The impact of technical progress on the oil and gas industry

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THE IMPACT OF TECHNICAL PROGRESS ON THE OIL AND GAS INDUSTRY

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Technical progress is a subject of interest primarily to engineers, and the study of such a subject or that of its impact on energy economics has rarely been of major concern to economists.

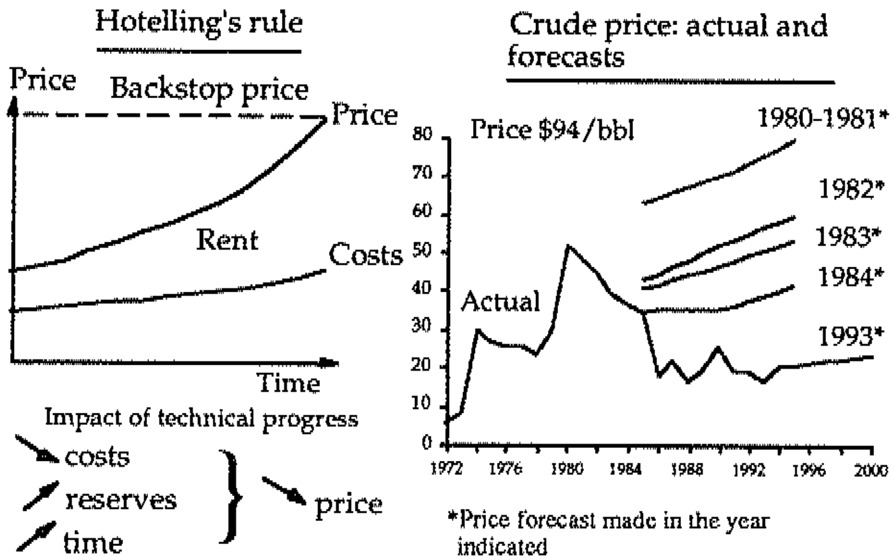
Nevertheless, in the oil and gas industry, most developments concerning supply and demand, and therefore prices, are in one way or another determined by technology.

We could even go so far as to say that the lack of consideration given to technical progress in oil price thinking has been the cause of past mistakes.

Generations of economists have believed, on the basis of Hotelling's rule, that the rent generated by the exploitation of a resource automatically increased year by year at a rate equivalent to the discount rate, so that the price of this resource ultimately equalled the cost of the substitute resource.

This belief has been applied rather hastily by energy economists and they collectively assumed that crude oil prices, over the medium or long term, would inevitably rise. But what is surprising, in retrospect, is to note that, whatever price has been taken as a starting point, virtually all past and current forecasts follow this rule.

HOTELLING'S RULE, CRUDE PRICE FORECASTS AND TECHNICAL PROGRESS



Now, although there is no question as to the soundness of the principle established by Hotelling, it proves difficult or even impossible to apply in practice, as does the transition from the concept of rent to that of price, because of the very fact of technical progress.

In the oil industry, technical progress makes it possible to reduce risks and cut exploration and production costs, to improve the rate of recovery and productivity, and it makes access to new resources and their effective production economically feasible. Overall, its role in lowering prices, although difficult to estimate precisely, can by no means be considered negligible.

In the refining and marketing sector, technical progress has resulted in a continual improvement of processes, products, plant and equipment, with a positive effect on performance and therefore on consumption. It also has an impact on environmental protection, and this is an area in which technology can turn a constraint into a challenge rich in potential downstream commercial opportunities.

Technology, however, is not the sole factor involved in progress. It cannot be separated from an analysis of the factors that dominate the oil and gas industry And this is why, before analysing its impact on the main sectors of the oil and gas industry, a brief outline of the oil and gas industry fundamentals for the comingtwenty years is necessary.

I - OIL AND GAS INDUSTRY FUNDAMENTALS IN THE YEAR 2000

1 - The petroleum scene

On the petroleum and energy scene, there are a number of developments that can be considered as certain.

PROJECTED WORLD DEMAND FOR ENERGY
(10^6 bbl/d)

	1980	1990	2000	2010	2020
OIL*	60	62	74	84	96
GAS	26	34	46	58	72
COAL	36	44	52	64	74
NUCLEAR	3	9	12	16	22
HYDROPOWER and OTHERS	9	11	16	18	22
TOTAL	134	160	200	240	286

*incl. non-energy uses

- The demand for energy worldwide will grow continually and steadily to keep pace with economic growth. All energy sources will contribute to this growth, particularly natural gas because of its intrinsic qualities and its availability, but also oil, used in a number of applications for which there is no alternative energy source.

  By 2010 the demand for hydrocarbons could have increased by between 35% and 45%, and represent around 60% of total world energy needs.

- Correlatively, dependence on Middle East oil will increase. This trend simply reflects a well known geological reality. The area accounts for two thirds of proven oil reserves and at the current rate of production they will last approximately another 100 years, compared to 20 years for the rest of the world and less than 10 years for most of the OECD countries. This increased dependence will nevertheless be partly offset by significant technical progress in exploration and production, which will have a decisive impact on the level and life time of production in a number of areas.

- The concern with environmental protection will also intensify. There has literally been an explosion in the last decade in the number of laws and regulations on the quality of air, water and soil. In western societies, in which many basic needs have already been satisfied, the demands of the electorate and of consumers have now become more qualitative in nature. This has been perceived at government level and by the oil industry, which has adopted a responsible attitude in the face of this major social phenomenon.

2 - The players

FUNDAMENTALS (1)

Petroleum scene →
- ↗ Demand for energy, oil, gas
- ↗ Dependence on Middle East
- ↗ Environmental pressure

Players →
- ↗ All face competition (Governments, operators, service companies, etc.)

Competitiveness and performance are priorities

The players, that is governments, oil companies, service companies, etc., are more than ever forced to accept the sole logic of the market, in which competition has become the key factor.

Where companies are concerned, political preoccupations and concern with volume have become less important and competitiveness and performance are the new priorities.

For governments, deregulation and privatisation are the order of the day.

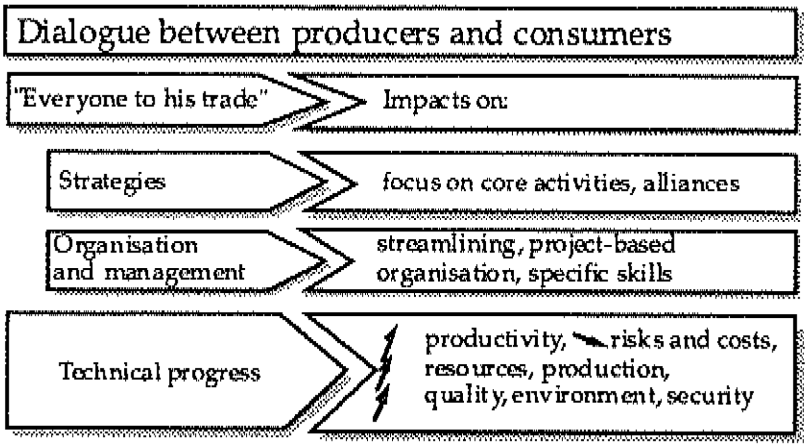
The shift is a fundamental one, and it may be ideological or merely pragmatic, depending on the context. But it would nevertheless be naive to jump to the conclusion that such aspects as purely political considerations, strategy and sheer determination are no longer relevant.

3 - Areas of progress

In this context, the areas where progress will be made in the oil and gas industry must be sought in technology, but equally in organisation and management methods and relations with suppliers and service companies. Nor should the political sphere be overlooked either.

FUNDAMENTALS (2)

Areas of progress



The aggressiveness of the 1970s and 1980s is gradually giving way to a desire for dialogue and even cooperation. The experience of the last twenty years clearly shows that producers and consumers are not only inter-dependent but that they can also create a win-win situation.

Another lesson to be learned from the past could be illustrated by the expression "everyone to his trade". This applies equally to business and to skills.

Past strategies based on the diversification into new businesses and the acquisition of non-oil assets have given way to a determination to focus on fundamental, core activities. Relations with suppliers and service companies are developing into genuine partnerships. At the same time, new alliances are taking shape.

Similarly, company structures are being simplified and streamlined, with a trend towards a focus on operational targets and a growing use of project teams. There is a strong emphasis on fostering initiative, independence and a sense of responsibility within the teams and the staff involved for the benefit of the company as a whole.

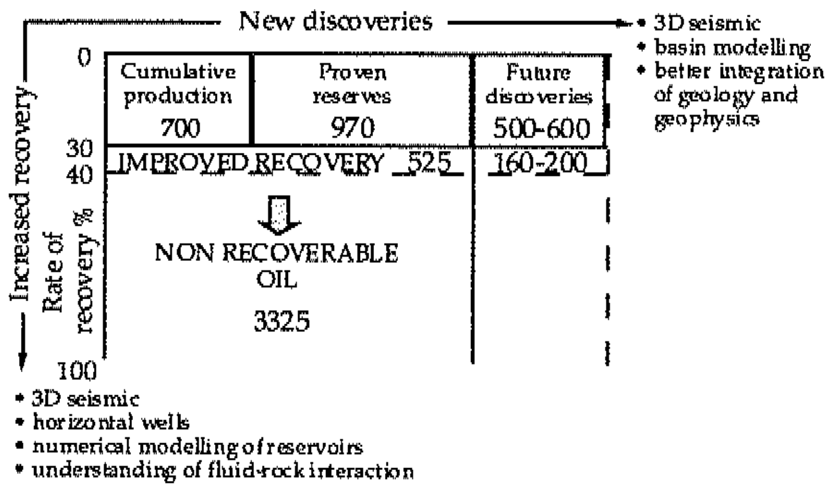
Compared with the speed of these changes, progress in technology has been slow but sure. However we must not overlook the fact that, in addition to its intrinsic value (that will be considered later), it is technical progress that makes these developments in structures and work methods possible.

II - TECHNICAL PROGRESS AND THE UPSTREAM OIL AND GAS SECTOR

Oil and gas exploration and production are undoubtedly one of the industrial sectors that benefit most from scientific and technological progress in a great variety of areas. But, paradoxically, the average success ratio in extensive exploration is currently only 1 out of 6 wildcats, and the recovery rate of oil from reservoirs is around 30%.

This basic statement sums up the major factors at stake in the upstream sector.

RESERVES AND TECHNICAL PROGRESS
(10^9 bbl at 1.1.1994)



In a context of moderate prices and increased competition, the rate of discovery has to be improved, as does the technical quality of discovery appraisal. Field development has to be optimised and recovery from and productivity of reservoirs has to be increased.

In the longer term, only continued major technical breakthroughs will enable reserves to be renewed and ensure a satisfactory crude oil supply-demand balance.

1 - The main challenges

The experience of the Institut Français du Pétrole serves as a basis for summing up the many challenges and determining the main priorities for the coming decade.

UPSTREAM TECHNOLOGICAL CHALLENGES

	OBJECTIVES	METHODS and TECHNIQUES
EXPLORATION	↘ risk ↗ wildcat success ratio from 1 out of 6 to 1 out of 3	• 3D seismic • basin modelling • integration of geology and geophysics
DRILLING	↘ cost of 30%	• automation • MWD
PRODUCTION	well productivity multiplied by 2 to 5	• horizontal wells • multiple completion • reservoir management techniques
OFFSHORE	↘ investment costs of 30 to 50%	• ↘ weight of platforms • new concepts • subsea production • multiphase flow

In the field of exploration and reservoir engineering, the main causes of failure are errors in analysis and structural imaging in more than half of the cases, insufficient knowledge of the quality and heterogeneities of reservoirs in a quarter of the cases, and faulty analysis of basin potential in the remainder.

Consequently, research and development efforts are concentrating on the following five priorities.

1) Research into the expulsion and migration of hydrocarbons and basin modelling.

2) Improving description of the external and internal structure of reservoirs, particularly by 3D seismics.

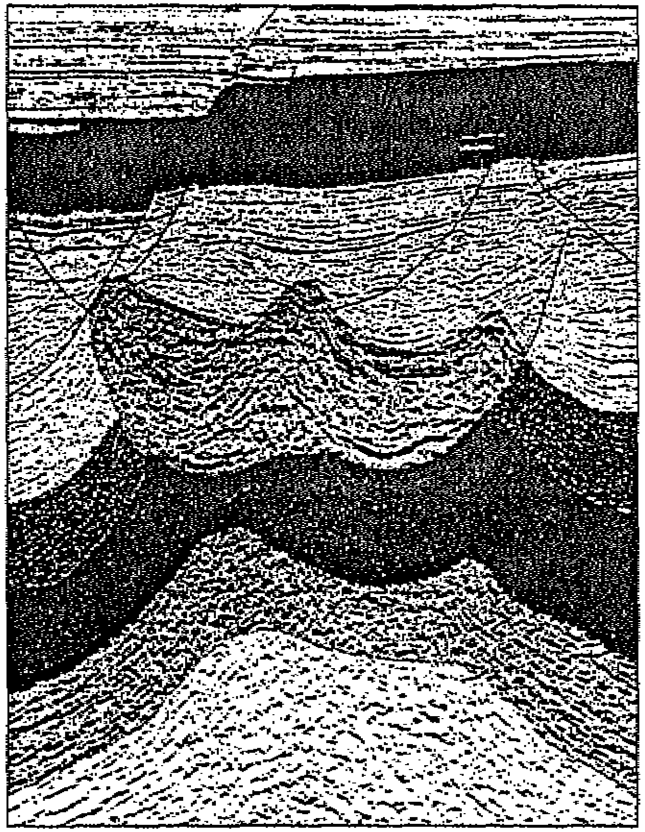
   This technique has been truly revolutionary in oil and gas exploration. As can be seen in the figure showing the results obtained by 2D and by 3D seismics, the latter radically improves seismic interpretation.

   With a slight increase in expenditure on geophysics, the overall cost of exploration-delineation-possible development is reduced. The advantages are significant, ranging from the detection of new structures to improved appraisal of known reservoirs.

2D and 3D SEISMIC

2D

3D



There is nevertheless still significant potential for progress in the future, be it in seismic data acquisition and processing or in its application to borehole surveys.

3) Integrated geosciences for reservoir characterisation, together with reinforced interaction between geology, geophysics and reservoir engineering.

4) Increased recovery and productivity of reservoirs by gas flooding and more particularly by horizontal wells. This technique increases costs by 20-40% compared to conventional drilling, but it improves well productivity by a factor of between 2 and 5.

   More efficient reservoir drainage also leads to improved rates of recovery. For instance, the western zone of the Troll field in the North Sea has 3.5 billion barrels of oil in place and the use of horizontal drilling has increased the rate of recovery from the initial estimate of 10% to 20%.

5) Protection of the soil and fresh water aquifers, which is a major concern today, and has led a number of companies to work in partnership - the European Rescopp programme is an example.

   In the drilling, development and production sectors, which largely involve service companies, applied research and technology are an important factor. In view of the huge capital expenditure and the operators' concern to ensure a return on investment with the price of the barrel in the region of $15, cost cutting and early production starts are priorities.

Consequently, research efforts are being directed along the following lines:

- development of slimhole drilling, which requires 6 times less site coverage than conventional drilling, resulting in savings of 20 to 35% , plus environmental spin-offs;

- improved production/footage ratio due to protection of producing layers against plugging, to well stimulation and to more complex well completion methods;

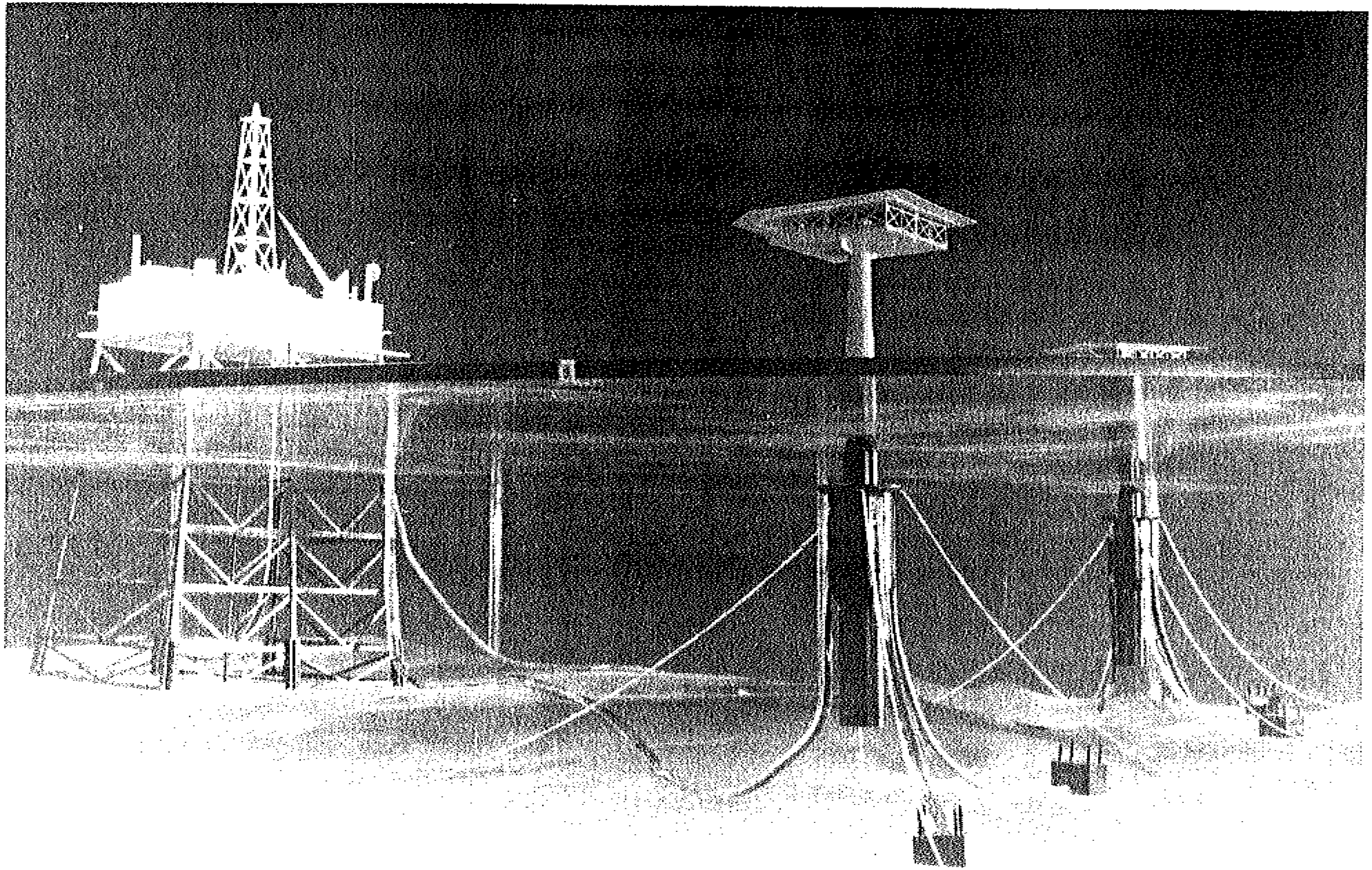
- optimisation of drilling through improvements in measurement while drilling and automation of some operations;

- reduction in development lead times due to offshore predrilling programmes, and in the number of platforms by the use of highly deviated wells with lateral departures of up to 6000 m;

- phased offshore development schemes designed to cater for reservoir evolution;

- development of concepts for improving production from deep offshore fields, for example by the use of flexible composite pipes. IFP's subsidiary Coflexip is the world leader in this area.

- reduction in the size and consequently in the weight and cost of offshore platforms;



FLOATING SUPPORT and MULTIPHASE PUMP

- subsea production combined with multiphase flow transportation systems, applicable in the case of fields located not more than 50 km from the processing station;

- improved safety due to quality control during platform construction, and to the use of non-normally-manned platforms and remote monitoring;

- improved environmental protection by drilling mud waste control and ultimately zero discharge.

2 - The impact on the oil and gas industry

The progress already accomplished and anticipated in the coming years will enable companies to increase their reserves and their level of production, to reduce risks, lead times and costs, and to improve the return on their investments, the safety of operations and their effect on the environment.

The outlook for both intensive and extensive exploration has been revolutionised by the development of new techniques and concepts that hint at a potential success ratio of 1 out of 3, which would reduce the risk incurred by half. Similarly, average recovery rates of 35 to 40% appear feasible with the range of technologies that exist or are being developed.

Investment and production costs and development lead times are continually decreasing. Studies carried out on fields developed at the end of the 1980s have pointed to the improvements that could be made on the technical level and on the safety level with currently proven techniques.

IMPACT OF TECHNOLOGICAL PROGRESS

Example of offshore field development

North Sea – water depth 130 m – 200 M bbl

	1994/1986	Main techniques
Investment	- 25%	• Highly deviated wells, horizontal drain holes or multidrain holes • Tender-assisted drilling • Lift-installed jackets • Integrated decks • Predrilling on template • Subsea production
Operating costs	- 10%	
Total cost	- 20%	
Production lead time	gain of 6 months	
Rate of recovery	+ 5 to 10% (*)	

(*) compared with 1986

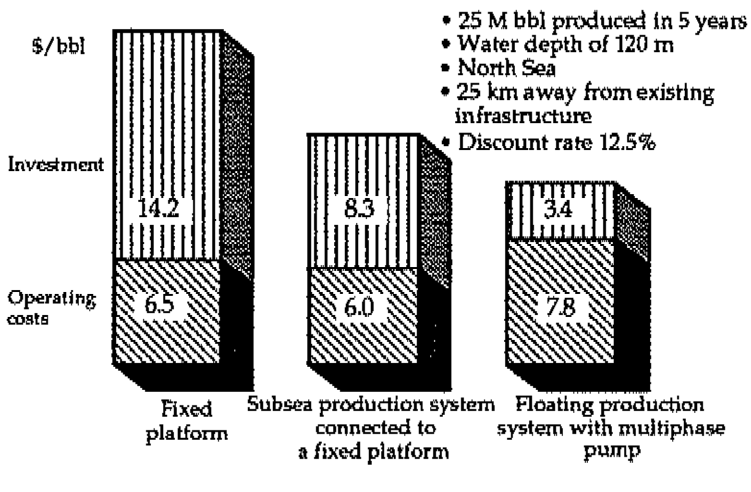
Overall, these studies point to:

- a reduction in the number of wells through better collection of data for improved reservoir description, and horizontal or multidrain holes;
- earlier production starts due to predrilling;
- substitution of operating for capital costs, by hiring equipment for limited periods as in the case of tender assisted drilling;
- reduction in the weight of offshore structures;
- increased safety of personnel and installations with the same capital investment;

If we take a North Sea field with recoverable reserves of 200 million barrels, the overall saving could be put at 20%. But, even more importantly, the reduction in investment, partly offset by increased operating costs, together with an earlier production start, restricts the financial exposure of the project and considerably improves its profitability.

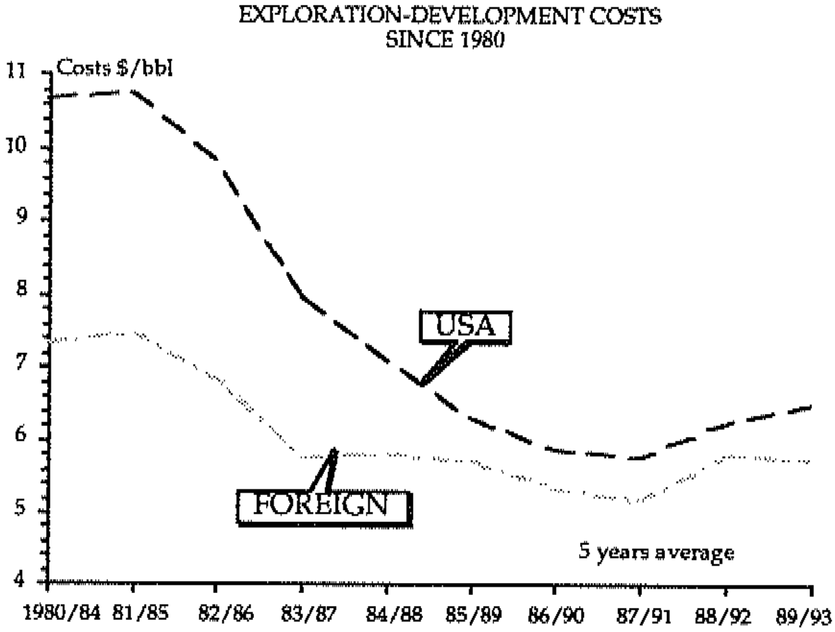
Furthermore, new zones at greater water depths are becoming more attractive. Offshore production at depths of over 200 m has increased from 5 million tons in 1985 to more than 50 million tons per year today.

COST OF DEVELOPING A MARGINAL FIELD



Lastly, new concepts combining subsea well heads with floating light production systems connected by flexible pipelines are making possible the economic development of marginal fields located in mature zones such as the Gulf of Mexico or the North Sea.

Here again, there is an impressive potential for cost cutting, such as reducing investment by increasing operating costs, the latter having much less effect on the profitability of the project.



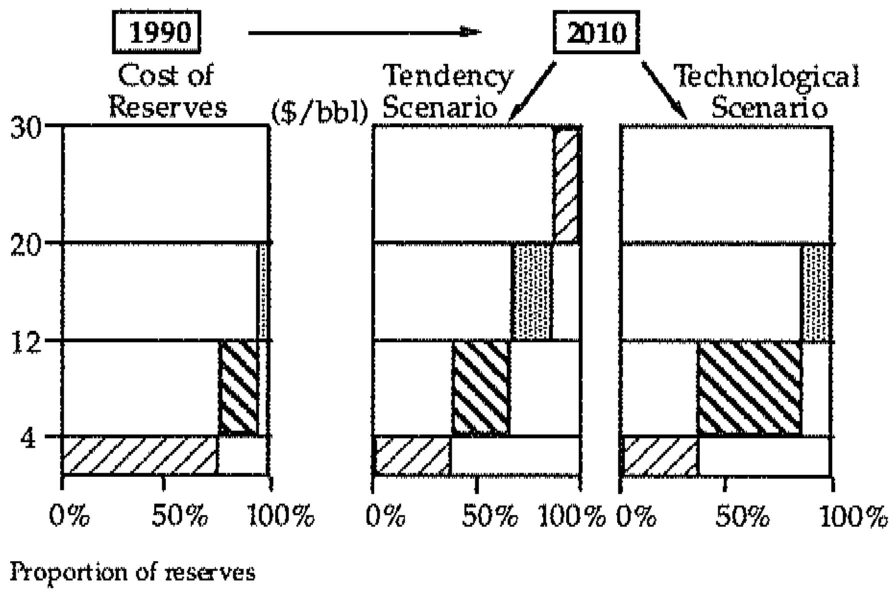
Another important development results from the behaviour of the players. Oil companies are making more and more use of service companies for drilling and surface equipment. Technological knowhow therefore spreads rapidly, through the association of different companies working on permits.

Companies are also concerned with maintaining a diversified services and equipment sector and avoiding any tendency towards a monopoly, while developing fruitful partnerships.

At the same time they are concentrating on what amounts to the fundamental knowhow of an operator, such as selecting a permit, discovering a field, appraising it and optimising its development.

The pace of technological breakthroughs has widened the gap between western companies and the state companies of the producing countries. The best way of bridging that gap would undoubtedly be the gradual return of the western companies to those countries with a high oil and gas production potential, i.e. to move back towards an integrated petroleum industry. The evolution of the political climate would seem to indicate that there is a good chance for some real progress in this respect.

IMPACT OF A TECHNOLOGICAL PROGRESS POLICY
ON PROVEN OIL RESERVES



In 1986 the Institut Français du Pétrole took the risk of estimating the impact of a concerted worldwide strategy with regard to upstream technology, and crude prices and supply in particular. The conclusions remain as valid as ever for the year 2010: the best way of satisfying the increasing world demand for oil is to invest in intelligence and technology.

III -TECHNICAL PROGRESS AND THE DOWNSTREAM OIL AND GAS SECTOR

The increasing demand for oil, mainly on the Pacific rim, the growing concern with environmental protection and product quality and the changing pattern of consumption, all imply considerable investment for the refining industry. The latter is having to face the growing uncertainty of markets and rapid fluctuations in margins and prices. In such a context the flexibility of refining schemes - the prerequisite for optimised operations and corporate profitability - is becoming the principal concern. Technology has to make a major contribution to that and, at the same time, to reducing capital investment and operating costs.

The natural gas industry, on the other hand, is having to face continually expanding markets and is becoming further and further removed from production zones. The total cost of intercontinental shipment in LNG form (liquefaction, transportation and regasification) is 10 to 15 times higher than that of oil. The major challenge therefore consists in reducing these costs so as to guarantee the viability of future gas development projects.

1 - The technological challenges

Unlike the upstream sector, genuine breakthroughs in refining technology are rare. The technical solutions required within the next 5 to 10 years are already available. However they are generally capital-intensive with high operating costs and energy consumption. This is why, in most cases, technical progress will take the form of improvements, even if new technology or concepts prove necessary in the longer term and in specific cases.

TECHNICAL TRENDS IN REFINING

	Technical routes	Impact
▶ Gasoline	• Ethers and oxygenated compounds • Selective oligomerisation • Aliphatic alkylation	. ↗ octane number . safety, environment
▶ Gas oil	• New hydrodesulphurisation catalysts	↘ operating conditions ↘ size of reactors
	• New components and additives	↘ NOx and particulate emissions ↗ cetane number, yield
▶ Conversion of heavy fuel oil	• New catalysts	↘ pressure, temperature ↗ selectivity
	• Technology, materials, pretreating	. improved processes . cracking of heavier feeds . integration with downstream processes

With regard to conversion, for both mature processes such as catalytic cracking or hydrocracking, and the deep conversion processes currently being developed, the major trends are the following:

- Improvement of existing catalysts or development of new catalysts designed either to simplify operating conditions and therefore to reduce investments and costs with the same end result, or to improve cracking severity and therefore product quality.

- Advances in materials and in technology allowing the optimisation of processes or improvements to reactors and fired heaters.

- The development of new, more severe pretreating processes for cracking heavier feeds. At the same time, specific research will be devoted to the incorporation of conversion into downstream processes.

Improved product quality and environmental protection are now the goals of research and development in the refining sector. Research at the Institut Français du Pétrole focuses on:

- improving the conventional reforming and isomerization processes;

- developing effective processes for the production of C7 ethers from olefins produced by catalytic cracking, together with the appropriate catalysts;

- aliphatic alkylation on solid supported catalysts to avoid any release or use of dangerous reagents;

- selective oligomerization of light olefins;

- improvement of hydrodesulphurization catalysts to lower the severity of operating conditions and reduce the size of reactors and consequently investment and costs;

- production of high quality gas oil cuts from cat cracked olefins;

- increasing the cetane number of naphthenic gas oils.

Further, research into high quality synthetic components and additives, together with basic research in a number of areas, will make a decisive contribution in the long term.

Natural gas technology is undergoing basically the same gradual developments as refining technology.

NATURAL GAS - TECHNICAL TRENDS

	Technical routes	Impact
LNG	↗ size of equipment plate fin exchangers cryogenic liquid expanders modular units	↘ investments ↘ own-consumption
Treatment processes	automation separation processes integration with upstream and downstream operations	↘ costs ↗ environment upgrading of co-products ↗ overall savings
Gas pipelines	materials turbines standardisation	↗ quality ↘ cost ↘ consumption ↘ cost
Chemical conversion	processes catalysts	↘ cost ↗ performance
Underground storage	seismic surveys modelling	↗ profitability

These developments will take place in five main directions:

1) Reduction in the cost of LNG chains, mainly through an increase in the size of equipment and economies of scale.

   Thanks to the techniques currently available for drivers, compressors, cryogenic heat exchangers, cryogenic liquid expanders, and modular construction concepts, self-consumption can be reduced from 12% to 6-8%, and investment costs by about 20%.

2) The development of innovative treatment processes, with special emphasis on raw gases containing large amounts of contaminants.

3) Technological progress in transcontinental gas pipelines with improvements regarding the steels used, energy savings and standardisation of equipment.

4) Chemical conversion of natural gas into liquid products and very high-quality components for motor fuels and lubricants.

5) Optimisation of underground storage techniques through new seismic methods or the development of modelling methods.

2 - The impact on the oil and gas industry

Market trends and environmental constraints are gradually increasing the sophistication and the costs of refining operations.

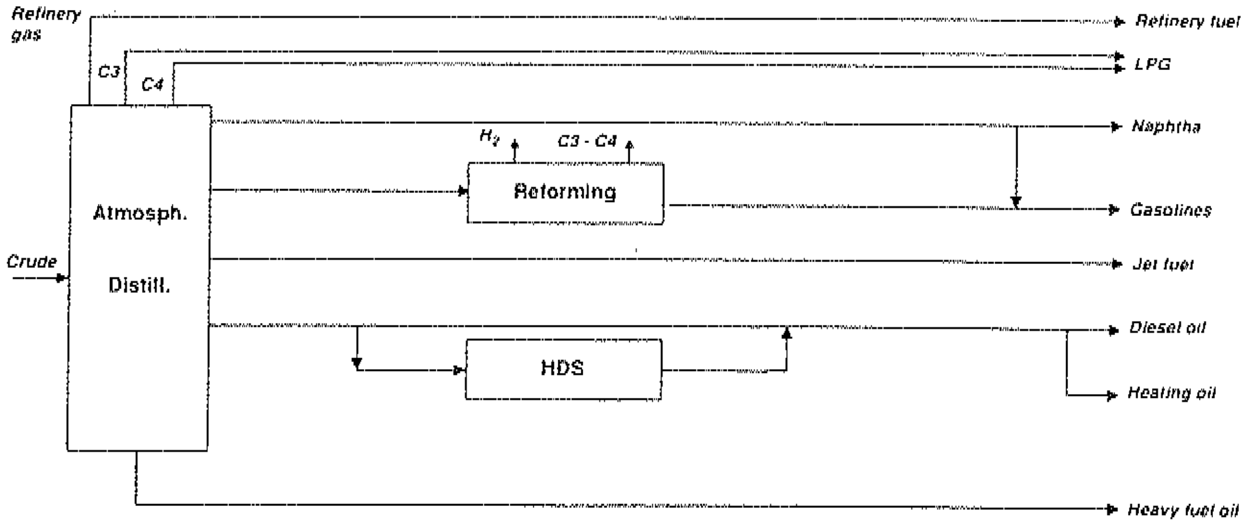
Technology is of vital importance. It enables refiners to meet new demands, or even to anticipate them or to encourage their development, under satisfactory conditions with respect to costs and, more importantly, to margins.

It allows greater flexibility, and in particular it limits the risk of financial exposure. Technical progress is effectively constant and steady, and applies first and foremost to existing plant and equipment.

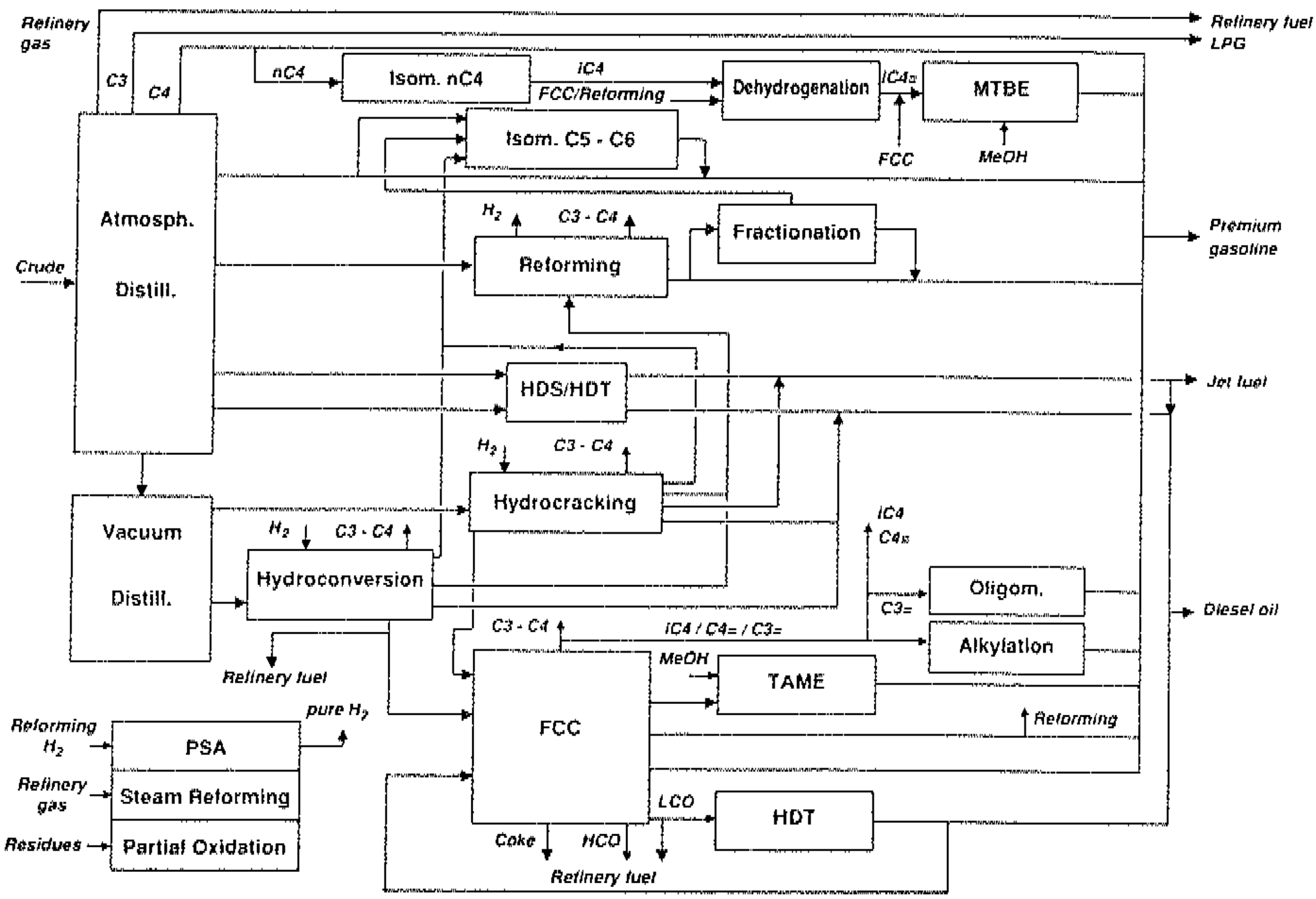
As in the fable by Lafontaine about the oak tree and the reed, technology provides the refining industry, i.e. the reed, with the necessary flexibility, year by year, so that it can adapt to market trends while minimising the capital investment required. We only have to look at the change in the European refining industry, which has been faced for the last 15 years with a structural decrease in the demand for heavy fuel oil.

The deep conversion of the early 1980s, i.e. the oak tree, was synonymous with colossal investment and costs and has not withstood the vicissitudes of time. On the other hand, the continuous improvements to processes, equipment and catalysts made possible by technological progress, and the involvement of personnel throughout the industry, have constituted a genuine achievement, since the European refining industry has fully succeeded in adapting to the 55% decrease in demand for heavy fuel oil in the space of a decade.

REFINING YESTERDAY



AND TOMORROW



Nevertheless, researchers and the industry itself sometimes feel that progress is too slow. A glance at the typical refining scheme for tomorrow compared with that in use not so long ago should suffice to prove the contrary.

The players are not unaffected by these phenomena. The combination of inadequate margins, the saving grace of technology and an often undreamed of degree of flexibility, led a company director to say "it is cheaper to inflict sleepless nights on my refinery manager than to put my hand in my pocket for the investment he asks for".

Last but not least, with the importance attached to quality and the priority given to the environment, the image of petroleum products and of oil companies is being upgraded in the eyes of the public. What better guarantee could there be for the future of the industry?

For natural gas, now the darling of the environmentalists, things are less complicated. Technology is the key to the development of long distance transportation and therefore to the future growth of consumption. In the longer term, with significant scientific and technological breakthroughs, a potentially great future could lie ahead for chemical conversion and the production of high quality synthesis fuels, and even stronger ties between the two great hydrocarbon industries.

CONCLUSION

It is tempting to look on technical progress as a paragon of virtues. In the case of the oil and gas industry, it creates reserves and supplies at acceptable costs, provides quality products and safeguards the environment. It is essential for our welfare.

This century has nevertheless taught us that Mr Hyde maybe lurking behind Dr Jekyll. To ensure against this risk, research should be continually submitted to the test of experience and the market should be the final judge.

The human role is also essential. Training at all stages throughout a career and new management methods reveal talents and a sense of responsibility that will always prove vital.

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