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Our research centre, ProBE (Centre for the Study of the Production of the Built Environment) has spent many years carrying out research on the construction industry across Europe, including the organisation of labour and vocational education. Relevant projects include:

- *Inclusive Vocational Education and Training for Low Energy Construction*, European Commission project led by European Construction Industry Federation (FIEC) and European Federation of Building and Woodworkers (EFBWW), with 10 country partners 2017- 2019. See: <https://www.fiec.eu/our-projects/completed-projects/vet4lec>

On the basis of this research we have published a number of articles pertinent to this enquiry and in particular to the questions:

Q 2 Does the UK workforce have the skills and capacity needed to deliver the green jobs required to meet our net zero target and other environmental ambitions

Q3 What needs to be done to ensure that these skills and capacity are developed in time to meet our environmental targets?

These articles include:

- Clarke, L., Sahin-Dikmen, M., & Winch, C. (2020). Transforming vocational education and training for nearly zero-energy building. *Buildings and Cities*, 1(1), pp. 650–661. DOI:<https://doi.org/10.5334/bc.56>
- Clarke L., Sahin-Dikmen M. and Winch C. (2020), ‘Overcoming diverse approaches to vocational education and training to combat climate change? the case of low energy construction in Europe’, *Oxford Review of Education*, 46/5: 619-636 <https://doi.org/10.1080/03054985.2020.1745167>
- Clarke L., Duran-Palma F. and Sahin-Dikmen M. (2020) Towards nearly zero energy building in Europe: challenges of vocational education, in the *Encyclopaedia of the UN Sustainable Development Goals. Industry, Innovation and Infrastructure* edited by Filho W.L., Azul A.M., Brandli L.L., Salvia A.L., and Wall, T. Springer
- Clarke L. Gleeson C. Winch C. (2017) ‘What kind of expertise is needed for low energy construction?’, *Construction Management and Economics*, 35/3, pp 78-89 <https://doi.org/10.1080/01446193.2016.1248988>

Energy efficient buildings requires a different construction process from the traditional one and changes in the vocational education and training (VET) systems both in building services and building envelope occupations. The construction industry is a major contributor to CO₂ emissions and reducing the energy footprint of buildings is fundamental to creating a zero-carbon economy. Globally, around 28% of energy-related greenhouse gas (GHG) building emissions are attributed to the operational phase (i.e. energy needed to heat, cool and power buildings) and 11% to the construction phase (i.e. materials and construction process/embodied carbon). This implies a fundamental transformation of building construction into a sustainable industry.

Low energy construction (LEC), or the delivery of buildings with extremely low levels of annual energy use (expressed in kWh/m² per year), can thus play a fundamental role in meeting national and international CO₂ emissions reduction goals, not only combating climate change but also making cities sustainable. However, realising the promise of LEC requires overcoming social obstacles. A key, often overlooked, issue is the lack of expertise needed for LEC, typically evident in the gaps between design intention and on-site energy performance, otherwise known as the performance gap. But the kind of expertise required is not merely ‘technical’. Indeed, LEC calls for sets of knowledge, skills and competences that challenge existing vocational education and training (VET) systems in construction, requiring upgrading to incorporate a deeper knowledge and understanding of energy efficiency, higher technical skills and a holistic approach to the building process. A broad set of transversal abilities needs to be developed involving competences not addressed in most VET systems, such as effective communication, project management, problem solving and autonomous working. At the same time, a major transformation of the construction industry is necessary if LEC is to replace traditional construction. In other words, a sustainable construction industry should aim to

meet economic as well as social objectives, including employment opportunities, labour standards, equality and inclusion and adequate and high-quality sector-specific education.

To achieve Nearly Zero Energy Buildings (NZEB) depends on workers equipped with the appropriate knowledge, skills and competences. Yet, there are disparate approaches taken to address this, from narrow and short training programmes reliant on the private sector, most prominent in Britain, to close a perceived technical ‘skills gap’ to more comprehensive attempts to mainstream NZEB expertise into construction occupational profiles, as found in, for instance, Belgium and Germany. The focus here is on the efforts to improve the energy performance of buildings to reduce the energy used for heating, cooling and hot water, addressed through improvements to the building envelope and use of renewable sources for the remaining limited energy needed.

Technical Challenges

LEC requires a highly qualified workforce and a broad scope of abilities incorporated in different construction occupations because, technically, it demands a fundamentally different approach from conventional construction methods, one that recognises the building envelope as a single thermal unit with renewable technologies and as made up of elements that come together through the social interaction of different occupations, including bricklaying, carpentry, plastering, floor laying, insulation, electrical engineering and plumbing. The ‘technical’ challenges illustrate the need for this broader, ‘energy literacy,’ expertise required for LEC. Broadly speaking, a nearly zero-energy building (NZEB) has very high energy performance, typically specified as meeting a specific maximum *primary energy (PE) per metre squared per year* (kWh/m².yr) and thus a specified carbon dioxide emissions target (kgCO₂/m².yr). However, definitions and interpretations of NZEB vary greatly, being broadly defined as very high energy performance plus on-site or nearby renewables. Different envelope options and alternative cost optimal solutions demand a high standard of on-site knowledge and skills allied to both traditional materials, such as insulation, as well as to more complex, newer demands such as thermal bridge details and low carbon heating technologies.

In addition, the energy performance gap observed in envelope construction and building services installation is another challenge facing LEC. Standard calculations assume that models describe the as-built construction but, as numerous researchers have shown, there is an energy performance gap between predicted and measured energy when testing building envelopes before occupation. Similarly, services installation demonstrates a wide range of performance associated with inadequate design, sub-optimal installation, commissioning and operation as, for instance, with monitored LEC heating installations, such as solar thermal, heat pumps, combined heat and power (CHP) and fuel cells - the types of heating systems identified as ‘renewables.’ If these technologies are to perform as intended, they must be recognized as complex, different from conventional systems and in need of enhanced VET. VET for renewable heat, for instance, must encompass maximizing the thermodynamics of technologies such as heat pumps, their need for low temperature heating, and continuous operation among others key characteristics.

75% of the existing building stock is considered energy inefficient. Modelling energy savings for renovation or retrofit is particularly challenging due to uncertainties such as:

- structural element U values, that is the rate of transfer of heat through a structure divided by the difference in temperature (i.e. the better-insulated a structure, the lower the U-value) and Psi values, measuring the rate of heat loss through a junction;
- existing levels of heating/cooling;
- occupant adaptation to achieve affordable comfort, resulting in ‘prebound’ (and ‘rebound’ effects and leading to over-estimation of post-retrofit energy savings).

In addition, renovation work is qualitatively different from new build in that it is replete with unforeseen complexities. Often only by exploration are building defects identified and their solution resolved on site. Thus, the renovation process is reliant on a rounded knowledge and competency component, and generally less amenable than new build to prefabricated solutions. In sum, renovation

urgently requires high levels of knowledge, skills and competence and therefore enhanced VET for LEC.

The training needs of construction workers

The transition to NZEB has significant consequences for the employment, education and vocational training of construction workers. NZEB is fundamentally different from traditional construction as it introduces the concept of energy performance into a production system driven by building on time and within budget. Buildings must meet specific energy performance targets through such measures as airtight building envelopes, thermal-bridge free construction and on-site renewable energy sources. NZEB also needs a co-ordinated construction process where building parts are put together to constitute a system and function to restrict energy use to pre-determined limits. Achieving this degree of precision depends on an adequately trained workforce. This is of critical importance as evidence shows that incorrect and poor-quality installation results in the performance gap between the energy standards intended and achieved, jeopardising emission savings. Failure to build to standards required indicates problems in terms of work organisation, employment structure and the quality of VET. The energy efficiency programme for building, together with digitalisation of the industry, calls for multi-skilled and highly trained workers, necessitating an overhaul of existing VET.

To develop NZEB competencies in the workforce, the EU launched, the Build Up Skills (BUS) initiative which established that across the EU over three million workers need to be trained to meet the needs of the energy efficiency drive articulated in the EU energy strategy. The investigation also revealed that, although countries are faced with the same task of upgrading existing initial VET (IVET) to integrate NZEB competences and providing continuing VET (CVET) for the existing workforce, the scale of what is needed varies substantially. NZEB competencies have been integrated into initial VET in only a small number of countries, such as Belgium, Denmark and Germany, and is non-existent in others or limited to specific training in the installation of renewable energy systems and available to those in building services occupations and at higher levels of VET, as in Ireland, Poland and UK. VET systems in only a small number of countries, are therefore adequately equipped to integrate LEC competences into existing IVET programmes and have already made significant progress in mainstreaming NZEB competences.

Overall, with the exception of Germany and Belgium where it directly builds on the IVET system, CVET training is fragmented in the great majority of European countries and is provided by a range of private providers, technical colleges, further education organisations, public training organisations and manufacturers of renewable energy systems. Most courses in UK are standalone, focusing on imparting narrow and specific skills rather than providing comprehensive, standardised and broad VET for LEC, and many are not monitored. Overall, CVET training provision is limited in occupational range and geographical reach with most courses catering to those with some existing training and qualifications, so that limited progress has been made in terms of meeting the 'quantitative skills gap'. In terms of the 'qualitative skills gap', the significance of knowledge of energy efficiency, higher technical skills, a holistic approach to the building process, and inter-disciplinary understanding, as well as transversal abilities (such as effective communication, project management, problem solving and autonomous working) are not addressed in most VET systems. These 'gaps' represent important impediments to developing NZEB as approaches are shaped, to a large extent, by existing traditions and VET models in different European countries.

Constraints and Enablers

Despite the diversity of the construction labour market and the VET system, the UK faces the following challenges in implementing VET for LEC:

1. *structural features*, in particular a very high proportion of micro firms, rendering problematic the mobilisation of resources for IVET and CVET and investment in plant, as well as co-ordination to meet targets regarding LEC/NZEB. In addition, there is a high failure rate in these smaller enterprises, negatively impacting on trainee development;

2. *varying qualification levels* of the workforce, which present particular challenges for CVET given its generally low take-up by those with low or no qualifications. In contrast to other economic sectors, many construction workers and trainee recruits do not have upper secondary completion;
3. *workforce diversity or lack of it*, including significant numbers of non-national workers whose qualifications may be unknown or unrecognised and for whom communicative ability may be an issue. In addition, the workforce is ageing, there are difficulties in recruitment, and few women in the workforce;
4. *skill shortages*, manifest in LEC related occupations;
5. *rapid technological innovation*, particularly in LEC/NZEB techniques as well as in the digitalisation of the sector, leading to needs in both CVET and IVET that may remain unfulfilled, including for new qualifications and the upgrading of curricula for existing qualifications.

An analysis of existing VET for LEC, allows key enabling factors to be identified that support effective training provision. Social partnership and consultative structures, for instance, such as those found in Germany and Belgium, facilitate the setting of common goals and targets, and the solution of problems. Levy style funding arrangements for VET facilitate responses to new developments within the sector and promote co-ordinated skills development. A relatively highly qualified workforce, as in Belgium and Germany, is important for successful CVET activity because it gives workers the basic knowledge and competence to master new concepts and techniques. And broadly based IVET, as also seen in Belgium and Germany, emphasises LEC underpinning knowledge, such as of Building Physics and Materials, and gives workers an overview of the sector and the construction process, as well as stressing transversal abilities such as communication, co-ordination and teamwork.

Finally, there are key outstanding issues for all those concerned with developing effective training in energy efficiency for LEC. There is a need for more awareness of relevant inter-occupational interfaces, particularly through broadly based IVET. It is also necessary, both for IVET and CVET, to put more emphasis on transversal abilities, particularly communication and co-ordination, so crucial for managing occupational interfaces, not just at supervisory but also at operative levels. Abilities to understand the whole project are needed as well to supplement inter-occupational co-ordination, with implications for the overall educational level of the workforce and for national recruitment strategies for the sector. Last, particular challenges exist where CVET relies just on learning outcome-based competence certification and where it remains patchy and uncoordinated, though a number of countries are making progress through use of the levy system and social funds.

Approaches to developing VET for NZEB

Notwithstanding differences, the central task for VET providers remains the same: to establish the knowledge, skills and competences required in LEC and develop effective strategies to integrate these into IVET and CVET. The development and delivery of VET for LEC are constrained not only by labour market conditions and NZEB implementation policies and possibilities but also by the characteristics of the VET system. There is much room for improvement, including in teacher training, facilities and teaching resources, work-based learning, the governance framework, qualification standards and funding. A general lack of awareness of energy efficiency within the construction sector, including amongst employers, workers, policy makers and the general public, acts as a barrier to increasing VET for LEC.

For VET provision responsive to the changing needs of the sector, appropriate in terms of content, level and delivery methods, and congruent with the experiences of the workforce, all stakeholders need to be involved. The unified model of VET governance found in, for instance, Belgium, Germany, involves social partners – employers and unions - alongside educationalists in the development and implementation of VET policy at different levels, including in drawing up occupational profiles, regional adjustments, and the development of programmes and curricula at the local level. Here too joint funding arrangements (state and employer levy) and the dual system, whereby trainees typically spend part of the usually three-year training programme at a vocational school and the other part at a company, combine to give employers a responsibility to invest in the training of workers and to influence VET policy and its implementation. As a result, in these two

countries VET for LEC has been fully mainstreamed and for relevant occupations LEC related competencies are integrated into existing occupational profiles, training programmes, curricula and exam regulations. The situation is different in UK where social partner input is varied, with unions being often marginalised and only large construction employers involved who do not employ directly on sites.

VET systems differ in terms of their approach to education. The dual system, for example, provides the opportunity to combine studying in the classroom with practice in training centre workshops and work-based learning. Whilst practical learning is part of IVET programmes everywhere, this may take place in a workshop rather than in a workplace, in part because, despite emphasis increasingly being placed on work placements and dual training and/or apprenticeship, many employers are reluctant to take on trainees. There are, however, core knowledge, skills and competences for LEC common for all, serving as guidelines for weaker systems to learn from.

Table 1: LEC knowledge, skills and competences covered in VET for envelope occupations (based on examples from Belgium, Germany, Ireland and UK)

Knowledge and understanding
<i>Climate change:</i>
○ energy costs and use ○ environmental protection ○ building protection
<i>Low carbon building/Energy efficiency and Building Physics:</i>
○ principles of energy performance ○ building envelope ○ heat retention and loss (season, heat exchange, properties of materials) ○ air tightness and insulation (types of insulation, consequences of poor insulation, thermal imaging) ○ thermal bridging (bridge types, measures against thermal bridges) ○ moisture and ventilation (condensation risks, consequences of poor installation) ○ window quality and positioning
<i>Low carbon building</i>
○ understanding principles of renewable energy systems and technologies ○ understanding how heating technologies can be integrated ○ understand effect that control systems have on heating
<i>Retrofitting:</i> Understanding effect upon building fabric of remedial or new installation work
<i>Whole LEC process:</i> Understanding sequence of works and roles of occupation/dependent occupations and in achieving energy performance required
<i>Efficient resource use and sustainable products</i>
○ understanding water efficiency on site ○ knowledge of responsibly sourced products and justification for using them ○ understand principles of materials storage, recycling and re-use opportunities
<i>Legal requirements:</i>
○ knowledge of regulations, rules and standards in low energy construction ○ EPBD and NZEB ○ national policies and building Regulations

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