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Skills Constraints for Low Carbon Transitions

Nicholas Jagger, Timothy J Foxon and Andrew Gouldson

Abstract

Achieving a successful transition to a low carbon economy, in the UK and other countries, will require sufficient people with appropriate qualifications and skills to manufacture, install and operate the low carbon technologies and approaches. The actual numbers and types of skills required are uncertain and will depend on the speed and direction of the transition pathways, but there are reasons to doubt that market mechanisms will deliver the necessary skilled workers in a timely manner. The range of market, government and governance efforts for the provision of low carbon skills are examined, particularly for their potential to cause a slower, costlier and less employment-intensive transition. The potential policy responses to these failures are considered, including standardisation of funding for training; formalisation of transferable qualifications; legally-binding targets for carbon emissions reductions and low carbon technology deployment; framework contracts and agreements between actors in key sectors; licensing and accreditation schemes for key technology sectors; government support for skills academies and training centres; support for first movers in niches; increasing mobility of workers; and providing a clear long-term cross-sectoral framework for a low carbon transition, including skills training.

The paper argues the importance of skills issues for the low carbon transitions and outlines the generic and low carbon specific potential causes of skills shortages as well as the probable impact of these types of shortages. The transition by changing existing sectoral and occupational patterns will disrupt the existing sectoral mechanisms to identify and remedy skills shortages. The nature of the low carbon transition also means that there are

pressures that could induce greater skills shortages. These shortages, in turn, could critically delay elements of the transition and increase its cost and duration. The paper also outlines the approaches used in the UK.

Introduction

The transition to a low carbon economy will require sufficient people with appropriate qualifications and skills to manufacture, install, operate and maintain the low carbon technologies and approaches. The actual skills and numbers required are uncertain and will depend on the speed and direction of the transition pathways. However, beyond some global estimates (for instance UNEP 2009), there has been a lack of studies of the skills requirements in sufficient detail to inform training provision. Given the importance of the low carbon transition, this paper argues that more attention needs to be paid to the skills and training aspects, in order to inform firms' strategies and government policies. This paper highlights the potential for a range of market, government and governance failures to impact on the transition to a low carbon economy. Some remedies are put forward - without these the paper raises the prospect of a slower, costlier and less employment intensive transition to a low carbon economy.

Background

The conceptual and theoretical understanding of skills and skills shortages is debated (Holt, Sawicki and Sloan, 2010). For concreteness, this paper conceives of skills as the abilities and competencies of workers to undertake the required functions. Given measurement problems, this is often proxied by the possession of appropriate qualifications, and this paper follows this route where appropriate. Additionally, skills shortages are seen as employer reported inabilities to recruit employees with the required skills, at the prevailing wages and conditions. These are the definitions of skills and skills shortages used in the UK

Employer Skills Surveys and those commonly used in policy debates (Frogner 2002). Another measure of relative skills relates to differential increases in median wages (Ruhs and Anderson, 2010), since employers may be expected to pay more for skills that are in short supply. However, since this type of data usually only exists for occupations that are covered by existing statistics, this may be difficult to use as an indicator for new areas and occupations.

The supply of these skills is likely to depend on a range of factors – some determined by labour markets and wider market conditions, others influenced by various government policies and wider institutional conditions. Matching the demand for low-carbon skills with the supply of the appropriate skills therefore depends on governments, markets and the supporting institutions working effectively.

Skills policy centres on the role of the government in funding or in otherwise supporting the provision of training. Market failures are associated with training provision because of the public good elements of skills provision and the likelihood that those who bear the costs of skills provision may not also reap the benefits. As a result, although there are efforts to persuade employers and individuals to fund training, often this is supported at least to some extent by governments. Another arena for government intervention in the market for skills and training is in predicting future demand in order to match supply and demand. The problem here is that employers are generally organised in sector based organisations, while training and skills relate to occupations which in turn are often found across more than one sector.

The skills required in the transition to a low carbon economy have been examined by a range of studies. GHK (2009) Cedefop (2009) and Cedefop (2010) provide a European view, Martinez-Fernandez, Hinojosa and Miranda (2010) provide an OECD wide view, while Pro Enviro (2008) and Bird and Lawton (2009) examine the UK situation. GHK (2009) and

Cedefop (2010) emphasise the 'light-green' jobs, where a wide range of jobs need to take on some green attributes. Examples of these include building managers, who need to understand how to minimise CO2 emissions, or accountants who need to understand the financial implications of emission's permit-trading. However, here we focus on the 'deep-green' jobs directly involved in manufacturing, installing and operating the high levels of low carbon technologies, including in electricity generation, energy efficiency equipment, vehicles and manufactured products, that could be created from a new wave of 'creative destruction' investment in the low carbon economy (Fankhauser et al., 2008). These deep-green jobs, which will be critical for the transition, may initially be relatively few in number (PriceWaterhouseCoopers, 2010), apart from potentially large numbers involved with domestic retro-fitting of low carbon measures (Gouldson et. al., 2012). However, given the rapid pace of change in the energy infrastructure associated with the low carbon transition (Fouquet, 2010), there may be problems in ensuring that there are sufficient people with the appropriate qualifications available in order to avoid time and cost overruns during the transition. The pace of change also means that the use of increased wages to respond to skill shortages will have little impact, as increased wages mainly influence new entrants (Chan and Dainty, 2007). This combined with the lags in the training system means that these automatic stabilisers are less efficient than normal. In addition to the challenges posed by the pace of change, further challenges are posed by the nature of the technologies involved, as well as a range of challenges that face skills delivery across the board.

This paper examines firstly the constraints resulting from generic skills constraints which impact all sectors and technologies, and secondly those that are specific to low carbon technologies. Each section is followed by some example remedies to these problems, mainly based on the UK policy environment. The paper questions whether sufficient remedies are in place, in the UK and elsewhere, in order to avoid skills constraints to the

low carbon transition. These problems may occur in all parts of the supply chain, including manufacturing, installation and operation of low-carbon options, including building retrofits where cost effective and profitable options are often not being taken up (Sunikka 2006). The paper concludes by suggesting that there is a need for greater integration of skills and employment issues into low carbon transition pathways and the discourse surrounding them.

Generic constraints

There are a range of market and governance failures that are likely to lead to the under-provision of skills. These are not specific to the low carbon sphere, but they are certainly relevant to it. These include:

- Short termism
- Labour market structure and flexibility
- Appropriability of skilled employees
- Negative spill overs.

Short-termism

Employers can be deterred from providing sufficient training, or recruiting sufficient appropriately trained individuals, as a result of short-termism. In the context of R&D investments, the ownership structure of organisations has been blamed for inducing a short-term perspective (Bushee, 1998; Osma & Young 2009). However, other national, organisational and individual factors have also been shown to induce short-termism (Marginson and Mcaulay, 2008). In the context of low carbon technologies, issues such as long lead-times for projects, cash flow issues and uncertainty can induce short-termism. Avoiding long term investment decisions, including skills development and acquisition (Ryan, Wagner, Teuber, and Backes-Gellner, 2010), can be rational in a short-term

environment. Short-termism also influences the structure of sectors, with the problematic pattern of sub-contracting a common response. This reduces pressures to train and allows shortages to grow un-noticed.

A particular feature of the building construction labour market – which is key in the transition to a low carbon economy - is that construction is heavily impacted by the business cycle, with labour-shedding during recessions and, subsequently, labour shortages during the recovery period (Ruiz, 2004). This is problematic, as the construction industry will be critical in building the new low carbon infrastructure and ensuring that domestic and commercial new build will be more efficient and low or zero carbon (Glass et al., 2008). In the UK, there has been a 10.8 per cent drop in the construction sector employees between the peak in fourth quarter of 2006 up to the fourth quarter of 2010 (ONS. 2011). The current forward indicators such as planning permissions granted also point to a further drop in construction sector activity. Table 1 shows that reported UK construction sector recruitment difficulties grew over the period 2003 to 2007 only to fall dramatically with the onset of the recession. However, more recent data from the Chartered Institute of Building suggests that concerns about skills shortages picked up again after the recession (CIOB, 2011). This indicates that, as expected, expanding construction activity is linked to increased recruitment problems and skills shortages. This means that the UK construction sector will be attempting to adopt low and zero carbon building techniques, requiring different and higher level skills, at a time when the industry will already have fewer employees than before the recession and will be struggling to expand. Previous recessions have led to construction sector skills shortages as the economy expands (Ruiz, 2004) and this looks likely to occur again. The problem is that the construction sector is heavily cyclical and the lags involved in the training systems mean over and under supply of skills occur during downturns and upturns in the market.

Table 1: Vacancies, hard to fill vacancies and reported skills shortages in the UK construction sector 2003 to 2011

	2004	2005	2006	2007	2008	2009	2010	2011
Per cent of employers with vacancies (1)	11.9	13.3	--	15.6	--	6.0	--	--
Per cent of employers with hard to fill vacancies (1)	6.8	7.1	--	8.2	--	2.0	--	--
Per cent of employers reporting skills shortages (2)	--	--	68	--	77	--	72	77

Source: (1) Analysis of UK National Employers Skills Survey (various years)
(2) Chartered Institute of Building (CIOB) Annual Skills Survey (various years)

Labour market structure and flexibility

Labour market structure (Forde and Mackenzie, 2004) and the flexibility of labour markets (Arulampalam and Booth, 1998) can impact on the extent and pattern of skills provision. The construction sector is particularly fragmented and dominated by lowest cost tendering which makes it difficult to address low-carbon issues (Sorrel, 2003). Fragmented and competitive labour markets do not have the capacity, or incentive, to invest in skills development as this leads to reduced co-operation and increased poaching (Brunello and De Paola, 2004). Equally, concentrated and monopolistic markets may be more able to invest in skills provision, but they may also be less efficient or responsive to changing skills demands. Most energy markets in advanced economies have seen extensive privatisation. This has been associated with reduced spending on R&D, but greater use of patents (Jamasb and Pollitt, 2011). Another feature of privatisation has been the fragmentation of

the energy sector, as regulators seek to increase competition (Newbery, 2002). This has led to a contract based industry with many sub-contractors working across the sector.

The construction industry is also characterised by a high degree of sub-contracting, and even sub-sub-contracting, with some workers only taken on for specific projects (Clarke, 2006). These contingent workers are the least likely to be trained, as there is no certainty that they will be working for the main contractors in the future (Forde, Mackenzie, and Robinson, 2008). This problem also applies to those on temporary contracts (Sauermann, 2006), which are common in the construction sector. The sub-contracting pattern of activity and employment also leads to a tendency to rely on poaching those who already have the skills, rather than training workers (Moen and Rosén, 2004). Sub-contractors necessarily operate over larger geographies as they seek the work they specialise in. This in turn means that they are more likely to respond to demand for skills internationally and often beyond the markets understood by national Governments and main contractors (Ngowi et. al., 2005). Also subcontractors generally as Small- and Medium-sized Establishments (SMEs) are also influenced by the relative lack of training by SMEs (Jameson, 2000).

Appropriability of skilled employees

The traditional understanding of employers' attitudes to training is based on Becker (1964) who argued that firms only had an incentive to provide firm-specific training, whereas employees had an incentive to acquire general training. However, Hashimoto (1981) argued that firm specific training could be seen as mutually advantageous to both the employer and employee. General training and, in particular, the certification of qualifications, allows employees to demonstrate their skills to other employers. This encourages mobility and, in turn, means that the employer does not gain the benefit of any training that they have funded (Brunello and De Paola, 2004). However, even with these

problems, it is clear that employers do fund general, transferable and certified training (Acemoglu and Pischke, 2000). The labour market is sufficiently imperfect to enable employers to gain even with the risk that the employee might leave (Acemoglu, 1997). However, the levels of training provided in these circumstances are still probably sub-optimal, at least within the UK (Finegold and Soskice, 1988; UKCES, 2010). This leads to sub-optimal levels of skills provision and makes the adoption of new technologies, such as low carbon technologies, which require higher levels of training (Boothby et al. 2010) more difficult.

Demand for low carbon skills is considered to be mainly latent (Pro Enviro, 2008) as employers need to be convinced that any training in the area will have a sufficient pay back. This latent demand also means that training providers are not yet delivering the skills needed. Government subsidies for low carbon activities can create niches (Nill and Kemp 2009) within which payback on skills training is more certain, which will allow the demand to be articulated and providers to deliver.

Negative spill-over effects

Negative spill-over effects can result from skills shortages in one sector of the transition (or other infrastructure projects) drawing resources away from, or pushing up the costs of, another project, potentially making it non-viable. Certain critical skills can be in demand by more than one sector, with relatively easy mobility between these for the skilled workers and the contractors they work for. The example which is often given is the transferability of skills between the North Sea Offshore Oil Industry and the Offshore Wind industry (Esteban et al., 2011). Despite this suggestion, the skills shortages in the offshore oil and gas industry itself (Hopkins, 2008), due to international expansion of offshore oil and gas, may mean that there will not be sufficient skilled workers available to transfer to the offshore wind sector.

There are similar linkages between grid reinforcement and rail electrification associated with high voltage electricians, between nuclear power and carbon capture and storage with pipefitters, and between nuclear power and offshore wind with high integrity welders. It does not make sense to have too many people with critical skills. However, it is possible for more than one sector to be expecting to rely on the same specialist sub-contractors. Often, market intelligence about skills availability is limited to specific sectors and does not adequately account for inter-sector transferability. Employers tend to know the patterns of labour market supply and demand in their own sectors, but they are less likely to know of development in other sectors which might impact on the supply of skills within their own sector. This problem is also to an extent institutionalised in the UK's employer led sector based system of skills planning.

Responses to generic constraints

The responses to generic constraints are equally generic. The generic response to short-termism is to induce a longer horizon through various methods. Many of these measures are the same as those used to address technical uncertainty which is covered later. However, there are a range of measures that, for instance, oblige contractors to provide training as part of a contract or that link training to obtaining planning permission. Other responses are linked with the way the technology is regulated with, for instance, planned tranches for offshore wind, providing a longer time horizon for the industry.

The policy arena contains a range of responses to low levels of training induced by labour market structure. These often involve statutory intervention, as the lack of training is seen as a classic case of market failure. A common policy option is sectoral training schemes, whereby employers are levied to pay for training (Stevens, 2001). However, even these schemes are argued not to work in terms of increasing the levels of training (Kamphuis and Glebbeek, 2010; Abdel-Wahab et. al., 2008), or in terms of increasing the returns to

training (Greenhalgh, 2002). Such schemes are common in the Netherlands and France and were once widespread in the UK and Australia. However, in the UK, these levy schemes are now limited to the construction sector and the engineering construction sector.

The standard response to problems of appropriability is to encourage, and subsidise, the acquisition of transferable qualifications. This means that in the UK training subsidies are linked to the acquisition of formal vocational qualifications. There is an increasing trend towards legislating for specific qualifications in order to practice certain professions or occupations. At times this 'licencing' is an effort by incumbents to limit entrants (Bryson and Kleiner, 2010), but in other situations it ensures minimum levels of competence and encourages entrants to train and maintain their competences through continuing professional development (Kleiner and Krueger, 2010).

Negative spill over effects clearly requires inter-sectoral skills intelligence that operates at a national and international level (PriceWaterhouseCoopers, 2010). Where problems become apparent, a combination of scheduling and integrated planning should reduce the problem. Given the existence of inter-sectoral and international mobility, at minimum, the possibility of such flows need to be documented and taken into account by single sector plans.

Low-carbon technology specific constraints

A second group of market and governance failures, which are likely to lead to the underprovision of skills, are specific to low carbon technologies. These are:

- Risk and uncertainty associated with the technology
- Novelty of the technology
- Scale and granularity of the technology
- Embeddedness and inertia.

These are outlined in turn below, with examples and possible responses to the problems.

Risk and uncertainty

The same risks and uncertainty that impact on the decisions to invest in various low carbon technologies also impact on the decision to invest in the skills that are associated with these particular technologies. Just as real options theory is often applied to making low carbon investment decisions under uncertainty (Frayer and Uludere, 2001 or; Gollier, Proult, Thais, and Walgenwitz, 2005), real options are also applied to human capital decisions (Bhattacharya and Wright, 2005; Badders, Clark, and Wright, 2007). Perhaps understandably, if there is uncertainty about a technology then there is a similar uncertainty surrounding investments in necessary skills. This is a particular problem when the training period is long, or where the skills cannot be transferred to or from other technologies. Equally, if the skills require substantial periods of training and, hence, substantial costs, employers and individuals need to be convinced that the requirement will not be one-off and that there will be a predictable future work stream.

Novelty

Some of the low carbon technologies that will need to be deployed as part of the low carbon transition use novel skills or, more usually, novel combinations of existing skills. For instance, solar electric installations often require people who have a combination of electrical skills and working at heights skills, while solar thermal installations similarly require people who can undertake plumbing, as well as safely work at heights. The construction sector is known to struggle with innovation (Whyte and Sexton 2011) and the issues are often more to do with new attitudes and approaches, such as maintaining air tightness, than completely novel skills. However, new skills, and unique combinations of skills, cannot be readily drawn from somewhere else as they have not been developed

before or there is not a comparable industry. This means that it can be difficult to obtain people who can train others in these skills; a problem that is especially the case where on-the-job training patterns are used. Such critical skills gaps are recognised to be a problem with low carbon technologies (Foxon et al., 2005). A particular problem with novel technologies is that low skills can lead to inappropriate or inaccurate installation or implementation. This, in turn, can lead to major rework costs and time slippages (Love and Li, 2000). Equally, repeated implementation failures can lead to lack of faith in the technology and slow the pace of adoption (Faiers and Neame, 2006).

Training and prior knowledge is an important component of firms' absorptive capacity (Cohen and Levinthal, 1990), or their capacity to benefit from other firms' innovations. This means that appropriate training, to enable a firm to adopt the latest low carbon technologies, becomes an important component of technology transfer, especially to developing countries (Ockwell, Watson, Mackerron, Pal, and Yamin, 2008).

Given that policy inducements are driving the pace of innovation for low carbon technologies (Popp, Newell, and Jaffe, 2009), it is more than possible that the pace of technical change outpaces the capacity of the training system to respond. This is particularly a problem when relying upon on-the-job training, as a limited (or non-existent) incumbent workforce makes this form of training difficult. Skills and qualifications providers are geared up for a much slower pace of change. If only because the training system has been reconfigured to be employer-led, this makes the system generally more reactive rather than proactive (Payne, 2008). This, in turn, means that there may not be sufficient appropriately qualified trainers or appropriate qualifications in place.

Policy and the requirement to avoid significant climate change, creates a need to drive the transition at a rate that is much faster than that witnessed under more autonomous transitions (Fouquet, 2010). Although, the development of knowledge intensive service

activities for innovation, such as specialised consultancies, means that faster innovation may be possible (Martinez-Fernandez, Miles and Weyman, 2011).

Scale and granularity

Scale and granularity becomes a problem when there are a lot of big projects with over-lapping skills requirements happening in parallel, at national and, even more so, at the international level. Large one-off projects, mean that there is a need to develop key skills that cannot readily be used again and, therefore, have limited scope for learning-by-doing. The absence of an incumbent workforce also means that it is hard to provide on-the-job training. Equally, there is a requirement for a mobile workforce, willing to move as the projects move. This, in turn, tends to limit the pool of people willing to enter the workforce, as they have commitments (family or otherwise) that tie them to specific localities.

An example of this is an analysis of nuclear power investments. This compares a number of small identical investments with one large reactor (Gollier et al., 2005). The analysis shows that a modular approach is much more effective with uncertainty over future electricity prices. Smaller projects also allow for more rapid learning-by-doing and can drive cost and efficiency gains through experience curves (Foxon, 2010).

Embeddedness and inertia

Embeddedness and inertia, in relation to commitments to existing processes and practices, amongst key sectors and stakeholders can lead to lock-in (Unruh, 2000; Barnes, Gartland and Stack, 2004). For example, Combined Cycle Gas Turbines (CCGTs) are relatively standardised and simple to build, with known costs over a relatively short lifespan (Roques, 2008; Watson, 2004). This makes CCGT investments more attractive to energy utilities than investment in low carbon technologies with greater uncertainty in costs and performance

in the current financial environment. However, CCGTs, although less polluting than coal, are still carbon intensive and are especially so if they are used in a load following manner (Bass, Malalasekera, Willmot, and Versteeg, 2011). Equally, embeddedness and inertia are prevalent in relation to skills sets of employees and firms, meaning that it is a less risky option for firms and individuals to invest in skills sets relating to currently dominant technologies.

Responses to technology specific constraints

The methods used to reduce uncertainty in terms of low carbon investments also act as incentives to provide or acquire low carbon skills. These methods in the UK include:

- the institutional framework of the Climate Change Act (2008) and the independent advisory Committee on Climate Change;
- legally binding emission reduction targets and five-yearly carbon budgets, leading to an 80% reduction in UK greenhouse gas emissions by 2050;
- the Renewable Obligation for large-scale renewable generation;
- long term feed in tariffs for small-scale renewable generation;
- a renewable heat incentive; and
- a proposed floor price for carbon.

However, there are a range of other measures that more directly reduce uncertainty over the demand for specific low carbon skills. These include framework contracts, to give longer term certainty, and strategic plans and scenarios. In the UK, the National Grid, the operator of the high voltage electric grid, has set up the Electricity Alliance. This involves 15 major contractors, operating as a partnership, aimed at providing reinforcement of the electricity grid, which enables sharing of knowledge and creation of greater certainty over electricity network investment plans.

Feed in tariffs have been an important, and very successful, aspect of Government policy support for renewables (Lewis and Wiser 2007). This is shown by the size of the wind power labour market in Denmark, Germany and Spain with 15.6, 34.9 and 23.0 per cent of the total EU 2008 direct wind power labour market (Blanco and Rodriges 2008: based on Table3). These three countries had earlier, larger and more consistent feed in tariffs than other European countries including the UK.

An interesting response to threats to a profession or occupation by rogue actors, undercutting or discrediting others, is an extension of the licensed occupations concept. This approach has been used in the UK, as a component of the regulation and support of the installation of microgeneration technology, with the Microgeneration Certification Scheme (DECC, 2008). A further example is the regulation of UK energy auditors, whereby an energy assessor must be qualified and also a member of an accreditation scheme approved by the Secretary of State (DCLG, 2007). This licensing approach is being extended in the UK to cover the forthcoming Green Deal where assessors and installers will have to be licensed to benefit from the scheme. The UK's microgeneration strategy also provides other measures aimed at reducing the negative impact of novelty (DECC, 2011a), in particular the effective creation of niche situations (Schot and Geels, 2008), where various forms of subsidy are designed to encourage uptake of renewables.

Other approaches more directly address the skills issues by setting up and subsidising specific skills bodies or training establishments. In the UK, this has involved the establishment of a range of skills academies that develop and promote a range of new qualifications designed to address specific skills needs in, for instance, the nuclear and renewables sectors (BIS, 2010), and investment in training of high quality PhD students through the formation of a number of Doctoral Training Centres in low carbon energy technologies at leading UK universities.

Apart from the response of dealing with microgeneration options, which offer low unit size and greater scope for learning-by-doing, there are a range of other responses to the problems of size and granularity. These include scheduling projects to produce a continual stream of work. The identification of key bottlenecks in advance can also allow better planning, as has been done by the UK nuclear industry (CITB Construction Skills, 2011). Another response is to create a nationally and internationally mobile workforce, able and willing to move to wherever the next large-scale opportunity it located.

Another response to dealing with novelty is to subsidise, or otherwise support, first movers. This is often referred to as the 'niche strategy' (Raven, 2007; Schot and Geels, 2007). However, these niches can sometimes turn into ghettoes, with difficulty generalising beyond specific localities (Davies and Mullin, 2010). The ability of niches to generate technologies and techniques is clear (Nill and Kemp, 2009). However, they may be less able to generate the scale of workforce needed for the widespread adoption of low-carbon technologies. In many ways, the effective responses to embeddedness and inertia are the same as those used when responding to uncertainty. However, it is also important for training providers to ensure that qualifications are kept up to date and reflect the latest developments. Equally, there is a need to ensure that employers, learners and potential students are aware of the future benefits of newer courses of study.

A clear challenge is created by the policy-driven nature of the low carbon sectors. Industry asks for 'long, clear, consistent and credible' signals from policy to drive investment, but political constraints tend to induce an incremental approach to low-carbon policy development. So, for example, in the electricity sector, though national carbon budgets provide a long-term framework, investment and skills training decisions will be made on the basis of electricity market arrangements, and uncertainty in the details of the current UK electricity market reform processes is likely to slow these decisions.

Discussion and conclusions

As a result of a range of problems, skills shortages could easily impact the low carbon transition, given the degree of uncertainty over transition pathways and novelty and scale of many of the technologies and investments required. Skill shortages can produce the following negative impacts:

- Increased costs – increased use of sub-contractors and overtime, as well as remedial work, usually leading to increased costs for employers and their customers;
- Increased time – extra time needed for on-the-job training and for remedial work leading to delays in delivering products and projects;
- Reduced competitiveness and capabilities – makes it more likely that a region or nation imports key technologies or sub-components;
- Reduced employment – could lead to increased capital intensity and to a `jobless transition';
- Co-evolution of all of the above – leading to virtuous or vicious circles – a lack of skills creates policy or market uncertainty which, in turn, dissuades skills provision (Foxon, 2011)

Attempts are underway to examine the skills requirements of the low carbon transition (PriceWaterhouseCoopers, 2010; Aldersgate Group, 2010). However, many of these either produce occupational or skills data that is too generalised to inform the planning of education and training (Cedefop, 2009) or, where sufficiently detailed information is available, it is bound up in specific transition pathways (Boettcher et al., 2008).

There is a need for greater integration of skills and employment issues (Fankhauser, Sehlleier, and Stern, 2008) into low carbon transition pathways and the discourse surrounding them. This will not only allow the potential problems outlined above to be

addressed but, equally, it will make it easier to reframe the debate about the transitions in terms of job creation (Lockwood, 2011; OECD/ILO, 2011).

The UK Government is currently placing emphasis on licensing as a way of ensuring minimum skills standards as part of the Green Deal, which aims to fund energy efficiency measures using savings on energy bills (DECC, 2011b). There is a need for monitoring and research into the effectiveness of this approach in addressing low carbon skills shortages. This is especially the case as some evidence from the United States suggests that licensing may not improve competence or safety (Kleiner and Park, 2010). Equally, the impact of the 2008-09 recession and subsequent slow recovery on the stock of construction skills needs to be monitored. This is because a weakened construction sector may not be capable of responding to the requirements of the low-carbon transition.

Ultimately, it seems that there is a need for new forms of policy intervention, and more broadly for new governance arrangements, focused on low carbon skills if we are to manage the costs, the speed and the employment intensity of the transition to a low carbon economy. The relationship between supply and demand is normally governed by a complex set of market and institutional factors. But where there are market failures, institutions have been developed to govern this relationship better. These institutions may have worked in the past, but they also fail on occasion, not least by failing to adapt to emerging priorities. We argue here that most skills institutions are sectoral in nature, but that as the low carbon skills agenda is cross sectoral in nature, existing skills bodies are often ill suited to meeting these new demands. The demands themselves are poorly articulated and this reduces the drive for institutional change. We conclude by suggesting that institutional change in the form of stronger cross-sectoral low carbon skills agenda is needed in order to address the institutional and market barriers identified above.

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