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Adapt or Perish: A New Approach for Industry Needs-Driven Master's Level Low-Carbon Energy Engineering Education in the UK

Paul Rowley [1,*] and Caroline Walker [2]

1 Centre for Renewable Energy Systems Technology (CREST), Loughborough University, Loughborough LE11 3TU, UK

2 Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1H 9JJ, UK; caroline.walker@imeche.org

* Correspondence: p.n.rowley@lboro.ac.uk

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Abstract: This paper describes the results of recent research carried out with the UK energy sector to assess low-carbon related skills gaps and training requirements at the masters-level. Via iterative engagement across the industry, the characteristics of the market for new 'needs-driven' industry-focussed masters-level training offerings were defined. The results, taken together with the outcomes of a gap analysis of existing masters-level training, support the creation of a new framework for masters-level energy education that will more effectively meet the growing unmet need for such skills in the UK and beyond. The outcomes of the research indicate that flexibility in both delivery mode and curriculum content across both technical and non-technical disciplines is essential, along with improved supplier agility to rapidly develop new courses in evolving engineering specialisations. Without responding effectively to such demands from industry, we conclude that the advanced skills needed across the highly dynamic UK and global energy engineering sector will be in increasingly short supply.

Keywords: masters level training; needs-driven training; Master of Science (MSc); distance learning; blended learning; competency-based training; training needs analysis

1. Introduction

Driven by increasing concerns about the social and environmental impacts of climate change and uncertainties in the security of future energy supplies, there has been a rapid evolution in recent years of new sustainable energy system technologies, policies and markets. In response, the UK government has put in place a legally binding commitment to achieve 'net zero' carbon emissions by 2050 [1]. Meeting this target will have profound implications for the future roles of engineers across a wide range of disciplines [2,3]. This ongoing and rapidly accelerating expansion of the 'zero-carbon' energy sector is already resulting in increasing demands for highly skilled sustainable energy specialists across many disciplines, especially within the engineering, information technology and commercial domains [4–6].

Within this global context, it is usually at national or regional levels that appropriate private or public sector responses to emerging skill needs are designed and implemented. Within the UK, the need for new advanced skills within the evolving energy sector has been noted for some years, as have the advantages that a highly skilled workforce brings to how well an economy, sector or company is able to adapt to changing conditions. Thus, given that highly skilled workers are shown to be better able to maximise the benefits of new technologies and identify market opportunities [7,8], it is clear that an appropriately skilled workforce is a pre-requisite for a flourishing, vibrant and sustainable low-carbon energy industrial and commercial landscape.

Whilst recent work has been carried out in the UK to assess workforce shortages at technical and trades levels [9], there has been little detailed research into specific advanced professional-level skills and competences needed within the energy sector. A 2015 report by the UK Commission for Employment and Skills assessed how skills needs are expected to evolve in key occupations, with a focus on the electrical and power systems sectors. Their qualitative analysis indicated that the mix of skills required of engineers is diversifying, with an increase in demand expected in the future for commercial skills. Key skills identified for this group include project-schedule and cost management, systems and risk analysis, data analytics, communication and negotiation skills and knowledge of new technologies (notably smart metering and smart grids). For energy engineering managers, the study anticipates a greater focus on an interdisciplinary approach, as well as a more commercial perspective applied to project management [10]. In addition to shortages of specific skills, this study identified as risk factors an ageing workforce and the loss of experienced workers and graduates to other countries, as well as a lack of STEM (science, technology, engineering and mathematics) graduates entering the sector.

Work carried out in 2017 by the Institution of Engineering and Technology (IET) reported that across the wider engineering sector, 60% of respondents identified skills gaps as their major challenge for achieving their strategic business objectives (with this as an increasing trend), whilst 73% were concerned with the lack of skills in the external marketplace [11]. All sectors reported relatively high levels of funding available for technical training, with the energy sector reporting training as being of very high priority (68%). With the demand for engineers expected to rise, talent retention was stated as a high priority, with 75% of companies reporting that they are focussing on retaining their employees by providing more developed career paths, indicating that the need for effective continuing professional development (CPD) options is likely to continue to rise [2]. In a 2018 study, the Institution of Mechanical Engineers' (IMechE) Learning Survey of 500 engineers (with 40% of these working in the energy sector) reported that their top CPD priorities by a significant margin were leadership and management, project management, creativity within engineering and change management. Respondents' priority technical topics were future energy systems, advanced manufacturing, pumps and compressors and structural technology [12].

In response to the increasing demand for appropriately skilled engineers in the UK and further afield, providers of advanced (i.e., masters or level 7) industry-focussed training have developed numerous offerings. These include full-time masters-level courses focussed on sustainable and renewable energy engineering [13] whilst masters-level CPD courses delivered *via* online or 'blended learning' methods are also available, although less numerous [14]. However, research into the efficacy of these offerings in terms of meeting the needs of organisations within the energy sector is scarce. This research gap constitutes a risk to the industry, given that the rationale for organizational investment in training programmes to meet their ongoing and evolving skills needs relies heavily on effectively identifying specific training needs in the context of company, team and individual imperatives [15]. Only then can the costs and benefits to the organization (and wider society) be justified, preferably within a robust framework of ongoing and iterative evaluation. Implementation of advanced CPD training is thus successful only to the extent that needs are carefully assessed, and that training programmes are developed and delivered to meet those needs [16].

In this context, the work described in this paper summarises the results of an industry consultation exercise carried out during 2018–2019 as part of Loughborough University's 'FlexiTEN' project. Funded under the Higher Education Funding Council for England (HEFCE, now Office for Students) 'Catalyst' industrial skills development programme, the research aims to assess companies' skills gaps and training requirements across the UK's low carbon and renewable energy economy. The UK's Office for National Statistics (ONS) has quantified this sector as comprising a turnover of over £46 billion in 2018 and employing over 224,000 workers [17]. For this study, companies were targeted across the key industries in this sector as identified by the ONS, including manufacturing, construction, professional & scientific services and electricity & gas supply. *Via* iterative engagement with stakeholders, the research also aims to define the characteristics and potential market for new 'needs-driven' industry-focussed engineering masters-level training offerings. Specifically, the objectives of the research include: (a) to identify the key industry drivers for advanced training across the UK sustainable energy sector; (b) to establish specific skills gaps within the sector, taking into account both organizational and individual characteristics; (c) to evaluate preferences for specific modes of training delivery, training curriculum content and forms of media; and (d) to identify opportunities for, and barriers to, the UK's academic sector in meeting unmet demand for industry-focussed CPD.

2. Methodology

A mixed mode methodology was employed, comprising (a) an initial interviewer-administered phase of 16 telephone interviews, followed by (b) a wider Internet survey phase involving over 120 respondents. The questions used for both the interviews and the online survey are shown in Appendix A and Appendix B respectively. The design of the mixed mode methodology followed the frameworks previously developed by De Leeuw [18] and Artino et al. [19]. Employee and company targets for both phases were selected to ensure statistical robustness. For example, care was taken to ensure that the sampling frame for interviewees and survey respondents covered all units of population interest, namely organisations within the key sectors of the UK's low carbon and renewable energy economy [17], including manufacturing, construction, professional & scientific services and electricity & gas supply. Subsequently, the risk of sampling error was minimized by ensuring that respondents were representative of the total population of interest, rather than solely a sample of this population.

Having identified the key sectoral drivers and broader economic and social trends for the sector, the training needs across technical and non-technical disciplines, together with preferred CPD training delivery modes were defined initially *via* semi-structured interviews. Then, the online survey was constructed in a manner consistent with Artino's 7-step process [19] in order to facilitate a robust statistical analysis of the industrial low-carbon economy advanced skills training landscape.

The overall conceptual framework for the research is shown below in Figure 1.

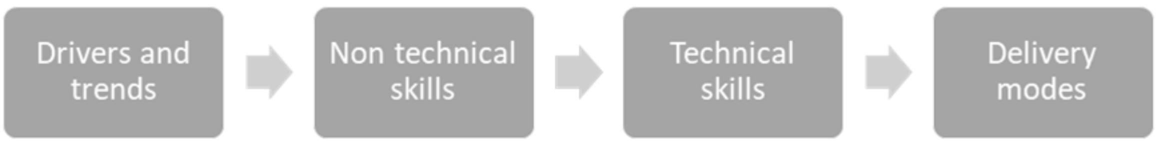


Figure 1. Research workflow.

2.1. Qualitative Industry Analysis via Interviews

A series of 16 in-depth interviews was designed to gather input from employees across a range of positions in companies from the UK's low-carbon energy sector's target industries [17]. This work then provided a framework for the questions included in the subsequent online survey, with the key purpose of gathering broader input around key points raised in the prior interviews. Taken together with our analysis of parallel recent skills needs studies, the results of the research provide an industry-led dataset to be used in subsequent analysis.

Consistent with the methodology of Artino et al. [19], a number of unstructured interviews were initially held to facilitate a broad discussion of the main aspects of the research and to ensure that the main drivers and issues were picked up for further investigation. Based on the information gathered during this first phase of work, and with a focus on gathering more detailed information on industry training needs in specific aspects, a framework was created for use in a second phase of 11 semi-structured interviews. These interviews (each typically one hour in duration) were carried out with employees across a range of company sizes and sectors relevant to the wider sustainable energy industry. Comments from all participants are reported anonymously.

2.2. Quantitative Analysis via Industry Survey

The second phase of work involved the gathering of quantitative information via an online industry survey in order to investigate some of the issues raised from the interviews in more detail. The survey questions were designed to gain an insight into aspects such as the relative importance of technical and non-technical areas for training, perspectives around accreditation and chartership, the level of preparedness for new advanced technologies, preferences for training delivery and attitudes towards self-funded *vs*. company-sponsored CPD.

The survey was promoted primarily through the Institution of Mechanical Engineers *via* their newsletters and social media channels, and *via* industry contacts from Loughborough University. Consequently, it should be noted that approximately 90% of our respondents identified their main accreditation route as via the Institution of Mechanical Engineers, with a bias towards the manufacturing sectors.

The key characteristics of the survey cohort are summarized as follows:

- 38% were from companies related to low-carbon equipment manufacturing and 32% from related professional, scientific and technical services;
- 80% identified product/process research, development and innovation as a key aspect of their business;
- 66% (83) were from companies with >250 employees and 34% (42) were from small and medium-sized enterprises (SMEs) with <250 employees.

Data from the survey were analysed primarily with respect to scoring on the Likert scale, which has been used effectively in training needs analysis to allow weighting of responses to be assigned by degree of preference [20]. We also examined the data according to overall positive or overall negative views, and with regard to differences in responses by company size. Note that the number of respondents in some specific categories was low in statistical terms, and so in these cases the data should be considered to be indicative only. Since there was some attrition as people were filling out the survey, the number of respondents varied for each question. Overall, 120 completed surveys were received.

2.3. SWOT (Strengths, Weaknesses, Opportunities and Threats) Analysis

SWOT analysis has been shown previously to be an effective method for characterizing industry-focussed skills training landscapes [21,22]. The approach adopts the perspective of the UK CPD training supply sector, which includes both private and academic (university) providers. Factors identified as being internal to the provider sector (strengths and weaknesses) and external to the sector (opportunities and threats) are thus intended to provide a helpful baseline framework for providers to design future offerings for industry. In the current work, both primary insights from our research were augmented by previous research to deliver a synthesis describing the key internalities and externalities, respectively.

2.4. Gap Analysis

Providers of professional services such as industry-focussed training are increasingly aware of the challenges involved in successfully meeting market demands, including service quality and ongoing evaluation of the client's service perceptions and expectations [23,24]. In this context, the use of gap analysis was adopted as an appropriate approach to examine the requirements for developing and delivering successful CPD into the sustainable energy engineering sector. The findings of such approaches can provide empirical insights on the gaps that can arise from erroneous perceptions of client expectations and experiences between training recipients and providers. With this in mind, the final aspect of the research focussed on gap analysis to assess the supply-side characteristics of professional training currently offered by academic (university) providers. This facilitated the identification of the extent to which offerings meet the main aspects identified in our preceding needs analysis. This involved comparing the needs of the low carbon and power/energy sectors to the main academic offerings. The intention is for the 'supply side' insights to be placed alongside our 'demand side' findings in order to support academic providers in developing or modifying offerings more suited to the needs of the wider sustainable and renewable energy industry, both in the UK and further afield.

3. Results

3.1. Overview of Industry Drivers

All interviewees identified advances in technology as driving changes in their organisations, whilst the survey data suggests that approximately half of the companies who responded were either 'somewhat prepared' or 'not prepared' for new advanced technologies (Figure 2). The response was similar when analysed by company size (<250 employees vs. >250 employees), indicating that small and medium enterprises (SMEs) within our sample are in general addressing this challenge at least as effectively as larger companies despite their (usually) more restricted resources. One interviewee suggested that this might be due to smaller companies generally being required to be more agile and adaptive to change in order to be competitive.

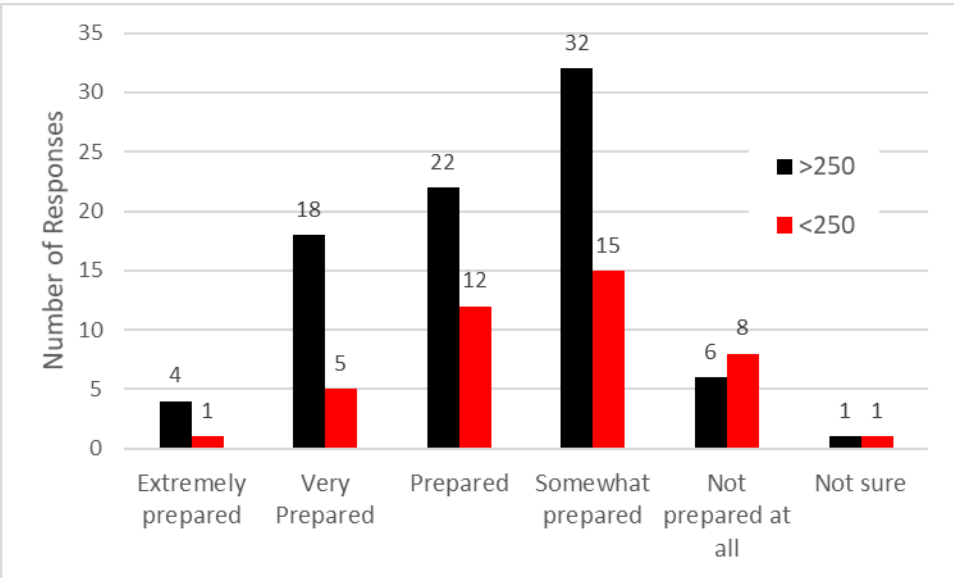


Figure 2. Respondents' views on preparedness for new advanced technologies.

In terms of drivers underpinning the need for skills in new advanced technologies, interviewees cited major ongoing technological and societal disruptions, such as the increased demand for renewable energy and low-carbon transport across the automotive, oil and power sectors. In others, interviewees highlighted disruptions being caused by new technologies driving inter-sectoral change in such areas as automation, artificial intelligence (AI), big data and virtual reality (VR).

The rapid pace of technological change was highlighted almost universally as a key driver for relevant CPD. The implication is that engineers' current technology-specific knowledge will become increasingly redundant, driving a need for continuous CPD. This also drives a parallel need for the acquisition of innovation skills needed to take advantage of new technology. In this context, companies are increasingly looking for engineers to be more adept at applying 'soft skills', and to develop their entrepreneurial capabilities and commercial skills.

Most interviewees identified that the requirement to work in increasingly diverse teams, often involving experts from other disciplines (such as design, software, etc.) means that CPD needs to cover a sufficient breadth of technical knowledge to allow for effective collaboration and communication across disciplines.

Major low-carbon engineering projects are no longer primarily delivered by one company, and so the requirement for skills around communication and stakeholder management are in increasing demand. As such, the role of the future engineer will be quite different to that of the past; personal flexibility, agility and resilience for taking on these changes will become increasingly important.

In comparison to our research, the IET's analysis [11] reported that 61% of respondents identified skills gaps as their major challenge for achieving their strategic business objectives (with this as an increasing trend) whilst 70% were concerned at the lack of skills in the external marketplace. All engineering sectors reported relatively high levels of funding available for technical training, with the energy sector reporting training as being of very high priority (68%). With the demand for engineers expected to rise, talent retention was stated as a high priority, with 75% of companies reporting that they are focussing on retaining their talent by providing more developed career paths, indicating that the need for effective CPD options is likely to continue to rise.

In our research, we specifically investigated how companies approach the issue of skills needs in new technologies. Overall, the survey indicated that 43% prefer to train existing in-house staff whereas 38% would look to fill skills gaps by collaboration with commercial partners, and 8% would hire staff with the new skills needed (Figure 3). When analysed by company size, in general larger companies (>250) were more in favour of filling skills gaps by collaboration than SMEs, whereas smaller companies seem more inclined to train existing staff. However, overall our data demonstrate a commitment for companies of all sizes to utilise CPD to fill skills gaps, hence emphasizing the potential for an appropriately designed Master of Science (MSc) portfolio to address this opportunity.

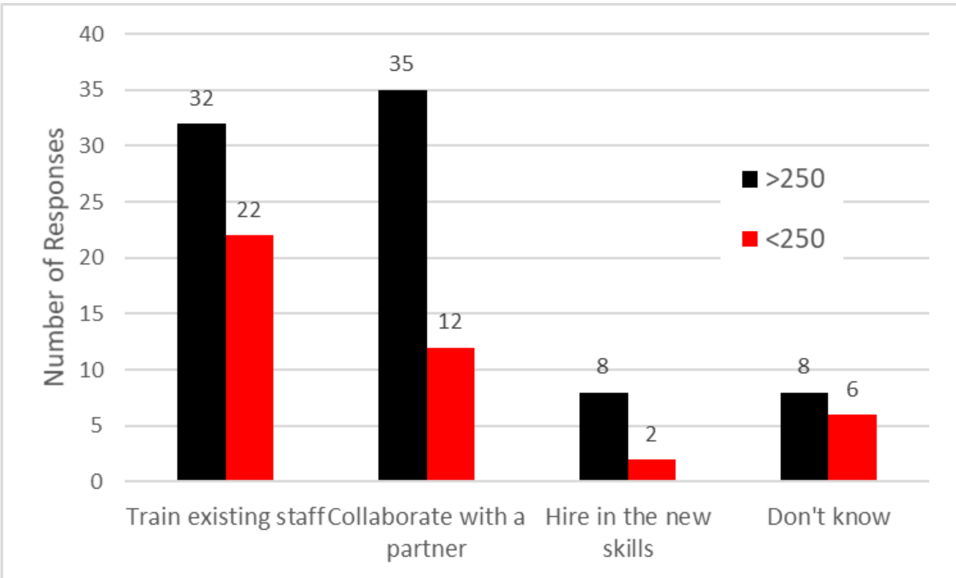


Figure 3. Industry approaches to addressing emerging skills gaps.

In terms of understanding the commitment of companies to fund CPD training, we also surveyed how current CPD was being resourced (Figure 4). Overall, 65% of survey responders said that they were sponsored by their company, with this percentage being higher (75%) in larger companies compared to SMEs (43%). In addition, survey responders in SMEs were more likely to be currently funding their own CPD (38%) than those in larger companies (10%). Although this may seem to contradict the finding that SMEs are generally in favour of filling skills gaps internally (see above), this could be due to SMEs' more limited CPD budgets combined with competing CPD priorities between the company itself and its employees.

In this regard, in several telephone interviews we found evidence for competing CPD priorities between individuals and companies. For millennials (those born between 1981 and 1996), career paths are changing; they are aware that it may no longer be possible to stay within one area of engineering for their whole career. For example, these interviewees stated that in new areas, such as smart energy systems, engineers who are able to transfer their skill sets from other relevant sectors (such as information technology) and who have an 'interdisciplinary' skillset will be in high demand.

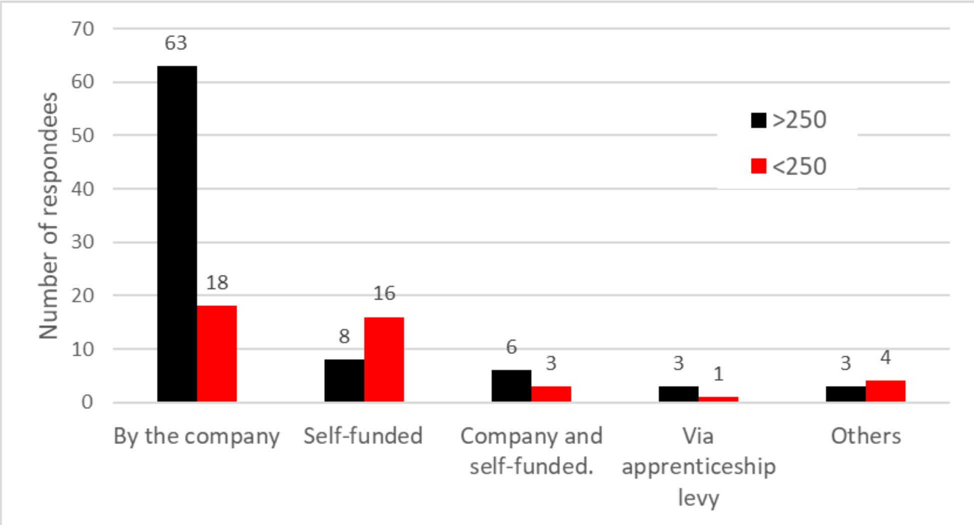


Figure 4. Industry funding approaches for existing continuing professional development (CPD).

Another key challenge will be for the current generation of younger ('millennial') engineers to develop sustainable careers, and the interviewees in this category described how they were 'future proofing' their careers by planning and financially supporting their own CPD path. In terms of engineers of all ages, their willingness to invest their own money in 'future-proofing' their careers was assessed in our online survey. We asked, 'As an individual, in the future would you potentially consider self-funding your own training for career purposes?' (Figure 5). Overall, we found 57% of respondents stating 'yes' and 34% 'maybe', indicating that the majority of respondents, regardless of generation, were considering financially supporting their own career development. When the data were analysed by company size, 74% of those in SMEs said 'yes' compared to 48% in larger companies (>250), indicating that those in smaller companies were more confident about the value of investing in their own CPD.

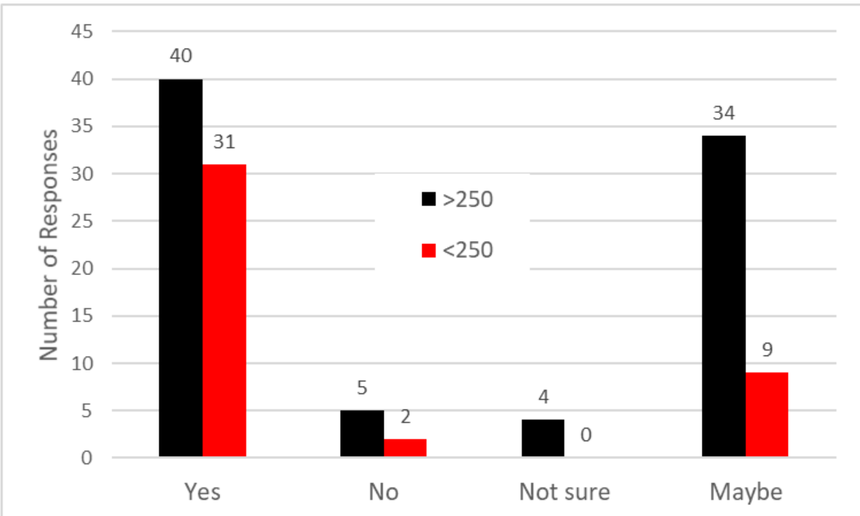


Figure 5. Individual employees' views on self-funding CPD.

In summary, our interview results taken together with the outcomes of our online survey indicate that there is a clear need for engineers to develop an appropriate blend of technical, soft and business skills. The drivers for this trend are long term and strong, and there is a broad commitment to funding CPD by both companies and individuals.

3.2. Perceptions of University Courses

The relatively high levels of potential funding from industry for the right CPD training in technical areas as reported in our research (as well as that carried out by the IET) suggests that there is a significant market opportunity for appropriately designed masters-level CPD programmes. Our research showed that several interviewees are already supporting their own CPD at MSc or Master of Business Administration (MBA) levels, as well as in terms of bespoke courses. The sponsoring of MSc and Doctor of Philosophy (PhD) projects was also a mechanism used by companies to support their own research and development programmes. For one company (which does not currently use universities for CPD), there was a positive view of working with universities in the future, providing that there was a significant change in the mode of development and delivery of courses. Data from our survey also supports this use of universities for CPD, with 50% of respondents indicating that they were currently using a small number of specific universities for professional level training. This level of university engagement for CPD was similar for both larger companies (>250) and SMEs, despite the latter generally having less resources to support CPD (Figure 6).

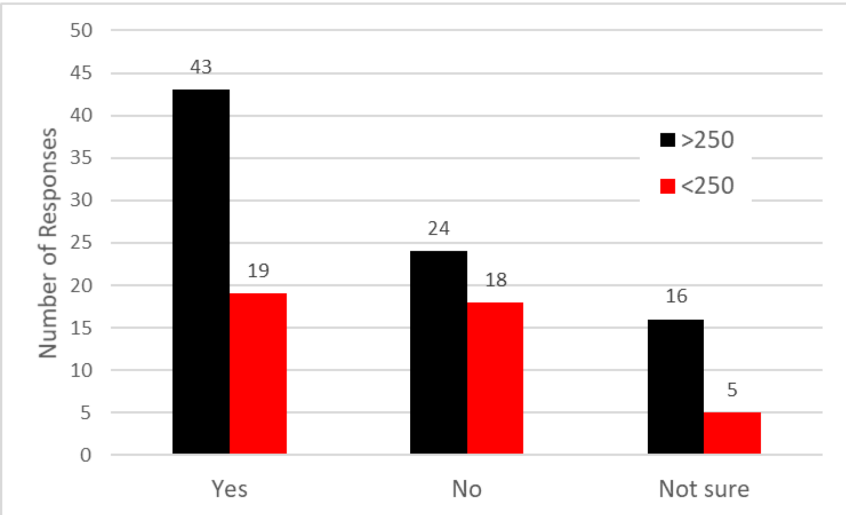


Figure 6. Companies' CPD provision sourced from universities.

While these drivers present an opportunity for developing masters-level CPD for engineers, the interviews also identified a significant risk, namely the current view of the university sector in general in terms of CPD provision, with universities being perceived as not well placed to fill specific technical skills gaps, being described as 'out of date', and 'lacking commercial awareness and industrial experience'. There was also scepticism whether universities can produce courses at a speed needed to meet the needs of technical training in emerging areas. Some interviewees stressed that any new technical courses must include a practical hands-on element and that this was especially important with regards to training in new low-carbon technologies. The courses also need to be 'leading-edge' and delivered by acknowledged experts.

Although our interviewees pointed to areas for improving the CPD offering, the survey asked, 'Would you like to be kept informed of the outcomes of the research?' and 81% said yes, further indicating that there is a sustained interest in new MSc offerings from the university sector.

Overall, the feedback suggests that, providing the higher education (HE) sector addresses some of the conceptions of the sector in the eyes of industry, and revisits how courses can be produced to match the pace of change in technology, universities would be considered positively in terms of CPD provision.

3.3. Opportunities for Training—'Millennials'

Our 'millennial' engineers (those born between 1981 and 1996) emphasised their increasing need for CPD in order to ensure that they have positive long-term career prospects. Several expressed their potential willingness to self-fund courses in order to advance their own careers; this is consistent with the high level of willingness to self-pay for CPD seen in our survey. This suggests that new and recent graduates should be a key part of the target market, and their needs should be considered in designing any new masters-level offerings.

Graduates themselves are acutely aware of how the low-carbon engineering sector is in a state of rapid change, and thus they are being strategic in their outlook in terms of keeping their skill sets broad, and focussing on transferable skills, in order to develop a sustainable career. One graduate intentionally moved directly into project management since he could see that routine engineering work (e.g., mathematical calculations) will be increasingly taken over by artificial intelligence (AI). Another graduate was moving between geology and engineering in order to be able to apply satellite mapping. They also highlighted skills gaps such as coding, which were not mentioned by the more senior industry interviewees.

A main driver in this 'millennial' group is the acceleration of their chartering journey, and general feedback was that this link is essential to make the business case for training. Our survey asked, 'How important is it for your training to be accredited for chartering?'; overall 36% responded that it was either essential or very important, with 27% responding that it was important. Once again, this agrees with the views from the early career individuals interviewed who saw chartering as the main route to their career development.

3.4. Opportunities for Training—Mid-Career and Senior Engineers

All participants described various approaches to accessing CPD for graduates and apprentices, and there is a clear focus in most companies to support early career engineers in developing their skills. However, although there is also a clear and pressing need for established engineers to continue their CPD in order to be able to apply new low-carbon technology, there does not seem to be a high level of investment or formal programmes in place to do this. For some in this group, CPD is generally self-led, typically using free material online, or involves attending industry events and independent learning (e.g., computer coding, new software such as Building Information Modelling (BIM)) to support new skills development. For employees in managerial positions, it is evident that 'change management' is becoming a key skill requirement, as new technologies can require major changes in methods of team working, with frequent resistance to adopting them. This raises the possibility that more investment for CPD for established engineers will become available moving forward, and CPD suppliers for this group should consider the specific needs of this potential client base.

3.5. Current Training Providers—Some Insight into Providers

Currently there is an evident gap in the marketplace for training around new low-carbon technologies, and as a result many companies are accessing training in these areas from manufacturers and suppliers on an informal, ad hoc basis. This could pose a potential threat to university providers in the longer term since suppliers of such technologies are likely to be both cost effective and up to date, with the advantage of being 'hands on'. Conversely, specific suppliers of advanced technology potentially present an excellent collaboration opportunity and resource for the development of a unique CPD offering that meets the requirements of being 'timely' and 'relevant'. Investigating options around such strategic partnerships may be of interest.

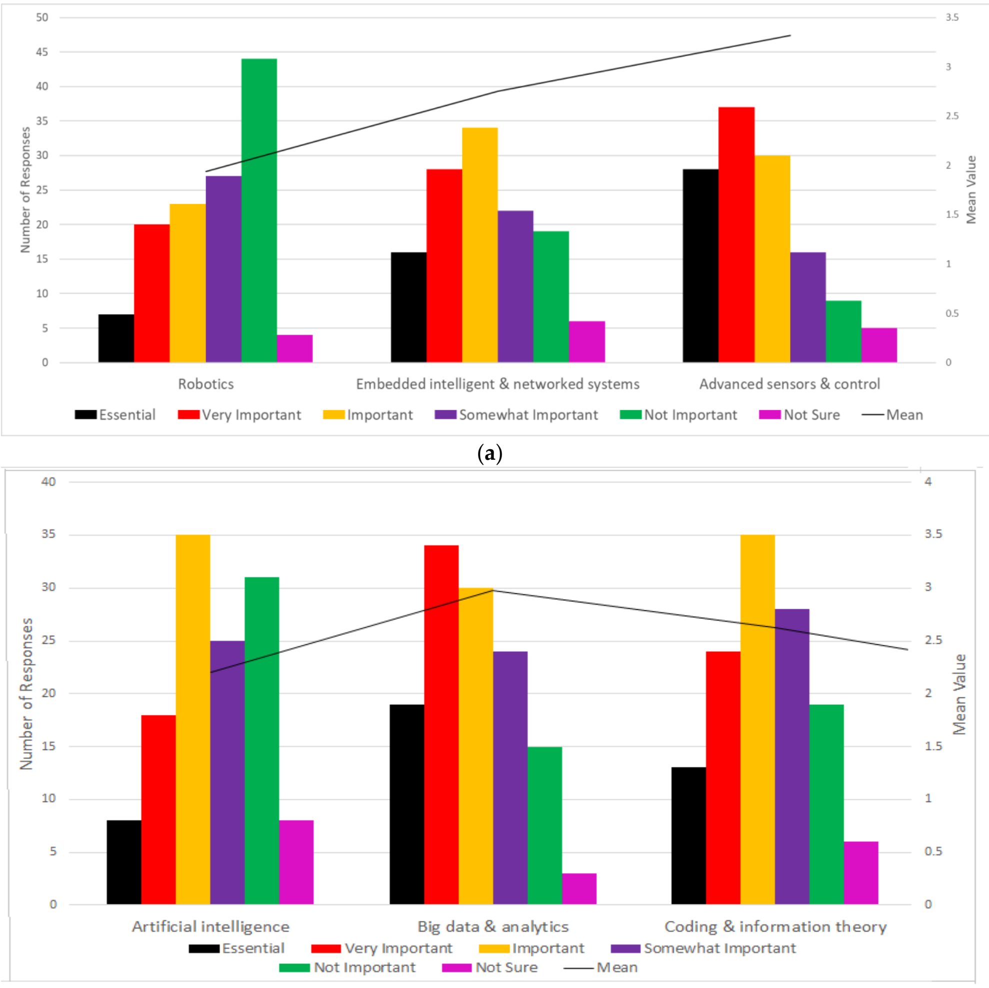
As may be expected, there is a variety of strategies being used to access relevant CPD. For example, large multinational companies generally have in-house programmes for soft skills and business skills, or external bespoke programme providers. Technical training is often arranged through internal academies or via suppliers or through conference attendance. In contrast, smaller companies are generally more reliant on external providers for soft skills training, and technical training is either sourced in-house or ad hoc with suppliers.

3.6. Technical Skills Gaps

From our interviews and review of industry reports, the first phase of our research identified a variety of topics as CPD priorities for industry, which depend somewhat on specific low-carbon industry sub-sectors. For example, 'renewable energy systems and low-carbon technologies' were identified as the top priorities in the previously cited IMechE survey and by interviewees in our current study. The IET survey also noted sectors with the highest spent on technical training were electrical/electronic and energy.

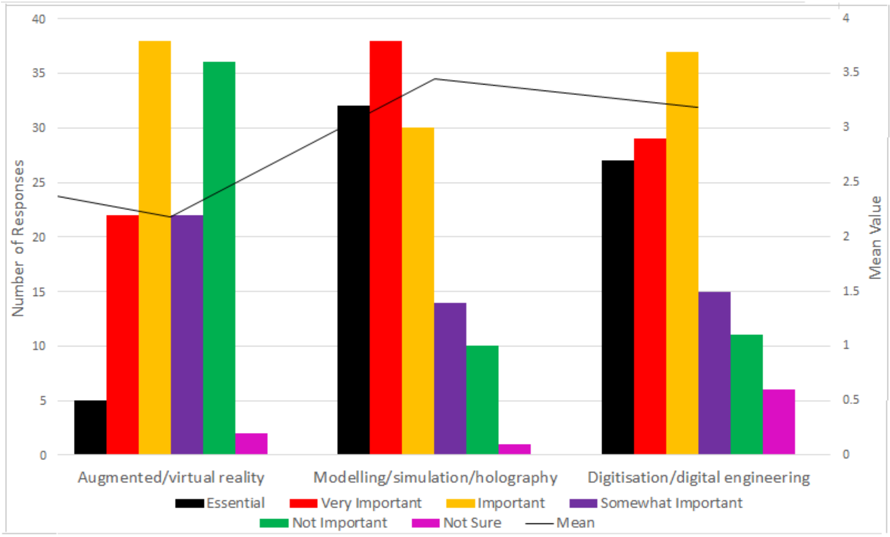
The key specific topics mentioned by our interviewees included robotics, modelling, 3D visualisation, coding, AI, digital technology, big data analytics, virtual and augmented reality, holography, technology interfaces, new energy generation technologies, collaborative innovation and advanced manufacturing

In order to establish the priority technical curriculum subjects, topics highlighted in the interviews were included in the wider online industry survey to generate more robust data, as shown in Figure 7a–c.



(b)

Figure 7. *Cont.*



(c)

Figure 7. (**a**–**c**) Addressing industry skills gaps: Priority subjects in advanced technologies.

For the more disruptive technologies, in contrast to the interviewee responses regarding key drivers, the survey data suggest that in general, topics such as AI or robotics are seen as neither 'essential' nor 'very important' (Table 1). This is in contrast to the current thinking around how these disruptive technologies will transform industry. Thus, the survey data suggest that there may still be a general lack of understanding in companies around the impact of disruptive technologies, and anecdotal evidence from our interviews suggested that that there may be generational differences at play here. We are not able to draw conclusions from our survey data regarding anecdotal interview comments about generational differences in attitudes to new disruptive technologies. As such, this aspect could be worthy of future work.

Table 1. Ranking of responses to the importance of 'disruptive technologies'.

Topic	Likert Average Score	Overall Positive (Important) %	Overall Negative (Not Important) %
Robotics	1.9	21	57
Artificial Intelligence (AI)	2.2	21	45
Big data and analytics	3	42	31
Coding and information theory	2.6	30	38
Augmented reality/virtual reality (AR/VR)	2.2	21	46
Modelling/simulation/holography	3.4	56	19
Digitisation/digital engineering	3.2	56	21
Embedded intelligent and networked systems	2.8	35	33

3.7. 'Soft' and Business Skills Gaps

With a greater range of technical specialists involved in projects, better communication and soft skills are needed to deliver projects successfully. Our research indicates general agreement in terms of the importance of gaining soft skills, and the view that such skills will support engineers' career advancement in terms of moving into management roles. The results also indicate a trend for these skills to be required much earlier in engineers' careers due to project teams rapidly becoming more diverse. One senior industry interviewee commented that graduates need to 'hit the road running' and 'quickly get out of the box' to develop broader skill sets (soft skills and business skills) when they join an organisation. It was also highlighted that skills gaps in graduates are becoming apparent at an earlier stage, especially in areas such as team communication, due to the more diverse nature of project groups. As an example of an innovative response to such issues, one company identified the need for senior engineers to develop their communication skills to work more effectively with their field engineers. In this case, the company is developing the use of real-time virtual visualization tools for its field personnel, which will allow senior engineers to remotely diagnose problems in conjunction with their field teams.

For business skills gaps, those identified tend to be more operational than strategic, and there is a view that engineers generally need to become more commercially aware. While most companies made some provision for soft skills training, training in core business skills does not seem to be as well supported, especially in the smaller-sized companies where there is an expectation that engineers will informally pick up business skills over time.

One company identified that they are looking to 'rediscover the human element in the technical world—the Human Six Sigma' and recommended that project and people management should be delivered as a joined-up CPD offering. Knowledge sharing and management is also highlighted in two multinationals as a challenge to ensure that learnings about new technologies are shared and retained within the company.

Key soft skills and business topics mentioned by interviewees in our research include: diversity in team dynamics; knowledge sharing; project and risk management; communication; mentoring; contract law; finance; commerciality; procurement and tendering; stakeholder management; reliance and flexibility; entrepreneurship and market dynamics (ideally tailored to a specific sector).

The relative priorities of these topics to support subsequent curriculum development were investigated further through the online survey and are summarised in Table 2. Likert scores are in general high and consistent across soft and business skills topics indicating overall agreement on their relative importance. However, analysis in terms of 'overall positive' (sum of 'essential' and 'very important') suggests that project management, communication and knowledge management are especially highly regarded. Both project management and knowledge management can be regarded as operational (rather than strategic) in nature, and this raises the question of whether the non-technical CPD topics within a new masters-level offering would be more attractive to the market if they were applied and sector-specific, rather than as a generic offer from a business school, for example.

Table 2. Ranking of responses to the importance of soft and business skills.

Topic	Likert Average Score	Overall Positive (Important) %	Overall Negative (Not Important) %
Project management	4.3	85	4
Law	2.9	28	31
Team leadership	4.2	39	4
Communication	4.4	86	2
Knowledge Management	4.1	81	3
Innovation and entrepreneurship	3.7	63	3
Understanding market dynamics	3.4	55	10
Change management	3.9	67	5

3.8. Modes of Delivery

There was strong agreement across interviewees and survey respondents in terms of the most important priorities in the delivery of masters-level CPD. The most important aspects can be summarized as follows:

- Flexibility is seen as key, to ensure that training can fit around fluctuations in workload, allow a good work–life balance, fit around holidays and allow last minute changes.
- Bespoke and tailored provision is seen as important to allow personalisation, strong relevance and better value.
- Blended learning with high quality e-learning is seen as being a central aspect of any training offering.

- A high degree of relevance is required in terms of learners' specific roles and their organisation's field(s) of activity.
- Programmes should be dynamic, with technical topics kept up to date.
- A modular structure is well regarded as an option, and for enabling a personalised programme.
- Course costs should be reasonable, but respondents/organisations are willing to pay for quality.

Our interviewees expressed a preference for flexible online (or blended) delivery, with fewer interviewees strongly favouring block release forms of delivery. These preferences were investigated further via the survey, with the outcome shown in Figure 8.

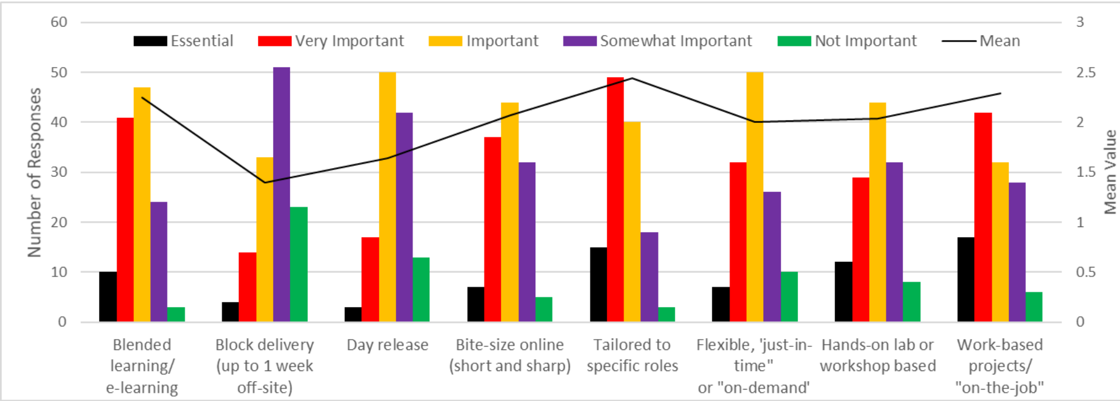


Figure 8. Industry preferences on training delivery modes.

In summary for this section, the wider survey data show broad agreement with our interviewees in terms of the essential requirements for industry-focussed masters-level renewable and sustainable energy engineering training, especially with regards to content tailored to specific needs and high quality blended/online training. The least popular options are around CPD in block delivery or day release format.

3.9. SWOT Analysis

Table 3 contains a description of the key strengths, weaknesses, opportunities and threats (SWOTs) currently affecting the wider sustainable energy engineering CPD environment in the UK. Drawing principally on results from our engineering professionals' and employers' interviews described in previous sections, the analysis contains primary insights from our own work which is augmented with meta-analysis of previously cited research. Taken together, this delivers a synthesis describing the key internalities and externalities of the CPD training environment, respectively. This analysis focusses primarily on sustainable engineering sector personnel skills, training, recruitment and career development aspects, with the intention of clarifying the wider current industry advanced skills training and career development landscape for the benefit of current and future advanced CPD training providers.

The analysis indicates that a number of factors are generic across all occupations, and indeed the wider low-carbon energy sector, whereas others are specific to one or more roles. The SWOT analysis approach adopts the perspective of the UK CPD training supply sector, including both private and academic (university) providers. Factors identified internal to the provider sector (strengths and weaknesses) and external to the sector (opportunities and threats) can thus provide a helpful baseline framework for the design of future offerings to industry. The implications are discussed in more detail in subsequent sections.

Table 3. SWOT (strengths, weaknesses, opportunities and threats) analysis: widening access to sustainable energy engineering CPD.

Strengths	Weaknesses
Employers acknowledge the pressing need to address key skills shortages across the sector. The wider energy sector is vibrant and dynamic, with numerous career development opportunities across engineering disciplines. Extensive cross-sector opportunities and synergies are widely achievable, such as data analytics and financial services. Examples of excellent industry-focussed training provisions exist, predominantly within companies that have a culture promoting internal training. Exemplars exist (e.g., Sheffield Advanced Manufacturing Centre) of academic/industry training excellence; templates for replication? Strong commitment to chartership and related CPD from industry professionals.	Lack of multi-stakeholder coordination and collective working to tackle skills gaps. Limited existing pool of experienced staff with relevant existing skills. High demand and competition for skilled staff resulting in a high level of employee mobility. Significant time and financial investment needed to gain skills within a highly dynamic sector. Issues in recruiting/retaining employees with the right blend of technical and 'soft' skills. Some sub-sectors have an ageing workforce, and internal planning for succession has been poor in some cases. Can take years to attain sector-specific advanced knowledge and skills; this is an issue for middle management roles especially.
Opportunities	**Threats**
Growing perception amongst potential recruits that the sector is attractive due to modernisation and investment to meet current challenges. Some providers are beginning to develop innovative flexible and tailored training products. Growing skills gaps represent opportunities for training young people in specific industry roles. Growing clarity available on progression routes (e.g., chartership) can assist talent recruitment and career progression pathways. Better sector-specific careers marketing and information can increase interest in the sector. Trend towards self-funding CPD, providing an upskilling-motivated workforce. Increasing development of technology platforms to drive more sophisticated and engaging ways to deliver blended training. Ethics-driven career paths are given higher priority amongst millennials, especially in energy for development training. Mandated CO_2 targets present opportunities for medium term compliance and risk training.	Current shortfall of STEM (science, technology, engineering and mathematics) skills and limited and future take-up. Increasing transition to a mobile and temporary/contracting workforce constrains expensive upskilling in a potentially unstable employee pool. Focus on progression into managerial roles reduces advanced engineering-specific skills pool. Perception that some energy sub-sectors, working environments and occupations are not attractive to younger candidates or employees in other sectors. Uncertain business outlook risks companies reducing investment into skills training. A growing global sector increases opportunities for skills overseas and could reduce the UK/regional skills pool. Pre-millennial workforce resistant to retraining (or supporting others to train) in AI, big data, coding, etc.

3.10. Gap Analysis

In this section, we focus on UK university masters-level provision, and assess its suitability in meeting current industry needs as evaluated in previous sections of this paper. As of mid-2019, over 70 masters-level programmes related to renewable and/or sustainable energy engineering were available in the UK across 40 institutions. Of these programmes, 25 were available as part-time study, and nine were available via distance learning. The growth in headcount for these programmes was approximately 30% over the preceding two years, and over 2/3 of the total cohort comprised full-time international students, with strong representation from Asia, especially China. Programmes are typically composed of a series of 'modules', each comprising of 15 'credits', equivalent to 150 total study hours. A major project module is common to all programmes, typically of 60 credits (600 total study hours).

Figure 9 represents a graphical analysis of 18 of the most popular MSc programmes covering renewable and sustainable energy engineering. The analysis focusses on two of the key characteristics identified in our industry needs analysis, namely (a) the degree of module choice available within each programme (as seen on the ordinate scale axis) and (b) the extent to which each programme focuses on technical subjects as opposed to broader management or other related non-technical subjects, as seen on the abscissa scale axis. It can be seen that programmes fall into two main categories, namely a group of more technical programmes offering varying degrees of choice in the module selection, along with 'broader' programmes, again with each offering a varying degree of module choice. Given the relatively high number of available relevant programmes in the UK, it is perhaps surprising that few are either targeted primarily at the CPD market, as evidenced by both the structure of the courses (typically offered in modules of 15 credits or 150 learning hours), or in their modes of delivery. Although around 50% of courses are available as part-time study, these predominantly require campus attendance, with only nine courses available via remote delivery. As such, this gap represents a risk to providers, given the volatility of MSc enrolments from the traditional UK/EU and international markets.

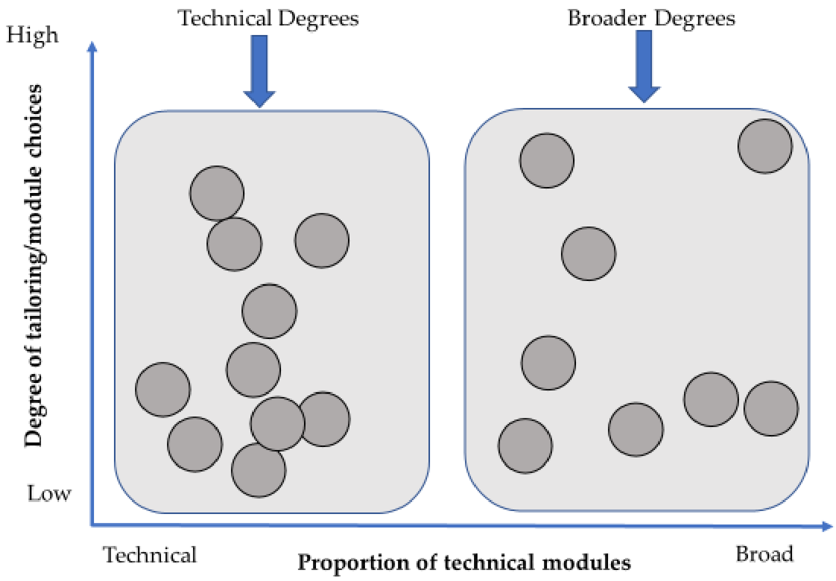


Figure 9. Characteristics of UK universities' Master of Science (MSc) courses in sustainable or renewable energy.

4. Discussion

By a conservative estimate, achieving a 'net-zero' UK economy by 2050 will require infrastructure investment in excess of £500 billion (£5 × 10^{11}) over the next two decades [25]. In terms of meeting the volume and variety of skills training demanded by the sector over this period, significant challenges and opportunities are apparent for providers of advanced (master's level) training across the sector. The provision of appropriate advanced CPD across technical specialisms, project delivery/management, financial/market and policy domains will be vital to the 'net-zero transition', and the academic community (ideally working in partnership with the private sector), needs to play a key role in developing, accrediting and delivering relevant courses [26]. However, there is currently considerable scepticism amongst industry in terms of the capability of UK universities to fully understand the specific requirements of industry, and to develop and deliver suitable advanced training in a timely manner.

Universities who want to grasp the rapidly growing opportunities within the industry needs-driven market need to understand and internalise the specific imperatives of the sector, especially with regards the rapidly evolving data-driven 'industry 4.0' landscape. This requires academic training providers to adopt new perspectives on the marketplace, and to make changes in their traditional approaches to development and delivery of masters-level training that is suited to the needs of industry.

Over recent decades, the nature of academic masters training has developed to serve the perceived needs of more 'traditional' market segments. Primarily, these segments have been characterized by students arriving direct from undergraduate programmes, studying full-time over one year, with a focus on the international non-UK market given its scale and potential revenues. Within this demographic, there exists a smaller proportion of full-time students who arrive after working some time in industry and are seeking a change in career.

Adapting such a framework to meet key industry demands in terms of subject choice, delivery mode and up-to-date content is not straightforward. Often, the somewhat sclerotic nature of UK institutions' accredited course approval procedures hampers their ability to rapidly develop new training offerings within the necessary timeframes. Inherent problems also exist in accrediting experience or training gained outside traditional academic environments, and in demonstrating the agility and flexibility needed to offer relevant applied training focused on specific specialisms within a coherent CPD career progression framework that may require creative solutions (such as mentoring) as part of the overall package.

Finally, the complex issues of benchmarking new programmes of flexible, dynamic and tailored CPD training and ensuring quality in terms of the training outcomes across different geographic jurisdictions and disciplines should not be underestimated. In this regard, new innovative approaches to achieving flexible work-based pathways towards professionally qualified engineer status are required. To this end, it would be to the benefit of both academic CPD providers and organisational or individual end-users to adopt frameworks such as that outlined by the Engineering Council [27], whereby academic supervisors work with employers and individuals to review competence and achievements and identify and define suitably challenging opportunities. Through this approach, the intention is for an individual to gain sufficient learning at the appropriate level to achieve an advanced degree. However, such flexible work-based pathways based on engineering 'learning contract'-based approaches are largely new and unfamiliar to both academic providers and employers, and as such would require careful design, implementation and ongoing evaluation.

In summary, the research described in this paper illustrates the need for all stakeholders to adapt to the dynamic and rapidly evolving 'net-zero' economy. On the one hand, the UK industry needs to quickly evolve in order to remain competitive within a global 'net-zero' product and services marketplace. On the other hand, UK universities need to rapidly develop new advanced CPD training solutions in order to become relevant within a very significant and growing industry-focussed international low-carbon skills training market.

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Glossary

AI	Artificial intelligence
BIM	Building Information Modelling
CPD	Continuing professional development
HEFCE	Higher Education Funding Council for England
IET	Institution of Engineering and Technology
IMechE	Institution of Mechanical Engineers
OfS	Office for Students
SWOT	Strengths, weaknesses, opportunities and threats

Appendix A. Structured Interview Questions

Appendix A.1. Overview

What are currently the main challenges with respect to skills gaps that engineers in the industry/your sector/organisation is facing at the moment? What is driving this?

In the longer term (5–10 years), are there any other skills gaps that you are aware of that the industry will have problems filling.

What is your view on the currently available CPD options for developing technical/business/management skills in these areas at the moment—Is it fit for purpose now and will it be fit for purpose in the future?

Appendix A.2. Technical Topics

What technical topics do you consider the highest priority for the industry/your organisation for CPD and filling future skills gaps? (why is this?) e.g., big data, industry 4.0.

Are there any additional areas, maybe more specific to your sector, that you think should be developed? Do you think that there will be a greater need sector specific training going forward?

How do you/would you currently cover filling technical skills gaps?

Some companies have suggested that in the future universities should be providing stand alone modules (e.g., 1 week intensive courses) to help fill skills gaps for engineers—do you agree/believe that it would be useful and an attractive option?

Some companies are looking for universities to provide tailoring of courses e.g., creating some 'private' modules for a particular organisation that might reference their own internal processes? In your opinion, do you see this as a trend—an attractive/useful concept?

(If yes, will ask if happy to come back and contact you to discuss this in more detail in the future?)

Appendix A.3. Business and Leadership Skills

In terms of business and soft skills, what do you consider to be a priority for engineers? Why? e.g., change management, innovation, Decision science (making decisions with big data), innovation management, change management, potentially entrepreneurial skills.

Do you see this changing in the future?

How do you/would you currently approach cover filling business/management skills gaps?

Again, if universities were to develop offerings for CPD in these areas to fit the future needs of organisations? What would you ideally be looking for?

Appendix A.4. What Is the Ideal Mix of Management vs. Technical?

It has been suggested that it would support engineers with their chartering if universities were to design a 'package' and qualification ie potentially an MSc, specifically for engineers. Do you agree?

Could you give a steer on the balance between modules on engineering vs. business and soft skills that you believe would fit best with the future need of engineers.

Appendix A.5. What Is Essential in the Mode of Delivery?

Some companies have stressed to us that universities need to consider very carefully the mode of delivery for courses in order to make it feasible for those combining work and study.

In order for engineers to combine their work with taking CPD courses at University what approaches do universities need to consider to make this work best? Will discuss around options such as, distance learning, block delivery of modules (face to face), number of years? Any other suggestions for flexibility.

Many university courses have included the option of an in-company research Project, which would be decided by consultation between the organisation and the academic mentor—in your experience, do you see that this is useful/practical/feasible?

What are your views on the provision of coaching and mentoring as a part of the delivery of university courses for those in full time employment?

Appendix A.6. Funding and Support

Universities need to understand the future of funding and support for engineers if they are going to develop appropriate options for CPD.

What do you believe is the balance between company funded CPD vs. self-funded CPD for engineers in the industry—Do you see this changing in the medium to longer term (3 years +)? What are the drivers?

Can you share how your organisation currently supports your engineers with external CPD courses? Who identifies them and how does the approval system work—are there different systems for (technical vs. soft)?

As mentioned above, it has been suggested to us that universities might create a 'engineer specific package/Msc'. In your opinion, would a company of your size consider this to be an attractive option and fund/support this if this were to be developed? If so, at what level in the organization (early career graduates, senior engineers, managers etc) would you support this (ask what sort of numbers).

The apprenticeship levy—do you believe that universities should be creating post grad level (masters level) options that would be able to be funded using this levy?

Appendix A.7. Anything Else?

In summary, how do you see the university sector supporting the CPD of engineers in the future? For example, do you think that they should be focusing on creating a tailored qualification (MSc), stand alone modules (e.g., 1 week intensive on a topic), or combining both or offering something completely different?

Is there anything else that you advise that universities should be focusing on in this area e.g., what else would industry be assessing or expecting when considering using the university for CPD?

Appendix B. Online Survey Questions

1. About you and your company	What is your company's main area of business?
	How many staff are employed in your company?
	Are product/process research, development and innovation key aspects of your business?
	What is your role within your company?
2. Training needs:	
In terms of you or your company's training needs, priority technical subjects include: (choose one or more)	Robotics
	Artificial intelligence
	Big data and analytics
	Coding and information theory
	Augmented/virtual reality
	Modelling/simulation/holography
	Digitisation/digital engineering
	Embedded intelligent and networked systems
	Power and energy networks
	Renewable energy/low-carbon technologies
	Electric and low-carbon vehicles
	Advanced sensors and control
	Lean/agile production
	Advanced manufacturing
	Holistic/through-life engineering
	Digital telecommunications
	Engineering materials
	Engineering risk
	Other(s) (please specify)
Priority Business/management subjects include: (choose one or more)	Project management
	Law
	Finance/investment/commercial
	Team leadership
	Communication

2. Training needs:	
Priority Business/management subjects include: (choose one or more)	Project management
	Knowledge management
	Innovation and entrepreneurship
	Understanding market dynamics
	Change management
	Other(s) (please specify)
	How important is it for your training to be accredited for Ceng?
	What accreditation route(s) are most relevant?
3. Future outlook	How prepared is your company for new advanced technologies?
	If experience in a new technology is needed, would your company...
	What would you say are the three biggest challenges to your business in the next year?
4. Training delivery: In terms of training delivery, courses should be: (choose one or more)	Blended learning/e-learning
	Block delivery (up to 1 week off-site)
	Day release
	Bite-size online (short and sharp)
	Tailored to specific roles
	Flexible, 'just-in-time"/on-demand'
	Hands-on lab or workshop based
	Work-based projects/"on-the-job"
	Other(s) (please specify)
	Is any of your professional-level training delivered by a University or other HE provider?
5. Funding	How is your own current professional training being funded?
	As an individual, in the future would you potentially consider self-funding your own training for career development purposes?
	Would your company consider using Apprenticeship Levy funding to pay for masters-level training?
6. Keeping in touch	Would you like to be considered for a free IMechE Team Diagnostic?
	Would you like to be kept informed of the outcomes of the FlexiTen project?
	If yes to either of the preceding questions: What is the name of your company?
	Please enter your contact details. Phone number and email address
	What is the best way to contact you?

References

1. Walker, P.; Mason, R.; Carrington, D. Theresa May commits to net zero UK carbon emissions by 2050. *Guardian* **2019**, *11*, 19.
2. Guthrie, G. Achieving net-zero greenhouse gases will take civil engineers into uncharted territory. *Proc. Inst. Civ. Eng.Civ. Eng.* **2019**, *172*, 99. [CrossRef]
3. Tavoni, A. Long-term scenarios: Energy pathways in the UK. *Nat. Energy* **2017**, *2*, 17034. [CrossRef]
4. Jennings, P. New directions in renewable energy education. *Renew. Energy* **2009**, *34*, 435–439. [CrossRef]
5. Skea, J. Research and evidence needs for decarbonisation in the built environment: A UK case study. *Build. Res. Inf.* **2012**, *40*, 432–445. [CrossRef]
6. Chilvers, J.; Foxon, T.J.; Galloway, S.; Hammond, G.P.; Infield, D.; Leach, M.; Pearson, P.J.; Strachan, N.; Strbac, G.; Thomson, M. Realising transition pathways for a more electric, low-carbon energy system in the United Kingdom: Challenges, insights and opportunities. *Proc. Inst. Mech. Eng. Part A J. Power Energy* **2017**, *231*, 440–477. [CrossRef]
7. Easton, B.; Gaddo, F.; Walker, H. *Powering the UK. The Role of the Power and Gas Sector in the Wider Economy*; Ernst and Young LLP: London, UK, 2011.
8. Lucia, Ó.; Burdio, J.M.; Acero, J.; Barragán, L.A.; Garcia, J.R. Educational opportunities based on the university-industry synergies in an open innovation framework. *Eur. J. of Eng. Educ.* **2012**, *37*, 15–28. [CrossRef]
9. *Energy and Utilities Workforce Renewal and Skills Strategy 2020*; Energy & Utility Skills Limited: London, UK, 2017.
10. Brennan, J.; Limmer, H. *Sector Insights: Skills and Performance Challenges in the Energy Sector*; Commission for Employment and Skills: London, UK, 2015.
11. Institution of Engineering and Technology (IET). *Engineering and Technology: Skills and Demand in Industry 2019*; IET: London, UK, 2019.
12. Institution of Mechanical Engineers (IMechE). *Learning Survey 2018*; IMEchE: London, UK, 2018.
13. Kandpal, T.C.; Broman, L. Renewable energy education: A global status review. *Renew. Sustain. Energy Rev.* **2014**, *34*, 300–324. [CrossRef]
14. Boreland, M.; Faiz, K.; Rowley, P.; Infield, D.; Arrowsmith, G. A European masters in renewable energy-alleviating skills shortages for the photovoltaic market. In Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, Osaka, Japan, 11 May 2003; Volume 3, pp. 2596–2598.
15. Ment, T.N. Training need assessment: A critical study. *Int. J. Inf. Technol.* **2011**, *4*, 263–267.
16. Brown, J. Training needs assessment: A must for developing an effective training program. *Public Pers. Manag.* **2002**, *31*, 569–578. [CrossRef]
17. Office for National Statistics. Low Carbon and Renewable Energy Economy Estimates. Available online: https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset (accessed on 27 March 2020).
18. De Leeuw, E.D. To mix or not to mix data collection modes in surveys. *J. Off. Stat.* **2005**, *21*, 233–255.
19. Artino, A.R., Jr.; La Rochelle, J.S.; Dezee, K.J.; Gehlbach, H. Developing questionnaires for educational research: AMEE Guide No. 87. *Med Teach.* **2014**, *36*, 463–474. [CrossRef] [PubMed]
20. Niazi, A.S. Training and development strategy and its role in organizational performance. *J. Public Adm. Gov.* **2011**, *1*. [CrossRef]
21. Natarajan, R. The role of accreditation in promoting quality assurance of technical education. *Int. J. Eng. Educ.* **2000**, *16*, 85–96.
22. Törngren, M.; Bensalem, S.; McDermid, J.; Passerone, R.; Sangiovanni-Vincentelli, A.; Schätz, B. Education and training challenges in the era of Cyber-Physical Systems: Beyond traditional engineering. In Proceedings of the WESE'15: Workshop on Embedded and Cyber-Physical Systems Education, Amsterdam, The Netherlands, 4 October 2015; pp. 1–5.
23. Wright, P.C.; Geroy, G.D. Changing the mindset: The training myth and the need for world-class performance. *Int. J. Hum. Resour. Manag.* **2001**, *12*, 586–600. [CrossRef]
24. El Fadel, M.; Rachid, G.; El-Samra, R.; Boutros, G.B.; Hashisho, J. Knowledge management mapping and gap analysis in renewable energy: Towards a sustainable framework in developing countries. *Renew. Sustain. Energy Rev.* **2013**, *20*, 576–584. [CrossRef]

25. Tollefson, J. IPCC says limiting global warming to 1.5 C will require drastic action. *Nature* **2018**, *562*, 172–173. [CrossRef] [PubMed]
26. Busawon, A.N.; Penlington, R.; Perera, N. Engineering continuing professional development and mobility in the European green job market. In Proceedings of the 2012 2nd International Symposium on Environment Friendly Energies and Applications, Piscataway, NJ, USA, 25 January 2012; pp. 224–229. [CrossRef]
27. Shearman, R.; Seddon, D. Challenges for academic accreditation: The UK experience. *Eur. J. Eng. Educ.* **2010**, *35*, 469–477. [CrossRef]