THE DEWHURST LECTURE
Confidence in People and Technology

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Dear friends and esteemed colleagues,

Here in Calgary, it is my privilege to deliver this address in the memory of Thomas Dewhurst, founder of the World Petroleum Congress, an event that, for decades, has regularly brought us together. This year, it is a special privilege and honor, because the 16th World Petroleum Congress will be the last of a century dominated by oil just as the 19th was dominated by coal.

Before turning our attention to the upcoming decades, let us take a moment to consider the past hundred years, a period of tremendous expansion for our industry. What forces drove this boom? Random chance and necessity, to speak like a biologist? Possibly. Market forces and the power of money, use today's terms? Probably. People and technology? Certainly. Throughout this century, our industry has shown remarkable adaptability, thereby proving that it is alive and well. Its ability to attract the huge amounts of capital needed to supply oil to a steadily growing market attests to its status as a strategic economic sector. However, this could be said about many other business activities as well. The great oil adventure went further, involving talented men and women fascinated by the oil business who could take advantage of the extraordinary tools offered by science and technology.

They deserve credit, because they glimpsed the immense possibilities lying ahead in a landscape illuminated by the fleeting sweep of the beacon of science. Back in their day, our predecessors used technology to pave the way for a brilliant future, and they are entitled to feel proud. Today, we look back and admire that brilliance. Yet their most valuable legacy may be the ability to reconcile the human and technological dimensions. This legacy can help us decipher our own future, which is uncertain by definition.

"Predicting the future is a hopeless, thankless task, with ridicule to begin with and, all too often, scorn to end with."[1]

These rather pessimistic words by the science-fiction writer Isaac Asimov apply perfectly to the oil and gas industry at large. How many doomsday forecasts have been made about oil and gas reserves, or about the impact of discovery and development costs on world economies or, more prosaically, about the price per barrel, only to be subsequently disproved?

In 1885, the State Geologist of Pennsylvania declared that the extraordinary oil boom was a transient phenomenon and that the present generation would witness its rapid demise[2].

That same year, John Archbold, one of the senior executives at Standard Oil, having been told by technical staff that the chances of discovering a new giant field were about one in a hundred, announced that he was ready to drink every gallon of oil produced west of the Mississippi[3] !

In 1919, an article predicted the early depletion of reserves in the United States. The author pointed out that the country had produced nearly 4.2 billion barrels of oil since the historic well at Oil Creek was drilled by "Colonel" Drake in 1859, and that no more than 7 billion additional barrels could be produced. He went on to say that there was no point in counting on Mexico, whose output would definitely top out at about half a million barrels per day, and that the only ray of hope for the long term lay in the tremendous

reserves contained in the oil shales of Utah, Colorado and Wyoming.

We are all familiar with the current production figures for the United States and Mexico. Furthermore, there is decreasing interest today in largescale oil shale development.

Many of us remember another era - the price shocks of 1973 and 1979, which gave rise to equally gloomy forecasts. Many experts believed that the money supply generated by the sharp increase in oil prices would cause substantial recycling difficulties in the medium term, which could then lead to a collapse of the international monetary system. Nothing like that happened. Inflation rapidly eroded the purchasing power of the petrodollar, whose real value merely decreased.

As for the subject of erroneous barrel price forecasts, it is by far too trivial to dwell on at length. Nevertheless, to illustrate and perhaps elaborate on this point, we might go back to the late nineteen-seventies. The price of the barrel was in the neighborhood of $30 and many thought it would reach $70 within fifteen years.

This impression reassured oil company executives, who questioned the economic viability of activity in difficult offshore regions, such as those of the North Sea, where the first major discoveries had just been reported. Consequently, they boosted capital outlay for this new sector of the industry. If, at the time, a forecaster had taken another tack from his peers and predicted the crude price trends that would actually occur, and if the industry had believed this prediction, then the fate of the offshore oil sector, not to mention the deep offshore, would have been completely different. Perhaps these new sources of supply would have remained unexplored, in which case there would have been greater dependency on OPEC countries and prices would have shot up to the heights predicted by the other forecasters.

The offshore industry should not make fun of errors made by forecasters, but crown the latter with laurels for making its existence possible.

Of course, this scenario remains extremely hypothetical. The gods, in their great wisdom, have placed a curse on those with the gift of prophecy, so that nobody ever believes them.

Does it follow, then, that nothing can be predicted in this field, apart from price stability? Maybe so. After all, forecasting any scenario will immediately send the pendulum swinging in the opposite direction and reduce the chances of its occurrence. A prediction of high prices will encourage capital investment in exploration and production activity and boost supply, which in turn causes prices to fall. A prediction of low prices will discourage capital outlay and eventually bring supply down, thereby triggering higher prices.

What a marvelous illustration of what Lewis Carroll described in *Alice in Wonderland.*

Apart from this perverse tendency inherent to oil price forecasting, why do forecasts often turn out wrong? It's because the forecasting process is incapable of accounting for the impact made by scientific and technological progress. Let's take an example outside the oil industry. At the end of the 19th century, an English journalist wrote that the number of horses needed to provide transport in London was increasing so fast that the city would be engulfed in horse manure in less than twenty years! Fortunately, the automobile came along just in time to disprove this prediction and save the city from dire straits. Today, we anticipate that soon the air in our cities will not be fit to breathe due to gas emissions from motor vehicles...

One last word on this topic, concerning the nature of forecasts. Perhaps we are making a mistake when, at all costs, we want to situate events in time. Perhaps it is impossible to see the future other than as a composite image, as an accumulation of multiple, temporal overlays on the same screen? Like in some fields of mechanics, perhaps it is impossible to determine an event and a timetable for its occurrence simultaneously. Besides, when we look through a telescope at the universe, don't we see an image that is temporally composite owing to the finiteness of the speed of light and the three-dimensionality of space?

What vision do forecasters offer us today? As we attempt to read the future, we must - as we mentioned earlier - reconcile the human and technological dimensions. On one hand, the level of oil and gas demand will be determined by man's needs, desires and choices for economic and sociocultural progress, not to mention the simple fact of his proliferation. On the other hand, technological changes and innovations will not only adjust the level of supply under economically acceptable conditions, but will also affect demand by enhancing energy efficiency.

Demographic and economic growth will be the two key factors driving energy demand.

Before the Year 2000, the planet witnessed the birth of its six-billionth inhabitant. In 2020, the world should number 8 billion people. Furthermore, it is expected that nearly 60% of the global population will be city-dwellers. Most important of all, perhaps, is the fact that 80% of the world population in 2020, or 6.5 billion people, will live in developing countries-in other words, in countries with rapid growth in energy demand.

According to existing models, oil consumption is closely related to the level of economic development. When per capita income is between $100 and $1,000 per year, oil demand is about 1 barrel per year. When income reaches $9,000 per person and per annum, oil demand rises to 14 barrels a year. This correlation is fairly simple, but the simplest models are not necessarily the worst when applied to complex situations. If we apply it to today's figures-counting 1.5 billion people in the developed countries, 1 billion in emerging countries, and 3.5 billion in developing countries-we obtain world demand of about 78 million barrels a day, which is very close to actual figures. If we make the same computation for 2020, we get oil demand of between 105 and 120 million barrels per day, depending on the magnitude of the trend to switch from oil to natural gas.

Therefore, it is tempting to postulate, along with a number of specialized agencies like the U.S. Department of Energy, the International Energy Agency and the World Energy Council, that oil demand will continue to rise at a sustained rate and that its level will mainly depend on economic growth in the emerging and developing countries.

The oil industry is perfectly aware of this trend. According to industry forecasts, capital outlay in refining capacity and petrochemicals will be about 10 times greater east of the Suez Canal than west of it.

As regards exploration and production, boosting output from 78 to 120 million barrels a day is not an unattainable feat. There is no problem of reserves, especially if Middle Eastern countries actually open up to foreign firms. Nor are there any financial problems. It would mean increasing the annual production capacity by 2 million barrels a day, then adding about 4.5 million barrels a day to compensate for the natural decline in oilfield production of about 6% per year. Given an average production price of $12,000/barrel/day, annual capital expenditure would amount to about $78 billion which, we might note in passing, is on the same scale as the personal fortune of Mr. Bill Gates!

It becomes much riskier to forecast events over the longer term, say, in about 2050. Here, it is important not to focus on the oil industry alone, but on the energy sector as a whole. Predicting the future by extrapolating from the past would be a mistake. To quote a Chinese proverb:

"He who contemplates the sky from the bottom of a well will think it looks small . [4]

One can object that should we admit the fractal nature of the universe, contemplation of the latter is not subject to the scale effect.

We would derive more profit from trying to identify the factors that might hinder oil industry development in the next twenty or thirty years.

Here again, we must reconcile the human and technical dimensions, whether for demand or supply.

The human factor could influence demand in two ways:

• First of all, developing countries could opt for a growth model different from the one implemented by today's industrialized countries.

• Secondly, countries with high levels of consumption could show increased concern for environmental protection.

As to the first point, the debate is wide open. The development of democracy goes hand in hand with improving the well being of the population at large. Is it possible for developing nations to accomplish this while bypassing the acquisition of individual means of transport, taken to be synonymous with the freedom and individualism that accompany democracy? The evolution of the Eastern European countries following the collapse of the communist system clearly indicates how hard it is to skip this stage.

Of course, developing countries can build new energy technologies into their political choices, and they can do it faster than the industrialized countries before them. This is relatively easy to achieve for centralized electric power generation, for instance, but much harder for individual means of transport, i.e., the automobile.

Even if, in the next twenty or thirty years, or beyond, the industrialized countries do not come up with any real alternative to fossil fuels in the energy balance, or to the use of hydrocarbons in motor fuels, the public at large is becoming increasingly aware of their environmental impact. Remember what happened to nuclear power. Chernobyl played a major role in making this energy unpopular with the general public by compounding an existing image problem, namely, the difficulty of finding a satisfactory solution for the disposal of nuclear wastes. Similarly, the proliferation of environmental problems involving oil-urban air pollution, oil slicks and so forth - could eventually reduce its relative share of global energy demand.

On the supply side, the most important human factor that might come into play is geopolitical. Could a disruption of the social balance in a major producing region like the Middle East have a lasting effect on supply and lead to the replacement of oil by other energies?

A brief review of past events shows us that the oil shocks of 1973 and 1979 had major consequences, in particular:

• The implementation of energy conservation policies by many countries,

• A decrease in the share of oil within the world energy balance,

• A diversification of sources of supply.

These, however, did not lead to any lasting discontinuity of supply. But these oil shocks were not caused by a violent disruption of the social status quo in these countries. On the contrary, they resulted from a political decision made by governments and backed by popular consensus. The man in the street supported the nationalizations and backed his leadership during armed conflicts.

Besides, the main effect of these two shocks was to swell the incoming flow of oil revenue, which permitted the emergence of welfare states, with oil money serving to bind societies that are centrifugal by nature.

In the name of what principle would these societies reject the well being that oil revenue brings? These populations have seen their standard of living rise thanks to state assistance, and the longer this continues, the more people have to lose if production stops for any length of time. The only way to overlook this simple economic fact would be to obey motivations grounded more in the irrationality of fanaticism than the rationality of profits and losses.

Moreover, it is possible to think that these countries will become part of the democratic world and join the world economy within the next twenty or thirty years, which would render this geopolitical risk obsolete.

On the supply side, technology has revolutionized the industry. By and large, the erstwhile standard notion of conventional and non-conventional oil has largely disappeared, giving rise to a technico-economic continuum. The reason is that there are no longer any technological barriers to exploration and production anywhere on the globe. Witness the deep offshore today and the very deep offshore tomorrow.

Of course, some problems remain to be solved, but the industry is confident that this is feasible. At the end of the 1980s, the questions concerning the deep offshore arising were:

1. Do opportunities exist?
2. Technically speaking, can we do it?
3. Is it economically viable?

These questions have become the following affirmation, for all reserves: "If opportunities exist, we will be able to exploit them at ever-decreasing cost."

One consequence of this bona fide revolution is that, looking to the long term, it is possible to add together all sources of oil. This includes existing proven reserves, estimated to be between 800 and 1,000 billion barrels, depending on the source, plus all volumes of oil that have not yet been discovered, irrespective of location or type, along with all resources that can be tapped by boosting recovery rates.

The second impact, equally revolutionary, bears on the capacity to obtain final energy sources by substituting one fossil resource for another. This holds true for motor fuels, in particular. Let's take an example. Increasing numbers of industrial facilities have been built to convert natural gas to diesel fuel using the Fischer-Tropsch chemical conversion process, which, by "liquefying" the gas, makes it possible to develop sources that have poor access to markets. The end product is a high-performance diesel fuel that easily meets stringent environmental standards and should give a substantial boost to the emergence of this technology on an industrial scale.

On the demand side, technology could have a considerable impact, although it is difficult, if not impossible, to say at what point in the future a valid substitute for oil might be found. The depth of field of our forecasting tool is too broad for us to distinguish any timetable. The only thing that we might venture to say is that, just as the Stone Age did not end because there were no more stones in the quarries, the age of oil will probably end before the last barrel of reserves has been taken out of the ground. In all probability, the cause will be an energy technology breakthrough.

Let's examine a few of the avenues being explored by the industry today.

First, the fuel cell. The basic operating principle has been around since the 19th century, but today the concept of using an on-board fuel cell to drive an electric motor is being investigated. The idea of an electric car is not new. Early in the 20th century, the first automobile ever to run at 100 km/hr was the Jamais Contente (Never Content), an electric car built in France. In recent years, there has been a strong revival of interest in this technology. The explanation for this trend is that advances have succeeded in making the fuel cell more compact. The CARB project launched in the United States aims to ensure that 10% of all vehicles marketed in 2003/2004 have zero emissions (excluding steam, of course).

The basic fuel used in fuel cells is hydrogen. Industry has two solutions: on-board storage or on-board generation. In the first case, if the electrolysis of water is excluded, the centralized production of hydrogen from natural gas appears to have the lowest environmental impact. In the latter case, hydrogen is produced by reforming methanol, itself produced from natural gas or biomass. Solutions that make use of heavier hydrocarbons, gasoline or naphtha are also being studied.

In either case, if the processes involved are developed rapidly, demand would shift from oil to natural gas. But we are not even close to solving the cost problems; in this respect, we find ourselves at the very beginning of the learning curve.

In the same vein, another technology could heavily influence the share of oil in the transport market: the development of a high-capacity, fast-recharge battery would enable the development of an all-electric zero-emissions vehicle that would be powerful, quiet and comfortable. But a quantum leap like this would have a substantial impact in many fields besides the motor industry.

Alongside these very real avenues of exploration, others are very far removed from reality. For the simple intellectual pleasure of it, let's consider a subject dear to the hearts of science-fiction writers: vehicles not subject to gravity. According to the theory of relativity, defying the pull of gravity signifies escaping from the confines of the space-time continuum. Today, we are only aware of two ways to do this, namely, via the human imagination or by building a virtual reality on a computer. Certainly, we would economize a great deal of energy if we could leave on vacation by taking a pill marked "The Bahamas", "Tahiti" or "Pebble Beach". Using computers would enable us to take an active

part in the action being developed on the screen, something we can't do with films and television today... but tomorrow is another story!

But time is passing, and I must bring my talk to a close. As I do so, I will also be ending forty years in the oil industry. The first word that comes to mind is "confidence." First of all, confidence in people. The oil business in all its diversity has always attracted and fascinated talented people. I've never met a geologist, a reservoir engineer, a driller, a producer or a chemist who did not consider our business to be an art, rather than a trade. And, by definition, art is eternal.

Secondly, confidence in technology. Even if the public at large does not always realize it, because the product does not have the same hi-tech direct content as a cell phone or a computer, the technology used in the oil industry is highly sophisticated. Oil has a curious fate, in the sense that it is always concealed from the gaze of the consumer. From its geological trap to the gas tank, it is and must remain invisible. The sight of an oil spill denotes an accident, an event that always has negative implications.

Deserving our confidence, technology has constantly pushed back the specter of depleted reserves and opened up the most hostile parts of our planet to resource development. In the years to come, I am confident that, in spite of the pessimism of some forecasters, technology will certainly afford us the means of reconciling man's need to consume energy with his desire to protect the environment for future generations.

My final remark is borrowed from one of the world's first historians, the Greek Thucydides. In his history of the Peloponnesian War, in about 400 BC, he wrote:

"In the technical realm, innovation always ends up victorious.

With these words that have come down through the ages without losing any of their freshness, let me thank you for your attention.

REFERENCES

1 Issac Asimov, Science Digest, 1965.

2 Daniel Yergin, The Prize, p. 52

3 Ibidem, p.52

4 Han Yu (786-824), Chinese philosopher and man of letters.

5 Thucydides, History of the Peloponnesian War, Book 1.71.