroleum supply chain: "Fulfilling the Promise". Accenture.

Moore Chuck (2005). Maximizing value in the petroleum supply chain. Petroleum Review, 1 March. http://www.aspentech.com/publication_files/Petroleum%20Review%20May2005%20Supply%20Chain.pdf

Moore Cynthia et al. (2005). Hype cycle for the oil and gas industry, 2005. Gartner Industry Research, 29 July.

OPEC (2004). *Annual Statistical Bulletin.* Vienna.

OPEC (2006). OPEC long-term strategy. Vienna. http://www.opec.org/library/Special%20Publications/pdf/OPECLTS.pdf

Pahladsingh Shanti (2005). E-marketplaces in the energy & fuels sector. eMarketServices, The Netherlands. http://www.emarketservices.com/upload/Reports/Report050407_Energy.pdf

Peterson R D, S Yawanarajah, D Neisch and S James (2006). Improving the quality and efficiency of subsurface workflows. Paper (SPE Paper 99482-MS) presented at the Intelligent Energy 2006 conference, held 11-13 April 2006 in Amsterdam, The Netherlands.

Rose David (2002). Trends in information technology costs and investment levels in the oil industry. Publication of Aupec Ltd, Aberdeen, UK.

Sampson Anthony (1975). *The Seven Sisters: The Great Oil Companies and the World They Made*, London, Hodder and Stoughton.

Sinopec Corp. (2005). China Petroleum & Chemical Corporation, Annual Report.

Skinner Robert (2006). World energy trends: Recent developments and their implications for Arab countries. Oxford Institute for Energy Studies, May.

UNCTAD (2003a). ICT and economic performance: Implications for developing countries. Chapter 2, *E-Commerce and Development Report 2003*, New York and Geneva.

UNCTAD (2003b). Marketing developing-country agricultural exports via the Internet. Chapter 6, *E-Commerce and Development Report 2003*, New York and Geneva.

UNDP, UNDESA and World Energy Council (2004). Energy Resources and Technological Options. Part IV, World Energy Assessment Overview, 2004 Update.

Wahlen Mona et al. (2005). Report on the consequences of large-scale adoption of integrated operation on the Norwegian shelf for employees in the petroleum industry and on the opportunitits for creating new jobs in Norway. SINTEF HiT Final Report, 1 December.

World Bank (2006). Prospects for the global economy. Chapter 1, *Global Development Finance 2006.*

Yergin Daniel (2006). Ensuring energy security. *Foreign Affairs,* March/April.

Notes

1. The terms petroleum and oil or crude oil have the same meaning and are used interchangeably.

2. See IEA, Oil Market Report, 12 May 2006, at *www.oilmarketreport.org*. One million barrels a day represent 50 million tons per year. At the same time 1 ton of crude oil is equal on average to 7.3 barrels, with higher indicators for light sorts of petroleum and lower ones for heavy crudes.

3. See *www.unctad.org/infocomm/francais/petrole/ecopol.htm*.

4. Oil and Gas Journal, 13 March 2006, p. 52.

5. IEA, Oil Market Report, 12 May 2006, p.15.

6. OPEC has 11 members: Algeria, Indonesia, the Islamic Republic of Iran, Iraq, Kuwait, The Libyan Arab Jamahiriya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela. Iraq is currently not subject to quotas discipline.

7. See *www.oilmarketreport.org*.

8. IEA, Oil Market Report, 14 March 2006, p. 15.

9. *The Economist*, 15 April 2006, p. 67.

10. Steady as she goes: Why the world is not about to run out of oil, *The Economist*, 22 April 2006. http://www.economist.com/finance/displaystory.cfm?story_id=6823506.

11. Such as upstream exploration and production operations, technical computing, downstream refining, marketing and retail.

12. Such as distributed computing, wide area networks and midrange computing.

13. What are smart fields?, *Digital Energy Journal*, April 2006.

14. Ibid.

15.. See http://www.aupec.com/

16. Ibid.

17. Ibid.

18.. See http://www.woodmacresearch.com/

19. Who is preparing the gasoline crisis? Argumenti I Fakti (in Russian), 19 April 2006.

20. http://www.nymex.com/energy_in_news.aspx?id=eincrudeprice.

21. Formerly International Petroleum Exchange -(IPE).

22. See http://www.nymex.com.

23. Interest rates and individual equity futures and options have the lion's share on the global derivatives markets.

24. Rebecca Holz, Trading volume: A remarkable start in 2006, *Futures Industry,* May/June 2006, pp. 10–13.

25. http://www.theice.com/market_data.jhtml.

26. http://www.nymex.com/hot_topics.aspx.

27. One does not see who is in the other part of the deal.

28. *Alexander's Gas and Oil Connection,* vol. 10, issue 21, 10 November 2005.

29. Types of crude oil around which are determined the international prices of other sorts of crude oil.

30. For more information on e-marketplaces for commodities see UNCTAD (2003b).

31. IOCs, NOCs, small and medium-sized independents in E&P, etc.

32. Independent refineries, small and medium-sized independents with a shortage in their own oil resources, IOCs, NOCs etc.

33. See www.rigzone.com.

34. *Oil and Gas Journal,* 6 March 2006 p. 28.

35. See http://www.nioc.com/computer_services/index.html.

36. UNCTAD urges "compensatory" funding for oil-importing developing countries, TAD/INF/PR/066 09/10/00. See http://www.unctad.org/Templates/Page.asp?intItemID=1528&lang=1.

37. See *http://english.sinopec.com.*

38. See *wwww.iocl.com*

39. See *www.ongcindia.com*

40. See *www.unctad.org*; *www.worldbank.org*