EXECUTIVE SUMMARY

Over the coming decades, the world will continue to rely heavily on large-scale supplies of oil and gas. According to demand projections from the IEA *World Energy Outlook* (WEO) Reference Scenario, the share of these two fuels in the world energy fuel mix will actually increase from around 57% in 2002 to some 60% in 2030, if energy policies worldwide do not change.

As a result, demand for oil and gas will expand by nearly 70% over these three decades. Even if governments took more vigorous steps to address environmental and energy-security concerns, as modelled in the IEA *World Energy Outlook*'s Alternative Scenario, worldwide demand for oil would be only 11% lower than under the IEA Reference Scenario's projections, and demand for gas only 10% lower. In addition, as output from the world's existing production sources inevitably declines, probably at a rate around 5% per year, this decline will need to be compensated with new supplies.

The hydrocarbon resources in place around the world are sufficiently abundant to sustain likely growth in the global energy system for the foreseeable future. But keeping pace with today's demand growth projections will oblige the hydrocarbon industry to take on a new, diverse set of business and technological challenges. This is largely because it will be more technically demanding to develop remaining world oil and gas resources and bring them to markets than was the case for previous output.

Ensuring the right conditions for sustained and accelerated technological progress in the oil and gas upstream sector will be a key factor for success in securing global security of supply for all countries.

The purpose of this book is to:

- Review future needs for technological advances to meet the challenges facing the hydrocarbon industry in the 21st century.
- Discuss embedded policy implications.
- Measure the impact that technological progress can be expected to have on tomorrow's hydrocarbon resources availability.

The big challenges for the future

Measured in units of oil equivalent, roughly 10 trillion barrels of conventional oil and gas are in place, and at least as much non-conventional oil and gas. Out of these 20 trillion barrels of oil equivalent (boe), 5 to 10 trillion can be considered technically, but not necessarily economically, recoverable, depending on recovery rates, technological progress and long-term price assumptions.

Proven reserves amount to about 2.2 trillion boe, which is not so far from the 1.5 trillion boe produced so far, over more than 100 years of exploitation. Indeed, 1.5 trillion boe is also a rough estimate of what needs to be produced over the next 25 years.

But the intensifying need to obtain supplies from more challenging conventional and non-conventional resources will impose very considerable demands on the sector's human, financial and intellectual capabilities. Conventional oil and gas resources will continue to dominate global oil and gas supply throughout the period to 2030. The existing base of either exploited or known reservoirs will provide the lion's share of future supply from conventional hydrocarbon. Steepening output decline curves, however, and the need to sustain economic field life through cost reductions and enhanced recovery methods, present major challenges in this context. Current worldwide average recovery rates for oil are roughly 35% and technological progress could substantially raise that percentage. In particular, increased use of CO_2 for enhanced oil recovery could simultaneously increase recovery factors and curb greenhouse gas emissions into the atmosphere. Gas recovery rates, on the other hand, average around 70% worldwide. As a consequence, enhancing recovery rates does not have the same significance for gas as it does for oil.

If future supplies of conventional oil and gas are to expand, it will also become necessary to obtain access to resources in more technologically demanding areas, such as:

- Deep and ultra-deep water.
- Deeply buried and more complex reservoirs.
- Arctic regions, where governments consider this desirable.
- The few remaining, remote, unexplored basins.
- Remaining prospects with smaller accumulations in known areas.

In terms of investment, projected requirements for natural gas supply will be close to those for oil over the next 30 years. Indeed, growth in demand for gas will outpace that for oil. Also, moving gas to frequently more distant markets is more costly than shipping oil. While the major calls for capital to mobilise oil stem essentially from exploration, production and refining, investment in gas supply will focus chiefly on transportation infrastructure to feed a fast growing market. New technology is needed to provide more cost-effective solutions; liquefied natural gas is one option that will play a large role if global markets are to be created and served.

Meanwhile, enhanced exploitation of substantial known resources of non-conventional oil and gas promises to produce much larger supplies of both fuels. Significant declines in the cost of extracting and producing these resources over the past two decades have already won them a sizeable share of the market. Boosting the relative fuel-mix shares of non-conventional oil and gas resources in future world energy supply will call for major investments in production and distribution capacity and for development and deployment of more cost-effective technologies. Government policies to encourage such investment can play an important role.

Given the broad span of challenges, expanding the global supply from both conventional and non-conventional resources will thus demand important advances in key technologies and the related science base to foster:

- Industry's technical capability to expand and meet projected needs.
- Further reductions in recovery costs.
- Successful handling of more challenging economics and greater investment risk.

Focus of the study

This study takes a detailed look at what kind of technological progress is required to underpin future oil and gas supply. The question is examined in terms of core technology, but also in terms of the role to be played by industry, scientific research, academia and governments in furthering technological progress in the industry.

The following technology areas are highlighted as central to ensuring future supplies.

- Improved ability to characterise reservoir heterogeneities and to image fluid movements, particularly in large carbonate reservoirs.
- Low-cost wells.
- A range of information technology-based, intelligent “e-field” systems allowing real-time management of reservoirs.
- A more streamlined, standardised, “assembly-line” approach to all operations in oil and gas fields.
- Renewed emphasis on better-performing enhanced oil recovery techniques, including the use of CO_2 to combine oil recovery with climate-change mitigation.
- Improving deepwater technologies to secure viability at a water depth of up to some 4 000 metres.
- Technologies for safe and environmentally sound operations in Arctic regions.
- Technologies for economical production of non-conventional resources, in particular heavy oils, bitumen, oil shales and non-conventional gas.
- Technologies to minimise the environmental footprint of all oil and gas operations.
- Technologies and actions to ease shipping bottlenecks.
- Technologies that reinforce the safety of installations.

Major ongoing industrial developments in each of these areas are explored and summarised.

Key conclusions and recommendations

The key problem is not the limit of geological resources. The overriding questions today revolve around the technologies, prices and policies that will make the world's vast resources economically recoverable and turn them into proven reserves.

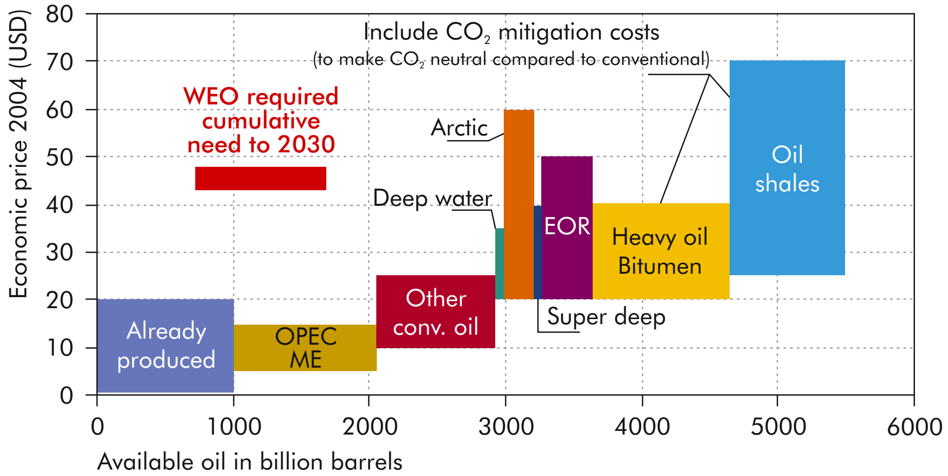
First, it will be necessary to mobilise some very large-scale investments, estimated at some USD 5 trillion over the coming three decades[1]. Then a widespread and determined R&D effort will be needed to bring in the technologies required. Industry clearly has the means, capabilities and incentives to perform the required R&D. Measures encouraging that effort would be beneficial. Public policy can play a key role in numerous ways, notably by focusing on the following:

- Providing a framework favourable to investment in new resources, including appropriate licensing, taxation, royalties and support for demonstration projects. Experience has shown that these can be instrumental in catalysing the technology learning required to make non-conventional resources competitive.
- Providing a policy climate that ensures continued active co-operation between technology developers in IEA countries and hydrocarbon resources holders in OPEC countries.
- Taking the lead in promoting technology development and facilitating investments that can reduce shipping bottlenecks.
- Actively participating in developing and facilitating the implementation of technologies that improve the safety of installations.
- Ensuring that CO_2 emissions reduction is given sufficient value to foster more widespread CO_2 enhanced oil recovery (EOR) and thus higher recovery rates.
- Supporting basic science in the biology and ecology of subsurface bacterial systems, since this can trigger breakthroughs in use of biotechnologies to enhance recovery or to transform heavy hydrocarbons.
- Vigilantly supporting industry's efforts to reduce its environmental footprint and thus to access resources in new areas.
- Continuing to spearhead science and technology advances linked to future exploitation of methane hydrate deposits, while ensuring strong industry participation. These resources are potentially very important to long-term supply but currently too far off for sole reliance on industry contributions.

From discussions with industry experts on the impact of future technologies, a shared perspective has emerged on the future availability of various types of resource, as a function of oil prices, but also taking into account likely technological progress. This perspective is expressed graphically in Figure ES.1. It shows the various oil prices (Brent) at which the exploitation of various volumes of different resources becomes an economical option. The cost of capture and storage of CO_2 produced during the extraction of non-conventional oils is taken into account.

1. Projected oil and gas investment requirements are not discussed at any length in this study. This figure of USD 5 trillion for worldwide upstream operations and transportation comes from analyses in the IEA World Energy Outlook 2004.

Figure ES.1 • *Oil cost curve, including technological progress: availability of oil resources as a function of economic price*



The x axis represents cumulative accessible oil. The y axis represents the price at which each type of resource becomes economical.

Source: IEA.

Currently, most companies base their investment decisions on a long-term price of USD 20 to USD 25 per barrel. The graph suggests that accepting a long-term price of, for example, USD 30/barrel would make an appreciable difference to the economic recoverability of large amounts of oil.

The analysis here focuses only on oil, for which extraction represents the dominant cost. Where gas is concerned, reserves are plentiful and the economics are dominated by the cost of transportation. Development of liquefied natural gas and other transportation technologies will determine the future supply equation.