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"Technology: The Key to the Future of Sustainable Energy"

Fellows of The Royal Academy of Engineering, distinguished guests, ladies and gentlemen; good evening. It is an immense honor and privilege to deliver this year's International Lecture, and I would like to thank my good friend Lord Browne, The Royal Academy of Engineering and The ERA Foundation for their gracious invitation to join you tonight.

I must confess that as a political science graduate and someone who basically came up through the "soft side" of the petroleum business, I find it somewhat daunting to find myself delivering a lecture on technology to a room full of distinguished engineers. As the Romans—who knew a thing or two about engineering—would say, "*Piscem natare doces*" [pis-ken nat-a-ray doh-kays]: it's a bit like teaching fish to swim! But my focus tonight will not be the cogs, gears and flywheels of particular technological tools and techniques. Rather, I want to look at the positive impact that advanced technology and engineering talent have on the petroleum industry, and the ways in which they will enhance our ability to provide much-needed energy in the decades to come. And as the past president & CEO of Saudi Aramco, that is an aspect of technology that I am *very* comfortable addressing.

Let me begin this evening with the larger landscape in which new petroleum tools and technologies will make their contributions, including the prospects for

substantial growth in demand for energy in general, and for petroleum in particular.

Talk of increasing oil demand may seem rather odd, since like nearly every other economic sector, the petroleum business is suffering as a result of the global economic downturn. In fact, last year was the first time in a quarter-century that global demand for oil dropped, and that downward trend has continued thus far in 2009. The International Energy Agency, for instance, believes global petroleum consumption will contract this year by a further 2.5 million barrels per day, or roughly three percent, to a little more than 83 million bpd of oil demand. Just to give you some sense of scale, that three-percent contraction is roughly equivalent to the production of Venezuela, Nigeria or Kuwait. The industry's woes have been compounded by the combination of rising inventories, the flight of speculative money out of the crude oil markets and generally negative market sentiment, resulting in crude oil prices that are down significantly from their highs of last summer. For the next few years, worries about the security of demand are likely to be of greater concern to the industry than security of supply.

And yet the long-term drivers of energy and oil demand growth remain intact, notwithstanding the current economic crisis and its impact on short-term energy consumption. Just as the weather outside our window at any given moment tells us relatively little about long-term trends in the climate, it would be a mistake to look at today's energy demand picture as an indicator of long-term conditions. Instead, we need to consider two fundamental drivers of increased energy demand, neither of which is likely to be reversed by an economic downturn even of the scale and scope of the current crisis.

The first of these trends is global population growth. Today we share the planet with some 6.7 billion other human beings, but that number is expected to hit nine billion by the middle of this century. Those new additions will have new homes to build and light and heat and cool, added economic and leisure activities to undertake, and additional journeys both near and far to make—all of which translates into an increased demand for energy and petroleum.

The second trend is the economic growth and rising living standards that will be manifested in developing nations. The current economic crisis may have slowed their rush to prosperity, yet countries like China and India continue to grow at rates that would be the envy of the developed world, even in economic good times. Over the coming decades, we will continue to see the narrowing of the gap in standards of living between industrialized nations and the rest of the world. Again, that spells greater demand for petroleum and petroleum products, which are essential to contemporary life and lifestyles.

But in some ways, it is the convergence of demographic growth and rising living standards—their "resonance," to borrow an engineering term—that will shape the future energy demand curve. Consider that by 2050 more than 60 percent of the world's population will live in either Asia or Africa, and that three-fourths of the projected growth in energy demand is expected to come from developing economies such as India and China. In other words, population growth will be greatest in the very same economies where standards of living will be rising fastest, meaning conditions are ripe for even stronger global energy demand growth.

That is why even in its most recent forecasts, made in the midst of the current downturn, the IEA predicts that by 2030 total world primary energy demand will rise by nearly 45 percent over today's levels. Furthermore, despite improvements in the performance of alternative sources, it envisages that fossil fuels such as coal, oil and natural gas will still satisfy roughly 85 percent of the planet's expanded energy needs two decades from now, with oil continuing to represent the world's single largest source of energy. In other words, fossil fuels will provide six out of every seven units of energy that mankind will consume for the foreseeable future.

But some may ask, "Aren't alternative fuels poised to supply a greater amount of energy?" Certainly we have heard a great deal about alternatives such as wind, hydropower, and ethanol and other biofuels, and in fact over the next twenty years supplies from renewables are projected to grow at a faster *rate* than oil. But the *volume* of new energy supplied by renewables will still be only half of the additional energy provided by oil or by gas, and only a fourth of the new energy supplies that are expected to come from coal, because these alternatives start from such a small base.

Consider, for example, that renewable sources of energy currently account for roughly a third of oil's share of the energy pie, but that much of that comes in the form of traditional biomass such as wood and animal waste used for heating and cooking among the world's poorest populations—energy use that is neither environmentally friendly nor efficient. Geothermal, wind and similar renewables currently account for less than one percent of today's total energy supply, meaning significant breakthroughs in their efficiency and economic performance and sizable investments in infrastructure will be required before they have a major impact on the global energy roadmap. All in all, an objective assessment of these sources

shows that even after decades of massive investments, substantial subsidies and favorable regulatory environments, they still face considerable technical, economic, infrastructure and even environmental obstacles.

Furthermore, oil-based petroleum products continue to be *the* fuel when it comes to transportation, with some 60 percent of all oil produced going to transportation applications. Given lifestyles in developed nations like the United Kingdom, the United States and other OECD economies, and rising living standards in the developing world, the planet's growing population will be increasingly mobile, and the cars, trucks, buses, planes and ships people will use to move themselves and their goods and products will run almost entirely upon petroleum. Of course, oil is also a vital input for the chemical and petrochemical industries, for agriculture and manufacturing, and for many other economic sectors. Simply put, oil fuels our modern civilization and serves as the essential lifeblood of the global economy.

Because of these realities, the IEA predicts that demand for oil will expand markedly over the next two decades, from roughly 83 million barrels per day at present to 104 million bpd by 2030. That's an increase of more than 20 million barrels per day, or roughly one-and-half times Saudi Arabia's current maximum sustainable crude oil production capacity.

Let me be clear, though: because the world's demand for energy will be growing so dramatically, we will need to draw upon all economically and environmentally viable sources of energy to meet our increased needs. If you talk to folks in the petroleum industry—and I believe Lord Browne will back me on this—you will find that they are *not* opposed to the development of alternatives and renewables, and that in the case of some of the major multinationals, they are themselves

staking out positions among these alternative energy sources. What you *will* find, though, is caution against moving too quickly to unproven sources of energy, and concern over policies and investment programs which make no reference to these alternatives' economic, commercial, technological or environmental viability—much less their level of consumer acceptance. That's because oil men and women understand just how much is at stake when it comes to supplying energy to the world's people. They know it's not just a matter of barrels and btus, but an issue of enabling prosperity and development, ensuring the continued prosperity of countless communities around the globe, and creating new opportunities for a better life for billions of our fellow human beings.

But if we are to continue to rely so heavily on fossil fuels, what about our finite resource base? Frankly, ladies and gentlemen, I think most of the truly daunting challenges facing the energy industry are to be found on the surface, and are related to the need for substantive, wise and timely investments; discriminatory tax and tariff regimes and skewed regulations; and well-meaning government policies which nevertheless distort energy markets and ultimately undermine our collective energy security. In other words, in terms of petroleum we're faced largely with a question of deliverability rather than one of availability.

Below ground, the world still has plentiful reserves of coal, natural gas and oil upon which to draw. When it comes to petroleum in particular, the in-place endowment of the world's conventional and non-conventional liquids—including tar sands, heavy oil and oil shales—is presently estimated at some 15 trillion barrels. Even after more than a century of widespread petroleum use, though, we have consumed only one trillion barrels, or roughly seven percent of that total endowment. When we also consider the prospects for sources like gas-to-liquids,

coal-to-liquids and even biofuels, all of which go toward the same end-use applications as oil, it is clear that the resource base is more than sufficient to meet even steadily growing demand for petroleum for many decades to come.

However, converting those subsurface resources into usable energy supplies will not be easy, and if the global petroleum industry is to meet its obligations to its wide range of stakeholders, it will need to rely on cutting-edge technical tools, new processes and systems, and above all on the talented men and women who will design, develop and deploy them. Since the earliest days of the oil business, technology has been a vital enabler for the success of the energy industry—and not just in the field of petroleum engineering. Given the nature of our work, oil companies also need high-powered computing technology backed with massive storage capacity, information and communications systems which allow us to monitor and control operations remotely and in real time, process and systems solutions which integrate the various strands of our business, new materials designed to withstand corrosive products and difficult conditions in the field and in our facilities, as well as safety engineering to ensure the wellbeing of our people and the integrity of our infrastructure. Moving forward, I believe that technology has the potential to be a true game changer when it comes to the way we find, produce, process, transport and consume petroleum, as well as other energy sources.

Of course, some people outside this room may think my faith in engineering and technology is misplaced. As the former French president Georges Pompidou famously said, “There are three possible roads to ruin: women, gambling and technology. The most pleasant is with women, the quickest is with gambling, but the surest is with technology.” However, based on my experience working with

engineers and technology developers in Saudi Aramco and in the wider petroleum industry, I will take my chances.

There are a number of technical and technology challenges facing the petroleum industry, and where engineering skills and talent will need to be brought to bear. Those challenges begin with locating new petroleum resources, including not only discovering new fields in new frontier areas, but also locating additional petroleum resources within existing fields. By using increasingly sophisticated seismic and other technologies to map subsurface reservoirs in greater detail, we are able to pick out hydrocarbon concentrations that previous generations of geologists and geoscientists missed, simply because they didn't have the necessary tools. As those imaging technologies and techniques, including sophisticated algorithmic computations, continue to progress, we will have an even finer picture of what's there thousands of meters beneath the surface.

That more detailed understanding is also imperative in addressing the next challenge, which is increasing the ultimate recovery rates for our reservoirs. Even today, with all of the technology at our command, our industry typically produces only a third of the petroleum locked away in any given field. That has to change, in my view, and even though our company has typically enjoyed higher recovery rates than the industry average, before I stepped down as president & CEO of Saudi Aramco I challenged our upstream engineers and professionals to take our recovery rates to at least 70 percent. As we have seen, the world will continue to rely on petroleum for much of its energy in the coming decades, and the petroleum sector needs to convert more of its in-place resources to readily available supplies.

The role of the engineer will be increasingly critical in achieving that mission, because in general the industry will be producing from more challenging reservoirs which contain more challenging types of oil. It is a paradox that in some cases, the job has become more complex because engineers have been so successful! For example, Saudi Aramco's upstream engineers identified areas of high porosity in some of our producing fields, which means that oil travels more easily through some channels in the rock than in others. As a result, we have to map our production strategies very carefully to ensure that slower moving hydrocarbons are not left behind over time, and that means a more complex engineering challenge. Elsewhere, companies are looking at opportunities in deep offshore or Arctic areas, are using enhanced recovery techniques to produce nonconventional heavy oil, or are exploring the possibilities offered by shales and tar sands.

Many of these unconventional oil resources pose unique environmental protection challenges which also call for engineering solutions. Regardless of the location or type of oil, or the upstream production activities needed to convert in-situ resources into supplies, we need to produce petroleum in a more efficient and more environmentally friendly manner. That challenge also extends to developing cleaner end-use technologies, and to ensuring that we unlock the promise of energy supplies with due attention to our stewardship of the environment. Many of my Saudi Aramco colleagues look at this as a "hardware and software" challenge: more efficient vehicles and the next generation of engines that will power them constitute the hardware element of the equation, while cleaner burning and more efficient fuel formulations make up the software component.

Companies throughout the industry, including both major multinationals and state-owned petroleum enterprises, are working hard on research and development

programs designed to meet these challenges, because they understand that energy and the environment are two inseparable sides of the same coin. Opting for economic growth and development without regard for their environmental consequences is untenable, as is adopting environmental protection measures which undermine human wellbeing and prosperity, particularly among the planet's poor. Humankind needs both growth *and* sustainability, and while there are undoubtedly policy and public perception issues which must be addressed, I for one believe that engineers and the solutions they can provide will constitute an essential element in sustainable development.

Ultimately, though, for all of its infrastructure and technology, the petroleum industry is still, at its heart, about people. In the front rank of the oil sector's human resource talent pool are engineers of one sort or another, but of course not all engineers are created equal. What, then, separates the good from the poor, or the great from the good? When I was leading Saudi Aramco, my management team and I always felt that engineering capability starts with technical talent and an individual's abilities in his or her chosen field of engineering. Those sorts of capabilities are essential, and there is always a place for razor-sharp skills and encyclopedic technical knowledge.

But we were also firmly convinced that good engineers also need to possess an adaptability to change, and even an enthusiasm for continuous and fundamental transformation. The laws of physics are unlikely to change anytime soon, of course, but the way we develop and utilize technology never stands still. You don't need me to tell you that the pace of technological change continues to accelerate at an exponential rate, and that the complexity and sophistication of the technical tools and systems which we use today are far greater than those of just a

few years ago—or that in turn they will be overtaken by the technologies of tomorrow. For example, the Apollo Guidance Computer used on the first manned mission to the Moon utilized about 4 kilobytes of changeable memory; forty years later, an iPhone which costs around 70 pounds in the high street has more than 130,000 times as much RAM as was used to land the first lunar module on the Sea of Tranquility. And who knows what computing, telecommunications or personal entertainment technology will look like ten or twenty years from now? Simply put, it is impossible to predict the future of technological innovation and development with any degree of accuracy, so we are best served by engineers who possess an appetite for continuous personal development and lifelong learning, wherever their careers, professional interests or the ebb and flow of technological developments may take them or their organizations.

But as I noted a moment ago, many of the petroleum sector's most pressing and most difficult challenges are above ground and are not primarily technical in nature—though of course these issues do impinge on technology and the way that it is used. Therefore, at Saudi Aramco we worked to develop engineers who could make connections between their own technical discipline and practice and the surrounding operating environment. They needed to understand their relationship to the world of finance and economics, to display business acumen and possess an understanding of commercial considerations, to navigate the sometimes treacherous shoals of public policy and public opinion, and to interact fully with the stakeholders they serve and the communities in which they operate. Paradoxically, being a good engineer today means having the ability to transcend engineering itself, and to bring an engineering sense and sensibility to the wider world. Certainly this is something which the Academy has embraced with its commitment to promoting informed thinking on issues of the day and its

engagement with the wider society, particularly here in Britain. I applaud that role, and believe that bodies such as this have a tremendous part to play in the ongoing debate and discussion about technology and its growing influence on our lives and our societies.

For that reason, I have always felt that we need more qualified engineers with well-developed communications skills, because one way or another, a good idea must be communicated to others before it can make a tangible difference in the real world. In other words, it's not enough to turn a crank, no matter how elegant or well-designed it may be. Rather, that crank has to drive some other wheel or cog and put that energy to productive use—and just as a chain, gear or drive shaft communicates energy to other parts of the system, a first-rate engineer has to both generate *and* communicate thoughts, concepts and data in order to be truly effective. And I think it's also important to note that part of being a good communicator is being a good listener, and actively seeking information, ideas and insights rather than passively receiving them.

My friends, judging from my experience at Saudi Aramco and my conversations with fellow petroleum industry executives, I believe that while the oil business is facing an increasing need for keen technical minds and engineering talent, we are successfully bringing many bright young people into the industry. While it may be easier to attract top talent somewhere like Saudi Arabia, where the petroleum and petrochemicals industries occupy such an important and prominent position in the economic and even social environment, I think that the oil business in general holds a great deal of promise and potential for engineers of many disciplines. The petroleum sector faces both tremendous opportunities and considerable challenges, and I believe top-notch engineers are eager to confront both.

Ladies and gentlemen, earlier I quoted a skeptical French president who, like me, was the product of a liberal arts education. To even the balance—or as you would say, to bring the system back to equilibrium—let me close with a word from a former American president, Herbert Hoover, who earlier in life was a mining engineer who worked in the US, Australia and China. Hoover said, and I quote:

> *To the engineer falls the job of clothing the bare bones of science with life, comfort and hope. No doubt as years go by, people forget which engineer did it, even if they ever knew. Or some politician puts his name on it. Or they credit it to some promoter who used other people's money with which to finance it. But the engineer himself looks back at the unending stream of goodness that flows from his successes with satisfactions that few professions may know. And the verdict of his fellow professionals is all the accolade he wants*

unquote.

Such modesty has indeed been the rule among the engineers with whom I have had the privilege and pleasure of working, but let me take the opportunity tonight to add my accolades and appreciation for the efforts that engineers of all stripes and disciplines put forward, and for the contributions that you and your profession continue to make to our lives and our livelihoods. Thank you.