IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

IChemE BioFutures

Biofutures Programme Final Report

December 2018

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The Development of this report was led by the **BioFutures Steering Group**

Foreword

Chemical engineering and society are facing some significant challenges including: the rapid development of the bioeconomy, the pressure to decrease greenhouse gas emissions and the increasing emphasis on sustainability. These challenges require chemical engineers to have a greater diversity of skills and knowledge and will dramatically change how we define chemical engineering.

These changes should be used to advance chemical engineering transformatively, particularly in combination with developments in artificial intelligence and big data. They are changes that the chemical engineering community and the Institution should embrace enthusiastically. In turn, this transformation will require fundamental changes to the ways IChemE functions and how the profession sees itself. This is a real opportunity and requires decisive action now to advance the Institution and the profession.

Today's chemical engineering has advanced dramatically beyond the capabilities of yesterday. As with the chemical engineers of today, we must continue to nurture, support and be encouraged by the new advances into the future including the fields of engineering biology, synthetic biology and industrial biotechnology.

Ian Shott, Chair of the BioFutures Programme

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Executive summary

The growth of the bioeconomy,[1] advances in industrial biotechnology and synthetic biology, as well as the development of artificial intelligence and big data, are transforming the chemical engineering profession. These changes, including the need for chemical engineers to learn new and more diverse skills, will create many new opportunities but will also put new pressures on the profession and the Institution.

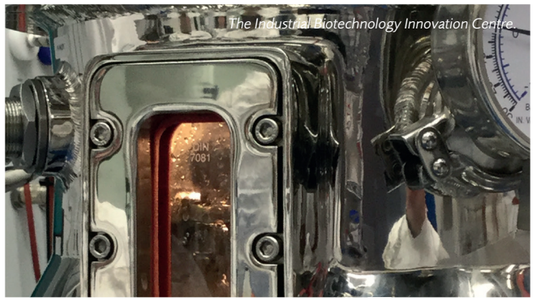
The **BioFutures Programme** was set up to help shape IChemE's strategy and ensure that IChemE remains the institution of choice for the evolving profession. The programme will also help develop IChemE's learned society function, support the work already developed with ***Chemical Engineering Matters***, and highlight the importance of chemical engineering careers in the **bioeconomy**.

The BioFutures steering group reviewed and identified four key areas where IChemE needed to make progress including: skills, careers, SMEs and policy. The steering group then formed four focussed working groups to review IChemE's current activities in these areas, with input from IChemE's global membership and extending into a large network of SME's across a range of international territories. This report summarises their findings and recommendations for consideration by IChemE's Board of Trustees.

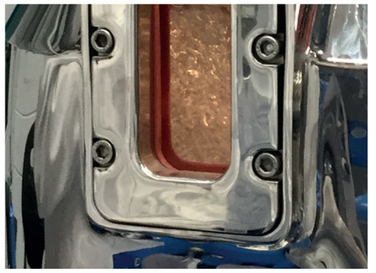
Key Findings

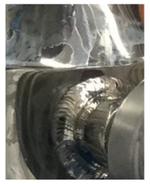
- IChemE would benefit from a clearer corporate and member engagement strategy, particularly with SMEs. The group identified areas for improvement in IChemE's current corporate and member engagement, promotional materials and membership processes.
- There was also a lack of knowledge and awareness amongst some bioeconomy-related companies regarding the benefits of employing chemical engineers and therefore a potential area for IChemE to promote the profession.
- There was a strong correlation between the bioeconomy and industrial biotechnology-related knowledge and skills wanted by industry and those currently covered by many of the universities questioned.
- However, industry felt there was a general lack of skills and knowledge provision among chemical engineers entering the industry. This suggests that industry would like graduates to have a deeper knowledge of these subjects.
- A large proportion of universities want to increase the biocontent of their courses, but the majority of those identified a lack of staff knowledge and a wish not to dilute established 'core' chemical engineering as potential barriers to increasing biocontent.
- There was also a strong desire amongst universities for IChemE's help to facilitate additional learning activities (like site visits, guest speakers, industrial placements and industry focussed projects) and to promote much greater academia-industry interaction.
- Bioeconomy-related industries highly valued an accredited degree as an indication of the quality of potential employees, but they valued chartership less highly.
- There is a wide variety of career paths available to chemical and biochemical engineers in the bioeconomy, which were inadequately represented in IChemE's current careers profiles (including the successful careers campaign, **whynotchemeng**).
- The major theme for policy topics centred around sustainability with four main areas – decarbonisation of the economy, resource utilisation efficiency, ecosystems services (covering water, land and air natural assets), and technologies that impact on health and wellbeing, food and nutrition and support the goal of sustainability.

[1] *Economic activities involving the engineering use of biology and purposefully bio-active substances.*



The Industrial Biotechnology Innovation Centre.

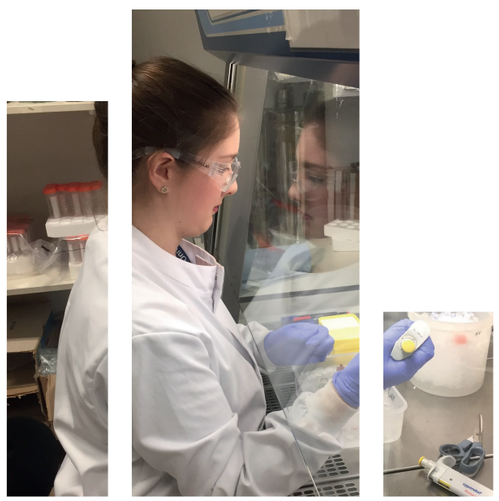




Recommendations

The BioFutures Programme has produced several recommendations to help address these findings. These recommendations include but are not limited to:

1) IChemE needs to improve its engagement with SMEs (including those working in engineering biology). To that end IChemE should review and develop its current corporate engagement strategy including:
   - a review of its current promotional materials for corporate and individual membership;
   - a review of its membership database and current strategy for monitoring membership trends to enable it to better understand the role and potential of SMEs;
   - a review of its corporate partner and individual membership processes;
   - promoting the contribution of chemical engineers to SME R&D and scale-up.



The Industrial Biotechnology Innovation Centre.

2) IChemE should help enable universities that want to increase their biocontent. This could be achieved through:
   - encouraging the sharing of best practice guidelines among universities;
   - improving IChemE's role in liaising between academia and industry;
   - developing (with relevant SIGs and industrial partners) bioindustry examples for universities to integrate into their core chemical engineering teaching.
   - ensuring clear guidance on how core principles can be demonstrated through the use of bioindustry examples
3) IChemE should continue to build on the success of IChemE accreditation and work on improving the recognition of chartered status within the bioeconomy and industrial biotechnology.
4) IChemE should foster the interaction between universities and industry to promote career opportunities in the bioeconomy and industrial biotechnology.
5) IChemE should produce and promote new case studies highlighting career opportunities in the bioeconomy and industrial biotechnology.
6) IChemE's Learned Society Committee should review the policy working group's report when considering topics and policy issues to address.

Introduction

In December 2015, ***The Chemical Engineer*** published an article calling for action to boost the skills diversity of chemical engineering graduates and prepare them for the greater diversity of roles requiring chemical engineers.

In a global context, the growth of the 'bioeconomy' and 'engineering biology' is having a great impact on the chemical engineering profession. Economic activity involving the engineering use of biology and purposefully bioactive substances ranges widely from fermentation to synthetic biology, biocompatible materials and the development and manufacturing of drugs and biologics. The biotechnology and bioengineering landscape is undergoing a transformation, which is driving a substantial need for chemical and biochemical engineering skills.

IChemE has already recognised the important role that chemical engineers play in this sector. The Biochemical Engineering Special Interest Group (**BESIG**) is one of the largest SIGs in IChemE, and other SIGs are closely related to the bioeconomy and industrial biotechnology (**Food & Drink**, **Pharma**). But IChemE has an opportunity to do more and develop opportunities for growth in this field.

The BioFutures Programme started work in 2017. The programme consisted of four working groups to address key areas identified by the steering group: skills, careers, SMEs (Small – and medium-sized enterprises)[1] and policy. This report summarises the findings and recommendations from this programme of work. Further details including reports from the individual working groups can be found on the BioFutures Programme **webpage**.

Methods

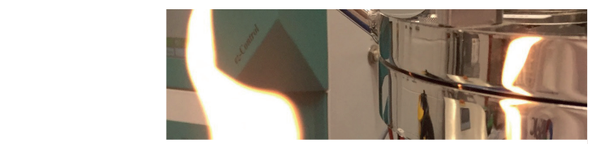
Full details of the methods used by the groups (and the limitations thereof) can be found in their respective reports. The working groups used various methods to address these key areas:

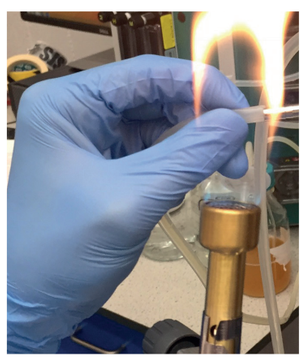
The skills working group conducted surveys of members from the biotechnology-related industries and from universities. The industry and universities surveys received a total of 159 and 39 responses respectively. This amounted to a response rate of 19.6% and 45% when compared with the initial target audience identified by the working group.

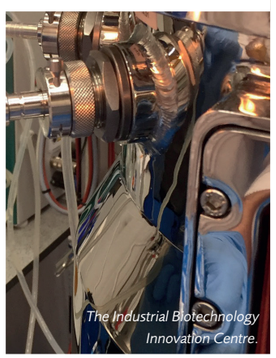
The careers working group interviewed a total of 39 individuals from across the bioeconomy representing a range of career paths, to inspire the next generation of chemical and biochemical engineers.

The SMEs working group approached 91 SMEs and conducted 38 interviews. The interviewees included members, and non-members, of IChemE.

The policy working group approached all BioFutures Programme members, relevant IChemE SIGs and National IChemE Boards through its policy consultation process.







The Industrial Biotechnology Innovation Centre.

[1] SMEs as defined by the OECD as having less than 250 employees.

*(**https://stats.oecd.org/glossary/detail.asp?ID=3123**)*

Findings

Skills

A majority of industry responders (62.5% of all responders and 83% of those that employ chemical engineers) believe that there was a common lack of skills and knowledge provision among chemical engineers working in industrial biotechnology and the bioeconomy.

There was a strong correlation between the industrial biotechnology-related topics wanted by industry and those currently covered by universities. However, the results suggest that industry would like graduates to have a deeper knowledge of these subjects.

Topic	Industrial importance Topic importance rated as high by industry (%)	Covered by universities (%)	Perceived competence by industry Graduate competency rated as high by industry (%)
Effective communication skills	92.7	43.9	59.4
Applying core chemical engineering skills to the biosector	88.7	65.9	55.2
Downstream processing and purification of biological substances	81.3	68.3	57.8
Fermentation	77.9	78.0	44.4
General background knowledge of biological processes	77.3	41.5	26.6
Bioreactor design	70.5	75.6	47.3
Sterilisation techniques	70.5	46.3	42.0
Big data analysis	47.7	2.4	25.9
Bioanalytics	42.2	17.1	8.0
Enzymology and biotransformation	39.0	34.1	8.3
Cell biology	36.0	46.3	14.3
Systems biology	35.7	14.6	10.4
Genomics, proteomics, metabolomics etc.	22.8	22.0	5.7
Synthetic biology	21.8	17.1	7.4

Figure 1. Comparison of industrial biotechnology-related topics according to i) percentage of industrial respondents that rated these topics of high importance, ii) percentage of academic respondents that indicated these topics were covered at their universities, iii) percentage of industrial respondents that rated chemical engineers as highly competent in these topics. These are colour coded to show high (green) and low (red) percentages.

There was a clear preference for industrial biotechnology-related topics that fall under the discipline of engineering. The greatest desire by industry was for chemical engineers to have a better understanding of topics more relevant to bioprocessing (for example fermentation, bioreactor design and downstream processing). More scientific topics (like synthetic biology and genomics) were less desired. There was also an unwillingness among industry for universities to sacrifice core chemical engineering skills at the expense of these topics.

There was no obvious evidence from the results, that an aggressive expansion of separate biochemical engineering degrees is supported by universities or industry. There was an indication that biochemical engineering should be seen as an integrated part of a chemical engineering. This highlights a need to encourage institutions to ensure adequate bioprocessing content is included in chemical engineering programmes to meet the identified future skills needs and for IChemE to continue to support those institutions that have, or wish to develop, dedicated biochemical engineering programmes.

Industry highly valued IChemE's role as an accreditation body of university programmes. A majority (62.1%) described an accredited degree as very or extremely important. However, chartered status was less valued by industry. Only 30.6% described chartered status as very or extremely important.

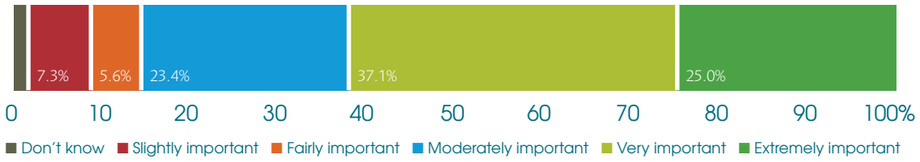


Figure 2. Responses of industrial respondents to the question 'Based on your experience, is it important for your chemical and/or biochemical engineers to have an accredited degree', number of responses = 159.

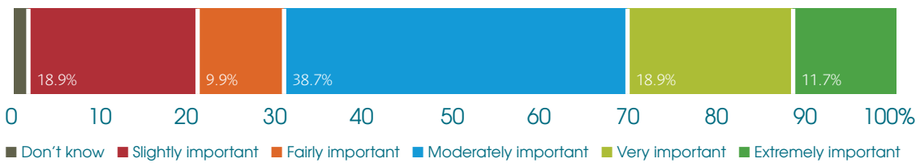


Figure 3. Responses of industrial respondents to the question 'Based on your experience is it important for your chemical and/or biochemical engineers to become Chartered', number of responses = 159.

The Industrial Biotechnology Innovation Centre.

A majority of universities offered at least one course with compulsory biocontent. It was found that universities accredited by IChemE offered a higher level of biocontent in their courses compared with those that were not accredited. Typically, this represented 20% of total course content and highlights the success of IChemE's accreditation guidelines in ensuring that biocontent is represented.

A majority of universities (64.1%) questioned said they wanted to increase the biocontent of their courses with the majority of those saying they see it is a potential growth area. Only 25% of those questioned said there were no limiting barriers to increasing biocontent. However, a majority (75%) did identify barriers to increasing the biocontent of their courses. Of the limiting factors identified, a large proportion identified their wish not to dilute core chemical engineering from their courses, the lack of experienced staff and the feeling that there are not enough jobs/enough demand to justify an increase in the biocontent of their courses.

There was overwhelming support among universities for IChemE to help facilitate additional activities (outside of lectures). There was particularly high support for facilitating industrial placements and visits to plants/facilities. This indicates an opportunity for IChemE to promote better collaboration between universities and local companies. There was also a lack of careers case studies of individuals working in industrial biotechnology and the bioeconomy, which highlighted the need for IChemE to showcase the careers available to graduates in this area.

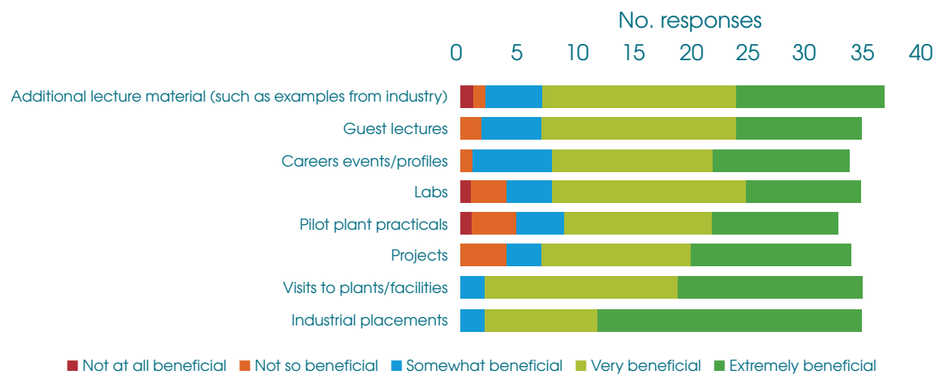
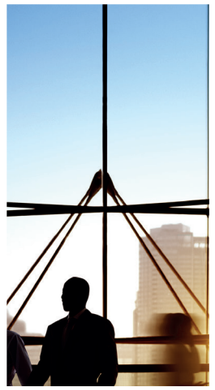


Figure 4. Responses of industrial respondents to the question 'Based on your experience, is it important for your chemical and/or biochemical engineers to have an accredited degree', number of responses = 159.








The working group observed that a large number of universities (38% of all respondents) indicated 'not wanting to dilute core chemical engineering' as a barrier to increasing the biocontent of their courses. The working group believe this identifies a case for addressing the perception and/or interpretation of what 'core chemical engineering' means and how universities can integrate biochemical engineering into their teaching of 'core chemical engineering'.

SMEs

Initial survey data of IChemE members working in the bioeconomy, confirmed anecdotal evidence that SMEs make up a larger proportion of companies in the bioeconomy. Approximately 40.8% of those surveyed worked in SMEs. This is approximately double the percentage of IChemE's core membership in SMEs (20.2%) – based on the 2017 IChemE UK Salary Survey.

Through the interviews conducted by the working group, it was concluded that IChemE lacks a coherent and effective strategy for adequately engaging with SMEs and chemical/biochemical engineers working in these companies and could benefit from addressing this opportunity.

IChemE, as an organisation, faces difficulties to clearly identify, monitor and evaluate its membership profile, particularly those working in SMEs. This makes it difficult to actively engage with those members in SMEs and to ensure that IChemE remains relevant and engaged with this diverse community.

The working group found that unless the interviewee was a long-time member of IChemE, they had little understanding of IChemE's value offering - or the benefits of employing chemical engineers, particularly for scale-up (26% did not employ chemical engineers). There was a lack of appreciation for the contribution chemical engineers make to the R&D stages of SME development – particularly among interviewees who were not familiar with chemical engineering. The potential contribution of chemical engineers during the R&D stages of SME development was better appreciated after interviewers had discussed this with them and highlights a potential area for IChemE to promote the profession.

The working group found that there was a lack of clear promotional material targeted towards those SME members in IChemE. As members of IChemE all interviewers also struggled to fully articulate the benefits of membership for staff in SMEs.

A barrier to joining IChemE (as a company and as a member) identified by interviews was the difficulty of the membership process, with some interviewees put off at the first stages of researching membership. This was particularly relevant for SMEs, and corporate membership, where cost versus benefit is an important factor. This also impacted the likelihood of employees in SMEs being members of IChemE. While the majority of interviewees were members of IChemE, they were predominantly self-funded as SMEs were far less likely to fund their employees' individual membership of IChemE. This is an additional pressure faced by individuals when deciding whether to continue their membership of IChemE (particularly for junior chemical engineers).

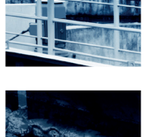
SMEs struggle to find the time or financial resources to take part in IChemE courses or events (and don't necessarily see the value). The SMEs that have chemical engineers did not feel they had the resources and time to adequately engage with IChemE. A key issue was the difficulty for SMEs to provide adequate mentoring and guidance for junior chemical engineering graduates to work towards CEng status. Those without chemical engineers didn't realise they could benefit from engaging. Opportunities for knowledge sharing and networking were described as very important by the majority of interviewees and highlights a particular area which IChemE could develop and highlight in a corporate strategy.

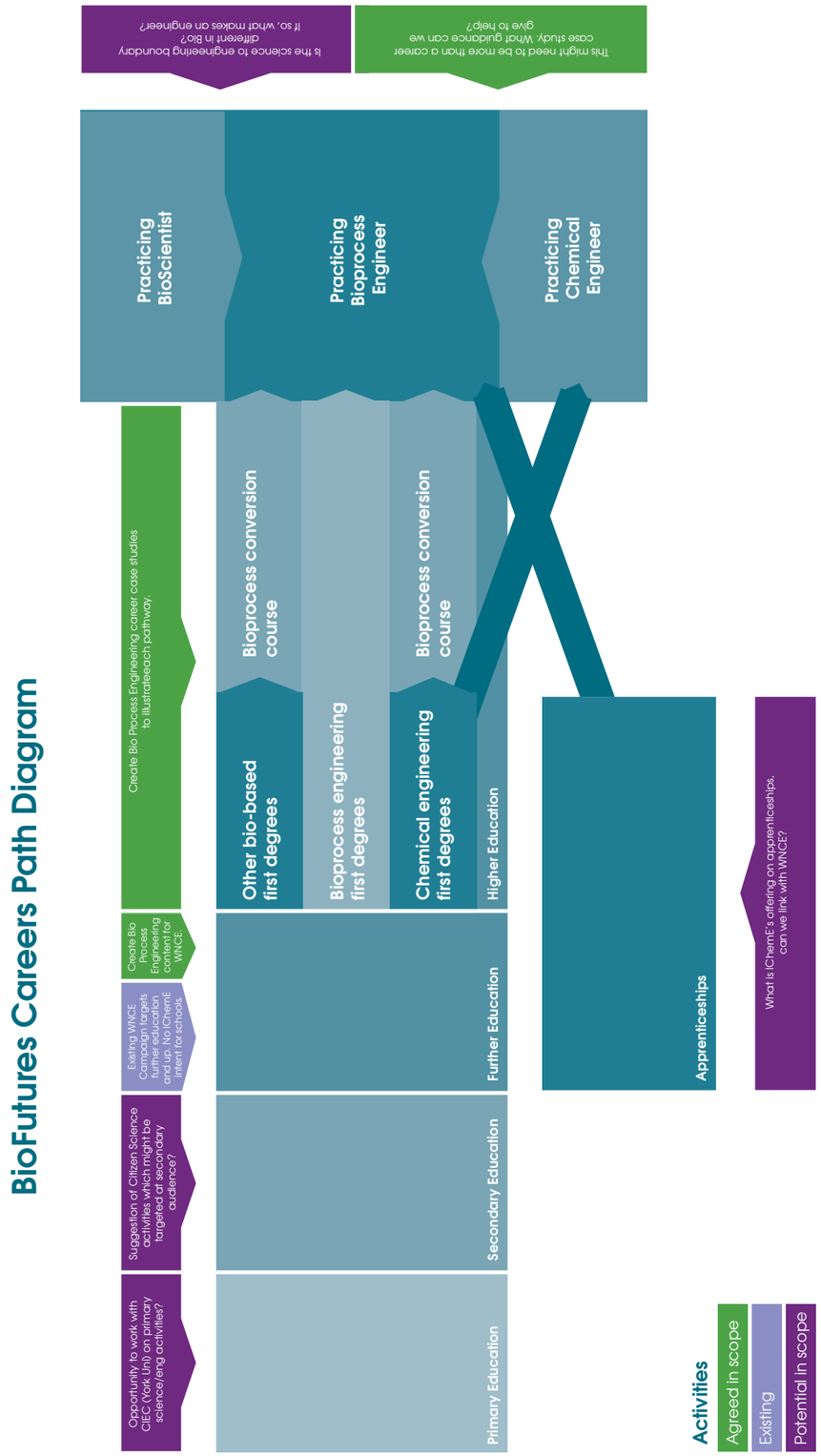
The working group found that a high number of SMEs already engaged with IChemE were consultancies. The group notes that other organisations have had successful engagement with SMEs though clusters or through a reduced cost membership scheme and that the organisation could benefit from such approaches.

The SMEs working group acknowledge that IChemE has limited resources and this will impact on any outreach strategy. However, IChemE has an opportunity to make some initial changes to engage with the community, build its profile and ultimately form a coherent strategy that would help IChemE grow and accommodate a diversifying membership.







Careers

Some initial work by the careers working group highlighted the various pathways that could be taken by individuals into the bioeconomy – and would develop skills the profession would recognise as process engineering. Using this initial analysis, the careers working group found that such career paths were inadequately represented in IChemE's current careers profiles (including **whynotchemeng**).

The group believes that developing a set of case studies to show these diverse career pathways would help to highlight the opportunities available for those wishing to pursue a career in the bioeconomy, broaden IChemE's profile, and help the Institution remain relevant for a diversifying membership.

The work of the careers working group also highlighted the potential for IChemE to help industry engage more with universities. The possibility of creating avenues for greater collaboration and activities between universities and industry would help reinforce the message of opportunities in this sector, while also expanding the opportunities for members to network and collaborate.

The group conducted a series of interviews with individuals from across the bioeconomy and at different stages of their careers. The careers working group interviewed a total of 39 individuals from across the bioeconomy. They represent individuals working in food and drink, pharmaceuticals, bioenergy and at the cutting edges of industrial biotechnological research. The profiles will be made available online and as free downloadable material.

Policy

The rapid growth of the bioeconomy and its role in combatting some of the major societal **challenges** make it an important area for policy and **decision makers**. Chemical engineers make a vital contribution to this area and as a profession - with a broad array of expertise - represent a unique source of information. This expertise and knowledge of IChemE's membership and the growth of the bioeconomy requires IChemE to evaluate its role in the sector and where it should prioritise its technical policy work.

Through the consultation process, the group found that there were several key policy areas for the bioeconomy, where chemical engineers are heavily involved. IChemE (and its membership) have the capability to address these issues (either due to current SIG activities or other activities like the IChemE Energy Centre).

Through the consultation process the working group found that these policy topics revolved around the central theme of sustainability. Sustainability applies broadly to economic, environment and societal outcomes. The bioeconomy will be at the forefront of developing a carbon neutral society that is sustainable, and chemical engineers, who bring a systems approach, will be a crucial part of delivering this. This challenge of a sustainable way of living will mean many new policy challenges will need to be addressed.

The policy working group identified four key policy areas. The expertise of chemical engineers and the contribution these areas have towards the greater theme of sustainability, make them priorities for future learned society activities. The four themes are:

Decarbonisation of the economy

The need to reduce Green House Gas (GHG) emissions from all sectors, including agriculture, construction, chemicals, and other industries as well as energy (power, heat, industrial energy and transport). Chemical Engineers, with their system approach to design, will be needed to drive system





thinking to help policy makers achieve their goals, and to identify and implement workable and effective solutions.

Resource utilisation and efficiency

This area focuses on the need for efficient resource utilisation and circular economy system thinking and includes designing for 'zero waste' and the use and application of renewable resources - including wastes. This also includes the impact of these new supply chain models and systems, especially with respect to the processing of remote biomass materials; and life cycle thinking and analysis.

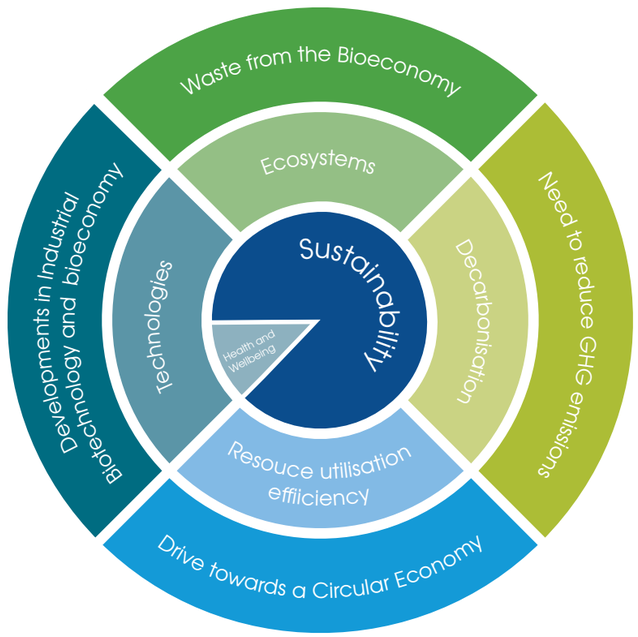
Ecosystems services - covering water, land and air natural assets

Ecosystems services, consisting of natural assets such as water, nutrient cycling and soil formation, are a critical element of sustainability.

Ecosystems services provide the resources and conditions which permit, for example, energy to be sustainably generated and chemicals to be sustainably produced.

Developments in industrial biotechnology and the bioeconomy

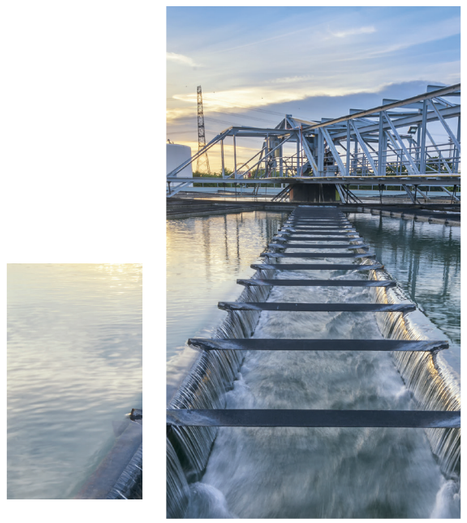
This includes the development of technologies that impact on health and wellbeing, food and nutrition and support the goal of sustainability (including the developments in synthetic biology and medicines).



Through the consultation process several issues were identified under these topic areas that IChemE's learned society activities could address. The most important issues identified by the group include (policy report):

- greenhouse gas reduction, mitigation and adaption
- decentralised or remote processing
- water treatment, recycling, distribution and natural capital
- new developments in industrial biotechnology and the bioeconomy (such as biopharmaceuticals, sustainable use of raw materials and synthetic foods).

As a professional engineering institution, IChemE also has a key role in monitoring developments in industrial biotechnology, the bioeconomy, artificial intelligence and big data and assessing their potential impact on and implications for current and future skills and education policy.










Recommendations

The BioFutures Programme has identified some clear areas where IChemE as an organisation could act. According to the findings of the working groups IChemE BioFutures Programme makes the following recommendations.

Skills

IChemE should ensure that its processes encourage universities that wish to increase the bioprocessing content of their chemical engineering degrees. IChemE should continue to support those institutions that already (or want to) have standalone biochemical engineering programmes. IChemE should encourage the sharing of good practice between universities that teach biocontent and those that wish to increase the biocontent of courses. Relevant SIGs should be encouraged to engage universities that want to increase the biocontent of their courses.

IChemE should address the perception and/or interpretation of what 'core chemical engineering' means. Within the university accreditation guidelines 'core chemical engineering' principles (such as thermodynamics, mass and energy balances and fluid flow) can and have been demonstrated by using biochemical contexts. As an accreditor IChemE should ensure that it has clear guidance and provides a set of FAQs that illustrate how core principles can be demonstrated through the use of relevant bioindustry examples and unit operations (such as metabolic pathway modelling, fermentation and chromatography).

Universities should consider integrating further examples from the bioeconomy and engineering biology into their core chemical engineering teaching. This will prevent excessive increases in course content and help bioprocessing be recognised as an intrinsic part of chemical engineering. Universities, IChemE's learned society activities, relevant SIGs and stakeholders should develop a resource of bioindustry examples for universities to integrate into their core chemical engineering teaching.

IChemE should look at improving its role in liaison between universities and industry members to improve universities' provision of additional activities (such as plant visits and industrial placements).

IChemE should continue to promote accreditation as the best means for universities to showcase the rigor and quality of the engineering content and learning outcomes in their courses.

IChemE should improve the recognition of chartered status within the bioeconomy. IChemE should review its promotion of chartered status and emphasise the benefits of chartered status for biochemical engineers and their potential employers. IChemE should also ensure its chartership guidelines and processes are relevant for chemical engineers working in the bioeconomy. IChemE should also seek to attract those converting from other academic backgrounds who meet most of, but not all, the requirements for MIChemE - such as biotechnologists or those who have undertaken conversion MSc programmes. This could be by ensuring there are industrial biotechnology-related examples for applicants to review and ensuring that applicants have access to mentors and reviewers with an awareness and understanding of engineering biology- and industrial biotechnology-related processes.

SMEs

IChemE must improve its corporate strategy and develop a SME strategy if it wishes to continue to engage with a diversifying membership. This strategy should consider its existing SME membership but also focus on attracting and retaining new members from SMEs.

IChemE should include company size in the data collected on members. This will ensure that

IChemE can adequately monitor, engage and aid those members working for SMEs

IChemE should follow up with members on a regular basis. This is particularly important in the first year following graduation.

IChemE's membership team should put in place mechanisms to support young members working in SMEs, recognising they require more support than in large companies, and may be required to pay their own membership.

IChemE's marketing team should review promotional materials to promote the benefits of membership – both corporate and individual membership. IChemE should review its corporate and individual membership application processes and see where streamlining could take place and where applicants could be better informed.

IChemE should look at the possibility of increasing access to its courses for SMEs. This could be through an SME discount for events/training and/or increasing the amount of available courses/content online.

IChemE should review and promote its mentor scheme to SMEs.

IChemE's learned society activites, SIGs and relevant member groups should consider the production of good practice case studies to highlight the impact of involving chemical engineers in the early stages of SME development and use this to promote the profession in the bioeconomy.

IChemE should increase its engagement with (and benefit to) the SME community. This could be achieved by providing SMEs more opportunities to network, share technical expertise, and provide informal mentoring – such benefits were highly valued by SMEs. This could be best achieved through the creation of an SME portal or more informal SME networks via regional member groups. This could encourage the sharing of best practice among SMEs and allow IChemE to engage with and monitor the needs of its SME community.

IChemE should review its outreach strategy, including its promotional material, and refocus its outreach strategy to accommodate SMEs and articulate the benefits of chemical engineers to the bio sector. This should also include reviewing the potential collaboration with other organisations and clusters, such as, **IBioIC**, **NIBRT**, **FIAL** and **CPI**. IChemE could also look at the potential of collaborating with other organisations (including universities and engaged consultancies) to form informal networks and clusters, which also aid in promoting greater collaboration across the profession. These clusters could be linked in to the work of IChemE's regional members groups.

Careers

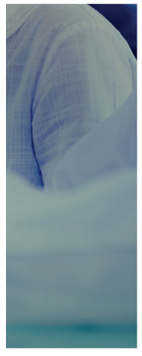
IChemE should work on and foster the interaction between universities and industry to promote career opportunities in the bioeconomy. This could enable universities and industry members to conduct site visits, act as guest speakers and/or promote work experience or industrial placements. IChemE will produce and promote new career case studies to showcase the roles of chemical engineers in the bioeconomy. These case studies should be reviewed in the future to ensure their continued relevance.

Policy

The policy group recommends that IChemE's Learned Society Committee (when formed) and relevant SIGs take the report from the Policy working group and use this to inform their future work.

IChemE should promote pathways to get more chemical engineers into government, regulators or councils so that chemical engineers can inform policy from a fact-based perspective on the inside. This aspect seems neglected in both university training and industry career development for chemical engineers.

IChemE should set up a new prize/medal for policy, whether that might be for a report that informs government, fact-based submissions for regulators, or via working within government/ regulators to make changes, or for other achievements related to policy. This would highlight the crucial importance that regulation and policy will have in the development of the bioeconomy.



Next steps

The report and recommendations will be sent to the Board of Trustees for Review and comment at the earliest opportunity - by January 2019.

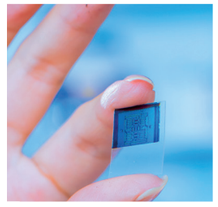
The BioFutures Programme ask the Board to approve and endorse the report. The overall report and relevant working group reports to relevant IChemE departments with a call to action– by February 2019.

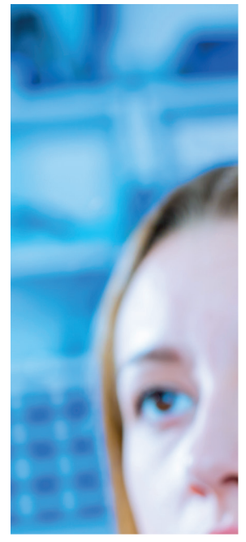
Other IChemE committees and boards, particularly those named in the recommendations will be sent the report and recommendations and asked for their agreement in principle to the recommendations – by February 2019

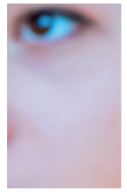
The recommendations will be prioritised and converted into an action plan by relevant stakeholders- by March 2019.

All responses, reports and action plans from stakeholders to be presented to the Board of Trustees and Learned Society Committee (when formed) – by May 2019

The Board of Trustees and Learned Society Committee (in consultation with other IChemE stakeholders) decide whether further work is needed – September 2019.







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