ChemEng Evolution Transcript Summary
Des King talks to Past President John McGagh

Desmond Frank King

Born in the UK in 1955, Desmond King was awarded a prize-winning first-class honours B.Sc. (Eng.) degree in chemical engineering from Imperial College, London in 1976 and a PhD in chemical engineering from the University of Cambridge in 1979. He then became a professor of chemical engineering at West Virginia University in Morgantown, West Virginia USA before joining Chevron in Richmond, California in 1981 as a process engineer, progressing through a series of technical positions in Chevron Research Company.

In 1994 he became the Technical & Maintenance Manager at Chevron's refinery in Burnaby, British Colombia, Canada before being seconded to Edmonton, Alberta as General Manager of Alberta Envirofuels.

Des returned to the USA in 1999 as Managing Director of Technology Marketing for Chevron Downstream and then was named General Manager of Chevron's Corporate Strategy and Planning at the time of Chevron's merger with Texaco in 2001. In 2004, Des moved to the UK to lead Chevron's oil refining activities in Europe. He served as the General Manager of Chevron's refinery in Pembroke, Wales, director of Texaco UK, Milford Haven Port Authority board member and Netherlands Refining Company board member - a joint venture between BP and Texaco.

From 2006 to 2009 Des served as Managing Director & CEO of Caltex Australia Ltd, the leading oil refiner, fuel marketer and convenience store operator in Australia. During this time, he was a director of the Australian Institute of Petroleum and a member of the Business Council of Australia.

In August 2009 he returned to the US as President of Chevron Technology Ventures, a division of Chevron that champions innovation, commercialisation and integration of emerging technologies and related new business models with the corporation. CTV's business units included advanced biofuels, renewable energy, venture capital and hydrogen refuelling stations. From 2009 to 2013, Des was a member of the DOE's National Renewable Energy Laboratory's external advisory council. In 2013, Des became the President of Chevron's specialty chemicals business, Oronite, a leading global producer and marketer of gasoline and lubricant additives. Des was a member of Chevron Corporation's Management Committee from 2009 until he retired from Chevron in 2018.

Des is a Fellow of IChemE and a Chartered Engineer. He was President of IChemE for 2010-2011. In addition to his commercial career, Des has edited books on fluidisation and is co-author of the fluidisation section of the Encyclopaedia of Chemical Technology. Des has published over 50 academic papers mostly on fluidisation including the "King Equation" for turbulent fluidised beds.

Summary

Modern lifestyle is built upon predominantly hydrocarbon energy sources. Energy demand over 2021 levels could increase by 25% to 2050 and by 50% to 2100, lifestyle and growing population will drive this. World population has grown from just under two billion when IChemE was formed one hundred years ago to nearly eight billion today and global population is projected to reach around ten billion around 2050. It is an engineering and scientific marvel that the world has been able to support such an incredible growth in the human population. Every person consumes resources and energy.

Unfortunately, nearly one billion people today do not enjoy the benefits of the Developed-World/OECD lifestyle. This problem overlaps with abundant energy access and must be tackled.

Chemical Engineers have had a key role to play in the production of large-scale hydrocarbon-based energy, Chemical Engineering pioneered technologies mean that we get much more out of a barrel of oil and this innovation needs to continue.

The hydrocarbon-based energy system is like a gigantic flywheel, it has much inertia and will take significant effort to change. Realistically, it will likely take a generation or two to change the inertia of the energy “flywheel” and make renewables the dominant energy source.

Climate change is the most important matter facing global society, we must move quickly to achieve IPCC goals and remove CO2 from the atmosphere; we must do this against a growing demand for energy.

Electricity use growth will outstrip overall energy demand growth. We are electrifying many aspects of the economy; transportation will be an important pillar for electrification.

Electrification production via renewables is proven but the problem is storage, much work is happening in batteries, and they are getting much more efficient. The concept of pressurising underground formations and storing excess solar and wind energy and releasing it at night or when wind is not blowing holds promise.

Switch to hydrogen use as an energy storage and transportation medium (and for cement plus iron and steel production) offers much promise. Production of hydrogen via electrolysis requires significant amounts of energy and will take time to become commercial.

Oil and gas companies have technology and knowledge to produce commercial scale Hydrogen from Natural Gas. A Carbon Capture and Storage solution is required to make this carbon neutral.

Assuming a ubiquitous (including post-combustion) Carbon Capture and Storage solution can be engineered but there still will be significant public and social issues need to be worked through. Acceptance of land-based CCS could be a particular social challenge.

Energy and the standard of living

I think before we can look forward, we need to look back because where we are today and where we are going is very much a consequence of history. When I think about it, it has been the availability of abundant, affordable energy that really has raised living standards over the last one hundred years.

We know the quality of life that most people enjoy today is likely beyond the wildest dreams of our forebears and we often forget that. My personal story is much less than one hundred years, but it is a reflection of this.

I grew up in rural eastern England in East Anglia, in Suffolk, in a small cottage. I was born in 1955 and we did not have electricity, so our family source of heat was a coal fire. I used to go up the stairs at night to find my way to bed with a candle. Then my father petitioned the Member of Parliament to get the electricity company to run a line out from the nearby village to where we lived, which was about a mile away. In 1960 we got electricity and our world changed with simple things we take for granted today, like electric light.

If we did not have electricity when I went to school in 1960, I could not have done my homework at night except under maybe a hurricane lamp. Also, once we got electric lights, we also had a refrigerator. Then of course we got a television and with the television we got to see light entertainment for the first time and, what was really a window on the world, we got to see the news!

So, between my birth in 1955 and age 5 in 1960 my world changed because of electricity, and we then began that modern journey that affordable, abundant, energy has granted. We originally had a motorbike and sidecar that could transport three people, but we eventually got a car so then we could go as a family to the seaside fifty miles away or to visit other family members in the next village.

And then in 1973, I remember I flew to see an aunt in America who married an American during World War II. That really was the culmination of a huge change in my life enabled by abundant, affordable energy. From no electric light in early 1960 to flying to almost the other side of the world in 1973. Now I think nothing of getting an aeroplane and going to the other side of the world at short notice; so, my life has changed a lot from needing a candle to go to bed at night. My quality of life has changed remarkably over 65 years.

And this has been the same for most of society over the last one hundred years. The bottom line is that affordable, abundant hydrocarbon-based energy has really raised living standards for the majority of people over the last one hundred years, but we still have others who have not been so lucky that we have to help. Let us not forget there is just under a billion people in the world that still do not have electricity and we need to do all we can to make sure their living standards can increase like ours have over the last century.

We know Chemical Engineers have played a significant role in making Hydrocarbon energy (and other derivative products) abundant and affordable. We have been pivotal in enabling hydrocarbon production as its use increased in line with population growth and rising living standards, without the abundance of energy we probably could not support the number of people we have on the planet today.

Look at the global population. It was about 1.5 billion in 1900, in 1950 it was 2.6 billion, in 2000 just over 6 billion, today nearly 8 and by 2050 we could have close to a 10 billion people in the world; some estimates for 2100 are even up to 13 billion, but whatever the final 2100 number, the population will be much bigger than it is today for sure.

Chemical engineers really have played a role making Hydrocarbon products affordable and abundant to enable that population growth, certainly my area over the last 40 years has been mostly oil and we can look at what chemical engineers have done to make fuel readily available and affordable for humanity.

There are many examples of how chemical engineers and their innovation have enabled us to get more and more out of a barrel of oil and that innovation will need to continue.

A problem for all humanity

The growth and lifestyle improvement we have enjoyed has had a downside though because over the last one hundred years we have been using mostly fossil fuel-based energy and we are now seeing the unintended consequences of that. Yes, this has driven affordable, abundant energy, but we have seen as a consequence the ramp up of CO2 emissions; in all honesty, which was an unintended consequence. People back in 1950 and 1970 were not thinking of the unintended consequence of higher CO2 emissions from having more affordable and abundant fuel but, this has driven global warming.

Today of the sixty giga tons of CO2 equivalent about 60 to 65% comes from fossil fuel energy use, in this lies the challenge.

When we look forward, global energy will likely continue to grow from today’s level out to 2100 as population continues to grow and living standards continue to evolve and improve, particularly in the developing world. Now there is some efficiency offsets that that help that. Historically over last several decades, total energy use has grown at about 2% per year.

From today onwards energy consumption is likely to grow at a slower rate to mid-century, maybe ½% to 1% per year.

There is some uncertainty about how it will recover exactly from the Covid 19 crisis, but ½% to 1% a year is probably in the realm of what we'll see for energy growth over the next 30 years to 2050 - what that means is by mid-century the world will need 25 to 30% more energy than it needs today, this is a very big number.

For the second half of the 21st century, with population growing likely more slowly or even flat, energy growth will probably be slower maybe in the range of zero to ½% per year, but that still means by 2100 we will need something like 30 to 50% more energy than we use today. Any way you cut it, the demand for energy is growing.

The global energy mix must rapidly evolve from fossil fuels to renewables or other sources that offer low or zero carbon sources.

That change is already underway, but it is probably not likely fast enough to meet the challenges set out by the IPCC if we are going to hold global temperature rises to under 2 degrees C, let alone under 1.5 degrees C.

We clearly need a more rapid change from fossil fuels to renewables and other low or zero carbon sources and that change is underway currently, but it is very difficult to affect rapid change in the global energy mix because the global energy system is like an enormous flywheel that takes time to change. Politicians and many other people believe that we can affect energy change as quickly as the information systems revolution but what Bill Gates said, at a speech at a DOE conference I attended, really stuck with me. He said people must realize that the energy system is not like information systems. The energy system is vast, the biggest system that the world has ever known, and it will take a long time and huge effort to change.

Coal is an example in point of how difficult it is to move away from a high carbon emission fuel.

Because if you look at coal in 1900 it provided over 95% of the world's primary energy; 95% of the world's energy came from coal and that has dropped to about 25% today. So, a huge drop and you would say, well, that is the end of coal because it has dropped so much; but in fact, coal production in tonnes per year only peaked in 2013. Coal has dropped substantially as a percent of the energy supply, but since the demand for energy has been growing so rapidly, coal production actually increased well into the 21st. century.

Mobilising Chemical Engineers for action

There must be significant changes to move away from fossil fuel energy systems, eventually you replace them, but the issue is when. Certainly, over the last decade or so replacement has happened with natural gas fired power plants replacing coal fired ones and through that change lowering CO2 per unit of electricity produced, but admittedly natural gas is still a hydrocarbon. But there is a huge inertia there that takes time to change.

But think about what we chemical engineers can do. We chemical engineers must use all our innovation over the coming decades to accelerate the global energy transition from fossil fuels to abundant and affordable energy as energy demand continues to grow rapidly. But this time the demand should not be met with fossil fuels, but from renewables, nuclear and hydrogen.

Our electric future

Certainly, renewables have made significant progress. But wind, solar, geothermal, bioenergy and hydro today make up just over 10% of primary energy.

Renewables play more in the electricity sector, where renewables today are probably just over or just close to 30% of electricity supply. But the opportunity by 2050 is to get renewables from about 30% of electricity generation to 50% or more. This is a bigger increase than it seems because the demand for electricity over the next 30 years and through the rest of the century is probably going to go up dramatically because the world is electrifying.

Today the world's energy need is about 25% supplied by electricity, so 25% of the world's primary energy is from electricity but that could well grow to 35 to 45% by 2050. Since total energy demand will also grow, in absolute terms the power generation from renewables would have to approximately triple by 2050. This is a huge challenge.

Mostly electricity goes into the systems for buildings and industry, but increasingly we are seeing electrification of the vehicle fleet which is part of the changeover. Today we look at vehicle miles travelled, or vehicle kilometres travelled, electrification is less than 1%. But we are seeing a rapid change, and it could well be 35% or more by 2050. So, electrification is going beyond its normal market niches.

With increasing amounts of electricity coming from wind and solar, the key challenge is large scale energy storage. If wind and solar are to really realize their potential, we must develop large scale electricity storage because obviously the sun does not shine all day and the wind does not blow all day.

Batteries show a lot of promise for large scale storage. Certainly, the cost curve must continue to come down, but a lot of people are working now on increased storage capability. One option is to use compressed air, some are even looking into using old gas caverns and pressuring those up using renewable energy then letting the pressure down to generate power. Large scale energy storage is a huge challenge that Chemical Engineers can be part of the solution for.

And where fossil fuels cannot be replaced then we must mitigate the CO2 emissions by carbon capture and sequestration. Again, an important role that chemical engineers can play.

Summary reflections

I want to summarize now; over the first one hundred years of the institution of chemical engineers we chemical engineers played a central role in raising global living standards by enabling fossil fuelled energy to become abundant and affordable in a world where population has grown from two billion to eight billion.

We accepted energy supply challenges early in the late 1800's through early 1900's and moved on to solve those challenges using primarily hydrocarbons and they got us to the point we are today. Developed countries enjoy a wonderful lifestyle, however, we still have a significant percentage of humanity that does not enjoy these benefits. The question is how do we maintain and continue to improve the quality of life for all humanity in the face of climate change?

How do we bring people who do not have electricity today and who do not have high lifestyle to the level of the OECD countries? We must strive to bring all up to developed world living standards but do it in a way that does not increase carbon emissions; we solved the challenge of bringing more energy abundantly and affordably to people in the 20th century using fossil fuels, but we cannot repeat this or even continue this pathway with fossil fuels.

To repeat this historical success, whilst using a non-fossil fuel-based strategy is essentially a world scale problem.

From now to 2100, Chemical Engineers must play a central role again, but this time to rapidly transition the world from fossil fuels to abundant and affordable alternative energy. The quality of life of future generations depends on the ability of Chemical Engineers to deliver on these challenges.

We are up for the challenge, and we can do it.

Points of supporting interest - for note

Hydrogen

Oil companies today generate huge amounts of hydrogen because they are using it in their own refining process. So, they are expert at producing hydrogen, albeit from natural gas, not from a renewable route and electrolysis of water.

To produce hydrogen from electrolysis needs large amounts of electricity so I think that this pushes full commercial production via electrolysis further out.

In terms of developing a hydrogen economy, hydrogen sourced from natural gas could come sooner but still what we are lacking in many parts of the world is a hydrogen infrastructure to distribute it as a fuel. We do not have hydrogen pipelines except in a few areas. We have lots of refineries down in the US Gulf Coast and locally they have hydrogen pipelines, but hydrogen pipeline systems are not widespread, so that is the challenge for hydrogen.

Hydrogen from natural gas needs the infrastructure. The technology is certainly there now, Chevron built five hydrogen refuelling stations about 15 years ago as a demonstration project with the US DOE. What they did was leverage the local natural gas infrastructure system and then use on site reforming to produce the hydrogen, so from a technology standpoint, leveraging the existing infrastructure can work, but it can be expensive.

While I believe is that large scale hydrogen production from the electrolysis route shows great promise, it is much further out.

The shorter-term route for large scale hydrogen production is certainly from natural gas. I see natural gas first and then electrolysis further out, but eventually we have to have something.

Another challenge is to replace the carbon emissions from the fossil energy used in cement and iron and steel production, because these production processes are both large emitters of carbon dioxide. So, if you can get them away from using hydrocarbons to hydrogen this will lower their emissions.

When thinking about low carbon options to produce electricity, what is often not talked about that much is nuclear. In most OECD countries nuclear does not get a lot of political airtime because of Fukushima and other general fears that people have. This is unfortunate because the overall track record of nuclear has been very good.

In China they have led the way in nuclear installations and that will likely continue. In OECD countries, France has a large nuclear generation power base. But generally nuclear is unlikely to have a rapid build-up in most countries because the general population is not in favour of the existing nuclear plants let alone more nuclear plants, and that makes it difficult politically for governments to support nuclear. But from a carbon cycle perspective the technology is attractive.

Carbon Capture and Storage

Carbon capture and storage is another key carbon-neutral enabling technology. Chevron has a huge carbon capture and storage facility off the northwest coast of Australia. The CO2 is separated from natural gas as it emerges from gas wells and the separated CO2 stream is then injected into deep reservoirs under the ocean. The CO2 does not come from combustion, it is naturally occurring with the natural gas. So, we know that carbon capture and storage technology is proven and works if there is an appropriate storage location.

I do not think we have fully tested if the public will accept carbon capture and storage if it is close to centres of population. They may fear that it could escape and asphyxiate people. Sequestering CO2 out in the deep ocean is one thing; sequestering huge amounts of carbon dioxide below land, particularly in areas of population, is another political challenge that will have to be addressed and it is not clear to me how that might be resolved.

I think you must compare the alternatives; would you rather have below land carbon capture and storage or live next to a wind or a solar facility? There will be elements in society who will oppose one or the other or both near where they live. The political challenges will be significant.

The 2100 Black-Swan

The ultimate Holy Grail is, of course, Fusion but whilst it shows great promise who knows when (or if) it will come to fruition. 2100 is about 80 years away and that is a long time and Fusion could be a huge game changer by then if there were to be breakthroughs, but Fusion is not yet built into anybody's energy forecast out to 2100.

This is the energy Black Swan.