A Roadmap for 21st Century Chemical Engineering

May 2007

IChemE
heart of the process

1957–2007
Jubilee of the Royal Charter

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Preface

What does society need; what are the desirable outcomes and how can chemical engineers work in partnership with others to make it happen? These are difficult questions. But IChemE believes that chemical engineers must be able to offer rational answers if our profession is to be taken seriously by decision makers and opinion formers. The 50th anniversary of the granting of the Institution's Royal Charter presents a timely opportunity for chemical engineers to engage in the wider debate.

However, in order to make a significant contribution to that debate, we must focus on the issues where chemical engineering, in conjunction with other disciplines, is capable of delivering credible solutions. This process will provide focus for IChemE's technical agenda in the years ahead.

The Roadmap initiative has identified many of the key issues facing our profession. The output sets out a range of positions clarifying IChemE's stance on those issues. The positions are supported by a series of action plans for consideration and implementation by IChemE. Our governing Council has given a commitment to identifying and allocating the resources needed to secure progress towards the outcomes described in this document. The Institution's technical Subject Groups will play a pivotal role in implementing the Roadmap and they will be properly supported in that mission. In addition, IChemE will forge new collaborations with other stakeholders in the global chemistry-using community in pursuit of a sustainable future.

Chemical engineering is playing an increasing role in meeting society's needs; from energy generation to food production, water supply to waste management and from consumer goods to healthcare products. IChemE is at the heart of this process and we will continue to support our members by promoting innovation, entrepreneurialism and leadership as well as technical excellence.

Inevitably, the exercise presented its own challenges. IChemE is a global institution with 27,000 members in more than 100 countries. And whilst individual nations and regions face broadly the same dilemmas in areas such as energy demand and access to water supplies, geopolitics, economics and resource constraints dictate differing priorities. The Roadmap recognises this and provides a framework for all chemical engineers, wherever they may find themselves, to address these challenges. Like all maps it gives us a route for a journey – from a starting point to a destination. But when that destination is 'the future', it might, and almost certainly will change over time. IChemE will respond to those changes by keeping the Roadmap under review.

I would like to thank all those who contributed to the production of this landmark document, including the six Technical Policy Commissions, the hundreds of individual members who participated in the consultation process and the IChemE staff who managed the exercise. The publication of the Roadmap is not the end of the story. On the contrary, it represents an important new beginning and we are presented with a rich resource to drive IChemE's technical agenda forward. The Roadmap will inspire and motivate our members to further achievement in the years to come.

Ian Shott

IChemE Technical Vice President
May 2007

Executive Summary

IChemE's governing Council identified a need for greater clarity in relation to the technical positioning of the Institution on key issues of global concern. In 2005, a task group convened by the Technical Vice President and Chief Executive of Excelsyn Ltd., Ian Shott, identified a set of priority topics.

This work was supplemented by the key messages arising from the technical programme at the 7th World Congress of Chemical Engineering and the output of a strategy workshop convened by the UK's Engineering and Physical Sciences Research Council that brought together leading thinkers from the chemistry and chemical engineering disciplines.

The following topic areas were identified as key themes:

- Sustainability and Sustainable Chemical Technology
- Health, Safety, Environment and Public Perception of Risk
- Energy
- Food and Drink
- Water
- Bioprocess and Biosystems Engineering

Six 'Technical Policy Commissions' were convened with representation drawn from the IChemE's Subject Groups. The commissions were tasked with the development of a series of position papers setting out some of the main challenges in each topic area. The position statements identified desirable societal outcomes and a range of chemical engineering inputs in pursuit of those outcomes. The initiative was coined 'A Roadmap for 21st Chemical Engineering' referred to throughout this document as simply 'the Roadmap'.

Council had stipulated that the Roadmap must be firmly aligned with mainstream opinion within the profession. The attitudes and opinions of the wider IChemE membership were assessed via a two-stage Internet consultation involving all Corporate and Associate members of the Institution. In addition, special consideration was given to the views of the substantial IChemE membership in Australasia and South East Asia and a special workshop was convened in Auckland in September 2006.

The core output from the process is a priority list of 20 position statements taking a global perspective on issues of public concern, with action plans for IChemE grouped under the six thematic areas. They express the views of the Institution on key societal issues where chemical engineering has a major part to play in delivering solutions. Within each theme the issues highlighted represent the major challenges as prioritised by the membership. A further 34 positions are detailed within the six thematic areas. These were seen by members to be a lower priority for action, but they are listed here to provide a complete overview of IChemE's stance in each thematic area.

The 20 priority position statements are here summarised in shorthand form:

Sustainability and Sustainable Chemical Technology

Sustainable Energy: rapidly pursue the global use of non-fossil primary energy sources

Reduce, Reuse, Recycle: drive the 3Rs mentality deeper into industry and consumers

Sustainable Technology: accelerate the introduction of innovative and sustainable technology

Health, Safety, Environment and Public Perception of Risk

Risk: build a common understanding of risk issues and influence risk reduction

Performance: create cultures to deliver real improvement in health, safety and environmental performance

Open Dialogue: proactively share learning from past successes and failures

Energy – Securing Reliable and Affordable Supplies in the Near Term

Nuclear Power: support a positive climate and R&D for new and replacement nuclear capacity

Continuing Fossil Fuel Use: accelerate the deployment of clean generation technology with carbon capture and storage together with increased efficiency in energy use

Renewable Energy: expand R&D and deployment of renewable technologies and power storage systems

Biofuels: pursue biomass gasification and Fischer Tropsch synthesis for biofuels production

Food and Drink

Waste Management: develop technologies that maximise the use of viable waste streams

Basic Production: develop precision agricultural technology and sustainable farming methods

Diet and Health: advocate further improvements in product labelling coupled with consumer education to influence choice

Innovation: develop science on a broad front to meet the sector's challenges with sustainability a vital consideration

Delivery of Safe Products: transfer technology and share best practice by encouraging dialogue across the supply chain

Water

Water as a Resource: develop and implement sustainable regional water management strategies as a global priority

Sustainability and New Technology: increase R&D on technologies that contribute to sustainable water supplies

Industrial Usage: support appropriate regulation to encourage more sustainable water supply, wastewater treatment and sludge disposal

Bioprocess and Biosystems Engineering

Provision of Well Trained Bioprocessing Professionals: expand recruitment of school leavers to biochemical and chemical engineering, enrolment of professionals into membership and provision of appropriate continuing professional development

Low Environmental Impact and Sustainable Bioprocesses: promote new pollution abatement strategies and design of sustainable processes.

Stakeholder dialogue specialists, Dialogue by Design, were engaged to carry out an online consultation process with the IChemE membership in two, three-week sessions during September 2006 and January 2007. Over 1100 members in 46 countries registered to participate. This subset of the IChemE membership was analysed and found to be broadly representative of the demographics of the Institution.

In the first phase, IChemE members were asked for comments on draft positions prepared by the Technical Policy Commissions. In the second, members were invited to review all the submissions to Session One and provide comment on the suggested action plans put forward by the Technical Policy Commissions based on the priorities identified by members. The Policy Commissions were instructed to take full account of the feedback from the membership in both sessions and reflect priorities accordingly, bearing in mind the fact that this was a qualitative consultation, not an opinion poll: its primary purpose was to collect ideas, arguments and information.

Key issues that emerged from Session One:

- The need for a hierarchy of approaches and technologies to reflect geographic, social and economic situations.
- Linked to the above, a need to differentiate between global and UK centric perspectives.
- Awareness that the intended audience must dictate the use of technical language and jargon and that different versions will be required if the intention is to reach policy makers and the public.
- Engaging with wider society is contentious. Contributions highlighted conflicting views from the membership on why and how to do this (educational role, better understanding of public values, etc) and recognition that the skills and strategy for wider engagement need developing.
- On a number of contentious issues, particularly genetic modification (GM) and nuclear power, some members felt that the terminology used was ambiguous and those who opposed GM, for example, felt the words were hiding support while those who support GM wanted the statements to be clearer. Divided opinion amongst the membership reflects divisions amongst the public at large.

Key issues that emerged from Session Two:

- There was strong support for all the proposed action plans with only minor disagreement across the board.
- The most important technical issues for chemical engineers were seen as the inextricably linked ones of energy, climate change and sustainability.
- Concerns were raised over the resource implications of implementing the action plans. The need to prioritise was emphasised in order to ensure that a limited number of initiatives could be done well.
- In all thematic areas, education and awareness raising in new technologies and new approaches were seen as vital roles for IChemE both to its. members, with particular focus on those working in developing economies, and the public in general.
- Regional priorities differ and whilst overall goals may be common the focus and pace of application will vary and this must be recognised in the implementation programmes.
- The process as a whole was well received with a real sense of involvement by participants; however, the objectives were seen as over ambitious by some contributors.

The themes have many areas of overlap with strong cross-linkages between several position statements. The themes of Sustainable Technology and Safety Performance underpin the majority of positions.

These linkages throw up the opportunity for symbiotic activity and in some cases the necessity for careful co-ordination to avoid potentially conflicting strategies. Overlaid on this is the likelihood that regional diversity arising from economic, environmental and social differences will tend to deliver both different priorities for action and rates of change. All of these issues are addressed.

The action plans provide specific direction over two, five and ten year time horizons to focus the technical activity of all the component parts of the Institution: Council, the Executive and staff teams, Subject Groups and regional networks. The primary responsibilities for implementing the action plans and the external partners necessary to complete the tasks are also identified thereby providing a starting point for further development, particularly where international relationships are concerned. The resource implications for the Institution are clear. The action plans address a broad and detailed range of issues and a process of careful review and prioritisation will be initiated in the third quarter of 2007. Resource constraints notwithstanding, it is encouraging to note that many of the Institution's network groups have already reviewed their objectives and work programmes with a view to implementing the first stages of the action plans. The inter-related topics of energy, climate change and sustainability are already priority technical topics for IChemE.

The Roadmap exercise represents an exciting development for IChemE. It builds upon much of the excellent work carried out by the subject groups and other technical networks within the Institution. However, the global web consultation brought an entirely new dimension to the technical policymaking process. Healthy member engagement in the process has yielded an outcome that represents the mainstream thinking within the profession. The methodology of expert task and finish groups developing positions and action plans and exposing these to member critique through an open web based consultation worked well and received praise from many sources. Members from 46 countries submitted over 25,000 comments indicating that the final output represents a broad consensus. The action plans based on the positions provide a clear pathway forward and the total output can justifiably be presented as 'A Roadmap for 21st Century Chemical Engineering'.

1. Introduction

In late 2005 IChemE Council identified a need for greater clarity in relation to the technical positioning of the Institution on key issues of public concern. A Strategy Task Force convened by Ian Shott, the Technical Vice President, met in workshop sessions to identify a set of priority topics. This work was supplemented by the key messages arising from the technical programme at the 7th World Congress of Chemical Engineering held in July 2005 and the output of a high level IChemE/RSC interface group convened by EPSRC. The Roadmap project was launched at the 2006 Assembly with the full backing of the members present.

The process of developing a Roadmap for 21st Century Chemical Engineering was targeted at putting the Institution, and its constituent groups and members, in a position to make a meaningful contribution to public debate on issues where the discipline, in conjunction with others as appropriate, can play a significant role in delivering solutions.

Four key topic areas were originally identified to focus the production of position papers and involve all the Subject Groups:

Sustainability and Sustainable Chemical Technology	Health, Safety, Environment and Public Perception of Risk	Energy, Food and Water	Bioprocess and Biosystems Engineering
Sustainability	Environment Safety & Loss Prevention	Energy Conversion Technology Coal Utilisation Oil & Natural Gas Water Food & Drink	Biochemical Engineering Pharma

Cross –Thematic Subject Groups

Computer Aided Process Engineering	Particle Technology	Fluid Separations Process Management & Control	Fluid Mixing Processes Project Management

Subsequently Energy, Food and Water were actioned separately resulting in six thematic areas. The project is assessing the contribution chemical engineering can make in these thematic areas which have many areas of overlap and should not be viewed as prescriptive. They offer a starting point for a debate within the membership and the development of a set of clear positions that will address key societal issues.

In each of these areas the question to be answered was 'What does society need, what are the desirable outcomes and how can chemical engineers work in partnership with other stakeholders to make it happen?'. Technical Policy Commissions in each theme, made up of Subject Group nominees, developed initial position papers which identified challenges, suggested solutions which imply the application of chemical engineering, and proposed positions that the profession might adopt to make things happen. These aimed at being forward looking contributions which take a global perspective. The next stage was to expose these drafts to a review by the membership to provide both rigour and a sense of ownership to the final output.

A process was developed to capture the input of the Subject Groups and the membership as a whole. In summary this process was:

1. Convene Technical Policy Commissions (TPCs) in each topic area with membership drawn from the Subject Groups including cross-thematic representatives (Appendix 1):

   These Commissions agreed a list of the key issues within each of the six themes for which policies and positions were required and prepared initial statements.

2. Engage with the membership on this scoping exercise:

   Using a web based consultation process, run by Dialogue by Design, the members were asked if they agreed with the positions, if there were any missing and which were their priorities for action (Appendix 2).

3. Finalise the position statements and prepare action plans:

   The TPCs used the extensive feedback from the membership to refine the position statements and identify action plans to achieve them.

4. Provide a second consultation opportunity for the membership to review the positions with the benefit of the analysis of the feedback from the first consultation and comment on the proposed action plans.

5. Finalise the papers for launch

The two consultation sessions ran during September 2006 and January 2007 and engaged 1135 members from 46 countries, broadly matching the demographic of membership. The output from the process is a priority list of 20 position statements expressing the views of the Institution on the key issues affecting society in the 21st century where chemical engineering has a major part to play in providing beneficial solutions. There are 34 additional positions under each thematic area, considered by the members to be of lower priority for action, but which complete the Institution's views in each area.

The action plans, shown diagrammatically in Section 3 and detailed in Section 4, provide specific direction over two, five and ten year time horizons to focus the technical activity of all the component parts of the Institution: Council, the Executive and staff teams, Subject Groups and regional networks. The individual responses to the second stage consultation also provide a valuable basis for the action plan projects to be scoped and defined in line with a call for the plan to contain SMART actions, i.e. Specific, Measurable, Action orientated, Realistic and Timely.

Section 4 also identifies the prime responsibilities for implementing the action plans and the external partners necessary to complete the tasks. The partners lists will develop further, particularly as far as international relationships (e.g. Engineers Australia, Malaysian groups, etc.) are concerned, as actions proceed.

The existence of these well defined and supported positions on key societal issues will contribute to more effective communication strategies, focus the Institution's responses to government consultations, allow IChemE spokespeople to make a coherent contribution to topical debate and facilitate more productive media relations.

2. Roadmap Overview

Roadmaps are presented under the six thematic headings for each of the 20 prioritised positions, which are shown in the priority order determined from the consultation under each theme.

Each consists of the background information to each position, the position statement itself and the action plan, in diagrammatic form, to achieve the objectives of the position together with a vision which describes the successful outcome of the action plan. The written versions of the action plans are presented in Section 4. The position statements considered by the members to be of lower priority for action, but which complete the Institution's views in each thematic area, are included under their respective themes. Where appropriate, comment is included on how these positions have or will be addressed.

The themes have many areas of overlap and there are several cross-linkages between the positions, the strongest being indicated by the green squares in the chart below. The themes of Sustainable Technology and Safety Performance underpin the majority of positions.

These linkages throw up both the possibility of symbiotic activity and in some cases the need for close co-ordination to avoid apparently conflicting strategies. Overlaid on this is the likelihood that regional diversity arising from economic, environmental and social differences will tend to deliver both different priorities for action and rates of change. These issues are addressed next.

2.1 Consistency and Symbiosis

Data on the consequences of climate change continue to be refined and the mitigation methods and timescales for remedial action remain an open question across the science and technology community as a whole. Not surprisingly therefore, these tensions are reflected in two of the positions and were clearly apparent in the members' responses to the consultation. The sustainable energy position (see 3.1.1) calls for global energy policies which break our predominant dependence on sources that emit fossil carbon as CO_2 in a 20-30 year timescale, whilst significant fossil fuel use is seen as unavoidable for a longer time in the energy position (see 3.3.2), reflecting the view from the July 2005 G8 Summit. The view from the Sustainability TPC does not preclude the continuing use of fossil fuels but it does foresee a quicker reduction to a lower level.

What is clear is the need for a portfolio approach to energy sources and in practical technology terms in the short run both views support the rapid deployment of carbon capture and sequestration, the expansion of nuclear power and focus on increasing the efficiency

Linkages between Priority Positions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	X		■		■		■		■			■								
2		X	■		■					■	■						■			
3	■	■	X	■	■		■	■	■	■	■	■	■	■	■	■	■	■		■
4			■	X			■								■					
5	■	■	■		X		■	■	■	■	■	■	■	■	■	■	■	■		■
6						X														
7	■		■	■	■		X													
8			■		■			X												
9	■		■		■				X											
10		■	■		■					X	■								■	
11		■	■		■					■	X									
12	■		■		■							X								
13			■		■								X						■	
14			■		■									X						
15			■	■	■										X					
16			■		■											X				
17		■	■		■												X			
18			■		■													X		
19										■			■						X	
20			■		■															X

1 = Sustainable Energy
2 = Reduce, Reuse, Recycle
3 = Sustainable Technology
4 = Risk
5 = Safety Performance
6 = Open Dialogue
7 = Nuclear Power
8 = Continuing Fossil Fuel Use
9 = Renewable Energy
10 = Biofuels
11 = Food Waste Management
12 = Food Production
13 = Diet and Health
14 = Innovation (Food & Drink)
15 = Delivery of Safe Products (Food & Drink)
16 = Sustainability and New Technologies (Water)
17 = Industrial Usage (Water)
18 = Water as a Resource
19 = Provision of Well Trained Bioprocessing Professionals
20 = Low Environmental Impact and Sustainable Bioprocesses

of energy use; and both support accelerated research, development and implementation of renewable energy sources based on sound science, including life cycle analysis. This leaves options open and the ability to respond to future developments in science and technology, and gives IChemE a sound basis for action.

There are three strong symbiotic threads running through the positions and action plans, the first being sustainability and innovation, the second being health and safety and the third, often unstated, being education and training. All the themes have positions focusing on the need to implement sustainable and innovative technologies which are pulled together under the Sustainability theme itself. Similarly health and safety underlies all the positions and action plans and is pulled together under the theme of Health, Safety, Environment and Public Perception of Risk. Education and training also feature in all the themes and although some actions are theme specific several, namely 3.1.3 Sustainable Technology, 3.2.1 Risk, 3.3.1 Nuclear Power, 3.3.2 Continuing Fossil Fuel Use, 3.4.3 Diet and Health, 3.6.1 Provision of Well Trained Bioprocessing Professionals, impact on undergraduate teaching and should be addressed collectively.

The second round consultation asked a specific question to ascertain if the action plans had different implications for different regions. Some of the issues raised are difficult to accommodate into the action plans and the main ones are therefore summarised here and need to be borne in mind during implementation.

a) Sustainability – the key issue of inter and intra generational equity, fundamental to sustainability, is clearly evident in the regional perspectives. There is clear agreement that sustainable development is a global issue but that whilst the goals should be common the focus and pace of application might vary between developed and developing economies.

b) Energy – energy solutions need to be tailored to each country's energy options but with a need for all countries to be mindful of the global implications.

c) Food and Drink – a need for a different approach in the developing countries where diet is about availability, making preservation important, farming is about subsistence, rendering fertilisers unaffordable, and disease prevention (cf avian flu) may require significant shifts in nutritional habits.

d) Water – confirmed by a strong response from Australia as a critical issue where almost every solution from desalination to recycling effluent hinges on chemical engineering input and where chemical engineers will be designing, running and maintaining advanced water infrastructure for many years.

e) Economics – there is only passing mention of economics (e.g. costs and benefits) in many of the sections though the importance of economic studies is recognised. Politics play a large part here, with governments and agencies unwilling, for example, to increase utility prices which could help to offset the increased costs of providing alternative, more sustainable, sources. Approaches will vary from country to country. This is an area that is firmly part of the engineers' remit and the process of 'internalising the externalities, i.e. ensuring that, the complete cost of any process is attached to the products of that process, must be built into the action plans.

f) Wider public engagement - many of the action plans call for engagement with policy makers, regulators and other agencies in a leadership role. There is clear need for an overall policy on this issue with guidance and education.

Additionally the workshop held at CHEMECA in Auckland proposed that minerals should be added as a separate thematic area, noting the following:

Several key drivers are shaping the minerals industry globally:

- accelerating minerals and resource demands from the rapidly growing economies of China and India;
- rising global population beyond 6 billion and the pursuit for better lifestyles in developing countries;
- meeting the global demands for metals such as iron, nickel, copper, etc;
- sustainability of the mining and mineral processing industries worldwide;
- life cycle costs of process and products.

Subsequently the IChemE in Australia Board recommended a response to these drivers by:

- the promotion of a greater level of R&D within the minerals area;
- encouraging the development processes that achieve higher recovery efficiencies particularly for low grade and marginal deposits;
- ensuring that the principles of sustainability mentioned elsewhere in the Roadmap are also emphasised for the mineral industry (e.g. life cycle assessment, etc);
- encouraging the development and promoting the widespread use of improved recycling methods;
- encouraging greater emphasis within chemical engineering programmes of mineral processing and related fields of study through the development for accredited dual degrees and minors through the accreditation programme. This need is particularly acute in Australia.

It is suggested that these issues be added to the Sustainability agenda and picked up as a regional priority by Australia and other regional groups where minerals extraction is a core industry.

Finally there are resource implications in attempting to implement an action plan with such broad and deep coverage and these issues will need careful review and prioritisation at the outset of the implementation process. As a starting point the consultation revealed that the members viewed the inter-related topics of energy, climate change and sustainability to be the most important technical issues for chemical engineers.

3. The Roadmap

3.1 Sustainability and Sustainable Chemical Technology

3.1.1 Sustainable Energy

Access to energy, clean water, food and healthcare are the prime indicators of quality of life. Energy is the prime driver of improvements in the other quality indicators and to raise its per capita consumption across the world to European levels (less than ½ US levels) would require a doubling of current consumption, rising to a three times increase if projected population growth is factored in. Currently over 80% of world energy is generated from fossil fuels. The planet cannot sustain the emissions arising from this level of use even if the reserves exist. Short term solutions to minimise the use of and the emissions from fossil fuels are required (see Position 3.3.2) but the prime imperative is to break our predominant dependence on sources that emit fossil carbon as CO_2 in a 20-30 year timescale.

IChemE supports the more rapid pursuit of a global energy policy based on using non-fossil primary energy sources (e.g. nuclear, including fusion in the longer term, and renewables, including solar, geothermal) coupled with the development of hydrogen, or other options, as energy carriers (or vectors).

Action Plan

Vision: Governments globally have co-ordinated implementation plans and delivery mechanisms in place before 2020 to achieve a sustainable target peak atmospheric CO_2 concentration of 550 ppmv (the Royal Commission's recommendation).

	2 years	5 years	10 years
GOALS	Co-ordinated ability to influence govmnts globally Hierarchy of status, applicability and cost of potential energy solutions	Actions defined by govmnts to implement sustainable policies National and international R&D programmes in place to support policies	Implementation plans in place globally to achieve target peak CO_2 concentrations
ACTIONS	Form international forum based on national groups Compile and publish literature review of available energy technologies	Monitor progress through the forum against agreed milestones and publish outcomes to influence progress	Continue to monitor progress through the forum against agreed milestones and publish outcomes to influence progress

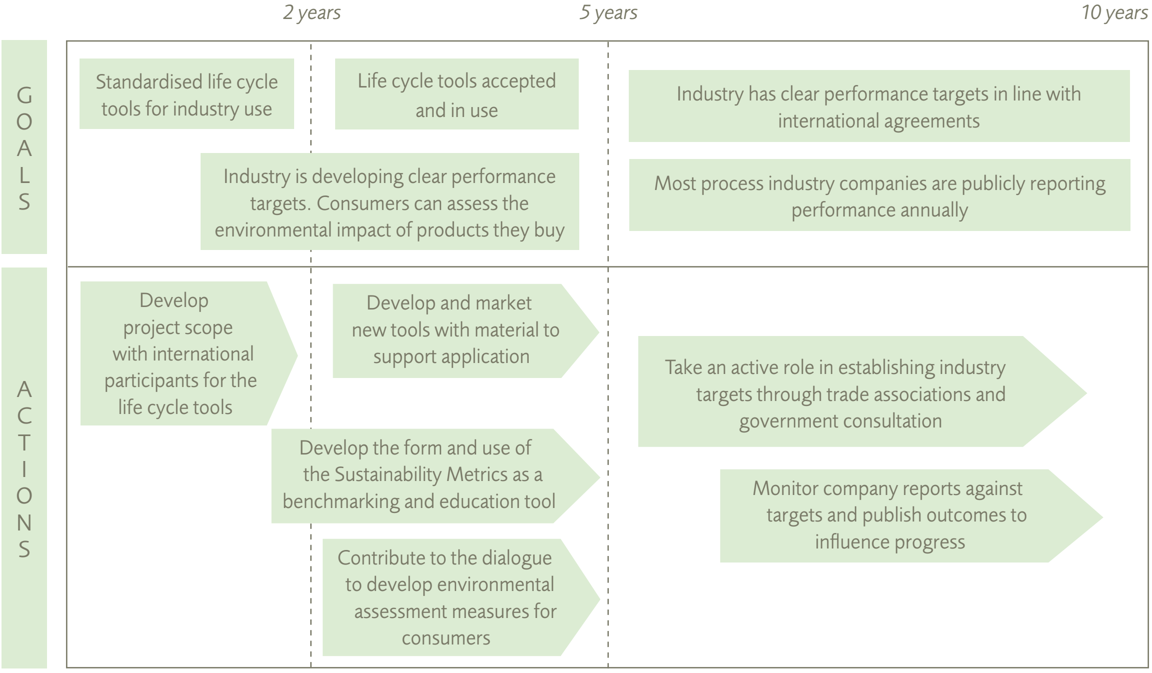
3.1.2 Reduce, Reuse, Recycle

We are profligate in the use of all the resources of our planet, and for a sustainable future our objective must be to dematerialise our way of life by reducing the quantity of raw materials, water and energy we consume and the waste we produce, by designing products to eliminate or reduce built-in obsolescence, recycling products at the end of their life and recovering and reusing as much of the material they contain as possible. Legislation can be a valuable driver since once-through production and consumption may often be cheaper and more convenient than the more complex option. The difficulty is in casting the legislation to promote the required behaviours and outcomes.

IChemE supports the continuing introduction of appropriate legislation, taxes and other fiscal measures to encourage a change of behaviour, coupled with targeted information and education to drive the 'reduce, reuse, recycle' mentality deeper into industry and the consumers of its products.

Action Plan

Vision: The concepts of reduce, reuse, recycle are integral to the design of all products and processes.



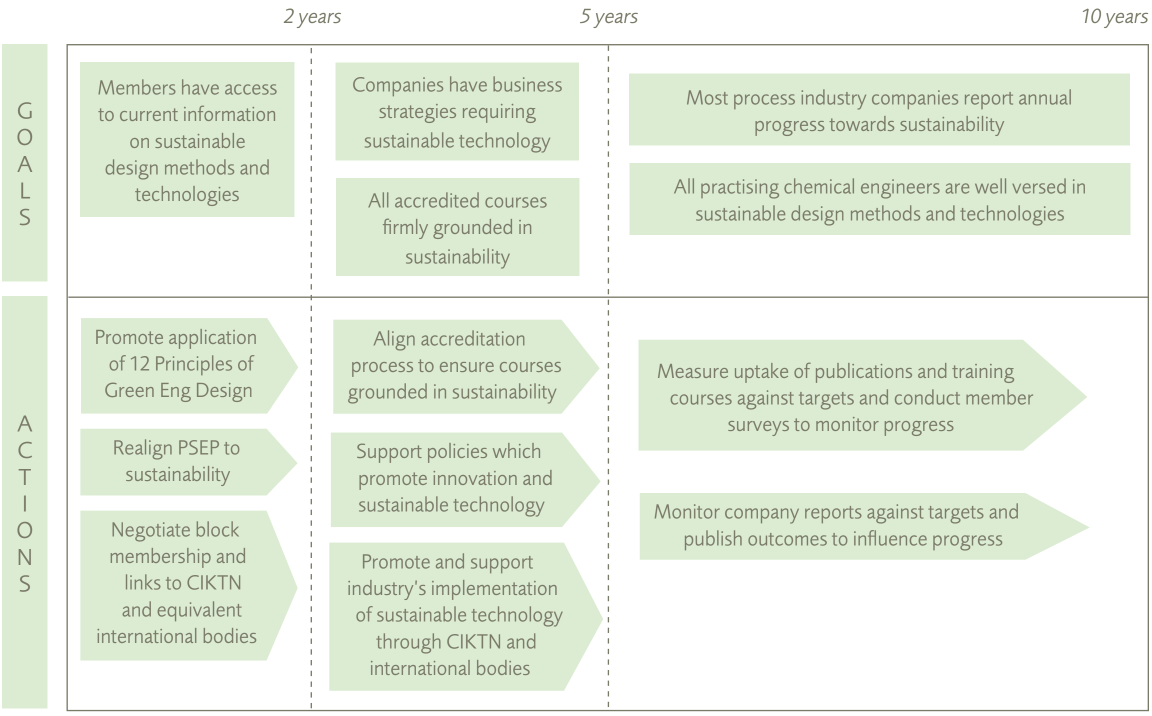
3.1.3 Sustainable Technology

As chemical engineers we have readily accepted the principle of the economy of scale, and as a result have designed and built ever larger production units, increasing plant efficiency and reducing per unit costs of production. The downsides of this policy include increased safety and environmental risks arising from higher inventories of hazardous material, the economic risk of overcapacity from simultaneous multiple world-scale plant expansions, and the legacy effects of written down plant impeding the introduction of new products and technology. New concepts such as process intensification, flexible, miniaturised plants, localised production and industrial ecology must become mainstream and we must continually reassess our approach to plant design and the acceptance of innovative concepts to render the chemical industry sustainable.

IChemE believes that the necessary change in business strategy to speed the introduction of innovative and sustainable technologies should be led from the boardroom, facilitated and encouraged by chemical engineers at all levels in industry, commerce and academia.

Action Plan

Vision: The design approach to all products and processes demonstrably incorporates the principles of sustainable development.



3.1.4 Important Second Order Positions

The remaining positions complete the Technical Policy Commission's thinking on Sustainability and Sustainable Chemical Technology. Several aspects of these positions are picked up in other action plans and these are cross-referenced here.

Education

The education of future generations of chemical engineers and realignment of the current generation with sustainability objectives is a vital component of the process of sustainable development. This, like safety, is a mind-set issue and as well as providing grounding in new and leading edge technology areas, the concepts of sustainable development and green product design must become inherent in undergraduate courses and in CPD in the way that safety was incorporated post Flixborough.

IChemE will continue its programme to integrate sustainable development into the core curriculum and ensure the accreditation process reflects its importance; will ensure that sustainable development is a component of CPD; and will work with other stakeholders to ensure such education is not resource constrained.

See Action Plan 3.1.3 Sustainable Technology.

Dialogue

Society, as a whole, has a major role to play in identifying sustainable products and processes and supporting their development through consumer behaviour. Communicating the facts to the consumer on these issues is a major challenge. As a profession chemical engineers need to listen to and engage in a genuine dialogue with third parties, e.g. green NGOs, and society as a whole, and communicate a balanced view.

IChemE will develop programmes, often in concert with other stakeholders, to engage in dialogue with the public to listen and learn, and to openly communicate both facts and uncertainties in the debate on sustainable products and processes.

See Action Plan 3.1.2 Reduce, Reuse, Recycle.

Tools

The business case for sustainable development is often hard to quantify, firstly because traditional accountancy practices do not identify the true life cycle benefits (e.g. the total savings from minimising a waste stream) and secondly because internalising the costs of externalities (e.g. cost of CO_2 emissions) cannot be achieved without the existence of appropriate mechanisms of national and international control. Chemical engineers have the necessary skills and competencies to contribute to the development of techniques to address these concepts.

IChemE will work with other stakeholders to develop an appropriate toolbox of concepts and methodologies (e.g. life cycle analysis) and communicate these to interested parties.

See Action Plan 3.1.2 Reduce, Reuse, Recycle.

Sustainable Design

Society is becoming ever more risk averse and consumers are requesting more information on the health and environmental impact of the products they buy and dispose of at the end of their lives. These positions are increasingly reflected in legislation affecting the chemical industry.

Increasing consumer knowledge and sophistication worldwide will sustain this trend. A new discipline of 'sustainable product design' is emerging and chemical engineers have a leading part to play in its definition, development and implementation.

IChemE will work with other stakeholders to define and develop the concept of 'sustainable product design' and ensure evaluation of the financial, environmental and social benefits and costs; and it will work to incorporate these concepts into chemical engineering courses.

See Action Plan 3.1.3 Sustainable Technology.

Market Policies

Sustainability is a global issue and the effective internalisation of current externalities can only be achieved through a proper use of global market forces brought about by governments, usually through international agreements on fiscal and regulatory measures. This is an essential prerequisite to support new style decision taking by industry.

Additionally the effect of financial markets to produce a tendency for short termism contrary to the needs of sustainability has to be taken into account.

IChemE, understanding how chemical engineering can support the profound changes required to deliver global sustainability, will in conjunction with other stakeholders, encourage governments and international bodies to implement strategies and policy which secure sustainable economies in the developed and developing world.

Crop Production

Whilst agriculture has become increasingly land efficient in terms of crop yields, it has become increasingly energy intensive to the extent that each calorie of food output now requires ten calories of input, ten times the input at the beginning of the 20th century. The globalisation of food production with the need for transportation to market adds further to its energy content and is also a cause of water appropriation from poor to rich ('their' water is consumed producing 'our' diet). Making agriculture sustainable requires a range of techniques which will include biotechnology (new strains, higher yield, disease and drought resistance, herbicide and pesticide resistance), more effective chemical treatments, and different farming practices. The use of crops, and more importantly crop waste, to provide renewable sources of both energy and chemicals will also benefit from these techniques. Chemical and biochemical engineers have a major part to play in bringing about a new approach to agriculture in a sustainable world.

IChemE supports the research, development and use of disease resistant and drought tolerant crops, and targeted agrochemicals, which have been evaluated to understand the financial, environmental and social costs; the use of the non-food element of crops as a chemical and energy source should be maximised.

See Food and Drink Action Plan 3.4.2 Basic Production

3.2 Health, Safety, Environment and Public Perception of Risk

3.2.1 Risk – Its Management and Public Understanding

Society demands the right not to be unreasonably affected by our activities. Total elimination of risk is usually not possible without giving up the benefits of the risky activity. The concept of tolerable levels of risk is used to strike the balance between risk and benefit. However, we must recognise that perceptions of risk differ widely within society and around the world. We believe the way forward is to create a common understanding of benefits and burdens through providing information and leading debate to build trust amongst all stakeholders. To achieve this, the processes we use to assess the tolerability of risk should recognise the priorities in the parts of the world where the risk has its impact without compromising good industry practice.

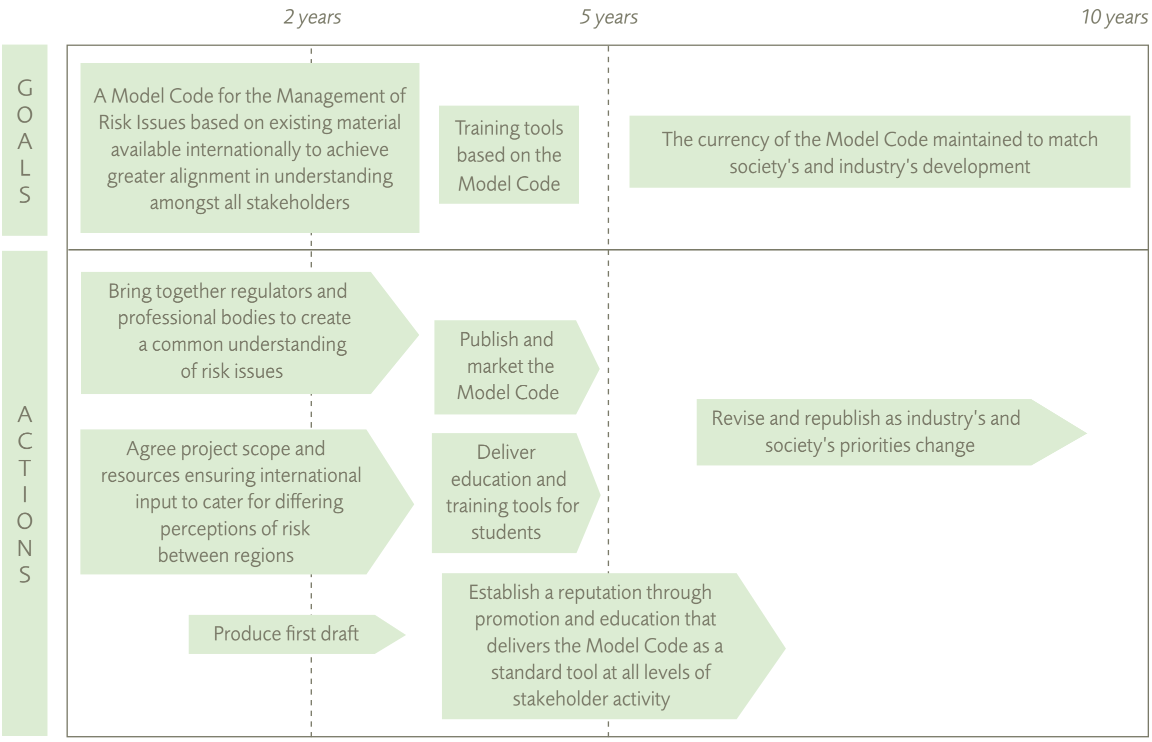
IChemE will reach out to the public, other professional institutions, governments and regulators, media, NGOs, employers and industry representatives to build a common understanding of risk issues.

For us to meet the demands of society to manage the risk of our activities at a tolerable level, chemical engineers have a duty to ensure that they will use the most appropriate methods to identify, assess, manage and control risks. As a profession we actively promote a hierarchy of measures: inherent safety → prevention → control → mitigation to achieve realistic and intelligent risk reduction measures that are cost effective and sustainable. These risk reduction measures must include people, equipment and manufacturing methods.

Chemical engineers and IChemE will seek to exert greater influence on the process sector, regulators and academia to develop and utilise new ways for cost effective and sustainable risk reduction. This may be carried out in conjunction with other relevant professional bodies.

Action Plan

Vision: A broad societal understanding of risk and a process sector consistently acknowledged as operating within it.



3.2.2 Performance – Health, Safety and Environmental Culture

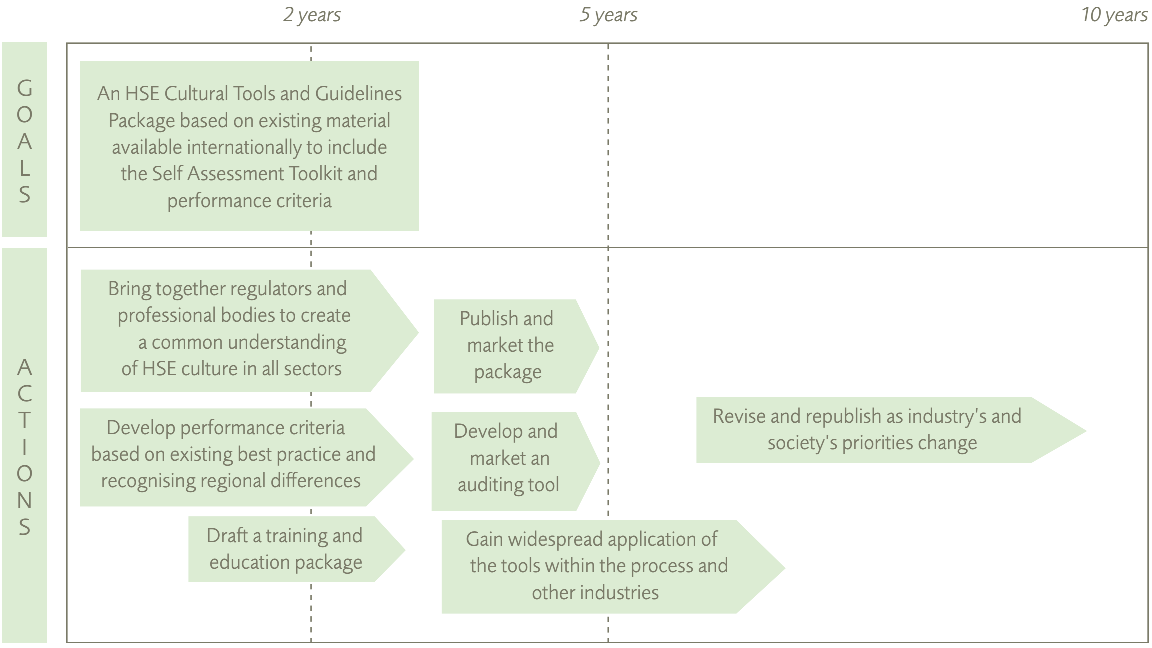
The industry's H, S and E performance and the public perception of it is the major factor in it maintaining its licence to operate and invariably it is the worst performers who attract attention, not the best. The chemical industry is already strongly regulated with every indication that this trend will continue unless industry can demonstrate a significant improvement in H,S and E performance.

To achieve this, organisations must embrace a corporate culture, driven by strong leadership that does not tolerate poor H, S and E performance. Major challenges exist in achieving a global approach that ensures a 'level playing field' as well as obtaining a common understanding on methods of measuring safety and environmental performance. Those who show outstanding performance should be rewarded through recognition; those who speak out against unacceptable practices need to be supported and protected.

IChemE will engage with corporate leaders, regulators, and other professional bodies to create cultures that deliver real improvements in H, S and E performance, and have benefits to all.

Action Plan

Vision: A targeted drive by all companies in the process sector to equal best in sector H, S and E performance.



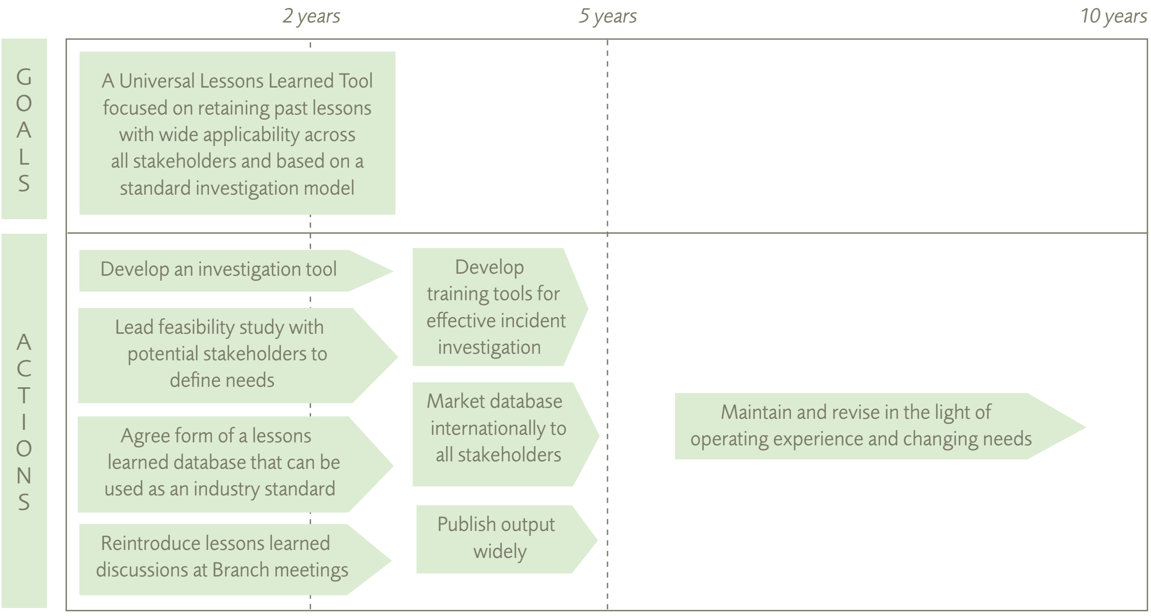
3.2.3 Open Dialogue – Learning from Past Successes and Failures

Repetition of past mistakes that threaten the health and safety of communities and of the environment in which they live is unacceptable. While there is universal agreement on the importance of learning from past experience around the world, very few organisations have a structured system for gathering such information and even fewer seek to disseminate it across industry. IChemE is dedicated to learning lessons from the past, reporting the lessons and the analysis, and disseminating information on incidents in a useful, relevant way that can be accessed by all members of the profession and others who wish to know. Training of engineers in accident investigation develops a core skill which is essential to ensure that lessons are learnt and widely disseminated. Started in the aviation sector, 'just culture' is an approach to how an organisation can promote improvements in the level and quality of reporting of safety information.

IChemE will work to influence industry groups and regulators to take a more proactive approach to passing on lessons learnt. We will strive to break down the barriers that blame and litigation create to prevent lessons from accidents being rapidly disseminated to those who would benefit through the adoption of 'just cultures' that focus on learning, not on establishing blame.

Action Plan

Vision: A mutually supportive approach to sharing H, S and E incident information across the process sector and beyond.



3.2.4 Important Second Order Positions

The remaining positions complete the Technical Policy Commission's thinking on Health, Safety, Environment and Public Perception of Risk. Several aspects of these positions are picked up in other action plans and these are cross-referenced here.

Relationships with Governments and Regulators

Regulation is a response to a reduction in public trust. Maintaining a positive dialogue between the profession and regulators is essential to preventing unnecessary regulation and 'red tape' but accepting the need for pragmatic, balanced legislation and effective implementation. This dialogue must remain clearly differentiated from that between the regulator and industry or its trade body representatives. The presence of many Institution members within the regulatory bodies gives a uniqueness and added strength in building a positive relationship and provides links to the experience within the wider chemical engineering community.

IChemE will continue to build links with governments as they develop their regulatory strategies, with the aim of avoiding over-regulation and allowing self-regulation where appropriate.

Dialogue with governments and regulators is a feature of all the action plans in this Section.

Sustainability and New Technologies

While it is natural that society aspires to progress through the adoption of new technologies or the further development of existing ones, new benefits will inevitably bring new risks with which we are, initially, unfamiliar. Nanotechnology is a case in point. Equally, to ensure a truly sustainable economy an equitable balance must be drawn between economic progress and the safety, health and environmental protection needs of the global community.

The education and training of chemical engineers in a total systems approach and in hazard identification and risk assessment methodologies qualifies them to take the lead when making the value judgments necessary to achieve this balance. Risks must be assessed across the whole life of a product from manufacture to disposal after use to ensure that risks and benefits are equitably shared.

Sustainable development, through innovation, will remain central to IChemE's activities. We recognise the need to develop better tools, methodologies, guidance and training to help make life cycle assessment (LCA) more accessible and useful to industry in the evaluation of new technologies.

See Sustainability Action Plan 3.1.2 Reduce, Reuse, Recycle.

Education and Training – Maintaining the Profession

The third report of the UK Advisory Committee on Major Hazards (ACMH), published in 1984, placed great emphasis on the role of education in the control of major hazards. This underpins the work carried out over many years by IChemE to strengthen process safety in the core material of accredited degree courses, and supports greater emphasis being placed on post graduate training with employers recognising the need to provide sufficient freedom for individual professionals to embrace an effective continuing professional development (CPD) programme.

While recognising the challenges that this presents, the Institution will ensure that the output of academia continues to match the requirements of industry and society as a whole, and promote the adoption of best practice in the management of CPD programmes.

Continuing education and training is a feature of all the action plans in this Section.

3.3 Energy – Securing Reliable and Affordable Supplies in the Near Term

3.3.1 Nuclear Power

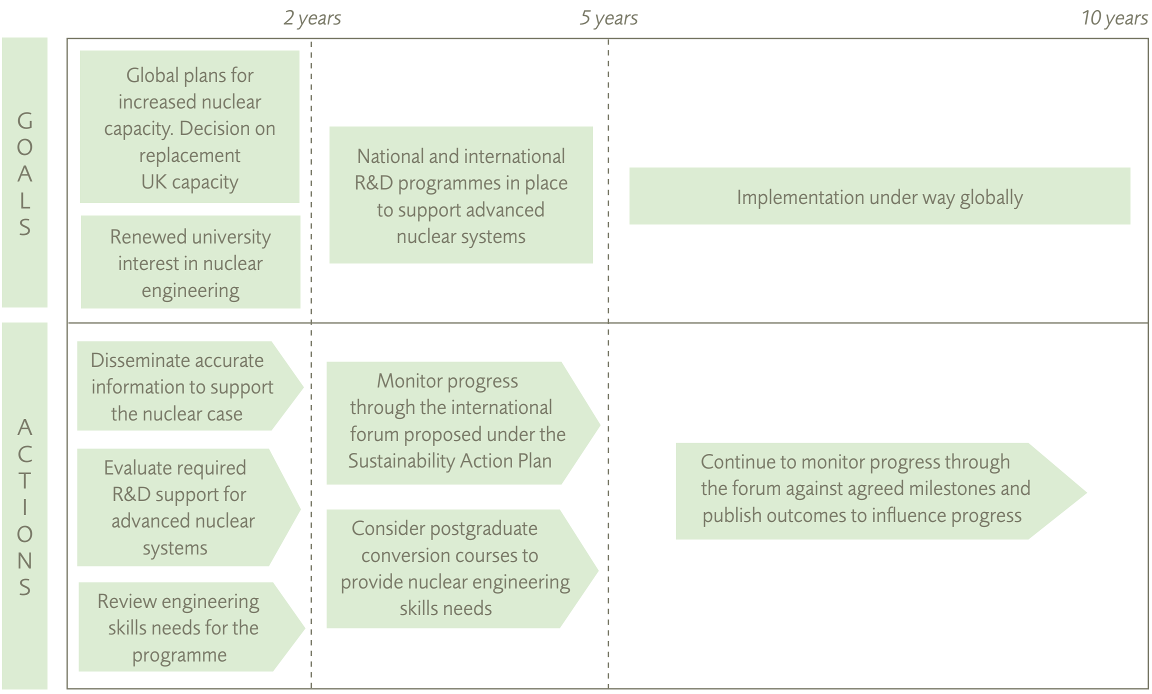
There are over 400 commercial nuclear reactors in the world providing 16% of the world's electricity via nuclear fission. The issue of nuclear power remains contentious although IChemE has remained broadly supportive believing that the benefits outweigh the risks associated, for example, with radioactive waste. The Institution welcomed a 2006 UK report which concluded that deep underground storage offered the only viable solution to both the UK's legacy and ongoing nuclear waste.

Both the Chinese and Indian governments have announced the most ambitious nuclear construction plans that the world has seen in decades. However, even if their current nuclear aspirations are realised neither country will be getting even 5% of its total energy from nuclear power in 2020. International concerns over nuclear proliferation have risen considerably since 2000 with plans to build reactors in Iran and North Korea. Against this backdrop, emotive arguments frequently obscure attempts to conduct a debate based on technical fact. There is no obvious source of CO_2 free electricity generation available to take its place and for the foreseeable future nuclear will provide a hugely significant contribution to global warming gas reduction.

IChemE believes that nuclear power will continue to fulfil a significant part of global energy demand in the short and medium term and calls on decision makers and opinion formers to conduct a rational debate that provides a positive climate for further R&D in waste management, spent fuel processing and advanced reactor design.

Action Plan

Vision: Global support for increased nuclear power generation capacity as key contributor to combating climate change.



3.3.2 Continuing Fossil Fuel Use

Several key drivers are shaping the energy landscape:

- rising and volatile crude oil prices;
- rising global population beyond 6bn and the pursuit of richer lifestyles;
- decreasing supplies of established primary energy resources, notably crude oil and natural gas;
- a conviction amongst mainstream climate scientists that greenhouse gas emissions are directly related to human activity and meaningful abatement measures should be implemented on a global scale within two decades in order to avoid catastrophic environmental consequence.

The relentless pursuit of economic growth, for the time being at least, inextricably bound up with energy consumption and resource depletion defines the setting within which professional chemical engineers must operate. This challenge is huge, yet chemical engineers are capable of deploying a range of innovative technologies, some proven, some requiring R&D that will reduce demand, increase efficiency, capture and sequester greenhouse gases and ultimately replace existing processes that are dependent upon fossil fuels.

In the short term at least (and there is conjecture within the chemical engineering community itself as to the likely time period), fossil fuels will retain a major share of primary energy globally. China currently uses around 7% as much oil per person as the USA does, India just 3%. If over the next 20-30 years, both nations were to reach even half of the US level of consumption, they alone would be using 100m barrels per day. This projection implies total worldwide oil consumption in 2050 of over 200m barrels per day, compared to 85m barrels per day in 2005, with dramatic implications for CO_2 emissions unless widespread deployment of new process technology is initiated. Meanwhile, coal provides more than two thirds of China's energy and half of India's and usage is expanding in both countries, making it clear that there is no serious solution to the world's climate problem without their active participation.

IChemE supports the view, expressed in the Gleneagles Communiqué arising from the G8 summit in July 2005, that because the world is locked into fossil fuels usage for some time to come the technological means of reducing CO_2 emission from their use must be implemented globally as an environmental and political priority whilst more sustainable options are urgently pursued (see 3.1.1).

IChemE believes that the widespread application of clean generation technology coupled with carbon capture and storage is essential to achieve major reductions in emissions. In the short and medium term fossil fuel use must be minimised by the application of currently available technologies to maximise the efficiency of electricity generation and use. Incentives should be introduced by governments in developed nations to manage demand and prompt a step change in the deployment of clean generation technology with carbon capture and sequestration.

Action Plan

Vision: The rapid global deployment of technology to minimise CO_2 emissions due to fossil fuel use by carbon capture and storage and increased efficiency of power generation and use.

	2 years	5 years	10 years
GOALS	Acceptance of fossil fuel use with capture and storage of CO_2 Improved technology options for capture and storage	Increased co-operation between universities and industry to reduce cost of capture technology	R&D programmes established on chemical processes that can use bulk CO_2 and 'fix' it
ACTIONS	Encourage governments to quickly establish demonstration projects Support R&D on improved capture and storage technologies Review educational needs to support sustainable power generation	Establish links with the Carbon Capture & Storage Association, the IEA and other international bodies and offer technical liaison Monitor and disseminate R&D output on capture and storage technologies	Forge a link between IChemE, industry and government for independent evaluation of technology developments Encourage R&D reducing the cost of storing CO_2 in solid compound form

IChemE recognises that although the challenge and the solution are global, the UK is well placed to demonstrate what is possible given the need for 35GW of replacement power generation capacity by 2020.

The potential exists for international joint ventures in pursuit of sustainable solutions suitable for global application and the Institution will continue to press the UK government to take a bold long term view.

	2 years	5 years	10 years
GOALS	A decision on UK replacement generation capacity with a broad mix to ensure security of supply	Primary energy mix refined in the light of CO_2 abatement costs	A cluster of UK based clean power generation projects with capture established
ACTIONS	Alert government to the dangers of delaying the decision on replacement generation capacity	Stay abreast of published data on costs of all generation technology options and advise government accordingly	Monitor and support progress by government and industry to achieve the target 35GW of new capacity

3.3.3 Renewable Energy

Solar

Most of the energy that is used on earth comes directly or indirectly from the sun. Photovoltaic technology, solar cells, generates electricity directly from sunlight but until recently usage has been limited to very small scale applications, e.g. roadside emergency telephones, calculators and small consumer electronic devices, due to high manufacturing costs. Total peak power of installed photovoltaic arrays globally in 2005 was circa 5300 MW. Manufacturing costs have fallen by 3-5% in recent years and worldwide production of solar cells increased by 60% in 2004 with further substantial growth anticipated. Shortages of refined silicon have hampered production in recent times. Continued research is necessary to develop more efficient and lower cost materials

Solar thermal power plants, which concentrate solar radiation to provide the heat input for conventional steam turbine or combined cycle steam and gas turbine power cycles, are attracting increasing interest, with several plants under construction.

Wind, wave, tidal and tidal flow, etc.

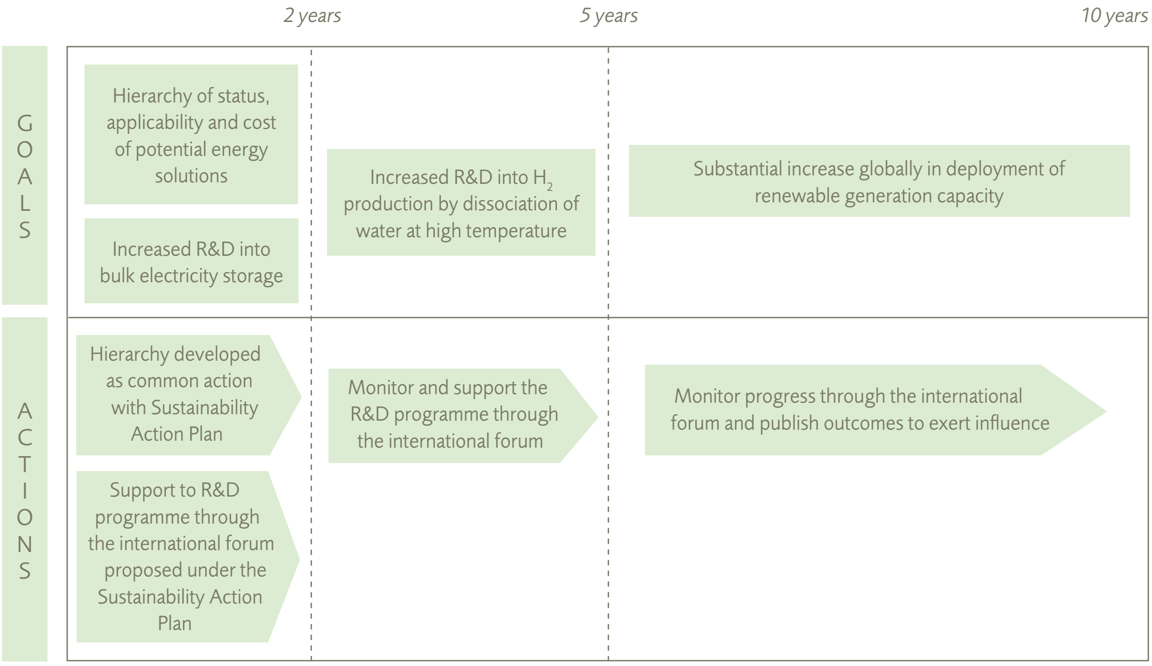
Wind generated power will continue to be deployed as improvements in technology reduce costs to compete with other methods of generation. In the absence of storage systems, intermittency results in wind power being a high cost CO_2 abatement option because of the need for a continuously available reserve. Continued R&D on power and heat storage systems is necessary.

Wave power remains at the experimental stage, as does tidal flow. None can be guaranteed continuous although well-spaced tidal flow systems could overcome zero-flow periods. The major factor holding back these technologies is cost arising from the structures to cope with storms.

IChemE supports increased R&D on the development and deployment of renewable technologies and power storage systems.

Action Plan

Vision: A significant global deployment of renewable energy sources based on sound science and tailored to regional needs.



3.3.4 Biofuels

Brazil has led the way in biofuels development since 1980, with ethanol from sugar cane accounting for roughly 40% of Brazil's non-diesel transport fuel since 2004. Biofuels initiatives have increased in many countries including the USA, China, Malaysia and the European Union and some states have legislated to set targets for their use in transport fuels. Mandatory quotas can distort the market and often stem from a farming lobby rather than decisions based on sound science. World biodiesel production has increased from negligible quantities in 1990 to over 2500 million litres/annum in 2005, and this trend is likely to continue. Motor manufacturers are confident of the capability of modern internal combustion engines to run on biofuels with appropriate quality specifications.

The EU and others have identified a number of environmental issues associated with biofuels at the crop-growing stage. Availability of water is a particular issue in many parts of the world and crop yields cannot be guaranteed without adequate rainfall or irrigation. Deforestation and displacement of food crops is a contentious issue as is the use of GMOs to increase crop yields. Cellulosic crops such as coppiced wood and miscanthus grass are likely to offer greater CO_2 reduction than food crops converted to fuel.

In the UK, the government's 5% target is also the manufacturers' upper limit for first generation biodiesel in blends to protect engine warranties. Fischer Tropsch (F-T) fuels that are superior to the usual definition of biodiesel overcome this problem. F-T jet fuel is also superior in that it is pure paraffinic material offering designers scope to improve performance and reduce emissions.

In the longer term, a combination of biomass gasification and Fischer Tropsch synthesis might offer an attractive route to the production of renewable transport fuels and the Institution argues that this option should also be pursued.

Action Plan

Vision: A regional specific whole systems approach to a biofuels economy to optimise the reduction in carbon emissions taking into account the environmental impact of source crops.

	2 years	5 years	10 years
GOALS	An understanding of the available crops for biofuels and the carbon profile of their growth	R&D programmes for better synthesis catalysts A scientific basis for the evaluation of source crops	A modelling system to optimise the source crop for various growing conditions
ACTIONS	Publish the options for biofuels production to stimulate debate Develop the benefits of second generation biofuels by F-T Examine the benefits of co-production of fuels and power	Assess the synthesis processes to convert high yield biomass into quality transport fuels Assist the evaluation of crop growing requirements to minimise environmental impact	Monitor the real reduction in system CO_2 emissions to confirm progress

3.3.5 Important Second Order Positions

The remaining positions complete the Technical Policy Commission's thinking on Energy. Several aspects of these positions are picked up in other action plans and these are cross-referenced here.

Energy Storage – Hydrogen and Fuel Cells

Although hydrocarbons provide an efficient form of energy storage and can be readily deployed at the point of use, e.g. in the fuel tanks of road vehicles, new energy carriers (or vectors) are required as part of the move to break our dependence on carbon for transport fuels and for energy storage from remote or intermittent renewable energy sources. Much attention is directed to the potential of hydrogen as a vector because it is clean on combustion, can be used in fuel cells and can be generated from water. However it is relatively expensive to produce, store and transport and because it is so light the energy density per volume of liquid H_2 is worse than a hydrocarbon fuel such as gasoline by approximately a factor of four. .

IChemE believes that financial support and R&D effort should focus on the search for new energy carriers as well as continue to be directed at both H_2 production and storage and fuel cells for both transport and stationary combined heat and power applications in the short to medium term.

See Action Plan 3.3.3 Renewable Energy and Sustainability Action Plan 3.1.1 Sustainable Energy.

The Chemical Engineering Community

A culture based on a professional commitment to sustainable chemical engineering has been developing within IChemE and the international chemical engineering community since the 1990s. An understanding of sustainable development principles and their application is a core learning outcome in IChemE accredited undergraduate programmes world-wide but more consistency and progress is needed.

IChemE reaffirms the clear requirement enshrined in its charter and bylaws obliging all members to act in the public interest and believes that this embraces an unequivocal commitment to uphold the principles of sustainable development. IChemE will support and promote the development and implementation of sustainable energy technologies and press for their deployment. In addition the Institution will offer all practicable training and support tools for chemical engineers and will facilitate the sharing of best practice amongst all scientific and engineering professionals.

Education and training is a feature of all the action plans in this Section and see also Sustainability Action Plan 3.1.3 Sustainable Technology

3.4 Food and Drink

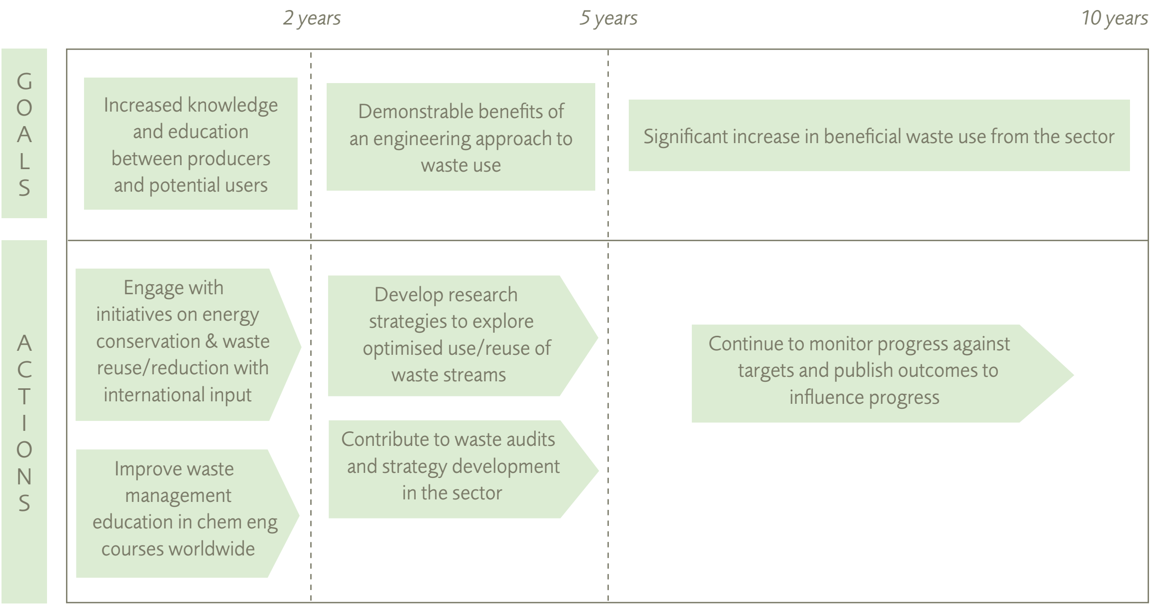
3.4.1 Waste Management

The industry supply chain from basic food production through to final product sale and use produces enormous quantities of waste which can be a valuable raw material in uses varying from energy generation and biofuels manufacture to chemical manufacture. The utilisation of these waste streams is an under-developed and vital part of sustainable development. A key concern in the food and drink sector is product safety and as such effective risk assessment and management strategies must be deployed. Equally chemical engineering principles need to be applied within the supply chain processes to implement innovative solutions for waste minimisation, the effective use of raw materials, promotion of energy and water efficiency and effective handling and treatment of waste.

IChemE supports the development of technologies to maximise the use of viable waste streams from the food supply chain.

Action Plan

Vision: A food and drink sector which seeks to reduce waste throughout its supply chain and find valuable outlets for waste that is unavoidable.



3.4.2 Basic Production

Although the Green Revolution has delivered a doubling of global food output on only 10% additional land, this benefit has not been universally shared and starvation remains a constant threat to millions. Additionally this production increase has depended on the use of fertilisers, pesticides, fungicides and herbicides, along with other mechanical inputs, for implementation, methods which have substantially increased farming's energy consumption and in some areas significantly damaged the environment. Organic and natural production strategies are important and should be part of a sustainable strategy. The incidence of animal borne diseases such as BSE has further undermined the public's confidence in farming methods. Open debate is key.

Efficient energy use, minimising the use of agrochemicals, safe waste disposal without risk to humans, animals, soil and water, maintaining soil fertility and safeguarding the ecological landscape are all key to ensuring that our means of feeding the growing world population is sustainable.

Opportunities for collaboration with other disciplines must not be ignored and are seen as adding value to this area.

Chemical engineers as experts in examining systems and energy flows must play a prominent role in the development of precision agriculture technology and rendering farming methods sustainable.

Action Plan

Vision: The application of chemical engineering principles seen as fundamental to the development of sustainable agricultural methods.

	2 years	5 years	10 years
GOALS	Higher profile for the contribution chem eng can make to the sector New chem eng led initiatives for improved production	New technologies evaluated Optimisation of current production practices	Long term strategy for the implementation of effective energy management in food and drink manufacturing
ACTIONS	Engage with initiatives on energy conservation and waste reuse/reduction with international input and sharing of best practice	Define key strategies for more sustainable energy generation and delivery to the sector	Seek multidisciplinary collaborations to develop best practice and improve the energy sustainability of the sector

Assurance of raw material supply is crucial for the food industry where extensive quality assurance schemes have been developed to support the whole food chain from agricultural practice to retail outlet. However the diversification that is evident within the agricultural sector, in part driven by the wish to explore alternative uses for crops, could lead to increased competition for raw materials destined for the food manufacturing sector. Governments must be cognisant of this potential when developing policy. This is a global issue and action is required beyond national levels to maximise the benefits offered from multidisciplinary engineering led and supported approaches in this area.

IChemE will continue to press government to take a science based approach in the development of policies for agriculture.

Action Plan

Vision: A multidisciplinary approach to the development of sustainable agricultural methods.

	2 years	5 years	10 years
GOALS	Global competition on a level playing field Acceptance of the role chem eng can play in agriculture	Clear benefit led demonstration of the chem eng contribution	Added value and sustainable strategy for the benefit of all communities
ACTIONS	Establish and promote with stakeholders common standards within the global industry Establish linkages with key agricultural bodies to promote a chem eng input to the sector	Define pilot projects to demonstrate the impact of chem eng in improving performance in yield, environmental impact and product safety	Seek a new strategic direction for the sector supported by best practice in materials science and engineering

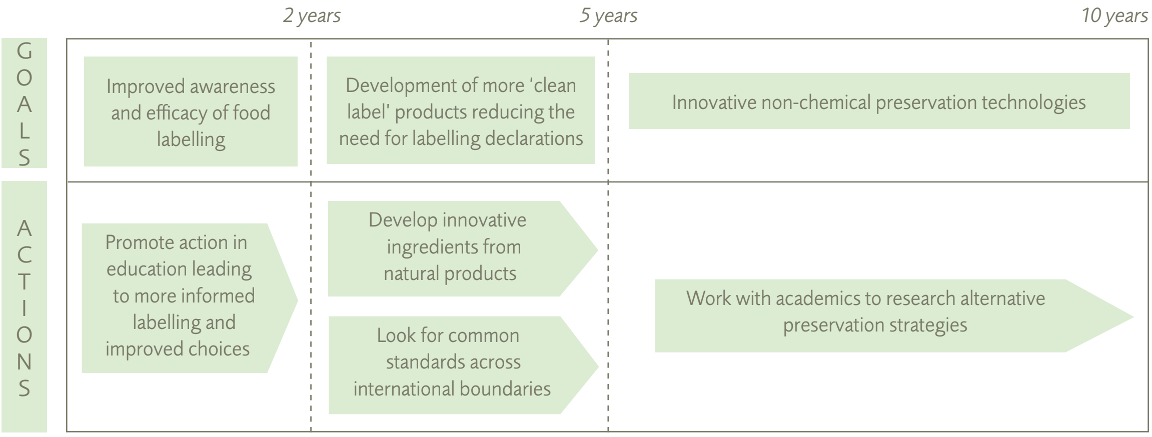
3.4.3 Diet and Health

The food and drink industry must have as its focus the delivery of safe, nutritious foods to satisfy and improve the diet and health needs of an ever more demanding global population, with due regard for the sustainability of raw materials supply and the environment. Within some markets, the major supermarkets have enormous influence over innovation, standards and approaches adopted by the manufacturers. This is clearly demonstrated in the UK where the value of this retail business is approximately £120 billion with a further £33 billion consumer spend in the food services sector. These supermarkets, together with the small number of multinational suppliers, form a powerful grouping which must continue to address the growing problem of obesity by measures including lowering the levels of sugar and salt in branded goods. Product labelling has also become a contentious issue with different and strongly held views evident amongst manufacturers as to how to communicate nutritional information. Consumer education is key as is the development and adoption of innovative new technologies

IChemE supports aproriate regulation to enforce clearer and standardised labelling of food products coupled with consumer education to influence choice and market driven demand.

Action Plan

Vision: A food and drinks sector focused on the sustainable production of safe, healthy and nutritious foods globally.

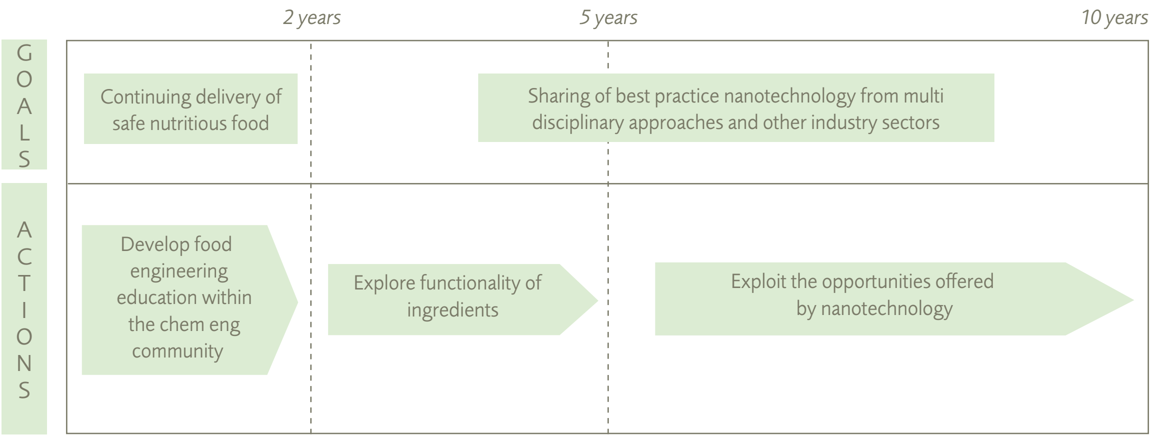


Chemical engineering contributes technically to the production of healthy foods through the manufacture and application of functional ingredients in processed foods, the application of encapsulation and nanotechnology as control mechanisms influencing the interaction between food and the consumer, and ingredient replacement and removal for diet and health benefits. Scientific innovations must be benefit driven to both manufacturers and consumers alike.

The delivery of safe, healthy and nutritious food demands the input of chemical engineers to explore new avenues in science and technology in collaboration with other disciplines.

Action Plan

Vision: The application of chemical engineering principles seen as fundamental to the development of the food and drink sector.



3.4.4 Innovation

Innovation within the food industry bridges a spectrum from far market and blue sky, usually supported by the larger organisations, to incremental development, often the preserve of small companies. Chemical engineering has an essential role in areas such as the scale-up of emerging technologies, e.g. ultra high pressure, electrical technologies, pulsed light; the control of processes both in terms of QA approaches (e.g. HACCP/ HAZOP/HAZAN) and process engineering control approaches; the validation and verification of the effectiveness of processing systems; the optimisation of manufacturing operations; increasing flexibility in plant and process intensification; and the application of nanotechnology concepts to food ingredients and products.

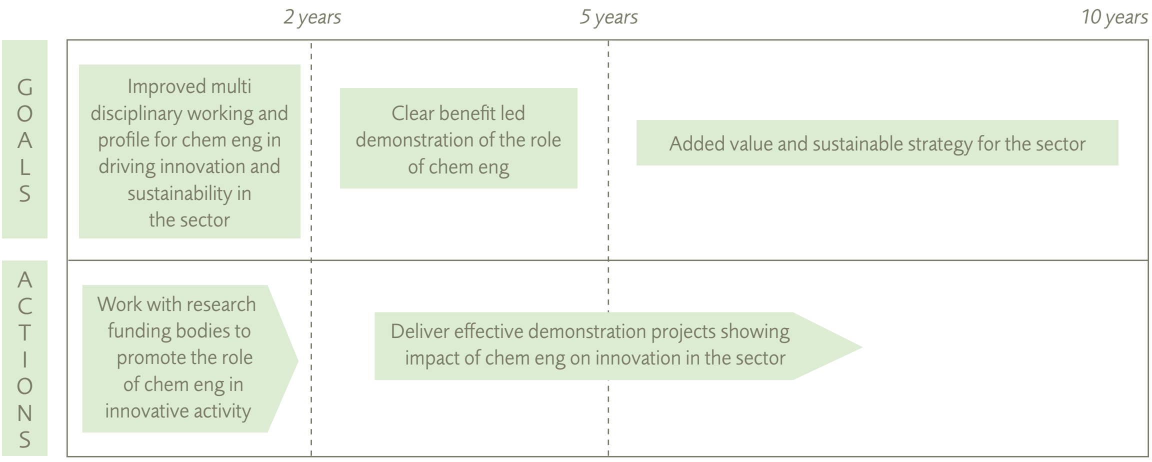
Commercial viability of innovative technologies is key as is the consumer perception of the risks and benefits of new technologies. Education is key in informing such perceptions. The environmental impact of the new approach will be one of the key factors.

Considering the range of these topics, it is clear that some are far from application in the manufacturing sector of today and require fundamental research to develop the knowledge of the science that underpins the area together with the necessary engineering approaches necessary to implement the new technology in the manufacturing arena. This is clearly a role for strategic research funding within the academic community.

It is important to encourage the blue sky development of science on a broad front compatible with the key challenges for the industry. Sustainability is vital and must be an active consideration for all involved in the food sector.

Action Plan

Vision: Chemical engineering playing a key role in innovation in the food and drink sector.



3.4.5 Delivery of Safe Products

In support of the challenge to deliver safe products is an ever increasing demand for traceability driven by both legislation and the industry's introduction of best practice and audit regimes. The polarisation of the industry between a large number of small/micro businesses and a smaller but highly influential number of multinational corporations does not help the spread of best practice throughout the supply chain. There is scope for technology transfer and education to support the transfer of best practice and increase the knowledge base and understanding of all stakeholders in the food sector. The closer integration of the communities which contribute to the development of the food industry – raw material supply, manufacturing company, retailing and the consumer are essential.

In technology terms chemical engineers contribute to the delivery of safe products through the management of thermal processing operations (pasteurisation/ sterilisation/chilling/freezing); the hygienic design of food processing factories and equipment; the in depth understanding of the materials science associated with materials of construction; and the development of effective product packaging and protection strategies.

Sharing of best practice requires a multidisciplinary approach and due regard for commercial sensitivities is of mutual benefit to all parties. Innovative approaches from other sectors are welcome with the requirements for safe foods a prerequisite of the highest priority

IChemE with other stakeholders will promote dialogue across the supply chain to support technology transfer and the sharing of best practice.

Action Plan

Vision: Continually improving standards in the delivery of safe food and drink products.

	2 years	5 years	10 years
GOALS	Increased knowledge in the chem eng community of the food sector and its practices	HIgher profile for chem eng in the sector	The opportunity to influence strategic thinking
ACTIONS	Promote the role of chem eng using existing technology transfer organisations and routes Support international conferences and dissemination events to the sector	Develop best practice guides demonstrating the role of chem eng in support of the sector's priorities	Establish chem eng at the centre of the sector through representation on high level government strategic bodies

3.5 Water

3.5.1 Water as a Resource

Water is essential to life on earth and must be available in adequate quantity and quality to all species. Communities, agriculture and industry throughout the world require sustainable water supplies. Over 1 billion people do not have access to adequate and safe water supplies and less than 10% of the world's population receives a treated supply. Climate change is affecting available water resources whilst population growth bringing with it intensive agriculture, increasing urbanisation and industrialisation mean that not only is demand growing but, globally, pollution of available sources is increasing. Contingent effects such as salination and desertification are also on the increase.

Evidence of water scarcity and ecosystem disruption is pervasive and spreading in both the developed and developing worlds, yet many governments continue to promote inefficient and ecologically disruptive practices including heavy subsidies for irrigation, unfettered pumping of groundwater and ill-considered dams and diversions. Governments worldwide must take a stronger line in water management, using regulation to conserve supplies and rehabilitate damaged ecosystems.

IChemE will work with other stakeholders globally to impress upon governments and international bodies the importance of developing and implementing sustainable regional water management strategies, especially by realistic pricing according to its value.

Action Plan

Vision: Governments globally recognise the need and take action to implement sustainable water management strategies.

	2 years	5 years	10 years
GOALS	The factors influencing the availability and cost of water are better understood enabling appropriate strategic choices	Water is viewed as integral to the total eco/socio/techno/economic system enabling shared values and strategy amongst stakeholders to provide a strong basis for high level influence	The international trends in provision and pricing are identified and published, influencing future policy and actions
ACTIONS	Contribute to debate amongst all stakeholders leading to the identification of options for long term harvesting of water Identify and publicise international case studies showing the realistic cost of water in different regions	Develop joint action plans with other stakeholders	Monitor international trends in water provision and pricing and report progress

3.5.2 Sustainability and New Technologies

There is a need to develop existing, and implement new, water and wastewater treatment processes which enable low cost, low energy intensive and low environmental impact purification to standards appropriate to end use from both traditional and poorer source waters. Chemical engineers will play a major role in these developments.

Membranes are steadily increasing their applications in water treatment and research is showing innovative ways of using them. However they still have to compete with the very robust methods developed over the last century. One driving force will be more pressure on land and hence the requirement for smaller footprints. Techniques such as reverse osmosis have an important role in widening the choice of water source and should continue to be developed by research. Looking further into the future it may be possible to develop an enzyme or catalytic reaction that destroys organic material and organisms in water leaving harmless or no residue, at an acceptable cost.

Equally on the demand side there is a need for industry to develop products and processes that reduce water use – such as self-cleaning fabrics for clothes, cars, windows, etc – so that water is not needed to clean them.

IChemE is committed to sustainable development and the search for technologies which contribute to sustainable water supplies. The Institution will continue to press governments and companies to fund research programmes which support this objective.

Action Plan

Vision: The sector accelerates its implementation of innovative and sustainable technologies.

	2 years	5 years	10 years
GOALS	Sustainability seen as central to the development of new water purification and treatment and sewage sludge disposal technologies	Governments, organisations and influential individuals knowledgeable in sustainable water management and provide support through appropriate R&D programmes	The extent of global progress is monitored and published, influencing future policy and actions
ACTIONS	Promote a sustainability hierarchy of water purification and treatment and sewage sludge use and disposal technologies	Run high-level conferences on challenges and emerging technologies for sustainable water management with international perspective	Monitor completed and on-going research programmes and report progress

3.5.3 Industrial Usage (including agriculture)

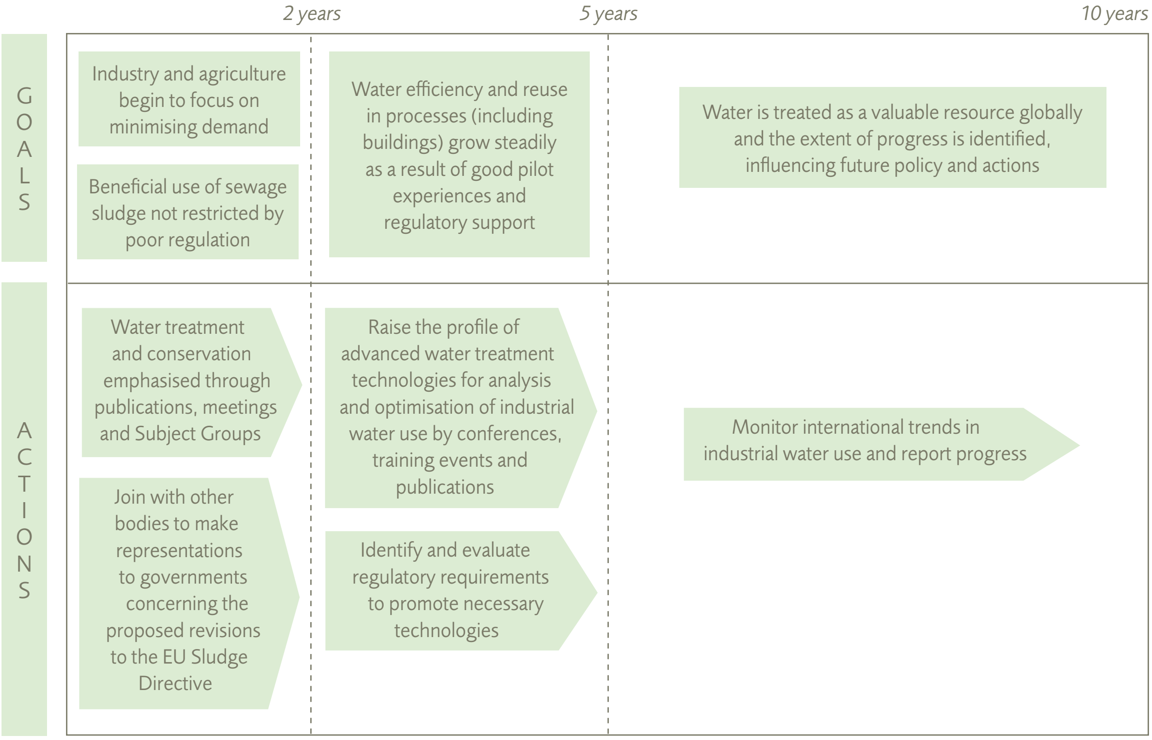
The abstraction of water for industry and agriculture and discharge of industrial wastewater also place the aqueous environment at risk. Sound industrial water management is vital to long term public health and environmental protection. While this is well established in the industrialised nations, it must now be applied in the developing countries as manufacturing industries including food and beverages, pharmaceuticals, petrochemicals, semiconductors and metal fabrication and finishing are relocated, creating demand for steam raising, cooling and process water and stressing scarce water resources.

Industry and agriculture worldwide must implement water management techniques and technologies to reduce water consumption by reuse and recycling and to recover raw materials and energy from waste streams. Chemical engineers must play a role in providing a benchmark for best practice in industrial water consumption and providing advice to industry.

IChemE supports the introduction of appropriate regulations which encourage/support more sustainable water supply and use and wastewater disposal, for example by water re-use in industrial and agricultural processes (including buildings and domestic houses), and beneficial use of sewage sludge rather than landfill.

Action Plan

Vision: Sustainable water management techniques accepted and utilised by industries globally.



3.5.4 Important Second Order Positions

The remaining positions complete the Technical Policy Commission's thinking on Water. Several aspects of these positions are picked up in other action plans and these are cross-referenced here.

Water Supply

In the developed world, consumers have high, and increasing, aesthetic requirements, while a large and increasing proportion of the high quality water supplied is used for purposes other than drinking. We wash our cars and flush our toilets with potable drinking water processed and distributed at significant cost and at the same time buy bottled water to drink which has been extracted and transported long distances, again at great cost. Personal choices, from diet to gardening, can help to conserve water sources and the public must be better informed about the relative value of tap water and bottled water and the costs, benefits and management of the risks in the appropriate use of non-potable water.

IChemE supports universal water metering (prioritised according to the foreseeable deficit in each water supply area) coupled with appropriate charges and tariffs and underpinned by a programme of public education to encourage more sustainable levels of water usage.

Discharge of domestic wastewater has contributed significantly to pollution of surface waters, particularly in respect of nitrates and phosphates, and the more recently recognised endocrine disruptors. Wastewater must be adequately treated to protect the water environment and downstream abstractions.

It is essential to ensure that water of any quality is transformed by appropriate and affordable treatment to meet the required standards and customer requirements and that water abstraction, treatment, use and discharge make minimum impact on the natural environment. Comparisons of the costs and benefits of providing water from different sources should be widely based, take into account the life cycle of the investment, environmental impacts, social costs (for example associated with loss of amenity from surface water reservoirs, traffic disruption associated with current leak repair technology) and opportunities for beneficial innovation.

IChemE encourages the development of treatment technologies which increase water supply options while remaining affordable, and supports the application of life cycle analysis to differentiate between alternative options.

See Sustainability Action Plan 3.1.2 Reduce, Reuse, Recycle.

Education

The education of engineers in all industrial sectors to be aware of the impact of their activities on water resources and the natural environment is a necessity. Chemical engineers, with their systems approach, have a sound basis on which to build additional specific skills and knowledge in water management techniques.

IChemE will encourage sustainable water management education within degree courses and the continuing professional development of its members in this area with due regard to the differences between regions of the world.

Continuing education is a feature of all the action plans in this Section.

3.6 Bioprocess and Biosystems Engineering

3.6.1 Provision of Well Trained Bioprocessing Professionals

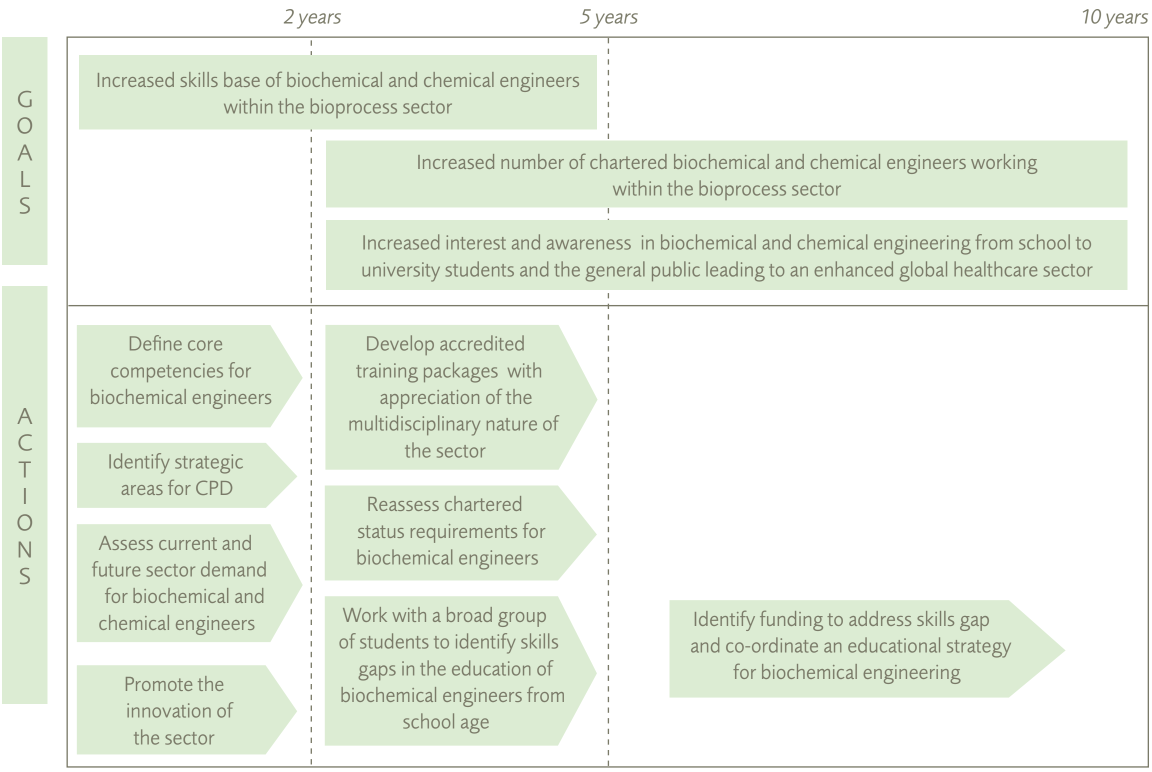
The range of scientific and engineering disciplines associated with bioprocessing requires assembly of a wider range of skills and knowledge than solely mainstream chemical engineering and fundamental life science. Professionals will need increasingly specialised technical skills but they will also require a broader range of expertise to take biologically derived or biologically active products from discovery through to market.

It is widely acknowledged that the biotechnology sector does not have enough adequately experienced bioprocess-related personnel in the global workforce. Additionally some misalignment exists within IChemE when mapping core bioprocess skills onto Chartered Engineer status. Greater flexibility in evaluating experience and qualifications should be demonstrated by the Institution.

IChemE seeks to expand the recruitment of school leavers to biochemical and chemical engineering courses, the enrolment of suitably qualified professionals into membership and the provision of bioprocessing related courses for continuous professional development.

Action Plan

Vision: The bioprocess sector is recognised as an attractive and challenging employment area by school leavers increasingly attracted to chemical and biochemical engineering courses.



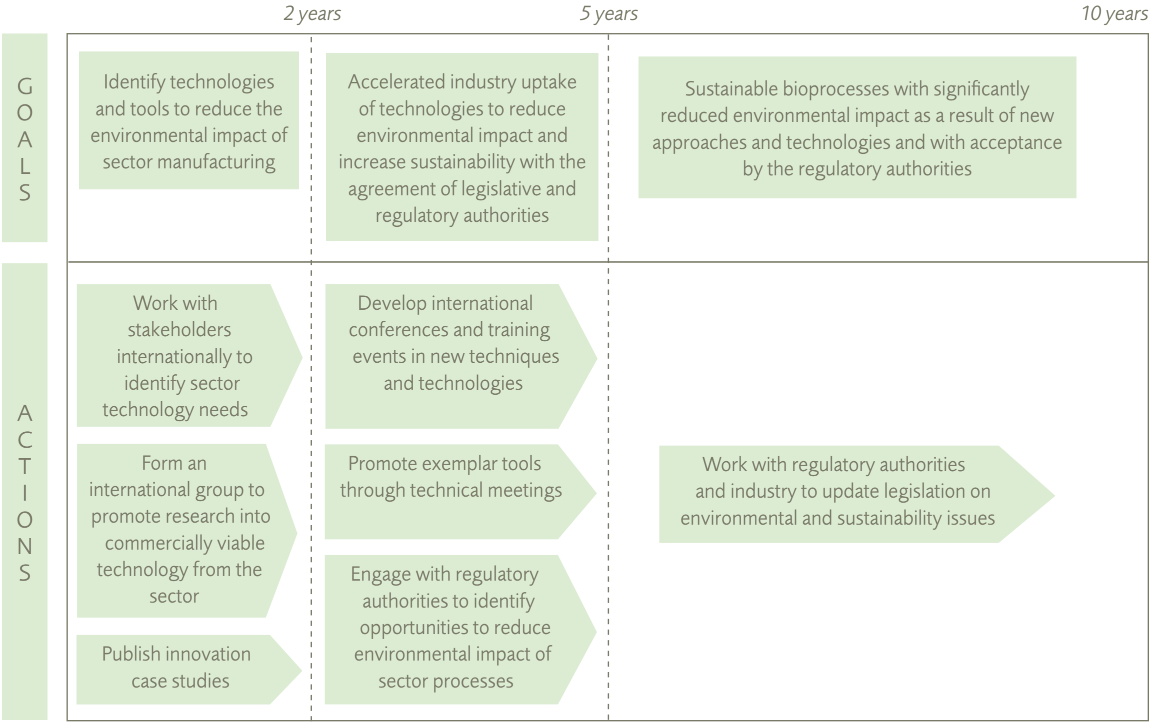
3.6.2 Low Environmental Impact and Sustainable Bioprocesses

The implementation of green processing routes and subsequent minimisation of solvent use has great potential to reduce the environmental footprint and improve the safety of biologically-active and biologically-derived products manufacture. Focus should also be given to reducing water usage associated with bioprocessing, utilisation of by-products and effective biological treatment of pollution. The recent emergence of biofuels and biomass-derived products offers significant opportunity to engineer successful alternative renewable solutions.

IChemE supports reducing the environmental impact of industrial activity and will through the Subject Groups encourage members to promote new pollution abatement strategies and the design of sustainable processes. IChemE will work with companies to highlight this approach and environmental success stories to the general public.

Action Plan

Vision: The bioprocess sector accelerates its implementation of innovative and sustainable technologies.



3.6.3 Important Second Order Positions

The remaining positions complete the Technical Policy Commission's thinking on Bioprocess and Biosystems Engineering. Several aspects of these positions are picked up in other action plans and these are cross-referenced here.

Quantitative Understanding of Biological Systems and Processes

Biological systems and processes cover a diverse range of activities associated with biologically derived and biologically active products and the relevant services. The processes are used in various industries including industrial biotechnology and agricultural biotechnology through tissue engineering; drug discovery and delivery technologies; diagnostics; genomics, etc., to therapeutics as well as chemically derived therapeutics. The pace of change in discovery science will demand additions and changes to the list of clearly recognisable products. Products and processes are becoming increasingly more complex and interlinked and engineers, alongside core science and medical disciplines, have a central role in their discovery, development and exploitation. New approaches will require the combined efforts of these disciplines.

A key differentiator of the biopharmaceutical industry from traditional pharmaceuticals is the extent of the hygienic and aseptic design requirements of equipment and facilities for the manufacture of the drug substances. Today, bioprocesses include techniques and operations utilising molecular biology, microbial fermentation, mammalian cell culture, transgenics, purification, analysis, and cover all aspects of the production process: from lab-scale development, through to large-scale manufacturing of active ingredients, their formulation and delivery. With the arrival of new techniques and technologies, chemical engineers need to understand the opportunities provided by new generation analytics and computational power in conjunction with the significant advances in fundamental life sciences. Challenges may therefore exist to exploit data generated from postgenomics technologies, as one example, to improve bioprocesses, develop predictive modelling of biological systems and understand emerging cell biology to develop new generation processes and products.

IChemE promotes the interaction of biochemical and chemical engineers with those from the life, physical and medical sciences by enhancing relationships with the relevant learned societies and by stimulating joint programmes of research and education.

Interaction with other relevant disciplines is a feature of all the action plans in this Section.

More Targeted, Cost Effective Medicines and Therapies

New, more targeted and cost effective medicines and therapies will play a major role in the future successful treatment of illnesses and it is important that these products are manufactured efficiently and safely. The increasing molecular complexity of drugs is increasing development times and furthermore the rate of product attrition, regulatory scrutiny, and recent well-reported problems with some drugs, will impact speed to market. A number of ethical and moral issues have been raised which will require resolution as these products and processes are developed.

New bioprocess technology and innovative manufacturing applications are prerequisites in the development of future generations of biologically-derived and biologically-active products. Advances are needed to more selectively biosynthesise chemical pharmaceuticals, make chemicals and pharmaceutical intermediates from renewable feedstocks, develop process routes for cell and tissue based therapies, manufacture novel bionanotechnology products, and produce animal and plant-based biopharmaceuticals.

IChemE supports frontier research, development and industrialisation leading to manufacture of enhanced medicines and therapies and will support members' application of the code of professional conduct when ethical and moral issues arise during their activities. IChemE will engage in dialogue with appropriate external stakeholders on such matters.

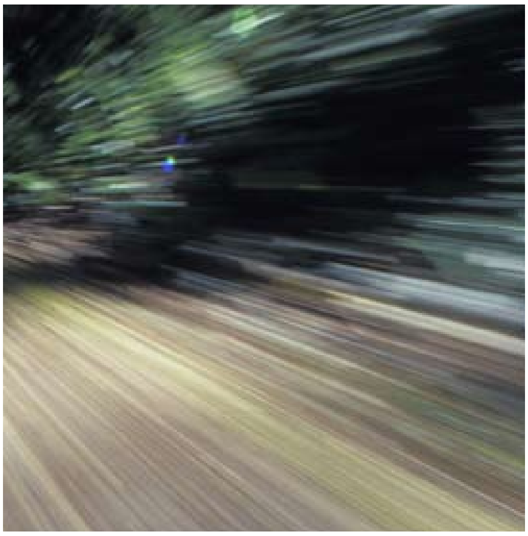
More Rapid and Efficient Process Development and Product Manufacture

Regulation and compliance issues mean that product costs are high while there is downward pressure on price due to both government pressure to minimise healthcare costs and the impact of generics. There is also pressure arising from the perception that more should be done to provide developing countries with access to affordable drugs and efficient supply chains.

Clearly profitable and thus sustainable companies are vital, which makes faster and more efficient process development and product manufacture imperatives.

There is scope to increase the speed and efficiency of process development and product manufacture by the involvement of engineers earlier in the R&D cycle, the deployment of high-throughput technologies to underpin process development, the use of scale-down processing and disposable manufacture, the application of Process Analytical Technology in monitoring and control, increased process efficiency via higher product concentrations and improved purification techniques, the integration of conventional manufacture with biocatalysis, and the application of data mining and bioinformatics 'systems' approaches.

Also of concern is the constraint imposed by regulatory authorities to the development and manufacture of biologically-derived products where there is still hesitancy in accepting follow-on biologics or biosimilar products and processes, thus ensuring continued lengthy timescales for product development, high cost of manufacture and difficulty in making product or process improvements.



4. Implementation

This section details in tabular form how the Roadmap action plans will be progressed by identifying the prime responsibilities for implementation and any external partners necessary to complete the tasks.

The partners lists will develop further, particularly as far as international relationships (e.g. Engineers Australia, Malaysian groups) are concerned, as actions proceed. These tables use the full forms of the action plans developed by the Technical Policy Commissions.

4.1 Sustainability & Sustainable Chemical Technology

4.1.1 Sustainable Energy

IChemE supports the more rapid pursuit of a global energy policy based on using non-fossil primary energy sources (e.g. nuclear, including fusion in the longer term, and renewables, including solar, geothermal) coupled with the development of hydrogen, or other options, as energy carriers (or vectors).

Outcome	Target	Action	Action By	Partners
The ability to influence national governments in a co-ordinated way and raise key issues at local, national and international levels.	Within 2 years	Form an international forum 'Engineers for Sustainable Energy' based on a network of national groups. Canvas support through EFCE and WCCE and the equivalent bodies of the other professional engineering and scientific institutions. Establish links with other bodies (NGOs, national environmental groups).	Centre + Sustainability SG Energy Conversion Technology SG + Branches worldwide	International chem eng groups, e.g. WCCE, EFCE National chem eng groups, e.g. Engineers Australia, AIChE Other national engineering institutes, e.g. RAEng, IMechE, ICE, etc
A broad understanding of the hierarchy of potential energy technologies, their development status, applicability and cost.	Within 2 years	Compile a literature review of available credible source material to include both favourable and unfavourable views of each technology (including well founded LCAs where published). Make the information widely accessible in formats appropriate to educate and influence members, decision makers and the general public.	Sustainability SG Energy Conversion Technology SG Centre	Resource provider (e.g. university post-doc) – to be determined -
Positive and co-operative action by governments internationally to implement sustainable energy policies, including fiscal and regulatory measures, targeted at limiting atmospheric CO_2 concentrations to a peak of 550 ppmv (or as revised in the light of new information).	Within 5 years	Monitor progress through the international forum against agreed milestones and publish the outcomes enabling national networks to influence progress.	Sustainability SG Energy Conversion Technology SG + Branches worldwide	-

Significant national and international research and development programmes in support of these global policies.	Within 5 years	Monitor progress through the international forum against agreed milestones and publish the outcomes enabling national networks to influence progress.	Sustainability SG Energy Conversion Technology SG + Branches worldwide	-
Implementation plans for sustainable energy projects which will achieve target peak CO_2 concentrations.	Within 10 years	Monitor progress through the international forum against agreed milestones and publish the outcomes enabling national networks to influence progress.	Sustainability SG Energy Conversion Technology SG + Branches worldwide	-

4.1.2 Reduce, Reuse, Recycle

IChemE supports the continuing introduction of appropriate legislation, taxes and other fiscal measures to encourage a change of behaviour, coupled with targeted information and education to drive the 'reduce, reuse, recycle' mentality deeper into industry and the consumers of its products.

Outcome	Target	Action	Action By	Partners
Standardised life cycle tools for industry use.	Within 2 years	Develop concept for potential project ensuring international input.	Sustainability SG	-
		Identify participants for a joint project with external funding.	Centre + Sustainability SG	To be determined
		Identify barriers to acceptance of current tools.	Sustainability SG	-
Tools accepted and in use by a broad swathe of industry.	Within 5 years	Develop new tools. Market tools.	Working group Centre	To be determined
		Develop education and training products to support application.	Sustainability SG	
Assist industry to develop clear performance targets.	Within 5 years	Develop the form and the use of the Sustainability Metrics as a benchmarking and education tool.	Working Group	Industry groups
Consumers have the ability to assess the environmental impact of the products they buy.	Within 5 years	Join in the public dialogue providing an independent technical view where appropriate.	Centre + Sustainability SG	-
Industry has clear performance targets across a range of parameters aligned with national and international agreements.	Within 10 years	Take an active role in establishing targets through agreements with national trade associations and/or contributing to government consultations and initiatives.	Centre + Sustainability SG	-
Most process industry companies are publicly reporting progress against targets annually.	Within 10 years	Monitor company reports against targets and publish the outcomes enabling national networks to influence progress.	Centre + Sustainability SG + Branches worldwide	

4.1.3 Sustainable Technology

IChemE believes that the necessary change in business strategy to speed the introduction of innovative and sustainable technologies should be led from the boardroom, facilitated and encouraged by chemical engineers at all levels in industry, commerce and academia.

Outcome	Target	Action	Action By	Partners
Members have access to current information on sustainable design methods and technologies.	Within 2 years	Promote the application of the 12 Principles of Green Engineering Design (ref. Anastas, P; Zimmerman, J. *Environ. Sci. Technol.* 2003, 37, 94A-101A).	Centre + Sustainability SG	-
		Develop training courses to include sustainable design methods and technology.	Centre	-
		PSEP realigned and retitled to focus on sustainability and sustainable technology.	Centre	
		Negotiate automatic individual membership of Chemistry Innovation Knowledge Transfer Network (CIKTN) and equivalent national and/or international bodies for members.	Centre	CIKTN + equiv. international bodies
		Provide links to CIKTN website and the websites of other national/international bodies from IChemE website.	Centre	CIKTN + equiv. international bodies
Most process industry companies, supported by government policies, have business strategies which necessitate the development and introduction of sustainable technology.	Within 5 years	Retain influence, through management board representation, in the CIKTN and equivalent national/international bodies to challenge, promote and support industries implementation of sustainable technology.	Centre + Sustainability SG + Branches worldwide	CIKTN + equiv. international bodies
		Contribute to government consultations in support of policies which promote innovation and the application of sustainable technology.	Centre + Sustainability SG + Branches worldwide	-
All undergraduate chemical engineering courses accredited by IChemE (including those in the 'new areas' such as China and Malaysia) are firmly grounded in sustainability and sustainable technology.	Within 5 years	Accreditation aligned to ensure achievement of this outcome.	Centre	
All practising chemical engineers are well versed in sustainable design methods and technology.	Within 10 years	Measure uptake of publications and training courses against established targets.	Centre	
		Conduct regular member surveys to monitor progress.	Centre + Sustainability SG	

Most process industry companies are reporting progress towards sustainability annually.	Within 10 years	Monitor company reports against targets and publish the outcomes enabling national networks to influence progress.	Sustainability SG + Branches worldwide	

4.1.4 Regional Variations

It is in the area of regional variations that the key issue of inter and intra generational equity, fundamental to sustainability, becomes clearly evident. There is clear agreement that sustainable development is a global issue but that whilst the goals should be common the focus and pace of application might vary between developed and developing economies. It could be that the new economies may leapfrog developed ones whose progress is held back by the legacy of their existing manufacturing infrastructure. There is a strong sense that developed nations, whilst not beggaring their own economies, must support the changes required in developing ones. Comments such as, for example, 'developing countries will only accept the strategy if the first world economies support them sufficiently with money and resources'; and 'developing countries probably offer the most significant improvement impact, but will need support to maintain their growth whilst implementing new technologies. Cost will be a major factor as will technical competence'. The position statements and action plans should be interpreted in this light.

4.2 Health, Safety, Environment and Public Perception of Risk

4.2.1 Risk – Its Management and Public Understanding

IChemE will reach out to the public, other professional institutions, governments and regulators, media, NGOs, employers and industry representatives to build a common understanding of risk issues.

Chemical engineers and IChemE will seek to exert greater influence on the process sector, regulators and academia to develop and utilise new ways for cost effective and sustainable risk reduction. This may be carried out in conjunction with other relevant professional bodies.

Outcome	Target	Action	Action By	Partners
The outcome of this collaboration project will be a **Model Code for the Management of Risk Issues**, which will draw on best practice in the management of risks at all levels (government, industry, local authorities, community groups, media and NGOs). The aim is to achieve greater alignment in the understanding of risk issues between all stakeholders. This outcome will further develop existing material, such as that published by the Royal Academy of Engineering and other bodies that publish in this area internationally. There is undoubtedly a priority to work on personal relationships and build up trust between the engineering professions the public and those who represent them.	Within 3 years	Establish IChemE in the leading role in bringing together regulators and other professional bodies to create a common understanding on risk issues related to major industry hazards.	Centre Safety & Loss Prevention SG Environment SG	National chem eng groups Other national engineering institutes
		Agree project scope and resources, ensuring international input, to deliver the Model Code.	As above + Branches worldwide	As above
		Resolve the challenges that have to be overcome in order to ensure that a common understanding on risk issues can be achieved at all levels. This will include how perceptions of risk differ across different communities worldwide.	Working Group	As above
		Produce a first draft.	Working Group	As above

However, care will need to be taken to ensure this is not misinterpreted or manipulated by any particular group of stakeholders. The Code will need to be supported by a concrete example to demonstrate the principles contained within it and the benefits that can be obtained through its use.				
Education and training tools are seen as an urgent outcome of this project but can only be accomplished after the first stage has been completed.	Within 5 years	Publish the Model Code and market internationally. Deliver education and training tools to provide a basis for school and undergraduate education on risk.	Centre Centre	As above As above
	Within 7 years	Establish a reputation through promotion and education that delivers the Code as a standard consultation tool at all levels of stakeholder activity. Revise in the light of experience and republish.	Centre + Safety & Loss Prevention SG Environment SG + Branches worldwide Centre + Working Group	As above As above
The timing of this stage will depend on the speed of development of leading economies worldwide.	Within 10 years	Revise as industry repositions itself globally.	Centre + Working Group	As above

Note: the term **Risk Issues** includes: methodologies to determine safety, health and environmental risk, assessing tolerability, acting on reasonably practicable risk reduction measures (including both engineering and human factors related solutions), and providing risk information to the regulators, those who work at the facilities, those who live nearby, customers who purchase products and those who handle waste materials. Both risk assessment and cost benefit analysis will be addressed. A particular challenge is how we address the risk assessment in the development of new areas of technology.

4.2.2 Performance – Health, Safety and Environmental Culture

IChemE will engage with corporate leaders, regulators, and other professional bodies to create cultures that deliver real improvements in H, S and E performance, and have benefits to all.

Outcome	Target	Action	Action By	Partners
A coherent **H, S, and E Cultural Tools and Guidelines Package**, which will include the Self Assessment Toolkit and performance criteria. IChemE has already rolled out a first draft *Self Assessment Toolkit For Safety, Health & Environmental Assurance* that addresses the roles and responsibilities of those working within corporate bodies (governments, regulators and industry). There is an intention to share this after an initial period of internal use by IChemE members. Other cultural issues that impact heavily on performance, including radical approaches such as the 'just culture' currently in discussion within the professional bodies, also need to be addressed by IChemE in order to support its members. This project must also recognise codes and standards that are already well established, such as Responsible Care. The outcome must have international application, necessitating consultation with bodies such as AIChE, and similar engineering professional representative bodies worldwide.	Within 3 years	Take the leading role in bringing together regulators and other professional bodies, including non-engineering bodies such as IOSH and the professional management institutions, to develop a common understanding of the fundamentals behind SHE culture that covers all corporate sectors. Develop performance criteria based on what is already available and considered to be best practice, while recognising the needs in different parts of the worldwide community. Draft a training and education package based on established IChemE training resources and packages. Note: the Baker Panel report into the 2005 BP Texas City explosion was published after the end of the second round of consultation. The findings and recommendations are generally recognised to have international applicability, which may well influence the final shape of the training and education package.	Centre + Safety & Loss Prevention SG Environment SG SGs + Branches worldwide Working Group	As for Model Code + Non-engineering bodies, worldwide, e.g. IOSH, IOM As above As above
	Within 5 years	Publish and market the package.	Centre	As above
	Within 5–7 years	Gain widespread application within the process and other industries. Develop and market an auditing tool.	Centre + SGs + Branches worldwide Centre + Working Group	As above
	Within 10 years	Revise and republish as industry and societies priorities change, leaving the main premise undiluted.	Working Group + Centre	As above

4.2.3 Open Dialogue – Learning from Past Successes and Failures

IChemE will work to influence industry groups and regulators to take a more proactive approach to passing on lessons learnt. We will strive to break down the barriers that blame and litigation create to prevent lessons from accidents being rapidly disseminated to those who would benefit through the adoption of 'just cultures' that focus on learning, not on establishing blame.

Outcome	Target	Action	Action By	Partners
A **Universal Lessons Learned Tool** that: - Disseminates lessons stemming from successes as well as failures - Focuses on retaining the lessons of the past (many companies already learn lessons but then forget and repeat them) - Is designed to be shared with all other levels of stakeholder - Is based upon a standard investigation model to identify root causes of success/failure in a consistent manner - Is available to all at a reasonable cost	Within 3 years	IChemE leads a feasibility study with other engineering professional bodies and other stakeholders to meet the legal and reputation challenges of those who do not openly disseminate lessons that others can benefit from.	Centre Safety & Loss Prevention SG Branches worldwide	As for Model Code
		Develop an investigation tool that compliments the lessons learned tool taking account of what is already published and considered best practice. This will promote the 'just culture' approach adopted by the aeronautical industry.	Working Group	As for Model Code
		Agree the form of a lessons learned database that can be used by the regulator, companies and other professional bodies as an industry standard.	Working Group	As for Model Code
		Develop a demonstration programme, including an education and training element in its use.	Working Group + Centre	As for Model Code
		Reintroduce lessons learned discussions at IChemE Branch level.	Safety & Loss Prevention SG + Branches	-
	Within 5 years	Develop training tools for effective incident investigation – root cause analysis, and accident database management.	Working Group	As for Model Code
		Market database internationally to all stakeholders.	Centre	
		Publish output widely.	Centre	
	Within 10 years	Maintain and revise in the light of operating experience and any changing needs of industry and the public.	Working Group	As for Model Code

4.3 Energy

4.3.1 Nuclear Power

IChemE believes that nuclear power will continue to fulfil a significant part of global energy demand in the short and medium term and calls on decision makers and opinion formers to conduct a rational debate that provides a positive climate for further R&D in waste management, spent fuel processing and advanced reactor design.

Outcome	Target	Action	Action By	Partners
Plans in place globally for increased nuclear generation capacity. Particularly urgent need for a decision to commence replacement of UK's generating capacity that is being decommissioned due to age.	Within 2 years	Support governments' plans to add to or replace existing nuclear capacity.	Centre + Energy Conversion Technology SG	National chem eng groups Other national engineering institutes
		Support continued process R&D on waste handling systems.	Energy Conversion Technology SG	As above
Establish a renewed university interest in nuclear based process engineering.		Review educational requirements at universities to provide the engineering skills needed to design, build and operate the capacity required.	Energy Conversion Technology SG + Centre	As above
		Disseminate factually accurate information about the need for nuclear power generation if carbon abatement targets are to be met.	Energy Conversion Technology SG + Centre	As above
		Evaluate the R&D support that might aid the progress of advanced nuclear systems.	Energy Conversion Technology SG	As above
Establish whether economic forces would drive nuclear towards becoming a larger proportion of generating capacity than in the past.	Within 5 years	Offer to work with governments (e.g. DTI and DEFRA in the UK) to evaluate carbon abatement options for power generating and rank nuclear alongside renewable generation and carbon capture and storage as abatement techniques.	Energy Conversion Technology SG	-
		Monitor progress on national and international R&D programmes through the International forum proposed under the Sustainability Action Plan.	Sustainability SG Energy Conversion Technology SG + Branches worldwide	-
		Consider postgraduate conversion courses to provide the nuclear science needed for operation and safe waste handling.	Energy Conversion Technology SG + Centre	
Implementation of nuclear programmes under way globally.	Within 10 years	Continue to monitor progress on national and international R&D programmes through the international forum against agreed milestones and publish outcomes to influence progress.	Sustainability SG Energy Conversion Technology SG + Branches worldwide	-

4.3.2 Continuing Fossil Fuel Use

IChemE supports the view, expressed in the Gleneagles Communiqué arising from the G8 summit in July 2005, that because the world is locked into fossil fuels usage for some time to come, the technological means of reducing CO_2 emission from their use must be implemented globally as an environmental and political priority whilst more sustainable options are urgently pursued (3.1.1).

IChemE believes that the widespread application of clean generation technology coupled with carbon capture and storage is essential to achieve major reductions in emissions. In the short and medium term fossil fuel use must be minimised by the application of currently available technologies to maximise the efficiency of electricity generation and use. Incentives should be introduced by governments in developed nations to manage demand and prompt a step change in the deployment of clean generation technology with carbon capture and sequestration.

Outcome	Target	Action	Action By	Partners
Acceptance gained of fossil fuel use, especially coal, with capture and geological storage of CO_2. A wider understanding of the technological options of CO_2 capture pre-and post-combustion. Development of improved sorbent systems and the introduction of bulk gas separation techniques to CO_2 capture at the power plant scale.	Within 2 years	Support studies associated with the safe handling of bulk CO_2 under dense phase conditions in process vessels and pipelines.	Energy Conversion Technology SG	Thro' the international forum
		Work with geologists to promote a public understanding and support for geological storage.	Energy Conversion Technology SG	Thro' the international forum
		Encourage governments to move quickly to establish demonstrator projects	Centre + Energy Conversion Technology SG	Thro' the international forum
		Create mechanisms for communicating the importance of the role of capture and storage to enable sustainable fossil fuel use to develop.	Energy Conversion Technology SG Sustainability SG	Thro' the international forum
		Explore opportunities for EU funding (Cordis) for dissemination.	Energy Conversion Technology SG	-
		Support and encourage R&D on improved capture techniques, gas separation, etc.	Energy Conversion Technology SG	Thro' the international forum
		Highlight the urgent need for new graduates in all engineering disciplines to support the task of reducing carbon from the power sector. Review educational requirements at universities to provide the engineering skills needed. This needs to cover power generation options, applied thermodynamics and a wider range of processes.	Centre Energy Conversion Technology SG	National chem eng groups Other national engineering institutes
Increased co-operation between universities and the industrial gases companies to reduce the cost of capture technology.	Within 5 years	Establish links with the Carbon Capture and Storage Association, the IEA and equivalent international bodies offering technical liaison on key issues.	Centre + Energy Conversion Technology SG	-

		Ensure university courses offer a fuel cell technology component to encourage and support application. Likewise with R&D support.	Centre + Energy Conversion Technology SG	-
R&D programme established of other chemical processes that can use bulk CO_2 and 'fix' it.	Within 10 years	Forge a link between IChemE, industry and governments for independent evaluation of technological development.	Centre + Energy Conversion Technology SG	Thro' the international forum
		Encourage R&D reducing the cost of storing CO_2 in solid compound form.	Energy Conversion Technology SG	Thro' the international forum

IChemE recognises that although the challenge and the solution are global, the UK is well placed to demonstrate what is possible given the need for 35GW of replacement power generation capacity by 2020. The potential exists for international joint ventures in pursuit of sustainable solutions suitable for global application and the Institution will continue to press the UK government to take a bold long term view.

Outcome	Target	Action	Action By	Partners
Reinforce the urgent need for a decision on replacement generation capacity with a broad mix to ensure energy security.	Within 2 years	Alert government to the dangers associated with delaying a decision on replacement coal and nuclear generation capacity.	Centre + Energy Conversion Technology SG	Other national engineering institutes
Primary energy mix refined in the light of CO_2 abatement costs.	Within 5 years	The balance between the primary energy sources in a carbon-constrained world will be related to carbon abatement costs. Stay abreast of published data on cost of all technology options and inform government accordingly.	Energy Conversion Technology SG	-
A cluster of UK based clean power generation projects with capture established.	Within 10 years	Support government and industry led initiatives to achieve the target of 35GW of new capacity. This is over ⅓rd of the UK's installed capacity and is a massive task and the engineering resources needed should not be underestimated.	Centre + Energy Conversion Technology SG	Other national engineering institutes

4.3.3 Renewable Energy

IChemE supports increased R&D on the development and deployment of renewable technologies and power storage systems.

Outcome	Target	Action	Action By	Partners
A broad understanding of the hierarchy of alternative technologies, their development status and cost.	Within 2 years	Combined action with Sustainability Action Plan.	Sustainability SG + Energy Conversion Technology SG	Resource provider (e.g. university post-doc) to be determined
Increased R&D effort into bulk electricity storage that is vital to accommodate the intermittency of several renewable systems.		Support this R&D programme through the international forum proposed under the Sustainability Action Plan.	Sustainability SG Energy Conversion Technology SG	International forum
Increased R&D into the production of hydrogen by the dissociation of water at high temperature associated with nuclear generation.	Within 5 years	Support this R&D programme through the same international forum as above.	Sustainability SG Energy Conversion Technology SG	International forum
A substantial increase globally in the deployment of renewable generation technologies.	Within 10 years	Monitor progress through the international forum.	Sustainability SG + Energy Conversion Technology SG	International forum

4.3.4 Biofuels

In the longer term, a combination of biomass gasification and Fischer Tropsch synthesis might offer an attractive route to the production of renewable transport fuels and the Institution argues that this option should also be pursued.

Outcome	Target	Action	Action By	Partners
A better understanding of the crops that are available to produce biofuels and the carbon profile of their growth and processing which are important to the future direction of production, while engine requirements determine the most appropriate blend of components.	Within 2 years	Set out the spectrum of options with the associated technology and carbon footprint to stimulate a technical debate on the available crop materials for biofuels. This helps to identify the advantages and disadvantages of alternative fuels.	Sustainability SG Energy Conversion Technology SG	To be determined
		Explain the limitations of ethanol, some biodiesel product, FAME and DME along with the need for redesign of engines to accommodate some variants.	Energy Conversion Technology SG	-
		Understand the benefits to be derived from second-generation biofuels largely based on the Fischer Tropsch process that enables the enhancement of fossil fuel derived product.	Sustainability SG Energy Conversion Technology SG	-

		Examine the process and economic implications of co-production of fuels and power with possible module opportunities.	Energy Conversion Technology SG	-
R&D to develop better catalyst technologies that improve/control product yield from synthesis processes. A science based starting point for evaluation and optimisation of source crops, processing and the CO_2 reduction impact.	Within 5 years	Provide independent assessment of synthesis processes that will convert high yield biomass into high quality transport fuels. Assist in identifying the evaluation of crops, their fertiliser and water requirements and impact on soil to minimise environmental impact.	Sustainability SG Energy Conversion Technology SG Sustainability SG Energy Conversion Technology SG	- - - -
A modelling system that will optimise the type of energy crop and process in temperate and tropical conditions for effective CO_2 control.	Within 10 years	Ensure that real reduction in system CO_2 emissions results from the steps being taken.	Sustainability SG Energy Conversion Technology SG	-

4.4 Food and Drink

4.4.1 Waste Management

IChemE supports the development of technologies to maximise the use of viable waste streams from the food supply chain.

Outcome	Target	Action	Action By	Partners
Increased knowledge and education of both sides of the debate.	Within 2 years	Engage with current government initiatives on energy conservation and reuse/reduction seeking international input and sharing of best practice. Improve waste management education related to chemical engineering courses offered around the world.	Food & Drink SG Sustainability SG Energy Conversion Technology SG +Branches worldwide Centre + Food & Drink SG	Food Processing KTN + equiv. international bodies
Demonstrable benefits of an engineering led approach.	Within 5 years	Develop research strategies to explore optimised use/ reuse of waste streams. Contribute to waste audits and strategy development in the food and drink sector related to waste management.	Food & Drink SG Sustainability SG Food & Drink SG	Food Processing KTN + equiv. international bodies
	Within 10 years	Continue to monitor progress on research programmes against targets and publish outcomes to influence progress.	Food & Drink SG	-

4.4.2 Basic Production

Chemical engineers as experts in examining systems and energy flows must play a prominent role in the development of precision agriculture technology and rendering farming methods sustainable.

Outcome	Target	Action	Action By	Partners
Higher profile for the contribution engineering can make in this area. New engineering led initiatives.	Within 2 years	Engage with current government initiatives on energy conservation and reuse/reduction seeking international input and sharing of best practice.	Food & Drink SG Sustainability SG Energy Conversion Technology SG + Branches worldwide	Food Processing KTN + equiv. international bodies
Evaluation of alternative technologies. Optimisation of current practices.	Within 5 years	Define key strategies for more sustainable energy generation and delivery to the food and drink sector.	Food & Drink SG Sustainability SG	As above
Long term strategy for the implementation of effective energy management in food and drink manufacturing.	Within 10 years	Seek multidisciplinary collaborations to develop best practice and to improve the sustainability of the food industry with respect to energy.	Food & Drink SG Sustainability SG	As above

IChemE will continue to press government to take a science based approach in the development of policies for agriculture.

Outcome	Target	Action	Action By	Partners
Competition on a level playing field. Acceptance of the role engineering can play in this area.	Within 2 years	Promotion of common standards within the global industry. Establish linkages with key agricultural bodies to promote an engineering input to the sector.	Food & Drink SG	Food Processing KTN + equiv. international bodies
Clear benefit led demonstration of the engineering contribution.	Within 5 years	Define some pilot projects to demonstrate the impact of chemical engineers in improving agricultural performance in yield (through good practice and the development of appropriate agrochemicals), environmental impact and product safety.	Food & Drink SG	To be determined
An added value strategy for the benefit of all communities.	Within 10 years	Seek a new strategic directions for the agricultural sector supported by best practice in materials science and engineering.	Working Group	To be determined

4.4.3 Diet and Health

IChemE supports appropriate regulation to enforce clearer and standardised labelling of food products coupled with consumer education to influence choice and market driven demand.

Outcome	Target	Action	Action By	Partners
Improved awareness of food labelling.	Within 2 years	Promote action in education leading to more informed labelling and choices.	Centre + Food & Drink SG	To be determined
Development of more 'clean label' products reducing the need for labelling declarations.	Within 5 years	Develop innovative ingredients from natural origins.	Food & Drink SG	To be determined
		Look for common standards across international boundaries.	Centre + Food & Drink SG	To be determined
Innovative non chemical preservation technologies.	Within 10 years	Work with academics to look at alternative preservation strategies.	Centre + Food & Drink SG	To be determined

The delivery of safe, healthy and nutritious food demands the input of chemical engineers to explore new avenues in science and technology in collaboration with other disciplines.

Outcome	Target	Action	Action By	Partners
Continued delivery of safe nutritious foods.	Within 2 years	Develop food engineering education within the engineering community.	Centre + Food & Drink SG	Standing Conference
	Within 5 years	Explore functionality in ingredients.	Food & Drink SG	To be determined
Sharing of best practice in nanotechnology from multi disciplinary approaches and other sectors.	Within 10 years	Exploit the opportunities being presented by nanotechnology.	Food & Drink SG	To be determined

4.4.4 Innovation

It is important to encourage the blue sky development of science on a broad front compatible with the key challenges for the industry. Sustainability is vital and must be an active consideration for all involved in the food sector.

Outcome	Target	Action	Action By	Partners
Improved profile of engineering.	Within 2 years	Work with government funding bodies to promote the role of engineering in blue sky activity.	Centre + Food & Drink SG	To be determined
Demonstration of the vital role engineering plays.	Within 5 years	Deliver some effective demonstration projects showing the contribution of the engineering profession in this area.	Food & Drink SG	Food Processing KTN + equiv. international bodies

4.4.5 Delivery of Safe Products

IChemE with other stakeholders will promote dialogue across the supply chain to support technology transfer and the sharing of best practice.

Outcome	Target	Action	Action By	Partners
Increased knowledge in the engineering community of the food manufacturing sector and its practices.	Within 2 years	Promote the role of chemical engineers using existing technology transfer organisations and routes. Support international conferences and dissemination events to the broad base of the food industry.	Centre + Food & Drink SG Food & Drink SG	To be determined -
A higher profile for chemical engineers and the engineering professions.	Within 5 years	Develop best practice guides demonstrating the role of engineering in support of food manufacturing priorities.	Centre + Food & Drink SG	To be determined
The opportunity to influence strategic thinking.	Within 10 years	Establish engineering at the centre of the food manufacturing industry through representation on government strategic bodies at the highest level.	Food & Drink SG	To be determined

4.5 Water

4.5.1 Water as a Resource

IChemE will work with other stakeholders globally to impress upon governments and international bodies the importance of developing and implementing sustainable regional water management strategies, especially by realistic pricing according to its value.

Outcome	Target	Action	Action By	Partners
The factors influencing the availability and cost of water in major metropolitan conurbations, rural communities and the industrial/agricultural sector are better understood, enabling appropriate strategic choices to be made.	Within 2 years	Contribute to rational debate and identification of options for the long term harvesting of water by fostering understanding of the options amongst industrial, agricultural and domestic consumers through government liaison, publications and media contact. Identify and publicise international case studies showing the real cost of water in different regions, taking into account threats to existing sources and the cost of developing new sources.	Centre + Water SG Working Group	To be determined To be determined

Engineers and regional authorities view the water sub-system as an integral part of the total regional eco/socio/techno/economic system enabling shared values and strategy to provide a strong basis for high level influence.	Within 5 years	Develop joint action plans with other stakeholders.	Water SG	To be determined
The international trends in provision and pricing are identified and published, influencing future policy and actions.	Within 10 years	Monitor international trends in water provision and pricing and report progress.	Working Group	To be determined

4.5.2 Sustainability and New Technologies

IChemE is committed to sustainable development and the search for technologies which contribute to sustainable water supplies. The Institution will continue to press governments and companies to fund research programmes which support this objective.

Outcome	Target	Action	Action By	Partners
Sustainability is seen as the central factor in the development of new technologies for water purification and wastewater treatment including sewage sludge disposal.	Within 2 years	Promote a sustainability hierarchy of water purification, wastewater treatment and sewage sludge use and disposal technologies.	Working Group	To be determined
Governments and influential individuals and organizations are alert to what is required for sustainable water management and support it through appropriate R&D programmes.	Within 5 years	Run high-level conferences on challenges and emerging technologies for sustainable water management with international perspective.	Centre + Water SG	-
The extent of global progress is monitored and published, influencing future policy and actions.	Within 10 years	Monitor completed and ongoing research and report progress.	Working Group	To be determined

4.5.3 Industrial Usage (including agriculture)

IChemE supports the introduction of regulations which encourage/support more sustainable water supply and use and wastewater disposal , for example by water reuse in industrial and agricultural processes (including buildings and domestic houses), and beneficial use of sewage sludge rather than landfill.

Outcome	Target	Action	Action By	Partners
Industry and agriculture begin to focus on technologies and processes which minimise the demand for water. The beneficial use of sewage sludge continues, unhampered by unjustifiably restrictive regulation or unfounded poor perceptions.	Within 2 years	Emphasise water treatment and conservation in industrial and agricultural processing through publications, technical meetings and Subject Groups.	Working Group	Other national engineering institutes
		Join with other bodies to make representations to government concerning the proposed revisions to the EU Sludge Directive.	Centre + Water SG	CIWEM
Water efficiency and water reuse in industrial and agricultural processes (including buildings) grow steadily as a result of good pilot experiences and regulatory support.	Within 5 years	Raise the profile of the benefits and risks of advanced water treatment technologies for analysis and optimisation of industrial water use by international conferences, training events and publications.	Centre + Water SG + Branches worldwide	-
		Identify and evaluate regulatory requirements to promote necessary technologies in liaison with governments and other relevant bodies.	Working Group	To be determined
Water is treated as a valuable resource globally and the extent of progress is monitored, influencing future policy and actions.	Within 10 years	Maintain international trends in industrial water use under review and report progress regularly.	Working Group	To be determined

4.6. Bioprocess and Biosystems Engineering

4.6.1 Provision of Well Trained Bioprocessing Professionals

IChemE seeks to expand the recruitment of school leavers to biochemical and chemical engineering courses, the enrolment of suitably qualified professionals into membership and the provision of bioprocessing related courses for continuous professional development.

Outcome	Target	Action	Action By	Partners
Increased skills base of biochemical and chemical engineers within the bioprocess sector.	Within 2 years	IChemE to work with Subject Groups, other professional bodies, academia and industry to define core competencies and standards expected of a biochemical engineer.	Centre + Biochemical Engineering SG + Pharma SG	Other national institutes + industry groups + Standing Conference

		IChemE to work with Subject Groups, other professional bodies, complementary disciplines, academia and industry to identify strategic areas requiring continuous professional development training.	Centre + Biochemical Engineering SG + Pharma SG	Other national institutes + industry groups + Standing Conference
	Within 5 years	IChemE to support and promote the development of training packages in the areas identified that enhance biochemical engineering skills. IChemE to accredit training material where appropriate with particular appreciation of the multidisciplinary nature of biochemical engineering.	Centre + Biochemical Engineering SG + Pharma SG	-
Increased number of chartered biochemical and chemical engineers working within the bioprocessing sector.	Within 2 years	Assess the current and future demand for biochemical and chemical engineers in the bioprocessing sector through consultation with industry and academia.	Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies
		Define a target for the introduction of people to the sector based on these findings.	Centre	-
		Use established networks to promote science and engineering innovation to potential biochemical and chemical engineers.	Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies
		Involve industry and academia in career development events to assist with recruitment and raise the profile of the profession.	Centre	Bioprocess UK + equiv. international bodies + universities
	Within 5 years	Reassess requirements for chartered engineer status based on core competencies and standards identified for biochemical engineers. The chartership requirements will acknowledge the changing role of a biochemical and chemical engineer within the sector.	Centre	-
	Within 10 years	Monitor supply and demand of the skills base through consultation with industry and academia. Facilitate discussions between the two bodies to address issues as necessary.	Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies + universities

Increased interest and awareness in biochemical and chemical engineering from students within schools, colleges and universities and the interested public leading to an enhanced global healthcare sector.	Within 2 years	Identify groups outside the IChemE and globally that currently engage in public education in the biochemical engineering sector targeting junior school level through to interested adults. Establish more regular engagement of potential entrants into the sector via the Subject Groups and "*whynotchemeng*" campaign. Focus on how interactive the job is (Science and Engineering).	Centre + Biochemical Engineering SG + Pharma SG Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies -
	Within 5 years	Promote and support these groups where appropriate. Work with these groups to define IChemE educational scope and complete gap analysis.	Centre + Biochemical Engineering SG + Pharma SG	-
	Within 10 years	Fund or lobby for funding to address skills gaps, and co-ordinate the work required to provide a comprehensive educational strategy for biochemical engineering.	Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies

4.6.2 Low Environmental Impact and Sustainable Bioprocesses

IChemE supports reducing the environmental impact of industrial activity and will through the Subject Groups encourage members to promote new pollution abatement strategies and the design of sustainable processes. IChemE will work with companies to highlight this approach and environmental success stories to the general public.

Outcome	Target	Action	Action By	Partners
Identify technologies and tools to reduce the impact of manufacturing within the sector.	Within 2 years	Network with external international complementary interested parties and professional bodies to identify the needs of the sector in the areas of reduced process environmental impact and improved process sustainability (focusing on making peoples lives better). Set up an international group to work with other professional bodies (specifically research funding bodies) and industry to identify, support and promote new commercially viable technology that will reduce process environmental impact and improve process sustainability in the pharmaceutical and biotechnology sector.	Centre + Biochemical Engineering SG Pharma SG + Branches worldwide Centre + Biochemical Engineering SG Pharma SG + Branches worldwide	international chem eng groups + national chem eng groups + other national Institutes To be determined

		Biochemical Engineering SG/Pharma SG to work with other relevant Subject Groups and the Centre to develop, promote and support CPD and technical meetings focusing on environmental impact and sustainability issues specific to the biochemical industries and bio-technologies. Identify successful case studies and examples of innovation in the sector internationally that may be promoted by leaders in the field. Publish and distribute material through available channels, demonstrating IChemE commitment.	Centre + Biochemical Engineering SG + Pharma SG	Bioprocess UK + equiv. international bodies
Acceptance of new techniques and technologies to reduce environmental impact and increase sustainability as evidenced by continued uptake by industry. Engagement of relevant legislative and regulatory bodies in partnership will identify possible and acceptable improvement opportunities.	Within 5 years	Develop education and training opportunities for new techniques and technologies to high standards (IChemE accredited training). Exemplar tools promoted via CPD events and technical meetings and hosted by relevant Subject Groups.	Centre + Biochemical Engineering SG + Pharma SG	-
		Engage / partner with the relevant regulatory authorities to identify opportunities to reduce process environmental impact and increase the sustainability aspects of bioprocesses in an acceptable manner.	Centre + Biochemical Engineering SG + Pharma SG	To be determined
Design and implementation of sustainable bioprocesses with significantly reduced environmental impact following uptake of new approaches and technologies. Acceptance by the relevant regulatory authorities.	Within 10 years	Work with regulatory authorities and industry where updates to legislation impacting environmental and sustainability issues are required to promote the IChemE position.	Biochemical Engineering SG + Pharma SG	As above

Appendix 1 - Membership of the Technical Policy Commissions

Sustainability and Sustainable Chemical Technology	Health, Safety, Environment and the Public Perception of Risk	Energy, Food and Water	Bioprocess and Biosystems Engineering	Cross -Thematic SGs (all panels)
Miles Seaman Chris Tickle Malcolm Wilkinson Sustainability SG Committee members co-ordinated by Miles Seaman	John Atherton David Jacobi Martin Goose Andy Ingram – *Particle Technology SG*	Energy: David White Toby Chancellor-Weale – *Oil and Natural Gas SG* Food: Philip Richardson Water: *Water SG* Committee members co-ordinated by Chris Short Iqbal Mujtaba – *Computer Aided Process Engineering* SG Stef Simons – *Particle Technology SG*	Mark Bustard Andy Dorward Malcolm Rhodes Gary Lye Keith Plumb Philip Bowles Richard Ryrie Charles Immanuel – *Computer Aided Process Engineering SG*	Eva Sørensen – *Fluid Separations SG* Mike Yianneskis – *Fluid Mixing SG* Andrew Ogden-Swift – *Process Management and Control SG*

Appendix 2 - The Consultation Process

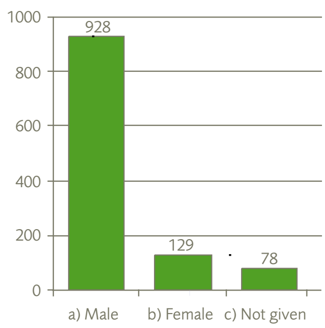
Dialogue by Design was commissioned to carry out an online consultation process with IChemE members. The structure and timetable of the consultation was as follows:

Session	Time period	Contents
One	4 Sep 06 to 22 Sep 06	IChemE members were asked for comments on the positions the Technical Policy Commissions had drawn up. They were given concise background information about each position and asked a question about each one ('Do you agree with it? If not why not?'), followed by two questions on each thematic area as a whole ('Have we missed any positions?' and 'Which is top priority for action?').
Two	15 Jan 07 to 2 Feb 07	Members were able to view online all the comments made in Session One (on a non-attributable basis) and the revised position statements. Members were asked for their input in two sections of the website: (1) Comments on the proposed action plans ('Do they offer a practical way for the Institution and its membership to achieve the objectives of the position statement? If not, what would you add?'), followed by a question on possible regional variations in each thematic area ('Do any of the action plans have differing implications for different regions of the world? If so, what are they?'). Finally there was one overarching question ('If you could instruct the Institution's governing Council to make just one intervention into the technical policy debate, either in your own region, or globally, what would you want it to say?') (2) Evaluation of the consultation itself with questions about the ease and merits of participation in the process and the quality of the material exposed for comment.

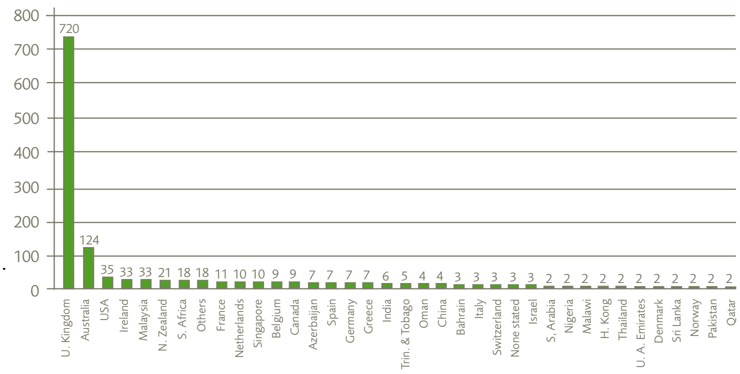
Both the Session One and Session Two consultations took place over three week periods. A total of 1135 people registered during the process with 506 submitting responses in Session One and 138 in Session Two.

The characteristics of the registrants were broadly representative of the membership base.

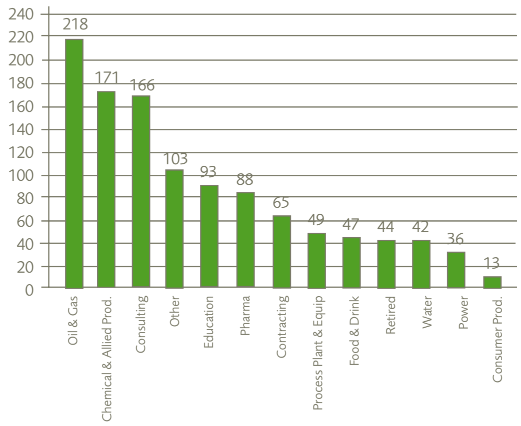
Count of registered users by gender



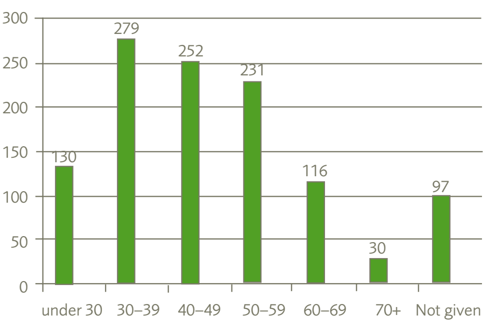
Count of registered users by country (countries with only one registered user in 'Others')



Count of registered users by sector



Count of registered users by age



1. Interpreting the results

The online consultation process was straightforward. Participants logged on to a website and registered to participate. On the website they were able to read background information about the consultation, its objectives, how the results would be used, and ground rules for participating in the process. Participants could then read the document on screen and respond to the questions it contained. Responses were recorded in boxes limited to 2000 characters (about 400 words).

At the end of the session all the comments were collated under a variety of group headings. If more than one point was made in a comment then it was grouped under more than one heading. Dialogue by Design used their in-house expertise gathered from running many similar consultation processes to ensure comments were collated as accurately as possible.

It is important to remember, when seeking to interpret the results, that this was a qualitative consultation, not an opinion poll: its primary purpose was to collect ideas, arguments and information. Care must be exercised, therefore, in attributing too much significance to the proportion of responses arguing in one direction or another. The grouping of comments under summary headings should not be interpreted on a purely statistical basis. The groupings are useful indicators of where there is commonality. Taken in relation to each other, they help to clarify the range of issues and concerns identified by a multiplicity of stakeholders, and where general agreement or specific differences exist. The categorisation of responses is also necessarily simplistic given their complexity, so for this reason again it would be unwise to draw firm quantitative conclusions from them.

1.1 Session One – The Draft Position Statements

Key issues that emerged:

- The need, across a number of themes, to allow for a hierarchy or prioritisation of approaches and technologies which might reflect differing geographic, social and economic situations.
- Linked to this a need to differentiate between global and UK centric perspectives.
- Awareness that the intended audience must dictate the use of technical language and jargon and that different versions will be required if the intention is to reach policy makers and the public.
- Engaging with wider society is contentious. There were conflicting views from the membership on why and how to do this (educational role, better understanding of public values, etc) and recognition that the skills and strategy for wider engagement need developing.
- Around a number of contentious issues, particularly genetic modification (GM) and nuclear power, there was some feeling that the terms were vague and those who opposed GM, for example, felt the words were hiding support while those who support GM wanted the statements to be clearer. Tensions amongst the membership mirror tensions in the wider public.

Key issues in the thematic areas:

- Sustainability and Sustainable Chemical Technology: 9% of respondents to the position on energy were against the inclusion of nuclear power in the suite of non-fossil fuel energy sources because of concerns on waste disposal and safety; some comments on crop production sought clarity on GM with a majority of those who raised it (9% of respondents) expressing concern about its development; the addition of fiscal and other incentives to that of legislation was supported as a means of driving the 'reduce, reuse, recycle' mentality.
- Health, Safety, Environment and Public Perception of Risk: all the positions were strongly supported though there was some concern that risk reduction should not be pursued as an end in itself without concomitant societal benefits and that the 'blame culture' and litigation are becoming increasing barriers to the open reporting of incidents.
- Energy: 12% of respondents advocated the necessity to deploy all available generation technologies together with focus on efficient energy utilisation as a portfolio approach to reducing CO_2 emissions and 13% of respondents had concerns about carbon capture and sequestration on the grounds of its longer term sustainability; the position on gasification was the most contentious in the consultation with 22% of respondents nervous of the IChemE promoting one specific technology; doubts about biofuels were expressed by 8% of respondents because of competition for land with food production.
- Food and Drink: the minimisation and utilisation of waste was the main theme of comments on these positions with calls for additional focus on packaging as well as production; innovation was strongly supported though caveated by the need to maintain an understanding of the risks and benefits of developments coupled with the requirement to properly communicate them to the public.

- Water: responses to these positions reflected the growing recognition of the global need to implement sustainable water management practices and a view that political will is sometimes lacking particularly with regard to agricultural usage and by developing country governments; there was a strong consensus that industry is capable of considerably reducing water usage with a preference for the use of both incentives and regulation.
- Bioprocess and Biosystems Engineering: these positions achieved more universal support than any other theme with recognition of the imperative for co-operation and interaction with many other disciplines in this field of technology.

1.2 Session Two – The Action Plans

Key issues that emerged:

- There was strong support for all the proposed action plans with only a 2% disagreement across the board.
- There was however concern about the resource implications of implementing the action plans with a need to prioritise to ensure a few things are done well rather than many things poorly.
- In all thematic areas education and awareness raising in new technologies and new approaches were seen as vital roles for IChemE both to its members, with particular focus on those working in developing economies, and the public in general.
- Regional priorities differ and whilst overall goals may be common the focus and pace of application will vary and this must be recognised in the implementation programmes.
- The most important technical issues for chemical engineers were seen as the inextricably linked ones of energy, climate change and sustainability.
- The process as a whole was well received with a real sense of involvement by participants.
- The objectives were seen as very ambitious requiring a lot of reading and hence time to respond to it.

Key issues in the thematic areas:

- Sustainability and Sustainable Chemical Technology: strong support for the formation of an international forum on sustainable energy with suggestions to link more widely than other engineering bodies and to make the forum more proactive and influential; a drive to advance the timescale for action in the area of reduce, reuse, recycle; the introduction of the concept of inter and intra generational equity through regional variations.
- Health, Safety, Environment and Public Perception of Risk: strong support for building a common understanding of risk focusing on major industrial activities between regulators, industry and the public; the toolkit for performance improvement needs to be complementary to existing codes, standards and programmes and have international application; the need to shorten implementation times across the plans.
- Energy: support for IChemE to play a role in overcoming the public resistance to nuclear power; a call to accelerate the plan for re-establishing nuclear engineering in universities and linking to existing initiatives in this area; the need for the international forum to be proactive in the development and deployment of renewable technologies.
- Food and Drink: waste management should include packaging and research strategies should be multi-disciplinary; a need to take a global view, particularly for the developing countries where diet is about availability, making preservation important, farming is about subsistence, rendering fertilisers unaffordable, and disease prevention (cf avian flu) may require significant shifts in nutritional habits; innovation should include novel processes for the efficient production of food.
- Water: a strong sense that the programme for sustainable water supplies must be accelerated and that IChemE has a lead role to play in the technical analysis, public discussion and development of options; implementation strategies must take account of global variations and input should be sought from all regions.
- Bioprocess and Biosystems Engineering: strong support for the action plans with emphasis on the need to develop stronger links with the life sciences and build the chemical engineering skills base in the sector by proactively promoting this career route in schools.

2. Comments on the Consultation Process

The number of respondents to the evaluation questionnaire was disappointingly low but nonetheless provided useful feedback.

In answer to the question 'If you registered for the consultation but did not submit a response what was your main reason?' 40% of respondents said they did not have time, 20% of respondents said the subject matter was not relevant to them and 13% said they had visited the site for interest only. No one reported that it was because they had found the online process too complicated or not easily accessible.

88% of respondents agreed that participating in an online consultation such as this was a credible way of engagement with less than 5% disagreeing and 55% expected their participation to make a difference although 11% did not and 34% were not sure.

Two thirds of respondents were happy with the clarity and ease of understanding of the position statements and action plans although 13% had problems and 20% were ambivalent.

92% confirmed they would be prepared to take an active part in the action plans they had positively commented on.

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