IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

Chemical Engineering Matters

3rd Edition

Why chemical engineering matters

Our world is a complex and evolving place. In the 21st Century, the requirements of a growing and ageing population will have significant impact on society. With global population expected to reach 8.5bn by 2030 and 11.2bn by the end of the century, demand on resources such as water, energy, food and raw materials will be greater than anything we have experienced. How do we meet the expectations of a modernised, global society whilst minimising the impact we have on our environment?

As my predecessor, Ed Daniels from Shell, wrote, "the future is challenging and uncertain". The puzzle is complex, but chemical engineering remains central to the delivery of sustainable water, energy, food and wellbeing. This applies to the developed economies and delivery of the UN sustainable development goals.

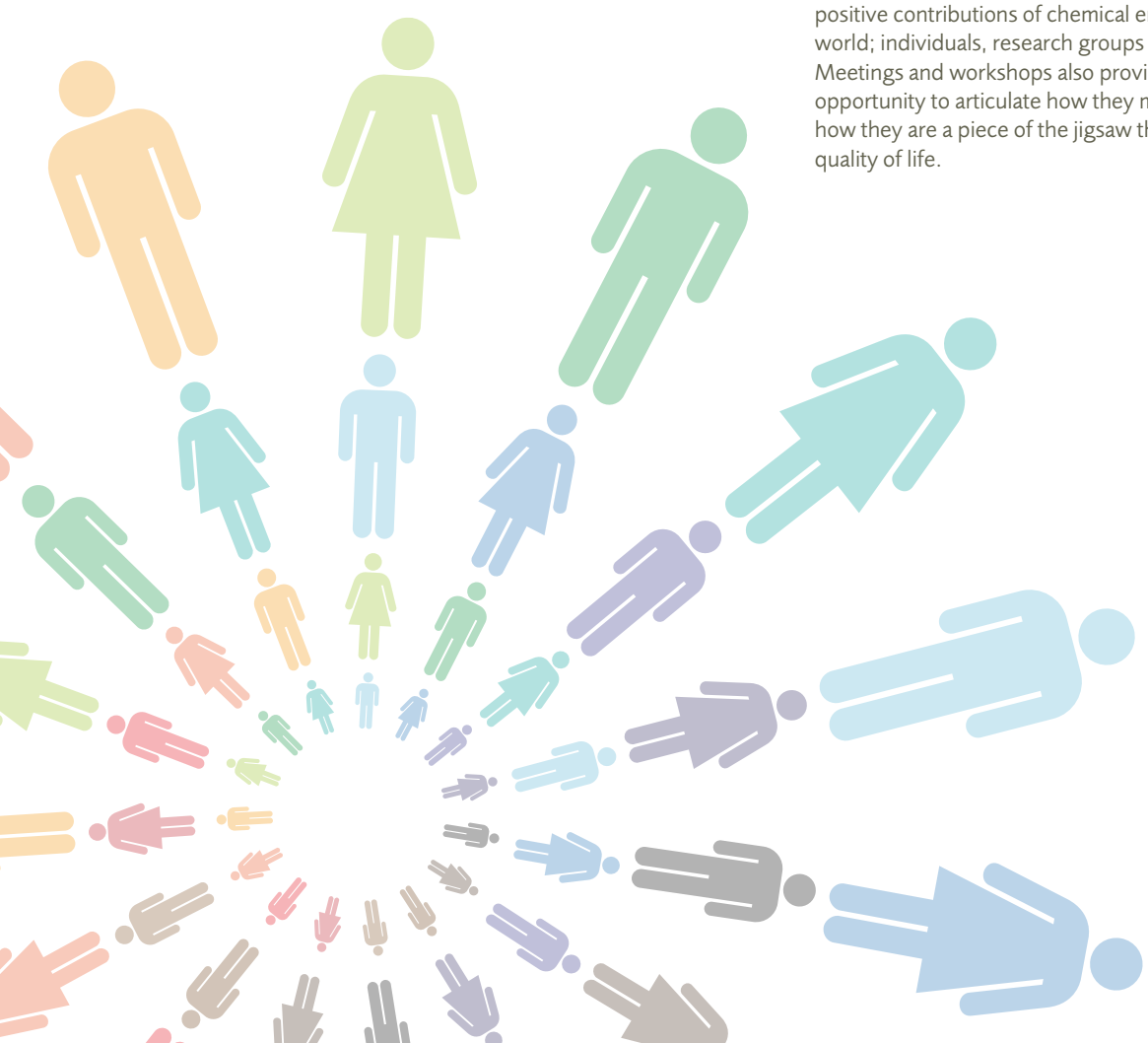
The breadth of the chemical engineering discipline puts the profession in a unique position. As a technical community, we collaborate with many other disciplines and have a track record of high impact contributions. These range from water and energy to medical research and boardroom safety contributions. Chemical engineers have even made it into space.

Grand challenges

Chemical engineers can and will play an important role in the design and realisation of solutions for the grand challenges we face. They have to provide their technical skills and knowledge, but they will need to contribute to the complex technical and in some cases ethical debates that surround the issues.

Chemical Engineering Matters is not about a programme of activities, it defines a mindset, a willingness to share, collaborate, and engage in the discussion. Chemical engineers have a desire to have impact and make a positive contribution. A vital part of this is to build a strong technical community that will encourage the sharing of ideas and perspectives and promote debate.

Since its launch in early 2013, the *Chemical Engineering Matters* initiative has been at the core of everything IChemE does – with, and for, the discipline, it is about advancing chemical engineering worldwide, for the benefit of society. So far, there have been workshops in four different continents, with over 2,000 people sharing views on challenges and opportunities faced by chemical engineers. The issues raised feature on every page of *The Chemical Engineer* magazine and every workshop has generated ideas. Former president Geoff Maitland's *ChemEng365* blog shared examples of positive contributions of chemical engineers around the world; individuals, research groups and corporate teams. Meetings and workshops also provided people with an opportunity to articulate how they make a difference and how they are a piece of the jigsaw that delivers sustainable quality of life.



Expert opinion

The chemical engineering community has a critical role to play. Discussion and debate among IChemE's 44,000 members in 120 countries offers a wealth of opinion, experience and expertise. Activity within the 19 special interest groups and regional member communities around the world is essential. This brings together specific technical knowledge and regional knowledge of challenges and appropriate, sustainable solutions. Meetings offer the opportunity to network and learn from each other, webinars offer knowledge and ideas to a wider community. Aside from technical events there are careers events, social activities, and discussions on the importance of diversity within the profession. Expert opinion from special interest groups and the leadership of IChemE's Safety Centre and Energy Centre help shape position statements on important issues such as climate change, training and skills, and future energy solutions.

I know and believe that chemical engineering matters. It makes a valuable contribution to society and the daily lives we lead now and in the future. I know that many other chemical engineers share this belief and are passionate about what they do. IChemE provides a forum and mechanism to build a global technical community. As a profession, we can leverage our collective input and spread the message to the chemical engineers of today and tomorrow. We can engage the public and those that define policy to share the message that chemical engineering matters, now more than ever.

Jon-Paul Sherlock

IChemE technical vice president, June 2016

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Executive summary

Mapping out the many ways in which chemical engineering impacts positively on the world around us is a complex but rewarding task.

IChemE's Chemical Engineering Matters initiative breaks the challenges down into four areas, which are central to quality of life: water, energy, food and drink, and wellbeing. Much of the work undertaken by chemical and biochemical engineers is applied in one or more of these areas. As the updated Chemical Engineering Matters model on the facing page illustrates, each is affected by six cross-cutting issues and concerns, such as process safety, education, and advances in biotechnology. The need for sustainability underpins all of this across the full product and process lifecycle.

The model prompts chemical and biochemical engineers in industry, education and research to assess the role of their work in delivering solutions that create, sustain and improve quality of life.

Safety and risk

Managing safety and risk in chemical engineering is very different from managing risk in other industries. Designing and operating high-hazard facilities, where accidents are rare, but can have devastating impacts, demands a more exacting approach to safety and loss prevention. IChemE focuses on collaborating and exchanging ideas with industry, government, regulators and other stakeholders. Developing a common understanding of risk and sharing best practice is of paramount importance.

The Institution's primary vehicle for this activity is the IChemE Safety Centre (ISC), which was launched in January 2014. The centre brings together operators, service providers, regulators and academics. Furthermore, the Professional Process Safety Engineer qualification, also launched in 2014, demonstrates the importance that IChemE attaches to process safety.

Education, training and skills

IChemE accredits higher education programmes at 67 university departments in 13 countries. The Institution also validates and accredits company training schemes and promote chemical engineering to school pupils – the work in this area in the UK has proved extremely successful and applications to study undergraduate chemical engineering degrees trebled between 2005 and 2015.

Chemical engineering research

Chemical engineers tackle many of the world's grand challenges. The need for properly-funded chemical engineering research is clear, and the sector is evolving quickly, with new tools such as molecular modelling, quantum chemistry, and synthetic biology emerging.

Chemical engineers can bring a unique perspective to multidisciplinary research. They are trained to think holistically, and to understand processes and whole systems in their full complexity. IChemE continues to press for adequate investment in research, and for first-rate teaching to be treated on an equal footing with research.

Water

Water is essential to sustaining life on our planet. However, clean water for drinking and domestic cooking is a limited resource which is coming under increasing pressure through population growth, industrialisation and agricultural demand. Environmental factors, including climate change, add further pressure. Chemical engineers have a huge role to play, be it treating and recycling wastewater or making industrial and communal water use more efficient. In addition, advanced treatment processes make it possible to recover valuable materials from wastewater, including metals, nitrates, phosphates and biogas.

Energy

Securing access to clean and affordable energy is one of the most pressing problems of our time. Chemical engineers, through their central role in designing manufacturing processes and understanding complex systems, are directly engaged in the quest for sustainable solutions.

Chemical engineers are supporting the development of carbon-free, low carbon and renewable energy solutions through new technologies, including electric and fuel-cell propulsion, biofuels, and nuclear power generation. Fossil fuels are required in the short- to medium-term and their climate impact must be mitigated via carbon capture. The exploitation of shale gas and coal bed methane continues to be a source of animated debate. IChemE believes that the risks associated with these processes can be managed appropriately.

The role of energy storage at scale, alongside managing electricity supply and demand, will be central in allowing renewables to reach their full potential.

Food

Global food production has broadly kept up with population growth, but limited availability of land and water, and the impact of climate change, threatens to disrupt this equilibrium.

Agriculture accounts for 30% of greenhouse gas emissions, and new farming methods are needed. Chemical engineers are working on processes to improve the overall efficiency and sustainability of producing food, including developing low-impact solutions such as

CO_2-enriched hydroponics. With as much as half of the food produced being wasted, we need to minimise waste and explore other options such as energy recovery from food.

Wellbeing

Increasing urbanisation impacts on physical, social and mental wellbeing. Major population centres must adapt to accommodate expanding population in a sustainable way, respond to changes in use, and be ready for potential extreme weather that may result from climate change. Chemical engineers support the quest for sustainability by creating new products and alternative materials with greater atom efficiency, reduced ecological footprints, and renewable feedstocks.

Ageing populations will shift the focus in healthcare from curing disease to treating the effects of advancing age and overindulgent lifestyles. Preventative medicine will continue to gain ground, as will biological and biochemical engineering. Transplant organs manufactured from biological materials and safer, more sustainable biochemical production methods will become commonplace.

Resources and manufacturing

Chemical engineering plays a vital role right across the manufacturing industries – from primary resource extraction to the production of finished goods. The potential for chemical engineers to improve extraction processes is substantial. The mining industry alone uses 3% of global power to crush rocks, and incremental efficiency gains can have a big impact. There is also significant scope to identify and exploit new renewable resources, design more flexible manufacturing plants, and reduce raw material consumption.

External influences

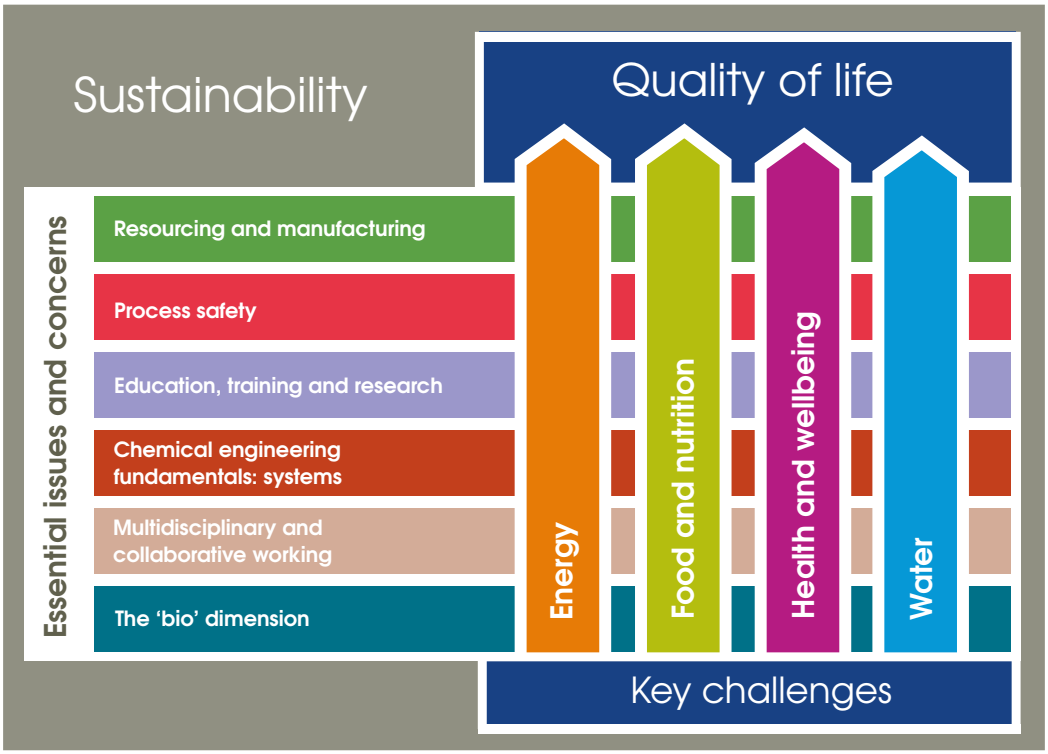
Chemical and process engineering is subject to a range of external influences, including politics, economics, public opinion and ethics. Professional engineers often express frustration at the perceived lack of scientific and engineering knowledge in political circles. IChemE encourages debate based on sound science and good engineering practice, and supports constructive dialogue with policymakers. But we are not the only actors, and collaborating with kindred bodies will lead to policies that command support across the science and engineering community, and amongst the wider public.

Public acceptance of industry, and confidence in technology and experts, has been disrupted by distrust, cynicism and sometimes outright hostility. Accidents in the process industries are infrequent but they can have a huge impact, resulting in negative headlines worldwide.

IChemE is working alongside the wider chemical engineering profession to highlight the positive benefits of the discipline. We will continue to support and train members who are interested in engaging with the policymakers and the media. Through its global corporate partnerships, the Institution encourages companies to be more forthright about the value that chemical engineers add to their business.

Chemical engineers don't need to be told that chemical engineering matters. This report will help chemical engineers to tell others.

Figure 1: The *Chemical Engineering Matters* model



Introduction

Providing thought leadership on technical matters is an important aspect of IChemE's work. Ten years have passed since the Institution first posed the question: "What does society need; what are the desirable outcomes and how can chemical engineers work in partnership with others to make it happen?"

This was always a challenging question. Nevertheless, identifying safe and sustainable solutions to difficult problems is what chemical engineers do. If the profession is to be taken seriously by decision-makers, opinion formers and an informed and increasingly demanding public, we need to advance credible answers.

Uncertain future

The world has changed dramatically over the last decade – a global financial crisis, political instability in Middle East and the UK's decision to leave the EU are just a few of the factors. The impact of unconventional fossil fuel, particularly the rise of shale gas, has taken energy markets by surprise. Meanwhile, concerns around climate change have escalated, culminating in the Paris Agreement in December 2015.

Crystal ball gazing is a risky business, but despite the uncertainties IChemE has made good progress. Its rising global membership – up from 26,000 in 2007 to over 44,000 today – gives IChemE the resources to understand and to influence events on a global scale.

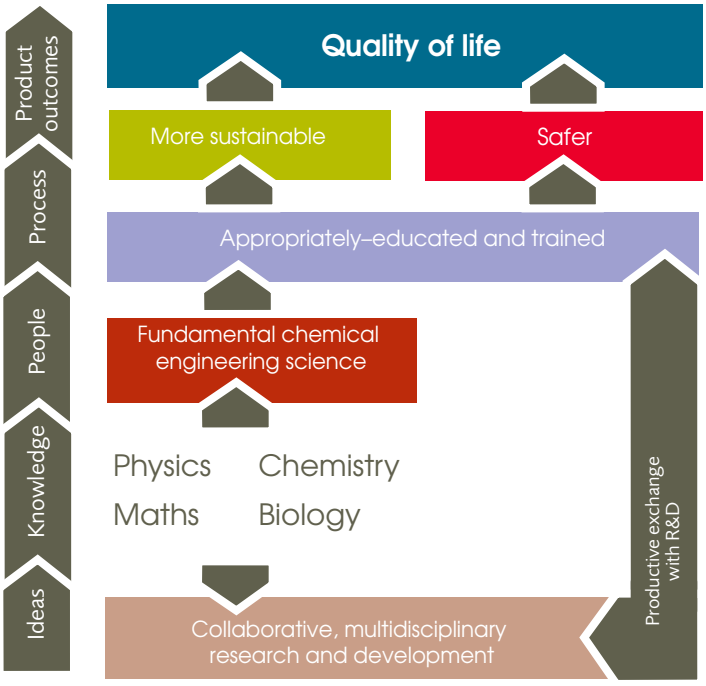


Figure 2: Chemical engineering and quality of life

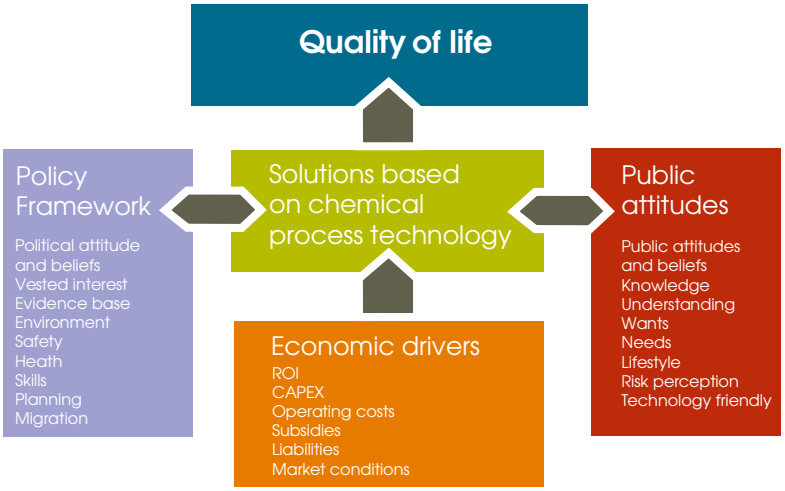


Figure 3: External factors

Quality of life

Chemical engineers are key to delivering secure, sustainable, affordable water, energy, food and healthcare – essential for quality of life. IChemE has worked to raise the profile of the discipline in these areas.

The ideas that underpin collaborative, multidisciplinary research and development depend on a sound grasp of biology, chemistry, maths and physics. With this knowledge, chemical engineers adopt a solution-based approach to design, build, operate and manage safe and sustainable processes that deliver the products and services which people need. They also educate and train the next generation *(Figure 2)*.

Four vistas

Chemical engineering solutions in each of the four challenge areas are presented as 'vista diagrams'. The vistas present solutions that are available now, in the near term, and those that are on the horizon. These diagrams will be the subject of animated discussion; they are incomplete and open to constant revision. Indeed, breakthroughs and step changes can occur and a vista may alter dramatically. The rich variety of solutions suggested is a compelling illustration of the possibilities offered by the profession. IChemE encourages chemical engineers in all sectors to identify the areas of the vistas that align with their activity.

The capability to deliver is shaped by factors beyond science and technology – economic conditions, Government policy and public attitudes often have a decisive role *(Figure 3)*.

This report sets out a work plan in the form of ten tangible actions that IChemE will pursue. These actions will support the international chemical engineering community as it strives to deliver safe and sustainable process solutions. *Chemical Engineering Matters* will continue to provoke debate, arouse interest and alert people to the power of a discipline that has shaped, and continues to shape, the world in which we live.

The fundamentals: safety and risk

IChemE is committed to working with government, regulators and other stakeholders to build a common understanding of risk.

There is also an emphasis on the importance of closer engagement with business leaders, regulators and other professional bodies. These relationships aim to develop a culture that delivers real improvements in safety, health and environmental performance. These objectives remain key to our future work programmes. Safety and risk management are core values, which chemical engineers must apply in every aspect of their work, irrespective of the sector. Continued promotion of a wider understanding of process safety is central to this ambition.

The Safety Centre

To underpin the fundamental importance of process safety, IChemE commenced operation of the IChemE Safety Centre (ISC) in January 2014. The ISC brings together the stakeholders in process safety – operators, service proviers, regulators and academia – to share and learn to improve process safety outcomes globally.

Good regulation, which is enabling in nature and strikes a balance of what is reasonable and practical to reduce risk, is important for all process industries. IChemE supports a non-prescriptive, goal-based approach to process industry regulation where the legal duty lies squarely with the organisation that creates risk and benefits from it. In the high-hazard industries, effective regulation also plays an important role in establishing and maintaining public confidence.

Everyone must play their part in managing risk, but the chemical engineer's role is particularly important in relation to process safety. Failure to manage process safety risks has led to many catastrophes. In 2008 IChemE launched a suite of new training courses addressing the fundamentals of process safety, along with a comprehensive professional development programme concentrating on human factors in process safety.

New partnership

A proactive approach to sharing lessons learned from process safety failure, and success, is key to IChemE's work. The *Hazards* symposia remain important fixtures in the global event calendar; they are recognised and well-supported international events, held in the UK, Asia Pacific and Australia. A partnership with the Mary Kay O'Connor Process Safety Center, based at Texas A&M University, will provide a platform for global collaboration on process safety. The *Loss Prevention Bulletin* has been updated and remains the key publication for sharing learning and good practice among those who are engaged in process safety.

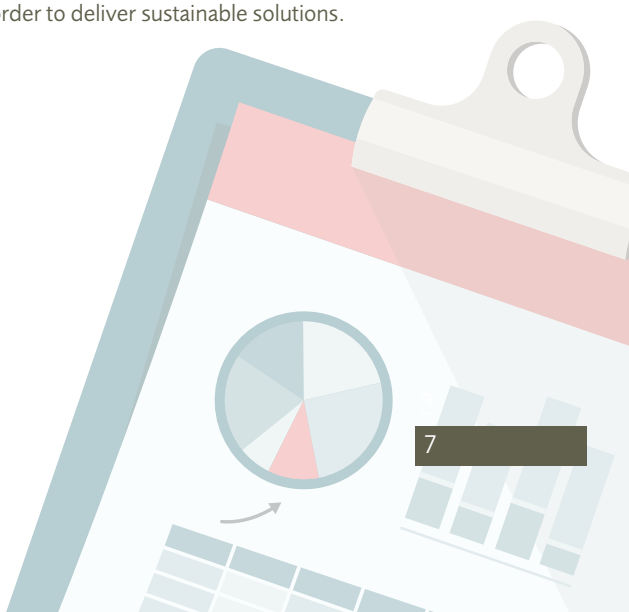
In 2012, the Organisation for Economic Cooperation and Development (OECD) published new guidance on corporate governance. Leadership on process safety from the very top of organisations is essential for successful and sustainable business performance. The ISC supports this via process safety training for executives and non-executive directors, addressing the knowledge gap within an organisation's decision-makers.

New qualification

To underline the fundamental nature of process safety competence within chemical engineering, IChemE has implemented a new qualification for process safety professionals. The registration 'Professional Process Safety Engineer' provides practitioners with a recognised, respected qualification at the same professional level as Chartered Engineer or Professional Engineer. This is supported by a specific Associate Membership focussed on process safety, which creates a pipeline for young engineers towards Professional Process Safety Engineer registration. IChemE continues to work to develop new competences in risk communication. In 2015, there were two workshops about communication and learning in process safety. These brought together experts and delegates from a range of backgrounds to discuss the challenges and solutions to these issues. This work will continue as we create stronger links and collaborate with the Mary Kay O'Connor Process Safety Center.

Process safety solutions

Risk assessment tools provide effective means to measure and manage risks and to communicate with others. Engineers provide society with important solutions; therefore, meaningful and comprehensive dialogue with stakeholders is essential. The ISC delivers meaningful engagement about how we manage and reduce, but never eliminate, risk in order to deliver sustainable solutions.



The fundamentals: education, training and skills

IChemE accredits Master's, Bachelor's and Diploma higher education programmes at 67 universities in 13 countries around the world.

The accreditation process is not prescriptive; rather it specifies the learning outcomes required of today's chemical engineering graduate. The profession continues to evolve rapidly and nowhere is the need to take account of change more important than in academic and professional formation. New graduates must acquire the skills to perform in a wide variety of roles across the four challenge areas. Industry requires graduates who are equipped with the knowledge, skills and personal attributes to function at a high level and make a difference early in their employment. Graduates must demonstrate a high-quality academic grounding in chemical engineering principles. IChemE's accreditation guidelines are reviewed regularly in response to changing international trends. This flexible and adaptable stance will continue.

Accredited degrees provide graduates with a clear pathway to qualification as a Chartered Chemical Engineer (CEng) or Incorporated Engineer (IEng). IChemE also offers other professional registrations including Chartered Scientist (Sci), Registered Scientist (RSci) and Chartered Environmentalist (CEnv). Chartered status remains the gold standard of IChemE membership, bringing with it international recognition and respect. By the end of 2015, there were over 12,000 Chartered Chemical Engineers worldwide.

Promoting career choices

In addition to its higher education work, IChemE supports employers and trainers across the talent pipeline. Its *whynotchemeng* campaign has seen considerable success with applications to study chemical engineering first degrees in the UK trebled between 2005 and 2015. The campaign has raised the profile of chemical engineering in different industries. The UK intake has reached record levels and *whynotchemeng* materials are also used to promote chemical engineering in Australia and South East Asia. The campaign will be refocussed in response to the skills demand in different countries and sectors and with a new emphasis on retention. IChemE will work to keep the best chemical engineers in the chemical engineering profession.

IChemE is strongly committed to diversity in the engineering professions and strives to avoid stereotyping. Today, more than a quarter of chemical engineering undergraduates are female. Men and women enjoy similar success rates in the application process for Chartered membership.

IChemE is dedicated to securing a steady flow of highly-skilled and motivated chemical engineering graduates and postgraduates. In addition, industry also requires highly-skilled and competent technicians. IChemE offers two categories of technician membership and it will continue to work closely with other science and engineering bodies to raise the profile of these key individuals. The Institution also works to ensure that the labour force is continually up-skilled, re-skilled or able to maintain knowledge so as to remain at the cutting edge of technology in a fast-moving landscape.

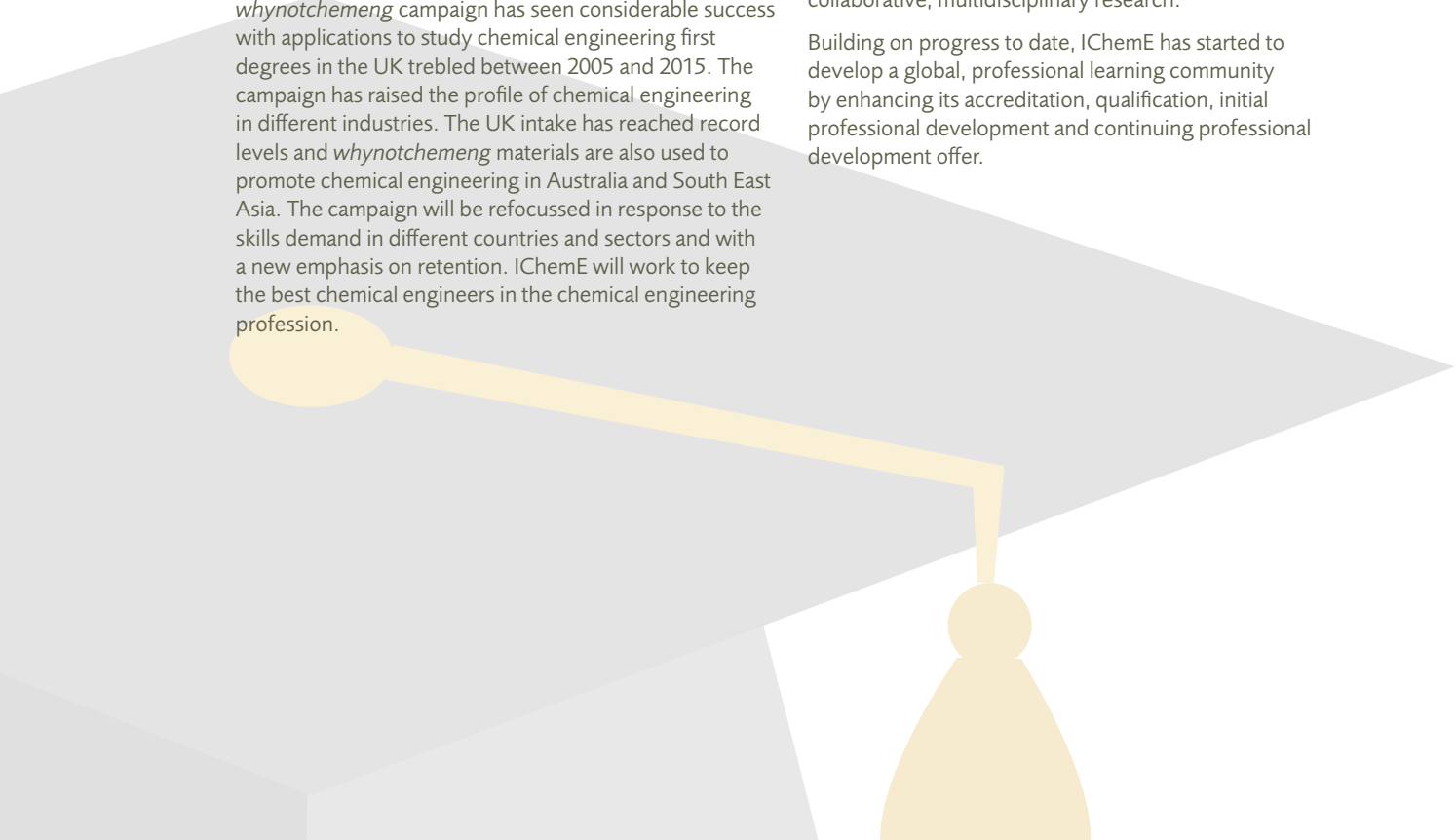
Company training

The Institution supports accredited company training schemes at over 70 global employers alongside a diverse offer of more than 80 training courses in both technical topics and transferable skills. IChemE will continue to provide high-quality professional development, training, and support for the chemical engineering community in response to the challenges and potential solutions described in the four vistas.

Supporting academics

IChemE has also identified a need to support and develop future academic leaders, thereby ensuring world-class undergraduate tuition and productive engagement in collaborative, multidisciplinary research.

Building on progress to date, IChemE has started to develop a global, professional learning community by enhancing its accreditation, qualification, initial professional development and continuing professional development offer.



The fundamentals: chemical engineering research

Chemical and process engineering will be at the forefront of tackling many of the world's tough challenges. On an international scale, the need for research is clear.

The European Union's 'Horizon 2020' programme, for example, highlights a set of societal challenges that includes secure, clean and efficient energy; food security and the bio-economy; smart, green transport; and resource efficiency – along with key enabling technologies such as advanced manufacturing and processing, biotechnology, and smart materials. All of these require chemical engineers' skills and chemical engineering tools. IChemE will help ensure they are applied.

Like other disciplines, chemical engineering is being subjected to huge changes. Process technology, transport processes and the classical unit operations will remain at the core, but chemical engineers must pay more attention to molecular transformations along with biological systems and concepts, while fully exploiting new tools like molecular modelling, quantum chemistry and synthetic biology. The concepts of systems thinking will provide a broad integrating framework. The boundaries between research and implementation and science and engineering will become increasingly blurred. Chemical engineers manipulate molecules, as well as scaling up processes and optimising economic and environmental performance.

Process and product

Above all, chemical engineers understand processes. This understanding brings benefits in many fields; from traditional chemical processing and design, to business, financial and other processes – from the nanoscale to the level of the global ecosystem. Chemical engineers are found in many walks of life, but they also operate in a multidisciplinary context. IChemE will encourage the application of innovative thinking to diverse fields, nurture closer links with other disciplines and celebrate success across the spectrum. Chemical engineering excellence can transform businesses and IChemE will publicise and advocate transfer of best practice across industries and organisations. Product innovation must be of equal importance to process innovation.

Research investment

This places big demands on practising chemical engineers, and on those who educate them. Undergraduate courses and postgraduate training need to cover a wide range of topics, while ensuring that the fundamentals of the subject are solidly embedded and that research and teaching are linked for mutual benefit.

The discipline must adopt new concepts and integrate them into curricula, so that finally, innovative and more sustainable processes will break through into industry. IChemE will press for adequate investment in the research base, for recognition and incentives for first-rate teaching as well as first-rate research. The Institution will work to foster more productive, multifaceted and effective relationships between researchers in academia and industry, as well as between the research base itself and business.

The number of young people entering the discipline is growing. This presents a new challenge. Finding the right people to teach them will be tough. In industry, chemical engineers are often very well paid. Pursuing a career in chemical engineering education and research is viewed as a passion, rather than a path to a large salary and material wealth. IChemE will work with universities to persuade some of the brightest and best young chemical engineers to consider the academic world for part of their careers. The Institution continues to support the dissemination of research at conferences such as *ChemEngDayUK*, *Chemeca* and the *Symposium of Malaysian Chemical Engineers*.

Funding challenges

IChemE recognises that in an era when much of the world is emerging from the severest economic downturn since the 1930s, public and private funding for chemical engineering research will be harder to obtain. In the face of this challenge, a new mood of optimism is required along with a willingness to publicise and promote the profession and the difference that it can make, more consistently and more compellingly than ever before.

This report has identified a huge range of possibilities where chemical engineers can shape the future. IChemE will work to identify shining examples of chemical engineering research that offer real potential to change lives. It will act as a broker between the researchers, funding bodies and industry to build a confident and outward-looking international chemical engineering community that will play its part fully in building a more sustainable future.

The sustainable water vista

Water is fundamental to life, but it is a limited resource. Ensuring that people have access to clean water is a significant global challenge. It is essential that there is a balance between supply and demand. This requires behavioural change and technological innovation.

More than a billion people (over 10% of the global population) have inadequate access to clean water. Population growth, industrialisation and increased agricultural demand are putting increasing pressure on water supplies.

Chemical process technology

NOW	NEAR
Increasing industrialisation in developed, emerging and nascent economies	Increasing demand for process water → Implement more energy-efficient water treatment and purification
	Increasing wastewater and environmental pollution from effluent → Promote the use of chemical process technologies to improve water conservation → Develop, deploy
	Poor industry and agriculture infrastructure results in water loss → Increased biorefining of sewage sludge → Promote energy sewage sludge
	Pursue step-change reduction in sewage sludge production
	Limited reuse of domestic and industrial grey water → Wider adoption of membrane bioreactors for process
	Wasteful/inefficient treatment of water to potable standard regardless of end-use → Increased wastewater recycling and reuse of 'grey water' in
	Cost-effective and robust treatment for grey/brackish water
Increasing use of water in fracking	Develop and use improved fracking chemicals and post-use water treatment

Safety and the environment

Global climate change alters hydrological cycles	Improve water conservation using process technology
Damming for irrigation and power generation resulting in negative environmental impact	Strengthen focus on ecosystem rehabilitation and remediation
	Implementation of water-sensitive urban and industry designs
Risk of water pollution from mining and industrial processes	Greater use of in-line measurement and monitoring of water quality
	Increased use of system-wide condition monitoring
Risks associated with high-energy and high-pressure systems	Wider deployment of advanced, intelligent controls

Policy

Lack of long-term infrastructure		Mutual support between industry and governments for implementing technology to
Lack of coherent water strategy globally and in different regions	Improved sharing of best practice	Drought resilient water supply technologies for
		Promote nutrient recovery programmes
Poor understanding of the economic importance of water	Promote innovation in water conservation, reuse and supply	Improve process audit and control in the water
		Work with policy and decision-makers to highlight

Society and public support

Strain on existing water resources	Increasing global population leading to greater demand for domestic and agricultural water	Improve awareness and understanding of
		Promote responsible use of water
	Developed nations are greedy and wasteful of domestic water	Promote understanding of the water footprint
		Highlight true cost of water and areas of use
	Shortage of technical expertise entering the water industry	Promote role of chemical
Future water shortages may result in energy and food shortages leading to political and social unrest		Work towards use

Water scarcity is being aggravated by interrelated environmental problems – eg desertification, salination and pollution and climate change – as well as over-extraction and large-scale national and international water diversion. Traditionally the water industry has relied on civil engineering to solve its challenges, but chemical engineers are being increasingly asked to provide advanced technology solutions. There are opportunities to improve the sustainability of municipal and industrial water supplies.

Recycling and reusing water

Chemical engineers have an essential role to play in resolving the challenges associated with recycling wastewater and reusing 'grey water' in industrial and chemical processes. Cost-effective and robust technologies are needed that recycle water, treat, remove contaminants (at macro and micro levels) and dispose of associated byproducts, such as concentrated saline.

In some scenarios, there is an opportunity to develop water distribution systems that separate potable water supplies from water destined for other uses.

In the near- to mid-term, chemical engineers will also support the development and implementation of technology and strategies that facilitate access to clean municipal water supplies, that lead to improved water conservation, and that process water in more energy-efficient ways.

Producing clean, safe water, making it readily available and improving sanitation and human waste management are significant global public health challenges. Sustainable desalination to provide clean, safe water will feature increasingly in some regions and chemical engineers will play a key role in developing more energy-efficient desalination processes.

Chemical engineers will also play a vital role in reducing water losses by improving infrastructure, processes and technology in a variety of settings, ranging from agriculture, mining and oil and gas extraction to process industries and the provision and distribution of potable water. IChemE will work to highlight the importance of sustainable chemical engineering in the water sector.

Maximising the value of waste

The amount of municipal and industrial wastewater is increasing. Domestic sewage is a growing problem in rapidly-expanding urban areas; and industrial wastewater may contain harmful contaminants as well as valuable chemicals. Dealing with wastewater is costly but, where not addressed properly, it can have a significant impact on the environment.

Using specialist technology in the treatment, reuse and recycling of water can offer significant cost savings in terms of the quantity of water used, reduced waste discharge and other cost benefits. Water treatment technologies can be used to extract commodities, including nitrates, phosphates and biogas from sewage sludge and to recover valuable substances, such as trace metals, salts, organic acids and rare earth elements from industrial effluent. Demand for recovered materials will increase as global demand continues to drive up commodity prices.

IChemE will work to highlight the importance of sustainable chemical engineering in the water sector.

There will be a greater adoption and development of technologies to recycle process water in industrial plants. Advanced digestion, granular treatment processes, fixed-film biomass reactors, anaerobic ammonium oxidation processes and membrane bioreactors all have important roles to play in effluent treatment.

The energy and water industries are likely to become more integrated and there will be greater multidisciplinary working and collaboration. Electricity is already produced from the co-digestion of sewage, industrial effluent and domestic waste. Biofuel cells may give access to electricity generation from wastewater, and low-grade heat from power plants and solar power may be used in desalination, for example, using membrane distillation.

Process safety and efficiency

There is a need to ensure process and product safety throughout the water network. Industrial processes, ranging from mining and hydraulic fracturing to manufacturing all carry inherent but manageable risks. These may be environmental risks in the case of unexpected/uncontrolled release, but they may also be related to the processes and systems, for example, high energy and high pressure.

Chemical engineers will play an essential role in a wider deployment of advanced, intelligent systems for in-line monitoring throughout entire systems and networks. Utility providers in some regions are already concerned about micropollutants (eg from pharmaceuticals, personal care products and disinfection byproducts). There needs to be effective regulation of these pollutants and work to reduce the impact of these contaminants. Chemical engineers will play a role in all of these areas, working to design and implement processes; however, appropriate regulation is essential.

Improved industry practice, supported by innovative chemical process technology and greater public engagement, will drive stronger performance in water management with a renewed focus on the environmental aspects of water on our planet, protecting catchments, sustaining rivers and working towards rehabilitation and remediation of ecosystems.

Policy, social awareness and understanding

The public needs to be educated to understand the pressures that are placing reliable water supplies at risk. Improved awareness of concepts such as a water footprint and virtual water will aid understanding and will, in turn, lead to more responsible use of water. Different countries have different needs, demands and challenges, so there must be support to facilitate understanding as well as a sharing of best practice and new ideas at global, regional and local levels. Some regions may choose to introduce universal metering and adopt pricing policies that promote responsible water use.

Sustainable water services require effective planning, construction and maintenance. Infrastructure can last for many decades and therefore the distribution networks, collection systems and treatment plants must be adequate and consider the long-term requirements, the need for flexibility and ability to adapt.

Chemical engineers can support growth by engaging with decision-makers to ensure there is a strategy to implement improved process technology and practices. Using process audit and control more effectively will identify weaknesses and focus improvements. IChemE will proactively communicate progress in this area.

The water vista diagram sets out the opportunities for chemical engineers in securing sustainable water supplies and will be used as a framework for further discussion and priority setting.

FACTS

By 2030, demand for water will be 40% higher than today
2050: 67% of the world's population will live in water-scarce areas
Water, sanitation, and hygiene were responsible for 842,000 deaths from diarrhoeal disease in 2012

The sustainable energy vista

Society needs fuel for heating, cooking and transport. Electricity powers industry and commerce, operates equipment and lights our lives. With the world's population rising and simultaneously becoming more affluent through global development and industrialisation, demand for energy is increasing rapidly.

Meeting this demand is a crucial challenge for the decades ahead. The main energy sources exploited to date are finite and often susceptible to geopolitical flux. Climate change adds a challenge to drastically reduce emissions of greenhouse gases. Future energy solutions must be sustainable as well as affordable. This is a challenge for all of society, though chemical engineers and the process industries have a particular contribution to make.

There is intense competition for mineral and biological resources. It is vital that scientists and engineers work together to assess the options and their environmental impact are assessed for the long term.

IChemE recognises the need to promote greater energy efficiency with step-change improvements in existing processes. This means developing advanced manufacturing processes that use resources efficiently while minimising energy consumption. Linked to this is the need for smarter energy management, with a flexible grid that delivers energy to where and when it's needed, and new and effective ways to store energy when we have a surplus. This is particularly important given the growth in intermittent renewable energy sources such as wind and solar.

Sustainability – people, perceptions and processes

Humanity cannot continue to consume finite resources and generate waste at current rates. The challenge of living within the limits of planet Earth without compromising future development must be solved. This requires a paradigm-shift in lifestyles, both in terms of behavioural and practical changes. How will this be achieved? What role will technology play? And how can chemical engineering make a difference? As well as contributing to solutions, chemical engineers must make the case for greater and more proactive action to counter the impact of ever-increasing resource demand.

Role and needs of policy and society

A sustainable energy strategy must benefit society, the economy and the environment. The pace of change will vary from nation to nation. Developed countries, which have already capitalised on the use of previously abundant natural resources, must take the lead using their knowledge and infrastructure to drive change. IChemE will support and encourage sustainable progress, avoiding and learning from past mistakes. Making this happen requires international consensus that often proves elusive. Nevertheless, we can act today to reduce the impact on the planet and address the uncertainties and instabilities that have the potential to spark global conflict. IChemE will work with kindred bodies around the world to demonstrate the value of sustainable chemical engineering.

The future energy mix

Ultimately, to maintain and improve quality of life sustainably we need widely-available carbon-free or ultra-low carbon energy. This will eventually entail using solar energy to power our homes and industries, distributed internationally and stored in advanced energy storage systems to give the system resilience. Personal mobility is highly valued, while the movement of globally-traded goods remains an economic necessity. Since we cannot reduce the energy needed for personal and commercial transport, we must decarbonise it. This may be achieved using a mix of electric and fuel-cell propulsion and fuels derived from biomass (food and agricultural wastes) and cellulosic crops grown on marginal land. Making the transition to a low-carbon economy will involve implementing a raft of interim solutions.

IChemE recognises the need to promote greater energy efficiency with step-change improvements in existing processes.

Fossil fuel use remains unavoidable in the short- to medium-term, but the impact can be greatly reduced by implementing carbon capture and storage (CCS) technology. In some parts of the world new nuclear power plants, including next-generation technologies, will provide a major component of the energy solution. Greater use of renewables including wind, wave and tidal power presents new challenges. The variable, yet forecastable, nature of renewables will drive new thinking of both demand and supply-side power management.

Carbon capture, storage and use

Carbon capture is proven technology, but at the start of 2016, there is no large-scale commercial CCS activity in the power generation sector. CCS can reduce carbon emissions, but it reduces operational efficiency, often to the detriment of the overall process economics. Carbon capture and utilisation (CCU) may also play a role, using CO_2 as a feedstock for chemical processes, microalgae or plant growth and mineral carbonation. Careful attention must be directed towards energy balances and rigorous life cycle analysis for new processes. IChemE acknowledges that these technologies offer a short- to medium-term solution that will support ongoing fossil fuel use, but their adoption depends heavily on carbon pricing and government intervention. Equal effort must

FACTS

2016: 80% of global energy supply comes from fossil fuels
IPCC modelling envisages that 80% of generation in 2050 will be supplied by low-carbon sources
The Paris Agreement empowers all countries to act to prevent average global temperatures rising above 2°C

be directed towards the development and widespread deployment of truly sustainable and commercially-viable processes based on renewable energy.

Tight gas and other 'unconventional' assets

Tight gas, including shale gas and coal bed methane, has attracted considerable attention since 2007. These assets offer improved energy security, with a lower carbon footprint and new routes to petrochemicals. IChemE believes that health, safety and environmental risks can be managed effectively via operational best practice and appropriate regulation.

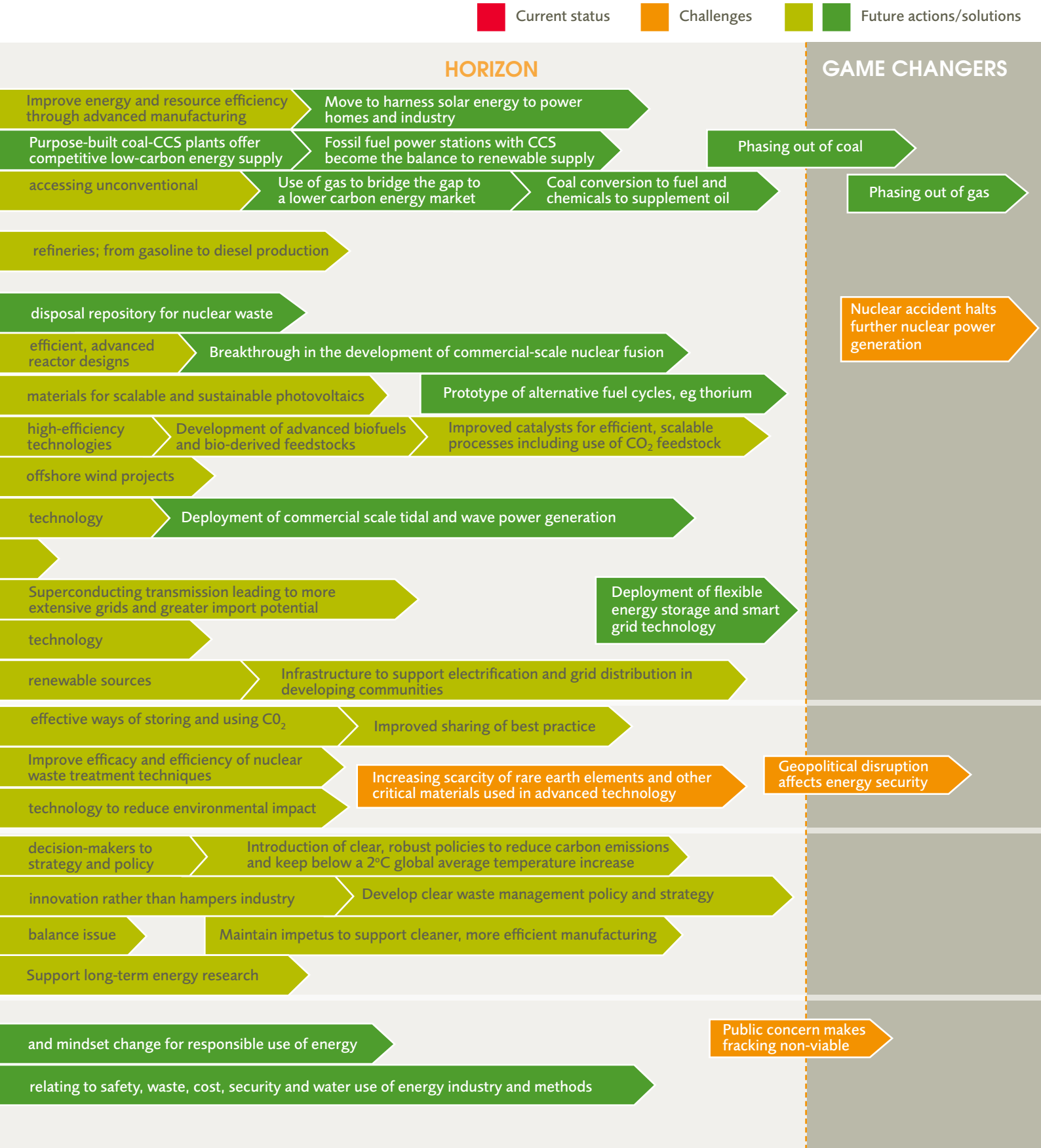
The sustainability of tight gas exploitation is a matter of animated debate amongst IChemE members and it has been argued that global carbon targets cannot be met if new build of unabated gas-fired power generation is allowed to proceed unchecked. The role of government policy is pivotal here and IChemE will continue to

	NOW		NEAR	
Chemical process technology	Changing energy balance, regional variations and environmental targets	Process industries	Promote stepwise changes in energy efficiency for existing processes and product design	
		Fossil fuels: COAL	Increased efficiency using advanced heat recovery	Development and retro-fitting of CCS technologies
		Fossil fuels: GAS: conventional and unconventional	Increased use of unconventional gas	Improved technology for gas resources
		Fossil fuels: OIL: volatile market prices	Changing nature of fuel types used	Reconfigure
		Fossil fuels: REFINING: transport and heating fuel		
		NUCLEAR: large-scale expansion in some regions	Improved treatment of nuclear waste	Established geological
			New phase of nuclear build in some regions	More sustainable, fuel cycles and
		Renewables: Solar energy: limited regional use	Development and deployment of more efficient	
		Renewables: Limited use of biomass energy generation. Demonstration plants using different feedstocks	Improved small-scale, biomass conversion	
		Renewables: Wide use of onshore wind power and increasing offshore	Increasing development of	
		Renewables: Few large-scale water projects	Development of efficient, reliable tidal/wave power	
		Renewables: Limited geothermal projects	Increasing use of geothermal heat resources	
		Electricity	Greater electric and hybrid vehicle numbers increases electricity demand	Consumer demand profile changing due to renewables and smart grids
		CHP and fuel cells	Wider use of CHP and fuel cell systems	Development of advanced fuel cell and battery
				Grid management to accommodate supply from
Safety and the environment	Increasing impact on environment	Limited standards and regulation of CO_2, SO_x, NO_x and particulate emissions from nascent and emerging economies		Develop and deploy more and reducing emissions
		Growing pressure for better treatment and disposal of nuclear waste		Clear policy, regulation and measures to deal with treatment and disposal of nuclear waste
		Concern of environmental damage, risks and pollution from unconventional gas extraction		Advances in understanding and extraction
Policy	Lack of clear strategy	Decision makers do not understand energy balance and challenge		Work with policy- and develop effective energy
		No clear bioenergy policy		Ensure political and economic impact of climate change promotes
		Hesitancy to develop and use nuclear power in some regions		Promote awareness of the energy
	Poor support structure for progressing technology from R&D to commercial deployment			Develop robust, supportive mechanism to bring technologies through to commercial deployment
Society and public support	Increasing global population	Rising energy demand	Greater public engagement	Actively promote lifestyle
	Increasing industrialisation			Address public concerns
	Public concern over safety and environment			

stimulate informed debate amongst its membership and more widely.

Energy storage and distribution

Storing and distributing energy are key pieces in the energy puzzle. The solution is likely to involve a combination of advanced batteries and super capacitors for stationary and mobile applications in domestic and commercial settings. Effective energy storage on a large scale can smooth the peaks and troughs in supply and demand and improve predictability. In many parts of the world, this will require major upgrades to transmission infrastructure and distribution networks. Surplus energy can be used to generate hydrogen through multi-cell electrolysis. Where local geography permits, pumped storage and air compression reservoirs can also be used to store power. Batteries also offer significant potential and IChemE will encourage the development of improved battery technology, mindful of the limited availability of some metals and minerals through genuine scarcity or geopolitics.



Safer, more efficient processes

Existing processes can become sustainable by making them more energy- and resource-efficient and by further improving the front-end efficiency of electricity generation. Better use of waste heat, process integration and more integrated supply chains all play their part. IChemE will continue to stimulate debate and promote sharing of best practice in these areas. It will work with industry and policy-makers to secure a shift towards cleaner, more efficient manufacturing. Support for forward thinking needs to come from all levels, embracing systems thinking and life cycle analysis. Continuous improvements in safety and environmental protection standards are required. The tragic events following the 2011 earthquake and tsunami in Japan and the explosions at the Fukushima Daiichi plant graphically illustrated how far-reaching the consequences of an accident can be. IChemE will work to secure outstanding safety performance in the energy sector.

The R&D landscape

In 2016, there is no obvious answer to the conundrum of how to provide secure, sustainable and affordable energy worldwide. Energy strategies require vision and long-term thinking supported by a vibrant research base. The Institution will work to secure adequate funding for energy research programmes from public and private sector sources. However, success also depends on the capability to translate research into innovation. IChemE will continue to encourage the evolution of effective mechanisms that move innovative energy technologies from research phase through demonstration to application and commercial deployment. The energy vista illustrates the diverse possibilities, and will be used as a framework for further discussion and priority setting.

The sustainable food vista

Major improvements in farming during the latter half of the 20th Century have ensured that, to date, global food production has kept pace with population growth. However, the pressures of a growing population and improved living standards in the developing world mean that there is a demand for more food, especially protein-rich foods that are water, land and energy intensive.

Land and water are finite resources with competing demands upon them. Furthermore, climate change may impact negatively on traditional food production methods and the availability of suitable land and water.

Population pressure and the demand for more food have led to greater awareness of the challenges faced and to the application of science and engineering solutions to food production. It is possible to meet demand without increasing energy, water or land use, as well as minimising waste production and safeguarding the ecological landscape. There are opportunities for chemical engineers and other disciplines to work with the agricultural industry to solve problems throughout the global food chain.

Minimising environmental impact

Food production is an energy- and resource-intensive process and modern agriculture accounts for 30% of greenhouse emissions.

In future, it will be necessary to ensure that the land and water from which food is obtained maintains the right qualities to produce food sustainably. Farmers will need to use appropriate fertilisers and minimise environmental pollution. The impact of plant and animal pests and diseases must be considered, and there must be coordination of treatments to ensure they are controlled in a safe and sustainable way.

Chemical engineers can help to meet the growing and changing demands for food by helping to develop novel technologies. This includes low-impact agricultural methods, such as CO_2-enriched hydroponics and greenhouses, and through the use of semiochemicals (chemicals such as pheromones, which can manipulate the behaviour of pests and beneficial insects). Chemical engineers can contribute to all parts of the food journey – from farm and field to the end consumer – by applying systems thinking and engineering principles. In considering life cycle analysis and overall environmental impact of food, the public and the food production industry have a responsibility to consider factors such as energy and water use.

Efficiency and waste

Waste in the food supply chain, from field to consumer, is significant. Approximately 30–50% of all food grown worldwide is lost, either before or after it reaches the consumer. In the move towards greater resource efficiency, both agriculture and the food and drink manufacturing industries must improve production efficiency. Food waste throughout the supply chain harms the economy and the environment.

FACTS

Every year 1.3bn tonnes of food, about a third of all that is produced, is wasted
By 2030, we will need 50% more food than currently
One in nine people suffered from chronic undernourishment in 2014-2016

Waste should be minimised as far as possible, and unavoidable waste should be re-used or recycled. This can be through composting or landspreading of liquid waste. Where this is not feasible, energy recovery from food waste through incineration, anaerobic digestion, pyrolysis, gasification or production of fuels and chemicals through fermentation is preferable to landfill. Chemical engineers can play an important role and achieve step-change improvements to reduce food waste.

Strategies are needed to use food waste more effectively. In particular, managing the large quantities of wastewater generated during processing. IChemE supports the development and application of new processes and technologies to minimise waste and to maximise the use of residual waste. New research strategies are needed to optimise the use and reuse of waste streams.

Food security

Global inequalities in food availability mean that there are regions of significant population density that cannot be supported by the land around them, often due to climate and political unrest. More effective transportation and storage of food and drink are a partial solution, but more could also be done to enhance local production. Where feasible, chemical engineers can establish local water supplies for drinking and irrigation.

National and internationational decision-makers have a responsibility to deliver food to where it is needed. However, the food industry can help identify where sufficient food has been distributed. Greater transparency will assist in improving access to food for all. Better storage and shelf-life should further improve consistent access to food and nutrition and reduce waste caused by spoilage.

Non-food crops offer significant potential for new raw materials with applications in the areas of energy, construction, fibres, packaging, pharmaceuticals and speciality chemicals but this diversification must be balanced against the need for land use to grow food. Chemical engineers should work with the farming industry and other science and engineering disciplines to optimise agricultural output while working to reduce escalating energy consumption and environmental degradation.

Food and agriculture industries will increasingly need to work alongside key decision-makers on regional and global-level strategies to increase innovation in food production. These strategies will complement regional models to optimise efficient and effective agriculture. Some governments already have policies in place to ensure food security, with initiatives to support local food production. This is particularly important, for example, in Australia where agriculture is a major part of the economy. Australia is largely self-sufficient in food and is a significant exporter to the growing Asian markets.

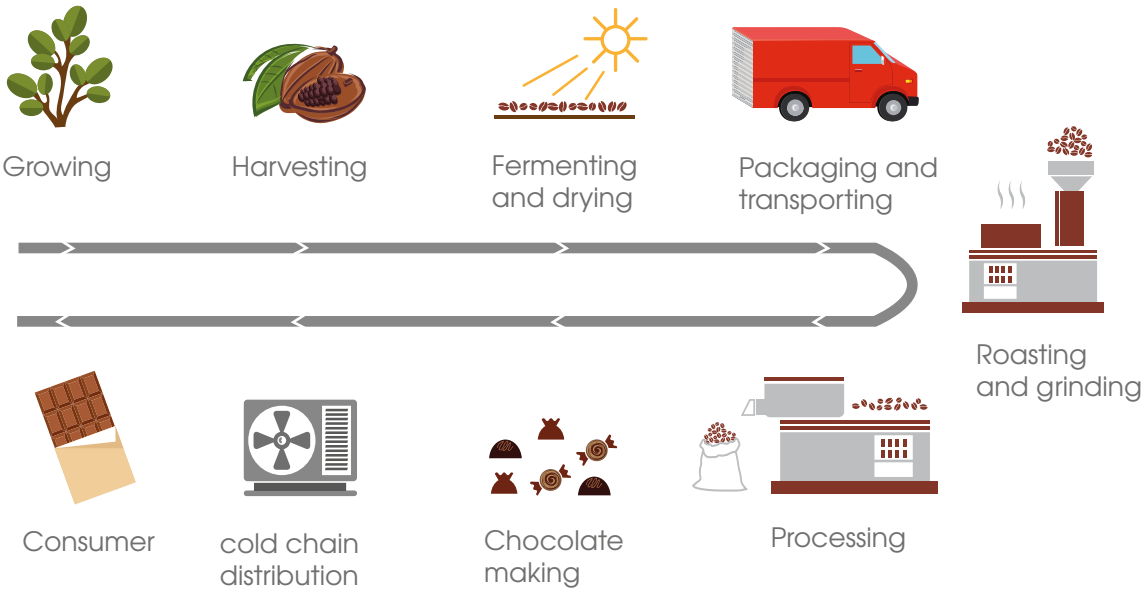
Process and product safety

Product safety is achieved by applying good practice, audit and traceability, process safety and appropriate environmental considerations throughout the supply chain. Some of these areas are not process safety issues in the traditional sense, but there should be awareness and understanding of all of these issues within the chemical engineering community.

The farming sector needs to improve understanding and acceptance of the role that genetically modified (GM) crops can play in meeting global food demand. Understanding the impact of pests and disease outbreaks within crops and livestock is essential.

Greater food production will not be achieved by simply intensifying current agricultural processes, as this can lead to larger or more frequent outbreaks of disease. Although vaccination, fungicides and other treatments may increase in use, so does nature's resistance to them.

From bean to bar



The policy dimension

The role of science and engineering in food production will grow in order to satisfy and manage demand within the limited land, water, energy and raw materials available. Food and nutrition has two main challenges. There are significant numbers of the global population that suffer from insufficient nourishment in terms of calories, vitamins and minerals. However, there is an increasing number of overweight and obese people that is also leading to greater prevalence of type II diabetes.

Effective food and nutrition for the world will involve improving current strategies and developing new technologies. In parallel with these developments, chemical engineers must engage with key decision-makers and other scientists and engineers in order to apply strategies and technologies appropriately. It is essential to learn about challenges, strengths and pitfalls of these approaches in practice and ensure effective policy. Sustainable supply and demand requires greater awareness of resource limitations and efficiency.

Although there has been significant resistance from the public towards GM crops, there has been some acceptance from farmers of their role and potential. With climate challenges and the demand for more food, genetic modification may play an increasing role in the future of food production. In these circumstances, it is essential to consider the environment, ecosystem and product safety. IChemE will encourage this debate.

The food vista sets out the range of possibilities for chemical engineering in all of these areas and will be used as a framework for discussion and priority setting.

The sustainable wellbeing vista

The World Health Organization defines "health" as a state of physical, mental and social wellbeing and not merely an absence of disease or infirmity.

Social wellbeing comprises many elements, including living in an environment that is healthy and promotes physical and mental harmony. Chemical engineering plays a fundamental role in facilitating health and social wellbeing to enable people to live healthy and fulfilled lives.

Chemical process technology

NOW

Greater demand for products due to increasing population and economic development

- Demand for new pharma and healthcare products for new diseases and ageing population
  - Increased incidents of antibiotic resistance → Develop new strategies and solutions to healthcare challenges
  - Learn from sharing of best practice → Share knowledge across engineering
  - Promote systems thinking and chemical engineering leadership → Secure a
- Manufacturing can be energy- and resource-intensive → Integrated feedstock and energy supply chains → Disposable technology for improved safety and reduced product changeover issues
- Limited material resources
- Need for new technology development
  - Promote the use of diminishing fossil resources as feedstocks not fuels → Improve processes to access high value and novel products from non-fossil resources
- Continual process equipment change is costly → Promote effective design and validation of manufacturing processes
  - Wider use of flexible manufacturing
  - Flexible, modular process facilities for pilot
- Growth of new and existing process industries → Promote role of chemical engineering in non-traditional and

Safety and the environment

Process industries are intrinsically hazardous

- Increasing impact on environment
  - Risk of pollution from industrial processes
  - Limited regulation and standards in nascent and emerging economies
- Increased biopharma poses new biosafety risks

→ Chemical engineers have a duty of care to manage risk for the public and employers

- Ensure process safety is
- Work across disciplines
- Support effective
- Increase awareness,

Different business models face different challenges and risks → Monitor and work to ensure high safety standards across all

Policy

Need for clear policy and strategy

- Work towards long-term, secure supply chain and resource management strategy → Engage with policy- and decision-makers to develop strategies for local manufacturing and sustainability
  - Improve value stream
  - Support for sustainable
- Further address end-of-life and reduce waste materials
  - Wider use of life-cycle analysis → Support, develop and implement
  - Minimise environmental impact → Encourage and support chemical
- Develop strategies for efficient product cycle time: concept to commercialisation
  - Support integration of distribution into manufacturing strategy
  - Promote chemical engineering work at the interface with other disciplines

Increasing cost of healthcare → Link industry with regulators to improve product robustness, patient safety and patent integrity

Society and public support

Increasing global population and economic development

- One third of the global population lives in poverty → Promote the role of chemical engineering in novel
- Ageing population changes demand → Shift towards proactive preventative healthcare rather than reactive
- Greater demand for materials, medicines, lifestyle goods and consumer products
  - Develop new healthcare strategies for an ageing population
  - Ensure teaching of modern processes/technologies while maintaining a
- Societal tendency to want more than is needed → Promote responsible consumption and use of materials and
- Developed markets often rely on imports rather than more efficient local supply → Promote understanding and

Sustainable lifestyles

The world is becoming urbanised. More people now live in towns and cities than in rural areas. Where urban growth is rapid, development is often haphazard and can have a detrimental impact on the environment. Furthermore, while people need a satisfactory living space, good social amenities and effective transport networks, this can conflict with the demands of commerce and industry.

To address this challenge, we must realise the concept of the sustainable city. Urban spaces must make the most efficient use of construction materials, energy and resources needed to build and maintain them. In addition, urban spaces of the future need to be flexible enough to respond to changes in use or environmental extremes.

Developed nations must lead the way by making fundamental shifts in consumption, recovery, and re-use or recycling. By applying the principles of green

Current status | Challenges | Future actions/solutions

HORIZON

Increased profile of biological engineering as a strand of chemical engineering

Implementation of integrated product and process design strategies

and science disciplines

paradigm-shift in energy and resource efficiency

Integrated production and distribution

Quality-by-design process development and continuous verification

Improve process atom efficiency

Improve material recovery by effective front-end design

processes, miniaturisation and modular components

and full-scale production

Mitigate risk with more efficient and less costly development pipelines

emerging fields/industry

Wider deployment of engineered drug delivery

acknowledged, understood and implemented at all management levels

to inform and address process safety by open dialogue

communication of risk

Inform public and other stakeholders of risk

understanding and practice of process safety in university courses

business models: large, multinational, SME and contract

management; link supply chain to market place

local manufacturing

Pandemic or catastrophic health episode

move to use of less hazardous materials and processes

engineers' engagement with policy-makers, opinion-formers and the public

Paradigm-shift in healthcare strategy and approach

Shift towards more sustainable cities, homes and lifestyles using process and design

approaches to providing future healthcare, goods and materials for wellbeing

Encourage and support interaction of chemical engineers with the public

firm foundation of chemical engineering fundamental principles

goods

Reduce raw material use, embrace material recovery, reuse and recycling

principles of sustainability

GAME CHANGERS

Wider application of biotechnology to primary production and manufacture

Widespread low-cost access to medicines and consumer products

Cost-effective, customisable personal medicine

Smart medicine

Increasing scarcity of rare earth elements and other critical materials used in advanced technology

Position environmental protection as central to the work of chemical engineers

Low-energy, low-cost material recovery processes

Eradicated diseases re-emerge

engineering from the outset, chemical engineers can help design processes and products that safeguard the environment and facilitate healthy lifestyles.

Sustainable industrial design

There is increasing pressure on all chemistry-using industries to improve material and energy efficiency. Chemical engineers are well equipped to design and deliver processes that are more flexible. These can be integrated into the wider supply chain with relatively low capital investment and reduced operating costs.

In some cases, demand for new products and enhanced properties will require us to identify alternative materials and develop new manufacturing processes. This requires greater atom efficiency, reduced ecological footprints, or the use of novel feedstocks, including biomass.

Life cycle analysis (LCA) is already a useful tool and can be further developed to map energy, water and resource use. Design and optimisation through applying chemical engineering fundamentals will improve financial and environmental protection. The leadership and systems thinking that chemical engineers bring will be invaluable in realising lasting, sustainable improvements.

New pathways in health and pharma

People are living longer, thanks in no small part to developments in healthcare in recent decades. Longevity and the associated demographic shift experienced by developed nations brings new challenges, including how to ensure physical and mental wellbeing into old age, and how to enable a shrinking workforce to support and pay for the needs of older people.

In developed economies, pharmaceuticals have been used effectively to improve public health. In particular, many infectious diseases that were common in previous generations have largely been eradicated. Now, the high-mortality, high-cost illnesses in developed countries are neurodegenerative conditions, cancers, and ailments often attributed to more affluent lifestyles – eg heart disease and type II diabetes.

Managing infectious diseases remains a challenge, as illustrated by the 2014 Ebola outbreak in West Africa. While the health of people in developing countries is improving, many are still unable to access basic sanitation and clean water. In addition, antimicrobial resistance is on the rise, and some infectious agents are now resistant to most current treatments. This is likely a result of inappropriate drug use in people and animals and poor infection control. These issues mean we need to identify and develop new treatment strategies and regimens.

The pharmaceutical industry is continuing to shift from reactive treatment towards prevention-based healthcare. There are significant cost pressures associated with new product development, and responding to changing legislation is a constant challenge for the industry.

The pharmaceutical pipeline is long, expensive and has high attrition rates. Failure to bring new active pharmaceutical ingredients (APIs) to market reduces revenues as other products come off patent. This means that there is less money to invest in research and development. Chemical engineering expertise will help reduce the complexity of API manufacturing and make processes easier to scale up and control. Chemical engineers can also improve cost effectiveness in a whole range of areas from vaccine manufacture and oral dosage formulation to validation and the determination of overall equipment effectiveness. IChemE will maintain effective support for chemical engineers in the pharma industry.

Biological & biochemical engineering

Many chemical engineers have yet to recognise the possibilities that exist in the bio domain, but biological and biochemical engineering offer great potential for health and wellbeing. Systems thinking helps bridge the gap between biology and process engineering, and will facilitate the development of personalised medicine and more targeted, cost-effective medicines and therapies.

There is a shift from small molecule drugs to biopharma products. In the future, there will be greater use of biosensors. Engineering will play an important role in the growth of biological materials for transplant organs, tissues and bone. Biochemical engineering has considerable potential for application in manufacturing processes that will use more sustainable feedstocks and generate novel products. However, there is still considerable work to be done to develop and grow the area of biological and biochemical engineering.

Chemical engineers will play a critical role in translating scientific discovery and innovation into high quality processes and products such as new medicines and medical devices. IChemE will actively promote the development of biological engineering as a professional discipline and facilitate interaction between all scientists and engineers involved in this diverse field. The Institution will promote awareness of the skills and application of chemical engineering fundamentals in the bioeconomy.

IChemE will actively promote the development of biological engineering as a professional discipline.

Process safety – people and the environment

Maintaining good health is not only about providing healthcare and material goods. It is also about having healthy and safe living environments. It is essential that chemical engineers communicate the concepts of process safety and environmental responsibility and risk to wider groups, including the public, policy- and decision-makers and non-governmental organisations (NGOs).

Process safety is improved, not only by learning from accidents, near misses and disasters, but also by sharing and learning from success. IChemE believes that process safety accountability must be defined and championed at board level to make this happen.

IChemE will seek, in conjunction with other relevant professional bodies, to exert a greater influence on the process sector, regulators and academia to develop and use new ways for cost-effective and sustainable risk reduction. The health and wellbeing vista diagram suggests the areas of intervention and will be used as a framework for further discussion and priority-setting.

FACTS

Total deaths from diabetes are projected to rise by more than 50% by 2025
2013 saw 48,237,390 reported cases of malaria
In 2012, outdoor air pollution caused an estimated 3.7m premature deaths worldwide

Resources and manufacturing

Water, energy, food and health all contribute to wellbeing. Their creation in turn relies on the availability of resources and raw materials, and the manufacturing processes required to complete the journey from resource to end product. The journey from indium and coalmines to the wellbeing derived from having a fully-charged smartphone is long, and full of chemical engineering challenges. Manufacturing is central to delivering wellbeing.

Chemical engineering matters in many steps of manufacturing, from raw material processing to producing finished goods. It takes in everything from the extractive industries through to manufacturing bulk chemicals such as paper and plastic, not forgetting industrial gases, fine chemicals and consumer products, and many more.

Chemical engineers design and develop safe and efficient processes and play an important role in innovation. In future, chemical engineers will help a growing and increasingly affluent population stay fit and healthy in a sustainable way.

Economics and the global marketplace

Resource extraction and manufacturing play an important role in all global economies, particularly in Asia. Demand for resources has grown sharply over the past decade, driven by growth in emerging economies. At the same time, the goods we use have become much more complex.

While the past decade has brought considerable pressures and uncertainty for the resource and manufacturing industries, investing in manufacturing can yield considerable rewards. By driving the development and delivery of new technologies, processes and products, chemical engineers play an important role in the efficient scale-up and rollout of these innovations.

Raw materials and the extractive industries

Many common raw materials are mined and extracted from the earth's crust. These finite resources include coal, oil and gas, metal ores and non-metallic minerals such as carbonates, silicates, phosphates and clays.

There are many challenges in minerals extraction where chemical engineers can make a difference. In particular, this includes water and energy efficiency, efficient resource recovery and reducing contribution to climate change.

Around half the energy used in mining goes into crushing and grinding – accounting for 3% of global power use. Even small efficiency gains here can have a huge effect on global consumption of water and energy, with all the benefits of reducing waste, mitigating climate change and cutting costs that entails. Many large mining operations are located in water-stressed regions such as Australia, South Africa and Mongolia. Redesigning the process can make a significant difference: for example, Rio Tinto's Argyle diamond mine in Australia cut water use by 95% between 2005 and 2009.

Resources are finite, and there is constant pressure to find and exploit new reserves. This drives development of new exploration and extraction techniques. Some metals occur in low concentrations in the ores of more major metals, from where they can be recovered if market economics and available processes allow. The iron and steel industry emits significant quantities of greenhouse gases including carbon dioxide, methane and nitrous oxide, thus driving global warming. Cleaner, more efficient processes and more recycling can reduce these emissions.

IChemE will actively support the role of chemical engineering in adopting economical, water efficient and low-carbon extractive technologies and processes.

Renewable resources

The resource industry also includes renewables, such as biomass sourced from land or sea. IChemE believes that chemical engineers should play a key role in a multi-disciplinary approach to identifying and developing new, sustainable sources of raw materials. Bio-based raw materials can be derived from agriculture, aquaculture, forestry and the food industry, yielding a broad range of products such as cotton, paper, plastics and biofuels.

This industry has its own challenges. In terms of resource generation, the availability of suitable land, climate, nutrition and other environmental factors can be real issues. The other big issue for renewable resources is their variability, and the Institution calls on the chemical engineering profession to rise to the challenge to design robust processes capable of dealing with feedstock variations. Sustainable plant lifecycles are essential, from commissioning, through operation to decommissioning.

Manufacturing

Manufacturing contributes £6.7trn to the global economy, is responsible for 16% of global GDP and 70% of total global trade. Producers of raw materials and manufacturers must adapt by operating at a global scale and responding to new demands for new products. Successful delivery also requires sustainable business models and the ability to adapt to consumer needs.

In these economically challenging times, there is huge pressure on manufacturers to remain competitive. Research and development (including product development) can help increase efficiency, and chemical engineers can contribute by optimising supply chains and implementing lean processes.

Just as processes must be flexible to adapt to changing consumer demands, multi-purpose production lines can accommodate different products. The advantage of steady state operation is greater efficiency through automation, energy use and consistency. Understanding unit operations and process control and applying them to complex systems will require new measurement techniques and a shift in manufacturing design mindsets which chemical engineers are well suited to bring about.

IChemE believes that chemical engineers should work together and with other disciplines to make processes more efficient and support the transition to a circular economy. This means reducing raw material use and/or designing products from which components can be recovered, reused or recycled at the end of their useful lives. These approaches will be particularly important where resources are already limited.

Responsible use, re-use, recycling and recovery

Although science and engineering work to develop new methods to access raw materials, we cannot continue indefinitely to extract materials from the ground. Even without finite resources, economic and geo-political turmoil can disrupt supply, so improving recycling and reducing the extraction of virgin materials makes good business sense.

In many countries and industry sectors, there is now legislation to address end-of-life of many products. Achieving this requires innovative design of products and processes, advances in product formulation and improved recovery and recycling of materials.

While industry works to meet these requirements, society needs to change its 'disposable' mentality. This must be supported by appropriate infrastructure to recover end-of-life products for recycling. IChemE will work with relevant stakeholders to engage with the public and policy-makers to drive home the importance of resource efficiency, re-use and recycling.

Process safety and the environment

Mining, the extractive industries and manufacturing can be hazardous activities. The importance of safe processes and operations, to both workers and the environment, cannot be overstated.

Mining presents a risk from fires, explosions and uncontrolled gas release, while the areas of concern for manufacturing mainly stem from bulk chemicals handling, toxic intermediates and highly mechanised operations with entrapment risks.

In some parts of the world, the extractive industries have caused long-term environmental pollution. In Africa, acid mine drainage from metal and coalmines has poisoned soils and water. Poor industry practice can also lead to contamination with toxins such as arsenic, lead and cadmium.

Chemical engineers play a role in embedding proactive process safety at all stages in the extractive and process industries; from design and development to operation and decommissioning. At a higher level, chemical engineers are called upon to develop strategies to minimise and manage environmental impact. The Institution believes that professional chemical engineers play a vital role in long-term planning, risk assessments, informing and adopting proper regulation and responsible practices. IChemE will continue to promote the role of chemical engineers in environmental remediation and push for greater process safety and the safety culture in the extractive industries.

FACTS

Manufacturing contributes £6.7trn to the global economy

Manufacturing is responsible for 16% of global GDP and 70% of global trade

47% of companies allocate 20% or more of their total technology spend on engineering, manufacturing and supply chain systems

External influences: politics

IChemE members are often frustrated with a perceived lack of scientific understanding and engineering knowledge amongst politicians.

However, adopting antagonistic positions is counter-productive. Constructive engagement based on sound science, good engineering practice and the pursuit of clear policy outcomes is far more likely to yield results.

The work of government is not easy and engineers who seek to influence policy-making must recognise the short-termism that is a consequence of electoral cycles. A majority of politicians, regardless of ideology, pursue power to bring about change, and most embark on this course with noble intentions. This necessitates fighting and winning elections, placing them at the mercy of an increasingly discerning electorate and also the factions and power bases within their own parties. Politicians must win the popular vote, thus they need to be 'popular'. Many of the outcomes that scientists and engineers advocate (eg nuclear power, wastewater reprocessing or the adoption of genetically modified organisms for food crop protection) are not 'popular' and it helps if this paradox is understood from the outset. IChemE will help chemical engineers and their employers to articulate the positive benefits of their work.

IChemE will urge governments to make better use of the professional engineering community.

Advocacy and engagement

Huge sums of money and political influence are traded in order to secure preferred policy outcomes. Spending by candidates, parties and outside groups and individuals in the 2016 US presidential elections may approach US$10bn. The world's largest public relations firm, Edelman, has over 5,000 employees worldwide with a global turnover in excess of US$812m in 2015. Trade bodies and other lobby groups, including engineering institutions also work to influence political decisions. They aim to shape policy to favour the development of technology solutions; but the resources deployed are tiny in comparison. IChemE continues to support limited programmes of advocacy and engagement with policy-makers and looks to engage with members and other stakeholders around the world to do so. This activity must be based on clear objectives and requests for specific policy goals.

Evidence-based policy-making is a much-repeated mantra, but there are also instances where policy is implemented based on carefully selected evidence. The credibility of any given body of evidence is of paramount importance and IChemE is well placed to comment and advise on the basis of its independence and rigorous professional standards. However, the Institution is not alone. Historically, this area has seen conflict between different engineering disciplines and sometimes between subsets of a single discipline – chemical engineers included. This should be avoided wherever possible, and IChemE supports broad alliances bringing together different groups from across the science, technology, engineering and mathematics (STEM) spectrum in pursuit of policy outcomes that are supported by the STEM community as a whole and in the wider public interest.

Systems thinking

The delivery of much public policy has an engineering dimension that needs to be considered at the start of the policy-making process. Policy-making can benefit from the contribution of chemical engineers, who bring systems thinking to bear on policy challenges. IChemE will urge governments to make better use of the professional engineering community and encourage the professional registration of engineers within the civil service. Where appropriate, chief engineering advisors should be recruited to government departments in addition to, or instead of, chief scientific advisors.

Finally, it is worth noting that chemical engineers are generally voters too, and some, albeit a minority, are engaged in the political process at a personal level. It is often said that politics is too important to be left to politicians and IChemE will support and encourage those members who seek to connect with their elected representatives and/or work within their local or national political systems. Chemical engineering needs good politics and politics needs good chemical engineers.

External influences: the economy

Chemical engineering is key to wealth creation. The UN calls on everyone to

"promote sustained, inclusive and sustainable economic growth, full productive employment and decent work for all" and "build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation."

This requires growth in GDP, improved technology and innovation, and greater resource efficiency. The latter implies that development relies on industrialisation.

The energy and chemical process industries are in flux. Uncertainty has affected imports and exports in some countries while others have concern about productivity. In 2015, private investment in energy, water and transport infrastructure in 139 developing countries dropped to less than half of the 2014 figure. This was mainly due to a reduction in projects in Brazil, India and China. Renewable energy projects accounted for over 60% of this investment, and water only 4%.

Sustainability is key

Political, regulatory, economic and technological challenges have made sustainability a boardroom issue and a key consideration for investors. IChemE believes that chemical engineers in the board room and on the front line of innovation and operations are well placed to bring about economically sustainable business.

Energy challenges

After falling between 2008 and 2009, global oil demand has increased again to over 95m barrels per day at the end of 2015. One third of this growth came from China, which now uses over 11% of the world's oil. Natural gas consumption rose to almost 3,400bn m^3 in 2014. Unconventional oil and gas have greatly increased available supplies. While 2010 saw construction begin on more new nuclear power plants than any time since 1980, output of nuclear power remained relatively stable at 2,411bn kWh in 2014, 11.5% of global electricity generation. Conversely, global wind power capacity reached 370 GW in 2014, compared to 47.6 GW in 2004.

Mitigation of climate change has led to the emergence of emissions trading schemes (ETS), though both the traded volume of carbon and its value have been falling in recent years. Carbon pricing continues to prove controversial, with policies stalling in many regions, but IChemE continues to support the principle to drive improvements in energy efficiency. While the likelihood of an international carbon trading framework or other firm action seems remote, the commitments of the UN Framework Convention on Climate Change and the Paris agreement in December 2015 may lead to more positive action. The Institution supports the principle of Intended Nationally Determined Contributions (INDCs) as a commitment to reduce greenhouse gas emissions and secure progress in the delivery of low-carbon technologies.

Free trade

The global labour force grew 17% in the decade to 2013, reaching 3.3bn. The labour pool has tripled since 1950 and people of working age (15–64) now account for two thirds of the world's population. Supply and demand are not balanced and the labour force is growing at divergent rates in different regions. For example, one quarter of the world's labour lives in South Asia but the region's share of the global economy is just over 3%. Combined with differing approaches to higher education and the number of trained chemical engineers in the labour force, it is clear that the labour demographics will have important implications for the process industries. IChemE is committed to the principle of free trade and the free movement of talent. It will work with governments in all parts of the world to ensure that the pipeline of chemical engineers continues to flow for industry, for educators and for the research community.

Economic uncertainty

Manufacturing has a symbiotic relationship with research and development driving investment and innovation. Global chemical consumption has more than doubled in the last decade to €4,280m in 2014. Despite the decline in the selling price of many chemicals, in 2014, combined sales for the global top 50 chemical companies exceeded US$961.3bn, 1% down on 2013. In 2013 the US chemical industry reported the first growth in jobs for a decade but globally, ageing assets pose challenges for the future. Cost pressures have led to job losses and changes in business models and manufacturing strategies. The EU has previously been a leader in world chemical sales, but in 2014, 18 of the 50 were in Asia, and accounted for 35% of world chemical sales. This has prompted calls for regional manufacturing strategies based on indigenous resources in Australia and the US. The optimistic mood around Australia's resources sector has waned, with several projects shelved in the face of falling prices and increased construction costs. Uncertainty is the new norm.

Chemical engineers must operate in the context of the wider global economy. They cannot change market trends but they can make a difference. IChemE will support and promote efforts by chemical engineers to drive efficiency improvements, particularly in the sphere of energy saving and waste reduction. The economic outlook remains uncertain and the signals are mixed. The US shale gas boom has aided recovery in some regions although security of supply and geopolitical uncertainty continue.

External influences: public acceptance

In the developed world the public was hugely supportive towards technology in the period after the Second World War and this upbeat mood endured into the 1970s.

This positive mindset coincided with a period in history that is viewed by many as the zenith of chemical engineering in Europe and North America. In the 1980s enthusiasm gave way to disappointment and sometimes to outright hostility. More recently, the prevailing viewpoint might best be described as ambivalent.

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This positive mindset coincided with a period in history that is viewed by many as the zenith of chemical engineering in Europe and North America. In the 1980s enthusiasm gave way to disappointment and sometimes to outright hostility. More recently, the prevailing viewpoint might best be described as ambivalent. Over the last 30 years public mood swings have driven a tendency amongst scientists to retreat into their laboratories. Meanwhile, engineers of all descriptions have never really excelled at promoting their efforts and explaining the value of the work to the person in the street. Chemical engineers have found themselves in a particularly difficult place. The absence of historical heroes with the visibility of Brunel, Faraday or Watt has confined the discipline to relative obscurity. Given the upstream nature that characterises much of the chemical engineer's work, it is hardly surprising that public polling carried out by IChemE has consistently revealed that it is generally unclear, even to the educated observer, exactly what chemical engineering is all about. IChemE members frequently express dismay at this state of affairs because, as this report clearly illustrates, chemical engineering is fundamental to progress in the key challenge areas of water, energy, food and nutrition, and health and wellbeing. The Institution is committed to raising awareness of the profession for example by highlighting the products and processes that are available through the application of chemical engineering.

Hazard and risk

One unhappy area where chemical engineering has been catapulted into the public eye is the sequence of high-profile process safety incidents, from Flixborough, through Bhopal and to more recent episodes at Texas City, Buncefield and Deepwater Horizon. Failures in chemical process systems were identified as causal factors in all of these catastrophic events, but interestingly the profession largely escaped the public anger that followed.

The operating companies were less fortunate and the reputation of the chemical industry suffered accordingly. Risk is an inescapable consequence of high-hazard process activity; nonetheless, accidents can be avoided. IChemE will help chemical engineers improve the communication of risk to non-experts in a language that can be understood.

Image problem

The STEM communities around the world are aware of the image problem. The term "public understanding of science" has entered the lexicon. Scientists and engineers have a formal obligation to communicate with the public; this is part of a new trend towards greater transparency and openness. At the same time, the concept of corporate social responsibility is more widely recognised, with many global companies publishing sustainability indicators in their annual reports. These developments are welcomed and actively supported by IChemE.

A force for good

In 2016 science enjoys wide coverage in the popular media and in literature in most parts of the world. There has never been a better time to raise public awareness of chemical engineering and IChemE will use this report in pursuit of that goal. It will work with the wider chemical engineering community to identify compelling examples of the positive benefits of chemical engineering. At the same time, it will support and train those members who wish to engage with the media or to communicate the benefits of their work to the public at large. The Institution will also encourage companies to be more forthright about the value that chemical engineering adds to their business.

IChemE believes that chemical engineering is a force for good. Chemical process technology has delivered massive improvements in quality of life for many centuries and that work continues in all parts of the world. This requires public acceptance and support. IChemE will work to secure public confidence in the profession and tirelessly promote the message: chemical engineering matters.

Ethics, values and diversity

Professional chemical engineers must operate to the highest ethical standards and act in the public interest at all times.

In 2015, new guidance was published by the Engineering Council. The guidance addressed matters of professional ethics and disclosure in the public interest – or 'whistleblowing'. The Institution's own Code of Professional Conduct was modified to reflect the new guidance. Revisions included a requirement on members "*to uphold the dignity and reputation of their profession and safeguard the public interest*".

Ethical responsibility

Whistleblowing is defined as: "the raising of a concern, either within the workplace or externally, about a danger, risk, malpractice or wrongdoing which affects others".

There is an ethical responsibility to "raise a concern about a danger, risk or wrongdoing which affects others ('blow the whistle') and support a colleague... who in good faith raises any such concern".

Integrity is also cited as a core responsibility. The obligation to take responsibility for our own safety and that of others is widely recognised and practised. However, it is not just about human safety, but also that of the physical and social environment we inhabit.

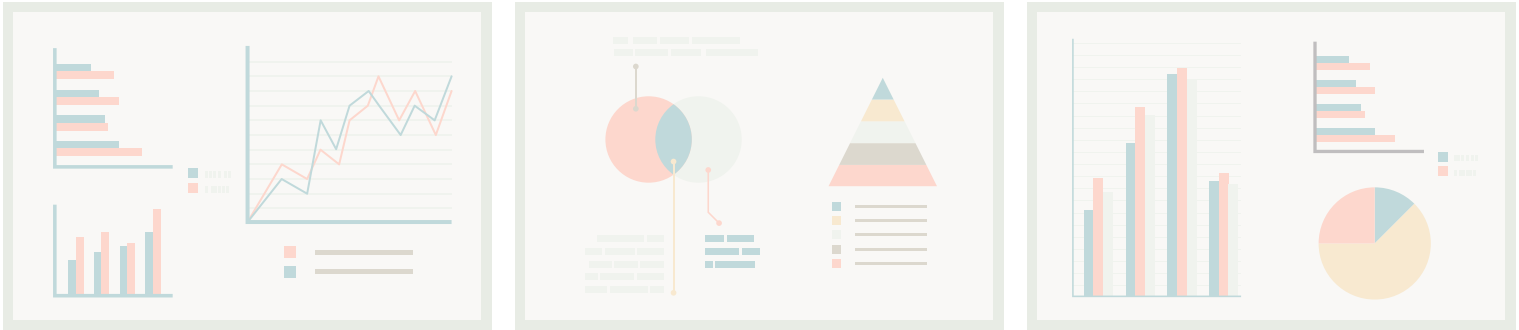
Professional chemical engineers and the team members that they manage have an ethical duty to act when they observe any form of wrongdoing. In 2015, IChemE completed work to review ethical conduct and professional duty. This resulted in the development of new training.

Equality and inclusion

Chemical engineers must treat colleagues and clients at all levels fairly and without bias. In addition to supporting the highest standards in ethical conduct, process safety and environmental protection, IChemE is committed to supporting diversity, equality and inclusion within the profession and the sectors in which chemical engineers operate. As a signatory to the UK's Royal Academy of Engineering Diversity Concordat and the UK Science Council's Declaration on Diversity, Equality and Inclusion, the Institution recognises and values diversity. This includes gender, ability, age, belief, family and cultural background.

Recognising diversity and ensuring inclusion are essential elements of good business practice. An inclusive culture secures engagement and commitment from staff and contractors at all levels. There is extensive evidence showing that where all parts of a workforce feel included and valued, increased productivity is the result. Effective leadership is fundamental to creating an inclusive environment. Professional chemical engineers are encouraged to lead by example.

IChemE will review the different aspects of equality, diversity and inclusion, and the challenges that these bring to the chemical engineering community. However, the Institution recognises that these issues present different challenges and require different interventions in different parts of the world. This work is supported by a committed group of members who support projects that include an evidence-based analysis of the gender pay gap, the promotion of female role models and a review of homophobia in engineering.



Putting the pieces together: ten actions for IChemE

1 Safety

Competence in process safety lies at the heart of the chemical engineering skill set. The goal of professional chemical engineers is never to put anyone in harm's way as a result of the processes they design and operate.

IChemE will promote a thorough understanding of hazard, risk, and risk reduction at all stages in the process life cycle, from design and construction, through operational management and leadership to decommissioning. The crucial role of human factors in process safety will also shape the Institution's approach.

IChemE has introduced the Professional Process Safety Engineer registration, which has attracted strong interest from industry. It will continue to develop the IChemE Safety Centre and promote the highest standards in corporate governance, education and research for process safety.

2 Education, training and skills

Sustaining the chemical engineering talent pipeline is fundamental to IChemE's mission. To advance chemical engineering worldwide, the Institution must support the supply of appropriately-trained chemical engineers to ensure that industry, academia and all those who depend on competent and capable chemical engineers have access to the right talent.

IChemE will support a global professional learning community via a new, integrated training and professional development offer, supporting skills development at all levels.

3 Research

Chemical engineering is changing, and the challenges the profession must address are becoming more complex. A sharp focus on core chemical engineering concepts and fundamental systems thinking must be maintained. IChemE will work to encourage multidisciplinary working and the effective exchange of knowledge and ideas between the research base and teaching. The interface with industry is equally important.

IChemE will press for investment in applied research at a level commensurate with the excellence of the underlying science. The Institution will also work to promote outstanding research that can change lives by supporting and organising technical conferences and events worldwide.

4 Water

Water is essential to life on Earth. It is a natural resource, which enables the production of food and energy, provides hygiene and sanitation and operates as the primary link between humanity, climate systems and the environment. Population growth, industrialisation and urbanisation are placing increasing pressure on the water economy.

IChemE will provide support to chemical engineers in the water community and explore new ways of promoting process technology in securing viable industrial and municipal water supplies. The Institution will work to raise the profile of the discipline in the sector, setting out its role in the delivery of sustainable water solutions.

5 Energy

Meeting growth in global energy demand presents a crucial challenge in the decades ahead but there is no universal solution. Fossil fuels will maintain a central position in the world's energy economy for several decades. However, these resources are finite and the challenge presented by climate change dictates that a paradigm shift towards decarbonisation and sustainable energy use is needed. IChemE recognises that the contribution from renewables will increase and whilst the Institution welcomes this development, it will argue for robust life cycle analysis and promote the fullest understanding of thermodynamics and energy balances for all proposed solutions.

IChemE supports chemical engineers in all parts of the energy economy, and the IChemE Energy Centre is developing a platform for the coherent policy positions. These will focus on the priority topics of energy efficiency; energy storage and grid management; nuclear energy; carbon capture, storage and utilisation; and sustainable bioenergy.

Putting the pieces together: ten actions for IChemE

Food and nutrition

The typical human requires around 2,300 kcal/d to support normal healthy living. The chemical engineer's understanding of mass and energy balances suggests that this is manageable in light of current global population projections, but food inequalities are a growing challenge. Distribution and societal factors lie beyond the control of chemical engineers. Nonetheless the profession can exert significant influence over the development of processes and technologies that can reduce waste and optimise the food supply.

IChemE will continue to highlight the role of chemical engineering and the positive contribution made in sustainable food production and supply from farm to the end consumer. The Institution will work to improve understanding of the complex relationships between food, water and energy summarised by the "nexus" concept. This involves collaboration with international partners, including the American Institute of Chemical Engineers (AIChE).

Health and wellbeing

In developed economies, the concept of wellbeing is tied to consumption, and much of the developing world is racing to achieve this lifestyle. The health of the chemical engineering profession has traditionally been linked to global consumption; with chemical processes feeding demand for consumer products. Human health and life expectancy are improving as a result of better sanitation, diet, housing and developments in healthcare, but sustainability is a pressing concern.

IChemE will promote the role of chemical engineers in delivering more healthy and sustainable lifestyles. The Institution will work to secure better integration between the consumer product and pharmaceutical industries and academe by conducting a review of the challenges and potential solutions in health and wellbeing.

Resources and manufacturing

Chemical engineering plays a vital role in extraction, recovery, re-use and recycling of a wide range of raw materials. Now and in the future, chemical engineers will play a vital role in improving the sustainability of these processes to meet demand.

Manufacturing is essential to produce the goods and services that society needs and wants. It is integral to economic development around the world. The industry must rise to the challenge of increased demand and the need to reduce energy and water usage. IChemE believes that chemical engineers are central to meeting these objectives.

IChemE will continue to highlight the valuable role of chemical engineering in mining, minerals, other raw materials sectors and manufacturing. The Institution will promote excellence in process safety, sustainability and innovation across the resources and manufacturing landscape.

External influences

IChemE is politically neutral and will adopt an independent position on issues that are viewed as partisan. However, the Institution recognises that political decisions should be evidence based and supported by the strongest possible input from the engineering community. The chemical economy is changing rapidly with the emergence of the BRIC nations and Middle Eastern countries as chemical manufacturers, for domestic consumption and for export. This dictates that different policy solutions will be needed in different parts of the world. IChemE recognises the need to respond to public concerns and engage productively in lifestyle conversations about the impact of chemical processes and products.

IChemE will work with its member groups and local leaderships around the world to develop coherent policy goals that will form the basis of engagement with opinion formers and policy-makers.

Ethics, values and diversity

IChemE is committed to ensuring good practice and embedding the highest standards of professional ethics and integrity across the discipline.

IChemE drives a policy of equality and inclusion for all members and stakeholders. The Institution will continue to review different aspects of diversity and promote good practice within the profession. Activity will include unconscious bias awareness training and building an evidence base for diversity within the profession. IChemE will also support member groups that support projects to raise awareness of key issues and solutions.

Where do I fit in?

Chemical Engineering Matters reflects the diverse opinions of IChemE's international membership. Particular emphasis has been placed on areas where chemical engineering has a significant global impact. The report has identified a series of strategic challenges and puts forward ideas on possible directions of travel for IChemE and the wider chemical engineering community. Readers can engage in the next stage of the conversation in several different ways:

- **IChemE values feedback from its members on any of the issues raised in this report, but more importantly we urge you take advantage of free membership of our special interest groups (SIGs). The SIGs cover the wide range of topics found in *Chemical Engineering Matters* and provide a regular forum for technical discussion. They can also provide a platform for sharing new research thinking and the latest developments in industry. Please use this report to spark new ideas and set new priorities.**
- **If you are an employer, IChemE can connect you to a wide range of expertise related to many of the process solutions identified in this report. Chemical engineers can help you grow your business.**
- **This report will be used as a catalyst for discussion and co-operation with other disciplines. Proposals for collaboration around any of the topics raised are welcomed. Other engineers and scientists are invited to submit ideas for joint meetings and projects.**
- **If you are a policy-maker at local, national or international level or in the media, you will see that IChemE is an advocate for solutions that will support a safer and more sustainable world. If you think that our members can be a useful addition to your contact book, please get in touch.**
- **IChemE encourages all chemical engineers to identify the areas of the vistas where they can make an impact. Please share this report with others.**

To continue the conversation contact:

email: cem@icheme.org

twitter: @ChemEngMatters and #chemengmatters

or call any of the numbers listed on the back of this report.

Acknowledgements

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