Future Research Directions in the Oil and Gas Industries

Dr. François Kalaydjian

Deputy Director for Sustainable Development,
Institut Français du Pétrole (IFP), Rueil-Malmaison, F-92500, France
francois.kalaydjian@ifp.fr

1. Introduction

To cope with a rapidly growing energy demand as forecasted for the next 25 years and answer to understandable societal aspirations to a sustainable development, the oil & gas and motor industries must prioritize the following goals:

- Ensure the security of energy supplies at an affordable cost for the greatest number
- Reduce the environmental impact of oil & gas development, production and consumption

In sum, these industries will have to make hydrocarbons available and "clean" for consumption. With this in mind, IFP has identified five major challenges:

- Renew and increase world oil & gas reserves
- Develop clean, high-efficiency refining processes to produce motor fuels and petrochemical bases. Make the most of each barrel of oil which will be produced, thus optimizing the use of hydrocarbon resources
- Diversify energy sources, especially for production of motor fuel and hydrogen on long term
- Reduce vehicle emissions and consumption
- Reduce CO_2 emissions, a key societal issue. Capture and storage technologies may contribute to solve this challenge

This talk will focus on the first two issues.

2. Key Features

2.1 Increasing and renewing oil and gas reserves

The challenge to "increase and renew oil & gas reserves" breaks down into the following points:

- Boost the exploration success rate
- Raise the recovery factor from 30% to 60%
- Boost the productivity to meet an ever increasing demand
- Develop high technology to gain access to hard-to-develop oil accumulations such as deeply buried or ultra deep offshore reservoirs as well as heavy and extra-heavy crude oils
- Promote the development of natural gas

Increasing the exploration performance especially in deeply buried horizons will require an improved 3-D seismic imaging involving an efficient elimination of multiple reflections and improved time to depth conversion algorithms. One key component will be then the integration of geophysics with geology by constraining the geological models with seismic data and thus better assessing the hydrocarbon distribution and quality at the basin scale.

Increasing the recovery from green fields as well as mature reservoirs will key to increase the global recoverable reserves. This will imply both adapted reservoir management and efficient EOR/IOR processes. Bringing the recovery factor from its current value of 30% up to 60% will contribute to augment the recoverable reserves by hundreds of billions of barrels.

Achieving this tremendous challenge will require to develop new workflows connecting a variety of approaches. This will start with a better reservoir characterization in order to minimize the uncertainties.

In that respect reservoir monitoring, e.g. data acquired while producing the reservoir (such as 4-D seismics) will help developing a more efficient management by integrating these data in real time and periodically updating the geological model. This will help identifying which kind, in which part of reservoir and at which cost it is important to acquire data for reducing the risks, provide much accurate production forecasts and result finally in a more economic and efficient production. Another component will be of course the possibility of performing simulations on even more detailed grids that will allow to better account for heterogeneities and maximize thus the recovery.

Increasing the efficiency of EOR/IOR processes will require to improve the modeling of the physical mechanisms involved (as this is the case for CO_2 flooding, thermal recovery of heavy oils, or wettability effects for water flooding fractured carbonate reservoirs) develop appropriate up-scaling methods to implement the physical ruling laws into the reservoir model, be able to offer an efficient numerical modeling coupling geomechanical, geochemical effects with fluid flow phenomena.

Finally, in order to take advantage of scale effects and optimize the economics, it will be desirable to connect the production of reservoirs belonging to the same petroleum system. This will demand to integrate on one hand the reservoirs to shared surface facilities and on the other hand basin and reservoir models to get a consistent and optimized production strategy.

Securing reserves is a must but will be not enough to be able to meet an ever increasing oil demand in the years to come. One major challenge will be to maximize the overall productivity of a field to produce the hydrocarbons at the appropriate rate. This represents a real challenge as the oil and gas to produce will become more challenging due to higher viscosities, higher concentration in asphaltenes, or higher concentrations in CO_2 or H2S while the quality of the reservoirs will get poorer. Again this will require to develop appropriate technologies for enhancing the productivity.

2.2 Develop clean, high-efficiency refining processes

The development of clean and high-efficiency refining and petrochemical processes would require two complementary approaches. The first one is to better integrate the production with the refining processes in order to favor the export of high quality products and minimize the carbon footprint of the transportation. An illustration of such a system is given by the refining on site of heavy oils presenting a high sulfur content. Another advantage of such an integrated process is to improve the overall economics by for instance reinjecting the CO_2 in a nearby reservoir and increase the production through CO_2 EOR process and promote the use of hydrogen.

The second approach is to improve the different components of the refining value chain. To this end it will be necessary to optimize the production of motor fuels and petrochemical bases (per barrel of oil produced) while reducing the environmental impact of refining operations. Processes will have thus to be "intensified". Advanced processes, use of nanotechnologies, advanced materials will be some of the ingredients that will be key to meet the success in that domain.

To initiate this type of change, new process technologies must be developed. They should include multifunctional reactors, reactive distillation and exchanger reactors as well as structured reactors, which promote heat and substance exchange. The process intensification approach also requires the development of microtechnologies (e.g. microreactors and microexchangers).

Appropriate real-time monitoring strategies must also be conceived to accompany these new technologies. High-performance online analysis methods and microsensors for micro units are two examples.

Another way of augmenting refinery process efficiency is to boost performance for the materials used: catalysts and adsorbents. Molecular modeling and experimentation with high-throughput technology, now under development, are used to identify compounds thought to be the most active and evaluate micro-quantities thereof. Furthermore, recent advances in nanotechnologies make it possible to verify/monitor/control the structure, texture and functionalization of catalysts and adsorbents, and therefore to improve their efficiency.

Finally, waste management is a key issue. One avenue of progress will be to eliminate toxic solvents (e.g., aromatics) and replace them with supercritical fluids characterized by superior solvent properties or with ionic solvents.

3. Conclusions

Shaping the energy world for the year 2030 requires to develop as early as possible new industrial processes. Research is already active to answer the two main challenges which relate to increasing the oil and gas reserves and reducing the carbon footprint of refining processes.

Research directions are numerous and complementary. For challenging the reserves they involve the development of new and efficient workflows integrating various disciplines such as geology, geophysics, reservoir engineering whereas regarding the development of clean and efficient refining processes it seems necessary to better integrate production and petroleum engineering.

This will demand to develop new products, new software packages, to take advantage of the progress made in information technology or nanotechnologies.

By doing so, the exploitation of the oil and gas reservoirs will be performed in a more efficient and timely manner leading to increase both the daily production and the ultimate recovery. This will contribute to ensure a continuous access to energy and reduce the environmental footprint of the oil and gas industry.

This will demand also to attract and mobilize the right people to develop those new research avenues. This will imply to develop from now on appropriate graduate education and training to reach those so challenging objectives.

4. References and Bibliography

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Speaker’s Biography

Dr. Francois Kalaydjian holds an Engineering degree from the School of Mines and a Ph.D. in Physics from the University of Bordeaux, France.

He has been with IFP since 1988, starting as a Research Engineer in Petrophysics in the Reservoir Engineering Research Unit. He became the Director of this Unit in 1997, and then Deputy Director of Exploration and Reservoir Engineering in 2002. He then became Deputy Director for Sustainable Development in 2005, being mainly involved in the development of CO_2 capture and sequestration related activities.

Francois Kalaydjian is a member of several societies such as the Society of Petroleum Engineers, the Society of Core Analysts, and the European Association of Geoscientists and Engineers for which he has served as a member of organizing committees for a number international forums and conferences. He is acting as the Vice President of the French Association of Petroleum Professionals (AFTP) and is on the Editorial Board of the International Journal of Greenhouse Gas Control.

He has authored more than 10 patents and 60 scientific and technical papers in the domain of petrophysics and reservoir engineering.