Low-carbon Jobs in an Interconnected World: Literature Review

Introduction

Kick-starting economic growth and addressing climate change are two increasingly interconnected challenges facing governments around the world. In the face of ongoing global recession and rising levels of unemployment, creating jobs is at the forefront of policymakers' minds and has become a 'primary goal' of economic recovery efforts (Houser *et al* 2009: 4).

According to recent estimates (ILO 2009), global unemployment in 2009 is projected to increase by between 18 and 50 million relative to 2007 levels, totalling between 210-239 million people. A central rationale behind recent economic stimulus packages is that public spending, particularly in labour-intensive industries such as infrastructure, construction and manufacturing, will result in job creation as companies expand their capacity to meet increased demand. Measures to generate and foster good, long term 'low-carbon jobs' offer the potential to simultaneously address current economic and environmental concerns. They are consequently the subject of a plethora of recent studies.

Despite the wealth of literature - or perhaps because of it - there is little consensus over what is meant by 'low-carbon' or 'clean energy' employment (UNEP/ SEF Alliance 2009: 56). 'Green jobs', which have often featured large in political lexicon, traditionally refer to occupations that contribute to preserving or enhancing environmental quality and health, such as protecting ecosystems, controlling pollution, and reducing waste and energy consumption (UNEP 2008: 3).

'Low-carbon jobs' on the other hand refer to employment in sectors that 'make up the clean energy economy', including energy efficiency, renewables, alternative transport and fuels (White and Walsh 2008a: 6). Defined primarily according to industry rather than occupation, they include a range of medium and high-skilled activities; in R&D, design, production, marketing and retail, transport and distribution, assembly, installation, maintenance and support services including legal, IT and technical consultancy (Pollin *et al* 2008: 9). Many of these activities are undertaken by individuals who work in 'indirect' low-carbon jobs, which tend to arise in second-tier supplier industries producing intermediate goods, as well as the service sector. Some studies (Houser *et al* 2009:18; UNEP 2008: 44) also extend the 'low-carbon' tag to include so-called 'induced jobs'; jobs which can be gained 'when energy savings are spent elsewhere in the economy'.

Another important conceptual dimension to note in the existing literature is that low-carbon jobs are, or should be, decent jobs. They typically range from entry-level positions to higher-skilled jobs and offer good wages, on-the-job training, opportunities for career advancement, and job security (Cleary and Kopicki 2009; UNEP 2008: 38; White and Walsh 2008a). According to a report by the UN Environment Programme and the SEF Alliance (2009: 57) most clean technology workers in the US including plant operators, power dispatchers and technicians earn higher than average wages. Creating low-carbon jobs is also considered as an important means to promote economic and social cohesion in local and regional communities, while in developing countries, low-carbon job creation goes hand in hand with 'efforts to advance decent work and pro-poor sustainable development' (UNEP 2008: 23).

Estimating low-carbon jobs in the electricity generation sector

Since the mid-1990s, the number of jobs in the traditional energy sector has declined in the US and Europe, as a result of liberalization programmes, privatisations and technological progress. In EU member states, it is estimated that between 1997 and 2004 there were 300,000 job losses in the electricity generation sector (EUTC *et al* 2007: 70). Although the energy sector is a relatively small direct employer and in most countries provides a relatively low contribution to overall GDP (Fankhauser *et al* 2008), the global demand for energy is growing. With governments increasingly aware of the need to reduce their over-reliance on finite sources of energy and tackle dangerous climate change, there has been a growth in the proportion of energy derived from renewable technologies. This in turn has created new jobs and, as clean energy development accelerates in the years ahead, prospects for low-carbon job creation are expected to increase (UNEP 2008).

The task of determining the precise number of existing and potential low-carbon jobs globally in the electricity generation sector - which forms the scope of this GCN study - is however highly problematic. Existing studies use different methodologies, based on varying assumptions, reporting formats and modelling techniques, which make direct comparisons very difficult (UNEP, 2008). Many of these studies focus exclusively on individual countries or regions. Moreover, the majority of the literature focusing on job creation at the international level tends to make estimates of jobs in low-carbon industries (i.e. wind, solar etc) as opposed to specific sectors, meaning that is difficult to accurately aggregate and extrapolate precise data for the electricity generation sector[1].

Among the few international surveys to analyse low-carbon job creation, the UN Environment Programme (2008: 6-7) estimates that in 2006 approximately 2.3 million people were employed in renewable energy industries.[2] This includes 300,000 people employed in the wind industry, 170,000 in Solar PV, 600,000 in solar thermal and 1.2 million in biomass-derived energy (mostly in growing and collecting feedstock, and processing industries). According to the report, Germany, Japan, China, Brazil and US account for the majority of low-carbon energy production and investment and have 'garnered the bulk of renewables jobs worldwide' (ibid. 8). The study also anticipates a substantial increase in employment in clean-energy industries by 2030, by which time approximately 2.1 million people will be employed in wind energy, 6.3 million in solar PV and 12 million in bio-fuel-related agriculture and industry (UNEP 2008: 128).[3]

A recent Climate Group (2009) report estimates that 10 million additional jobs could be created worldwide by 2020, but only if ambitious targets to cut carbon emissions are reached by the international community. This scenario requires Annex 1 countries to reduce emissions in this time-frame by 30 per cent relative to 1990 levels and emissions from non-annex 1 countries to return to 2010 levels. Unilateral action to curb emissions will create new jobs, say the report's authors, but on a substantially lower scale[4]. Instead, collaborative mitigation efforts by all countries that set a global price on carbon, coupled with ambitious international standards to accelerate low-carbon technological development and deployment, will be needed if job creation numbers are to be maximised.

[1] This is made more problematic by the fact that certain low-carbon sources such as bio-fuels are not only used for electricity generation, but also for heat and transportation.
[2] Although, by the authors own admission this is a conservative estimate, since it does not take into account a number of countries for which there is lack of systematic data (UNEP 2008).
[3] In a separate report with the SEF Alliance (2008: 78), the UNEP claims that renewable energy programs generate between about 16,000 and 22,000 jobs per billion dollars of spending.
[4] If the EU cuts its emissions by 30% relative to 1990 levels by 2020, the report claims that approximately 1.1 million jobs will be created in EU member states and up to 2.89 million globally (Climate Group 2009: 14).

Other existing studies (regional and country-specific) calculate future potential for job opportunities in relation to anticipated industry growth, as a result of policy initiatives and the upscaling of clean-energy investment. For example, a recent European Commission (2009) report estimates the net number of jobs created by reaching the 20 per cent target for the share of renewables in energy use in 2020 at 410,000. Similarly, Douglas Westwood (2008) estimate that if the UK government's 2020 Renewable energy target is reached – which requires 15 per cent of power to be generated by renewable energy technologies – an additional 133,000 British jobs in manufacturing, construction and operation activities could be created (although this figure does not account for potential job losses).

In the US, a study by Roger Bezdek (2007) finds that the U.S. renewable energy industry obtained $39 billion in revenues in 2006 and employed 200,000 people directly and another 246,000 indirectly. Assessing future opportunities under three scenarios, the report suggests that by 2030, 1.3 million direct and indirect jobs could be created under a "business-as-usual" scenario, 3.1 million under a moderate scenario that leads to a 15 per cent share of renewables in electricity generation, and 7.9 million under an advanced scenario which would see nearly 30 percent of electricity generated from renewables. The latter scenario 'would require strong national policies, including targets, standards, and invigorated R&D'. (Bezdek 2007: 24)

Other studies in the US have calculated the number of jobs that could be created as a result of financial stimulus packages for clean energy development. The University of Massachusetts and Center for American Progress (Pollin *et al* 2009) estimate that a US$150 billion investment in clean energy could generate 2.5 million jobs.[5] This would reduce unemployment from 9.4% to 8.4%.

An alternative approach in the literature is to measure the employment opportunities provided by clean-energy compared with carbon intensive industries. According to UNEP and the SEF Alliance (2008: 78) renewable-energy programs will generate, 'per dollar, an order of magnitude more jobs than will expenditures for fossil fuel plants or tax cuts'. The University of Massachusetts and Centre of American Progress report (2009) cited above, puts a figure on this; estimating that job creation opportunities among less-educated workers would be 'seven times larger than the number of jobs that would be created in this category…by spending the same amount of money within the fossil-fuel industry'.

Further to this, Daniel Kammen, Kamal Kapadia, and Matthias Fripp (2004) claim that renewable energy not only generates more jobs per dollar of investment than fossil fuel energy, but also per megawatt of power manufactured and installed and per unit of energy produced. According to their cumulative analysis of thirteen independent reports, solar PV, wind and biomass are all on average more labour intensive than coal.[6] However, similar analysis carried out by UNEP and the SEF Alliance (2008: 80-81) points out that mean deviations in such data are too great to enable a firm conclusion to be reached.

In a recent report, Samuel Fankhauser, Friedel Sehlleier and Nicholas Stern suggest that although clean-energy industries may be 'more labour intensive in the short term' especially in the production stages, net job creation may level out or even become negative as and when technologies mature, 'efficiency gains' are made and economies of scale increase (2009: 423). Whilst clean-energy plants and farms currently have a relatively short-life span and installations need to be replaced relatively often, as technologies become more cost-effective and competitive the numbers employed in

[5] In net terms, 1.7 million additional jobs will be created. This figure takes into account potential job losses from carbon-intensive industries if fossil-fuel spending were to decline by an equivalent sum.
[6] This is measured in terms of average employment over the life of a production facility (jobs/MW average).

renewable energy industries may decrease. Houser *et al* (2009) note a further caveat in that jobs may potentially be lost in other sectors ‘as a result of higher tax rates to recoup the fiscal cost of green stimulus programmes’ while the higher electricity costs of low-carbon alternatives may also lead to induced job losses elsewhere in the economy.

Some commentators have argued therefore that the challenge for governments in the medium-term appears to be more about ‘preserving employment in the electricity sector than increasing employment in absolute terms’ (EUTC and SDA 2007: 71). However, as ‘structural adjustment’ occurs and economies transition from carbon-intensive industries in favour of clean energy alternatives, climate change and low-carbon development policies have ‘the potential to create many more jobs than… [they] destroy’ (Fankhauser *et al*. 2008: 427). In the event that countries experience net job losses, this is likely to be due to ‘poorly designed policies and measures’ (Climate Group 2009: 15).

If, as many governments anticipate, Carbon Capture and Storage is to have a leading role in the future, this technology could potentially safeguard existing jobs in the coal industry whilst also providing additional employment opportunities in sequestration technology and the transportation of gases. However, as long as CCS remains commercially untested and relatively costly, the additional employment benefit relative to capital invested will be minimal (Fankhauser et al., 2008: 425).

Global Value and Supply Chains: where do low-carbon employment benefits and costs fall?

> ‘The value chain describes the full range of activities that are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and disposal after use.’ (Kaplinsky 2005: 101)

The growth of global supply and value chains has emerged in ‘a world marked by low energy prices, diminishing barriers to global trade, and the entry of the world’s most populous nations, India and China, into the world marketplace’ (BSR 2009: 3). Well-functioning global supply chains are ‘key enablers of faster speed-to-market, larger and more efficient production quantities, higher profits and sustainable growth’ (ibid: 3). Today, companies increasingly outsource, offshore and relocate to sites ‘where the most favourable economic conditions can be realised... where the required resources are available at the required scale’ and where their products and services can reach a diversity of local markets (Ramioul 2007).

In addition to improving market efficiency and competitiveness, the global integration of commerce has also helped to ‘employ millions of people formerly outside the formal world economy’ (BSR 2009:3, OECD 2007). Furthermore, restructuring value chains globally has affected the inter-organisational division of labour between companies (Gereffi et al., 2005). According to Monique Ramioul (2007: 16):

> ‘The way business functions are organised and coordinated beyond... [a] firm’s boundaries, at the level of the value chain, affects the way jobs are designed, the way people are allocated to these jobs, the way collaboration between workers is organised, and the way working conditions are shaped.

In light of this, creating markets for clean-energy technologies in one location will not only create employment opportunities in that location but also in other countries, precisely because supply and value chains are now global. The global market value of sales of products and services in the renewable energy industry is indicative of the scale of current global employment opportunities: between 2007 and 2008 this was estimated at £940 billion with the highest concentrations of export value in the wind (£1462 million), solar (£1143 million) and geothermal (£871 million) industries (Innovas 2009: 3).

There is however a notable absence in the literature of analysis looking at global supply and value chains for low-carbon industries and products, and their impact on job creation. Existing studies tend to approach the issue of employment potential from a national and/or regional as opposed to an integrated global perspective (see above). Nevertheless, the literature suggests that countries are likely to capture maximum employment opportunities along the value and supply chains as a result of either of the following scenarios.

1) In instances where low-carbon manufacturing firms move up the value chain and become *global leaders* in their sector.
2) In instances where there are *domestic opportunities* for firms to be key links in the supply chain, often as a result of large foreign manufacturers setting up in that country. (White and Walsh 2008b: 6).

Both scenarios suggest that in implementing market creation policies in low-carbon technologies, governments must analyse and understand their likely comparative advantage in the global value chain. In this regard, several lessons can be drawn from the electronics industry (see box 1).

Global Leaders

Firstly, firms and indeed countries may move up the value chain if they can establish themselves as global leaders in a given sector. This is largely dependent in the first instance on a secure and sizeable domestic market, strong political commitment and favourable economic support mechanisms (Bird 2009). These winners, it is argued, are also often the 'first movers' (EUTC and SDA 2007: 72-3). By accessing the market first, they are likely to gain the bulk of low carbon business revenues, 'get better primary return in the supply chain and retain and create new... jobs' especially in R&D, innovation, design and operations (UNEP 2008: 4). This comparative advantage 'accrues to a relatively small group of countries, at least until other countries catch up' (UNEP 2008). In the interim, these countries and firms also produce, as global market leaders, the highest proportion of 'export-related jobs' (Fankhauser *et al*. 2008: 427).

As one of the first countries to implement low-carbon policies and invest heavily in renewable energy, Germany has in turn captured a significant proportion of the global renewables market and jobs. In 2004, the country's share of the world market for renewable-energy production equipment and components was 17 percent. In 2006, more than 70 percent of German-manufactured wind power plants were exported, while roughly one in three wind turbines and solar PV cells in the world are German-made (cf. UNEP 2008: 96). Over the next decade, the share of German renewable sales for the export market is estimated at 69%, hence two thirds of jobs in the German renewable industry 'could be export related' (BMU 2006, cf. Fankhauser *et al*.: 425). According to recent data from the Federal Environment Ministry and Federal Ministry of Economics and Technology, 278,000 workers were employed in the renewable energy sector for heat and electricity generation in 2005, compared with 238,171 in conventional energy sectors. By 2020, the federal government estimates that employment in the renewable energy sector will increase up to at least 400,000 (BMU 2009).

At the company level, India's Suzlon provides an example of a multi-national firm that has developed comparative global advantage in wind turbine manufacturing and sales by acting early and decisively. In particular, it has set up expansive 'international innovation networks' of subsidiaries which allows it to 'stay abreast of wind technology innovations… [which] it can then incorporate into its own designs through its extensive research and development facilities' whilst maintaining control over intellectual property rights' (Lewis 2006a). Today, according to the company itself, Suzlon operates in 21 countries worldwide, employing over 14,000 workers, and accounting for 9% of the world wind energy market[7].

Countries and firms may also develop comparative advantage in the global clean-energy value chain by securing a position at the lower end of the supply spectrum. It may perhaps be easier to gain market access by focusing on specialised secondary activities such as the production and supply of component parts (e.g. cells, modules, wafers, and silicon for solar PV) which 'require... less investment and technical know-how' (UNEP 2008: 110). It has also been the case that traditional industrial-scale enterprises strategically reposition themselves to exploit low-carbon opportunities (Fankhauser *et al*. 2008: 426; EUTC 2007: 51). For example, large steel industry manufacturers have become an integral link in the supply chain for wind turbines, since high quantities of steel are required for the fabrication of tubular towers. Nonetheless, if it is easier for one firm or country to enter the market, it is likely to be so for many, meaning that a high level of competitiveness between firms attempting to break into the supply chain is likely.

It is also important to bear in mind the potential contradiction between renewable energy sources 'as a global source of jobs and renewables as part of national competitive economic strategies' (UNEP 2008: 9). If, as might be argued, countries such as Germany see investment in clean energy as a key dimension of their future economic strategy, 'a stellar export performance' by several countries may well imply 'more limited opportunities elsewhere' (ibid: 9). Thus, it is hardly surprising that many developing countries are eager to increase their foothold in global value chains for low-carbon products and services, which is evident in their request for a UN climate agreement to include both a formally mandated Technology Action Plan and an International Technology Fund. Given the importance for countries and firms of cementing their position on the global value chain, it may be the case that 'as renewables industries mature, they will increasingly be marked by difficult issues of competitiveness, trade rules, and wage differentials that are already familiar topics in other industries.' (UNEP 2008: 9)

[7] Suzlon (2009) Suzlon Corporate Website http://www.suzlon.com/about_suzlon/l3.aspx?l1=1&l2=1&l3=8

Box 1: Gaining comparative advantage in the global electronics industry

The electronics industry provides an interesting example of an international industry made up of complex global supply and value chains and, hence, dispersed employment dynamics. The global electronics market – which involves the manufacturing of components for circuit-board and microprocessors in telecommunications, medical equipment, optical technologies, photonics and consumer electronics - has been estimated at US$2 trillion each year, with semiconductor components accounting alone for US$275 billion of worldwide revenue (BIS 2007).

As with other capital and technology intensive value chains, there has been an increasing trend since the 1980s for leading brand-name firms in the electronics industry – such as IBM, Hewlett-Packard, Cisco Systems and Alcatel - to offshore and outsource key activities to contract manufacturers in third countries; notably the assembly of finished goods and the supply of key intermediate products (Gereffi 2005). In 2001, 90 per cent of consumer electronics sold in the US were produced offshore (USITC 2002). This process has enabled the reduction of operating costs and increased returns on capital investment at a time when growing demand, declining product prices and shorter lead times have characterised the market.

Asia has become the powerhouse of production for the international market, with China, Korea, Taiwan, Singapore and Malaysia accounting in 2002 for 25 per cent of global electronics production[8] (Ernst 2003). China, with its low labour costs and high productivity, has been a priority investment target for global industry leaders, with 85 per cent of China's high-technology exports emanating from foreign-invested enterprises (Gereffi 2005: 19). Indeed, the top five global contract manufacturers in the electronics industry - Solectron, Flextronics, Sanmina/SCI, Celestica, and Jabil Circuit all have operations based in China.[9] Accordingly, China enjoys a relatively high proportion of jobs in the global electronics industry. Chinese employment in the electronic information industry is reported to have grown from 3.01 million in 2001 to 7.61 million in 2005 (of which 5.51 million are employed in manufacturing)[10] (Jianmin 2006).

Traditionally, activities (and hence jobs) at the high-end of the electronics supply chain, in R&D and design, have tended to remain in a smaller number of locations, often where leading firms are based. In the disk drive industry for example, while 80 per cent of the jobs shifted to South-east Asia from the 1970s onwards, hard disk drive design largely remained based in the United States (McKendrick *et al*. 2000). However, comparative advantage is by no means fixed. Certain sectors within the electronics industry have witnessed globalisation of upstream activities, owing to increasing access to and exchange of knowledge, innovation strategies and sophisticated research capabilities (Ernst 2003). Taiwan[11] for example, is one of many emerging centres of excellence in Asia for chip design and is home to five of the top 20 worldwide fabless semiconductor companies, while the chip design departments of Samsung, SK Telecom, KT and LG Telecom are based in South Korea. (Ernst 2003:4).

In countries without the manufacturing capabilities or facilities to compete with emerging economies in Asia, governments have attempted to gain comparative advantage and create jobs by targeting certain supply chain activities for role specialisation. The UK for example specialises in software and design innovation for electronic chips 'across a wide spectrum of disciplines, which is recognised globally' (cf. BIS 2007).

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[8] Although revealingly only 16% of production supplies domestic markets in these countries. This is testament to the export market opportunities for electronics manufacturing firms.

[9] These five firms increased their total revenues from $6.6 billion in 1994 to $56.4 billion in 2001 (cf. Gereffi, 2005: 15)

[10] : The number of electronic information industry-related companies in China jumped from 7,500 in 2001, to 17,600 in 2003 and 67,000 in 2005, with approximately 56,000 of these manufacturing companies.

[11] Taiwan has also substantially increased its share of patents, 'a widely used proxy for innovative capabilities', in the electronics industry. Whilst in 1990, it did not feature among the 10 top countries in terms of the number of patents granted in the US, in 2000, Taiwan was the fourth largest country (with 4,667 patents granted by the US Patent and Trademark Office), ahead of France and the UK (Ernst 2003: 4).

Domestic Opportunities

However, it is not just global leaders in clean-energy technologies who may reap the benefits of new employment opportunities. Globally-operating companies tend to target countries for operations which are most suitable to particular supply chain activities (OECD, 2007). According to much of the literature, a significant proportion of jobs will be created in the country, region or locality for which the end product is intended. Certainly, jobs in installation and maintenance will tend to be based locally, yet there is also an increasing trend amongst foreign companies such as Vestas, Siemens and Suzlon to set up and locate production of components as near as possible to designated sites, stations and plants, which in turn means more local jobs (White and Walsh 2008a: 6). This is due in part to high transportation costs (UNEP 2008: 44) for large equipment and component parts and a lack of supporting industrial infrastructure (BSR 2009: 3). It is also in line with general business trends which suggest that manufacturers are increasingly abandoning global supply chains for regional ones, as a result of the 'rationalisation of production networks… pressure on the speed of delivery and the erosion of… cost or labour advantages some countries had enjoyed' (Milne 2009).

Consequently, regional and local firms have been able to gain important footholds in the supply chain and hence generate local job opportunities. In Bangladesh for example, Grameen Shakti microloans who have helped to install more than 100,000 solar home systems in rural communities in recent years, are now training local people to become certified solar technicians and repair and maintenance experts. The company aims to create over 100,000 additional local jobs (UNEP 2008: 8).

There is however a strong possibility that foreign companies operating abroad may rely on existing supply chains rather than build new ones that support local or regional job creation (cf. for example Gamsca's operations in Ohio, (UNEP 2008: 107)). Many foreign firms have long-standing supply agreements which, coupled with the inflexibility of what are often very large production lines (as in wind turbine manufacturing), prevents new smaller and medium sized firms from joining the market (Douglas Westwood 2008: 31). To counteract this, certain countries such as Spain and the US have introduced local content requirements (Bird 2009: 24; Lewis 2007a: 38) while China has imposed graduated import duties in order to encourage wind industry manufacturers to source locally-produced components (UNEP 2008: 106)

The extent to which specific countries, regions, or communities benefit from low-carbon employment therefore depends on the market opportunities available for renewable-energy firms but also 'whether the necessary industrial and knowledge base, as well as infrastructure exist' (UNEP 2008: 44). Bottlenecks in the supply chain, owing to weak infrastructure, a shortage of suppliers and a lack of skilled labour, lead invariably to delays, drive up prices and may force investors to re-asses the rate-of-return and go elsewhere.

Supply chain bottlenecks may present opportunities for new market entry and diversification, and hence new employment opportunities: for example in the UK indigenous firms in the aerospace and automotive industries are being primed as potential component suppliers for the renewable energy sector, based on their quality-assured manufacturing and service ability (Douglas Westwood 2008: 31). Nevertheless, without improving supporting infrastructure and the existing skills-base, it will be increasingly difficult for governments to effectively market domestic low-carbon opportunities to foreign firms and investors. As a result, there may be fewer domestic employment opportunities arising across the supply chain[12].

Finally, it is also important to note that whilst some countries may miss out on low-carbon employment opportunities due to underdeveloped or unstable domestic markets, others may lose jobs as a result of domestic emissions reduction policies. In particular, countries and regions with a large carbon-intensive industry base may lose jobs as a result of production relocating to countries without emissions caps (and/or with lower energy prices) (Fankhauser *et. al* 2008: 424; Fredrikkson 1999). Consequently, policies to re-train the workforce, match old workers to new jobs and ensure that local economies adapt to a low-carbon future will be necessary.

Policies and drivers for low-carbon employment creation

Experience from other technology sectors, such as information and communication technologies, suggest that technological innovation and development is a dynamic process with the potential to generate widespread global opportunities. It is also worth stating that predictions of information and communication technology markets often wildly underestimate the eventual scale of market development and economic opportunity. For instance, Thomas John Watson Sr, former president of IBM, allegedly declared in 1943 that '*there is a world market for about five computers*'[13]. Today IBM is one of the largest multinational computer and information technology corporations in the world, with 355,766 employees and an annual revenue of $91.4 billion in 2006 (cf. IBM Archives). Hence, data predicting the future growth of and job opportunities in low-carbon sectors should be considered with a certain degree of caution.

Nevertheless, much of the literature on low-carbon economic development - and the findings of this GCN study - suggests that creating new and sustainable low-carbon jobs largely depends on the maturity of domestic and international markets and the existence of favourable policy environments to stimulate the growth of clean-energy technologies and industries. The UNEP report (2008: 5) suggests active government policy to trigger the wholesale expansion of clean-energy industries is a key driver of low-carbon employment opportunities. Setting ambitious renewable energy targets, increasing funding for R&D, introducing economic support mechanisms such as feed-in tariffs, phasing out subsidies for carbon-intensive industries, improving the competitiveness of renewables by putting a price on carbon: all may help foster low-carbon enterprise, attract private investment and in turn create jobs (Fankhauser *et al*. 2009: 424; UNEP 2008). So too will policies and measures to remove bottlenecks in supply chains and barriers to delivery; including improving grid infrastructure and speeding up planning approval processes for renewable developments (cf. Bird 2009; Lewis 2007).

Since the implementation of such policies is unlikely to provide a quick fix, many governments faced with the immediate priority of tackling unemployment at a time of recession have opted to allocate a proportion of fiscal stimulus packages to low-carbon measures (Robins *et al*. 2009). Government spending is of course crucial to trigger low-carbon economic growth and offers the prospect of creating many immediate jobs, such as through major public works programmes to improve energy efficiency in households and public buildings. With many clean energy firms hamstrung by the credit crunch, public

[12] However, as low-carbon industries develop, domestic firms are likely to look to global supply chains (for example, for the provision of component parts), meaning that employment opportunities will increase elsewhere (BIS, 2009: 82).
[13] In 1943 IBM was a leading manufacturer of punch-card tabulating machines. It employed 21,251 workers and generated $131million in revenue.

investment may also be necessary to preserve jobs in the short term.[14] Nonetheless, some commentators (Houser *et al* 2009: 1) have suggested that whilst important, a 'green stimulus is no replacement for a comprehensive climate and energy policy', not only for reducing greenhouse gas emissions and dependence on foreign sources of energy, but also in fostering low carbon innovation and hence, securing long term, sustainable low-carbon jobs.

Much of the broader literature also emphasises the role of 'active labour market policies' (ALMPs) in safeguarding existing and generating new jobs, many of which may be applicable to low-carbon sectors (Brinkley *et al*. 2008). National and regional governments may intervene by offering financial incentives for clean-energy industries and investors, granting wage subsidies for low-carbon employers and reducing their pay role taxes. Governments may also set up inward investment programmes to leverage private-sector investment, which will be central to sustaining employment opportunities in the long term (Douglas Westwood 2008: 31).

In addition to maximising the number of jobs available, it is widely suggested that governments should implement policies to ensure that the work-force is equipped with the necessary skills to exploit low-carbon employment opportunities (Bird, 2009; UNEP 2008). In many industries, supply is struggling to keep pace with demand, owing in part to a 'skills gap' among the workforce (EWEA 2009). For example, German renewable firms have reported a shortage of qualified workers for knowledge-intensive low-carbon positions, such as designers, engineers and electricians (UNEP, 2005: 25). What is needed, it is argued, is a combination of training programmes and effective strategies to attract more people to low-carbon sectors (Bird, 2009). This may include, *inter alia*, introducing specialised university courses in Solar PV or wind turbine design and engineering (UNEP 2008: 25); measures to encourage young people to study Science, Technology, Engineering and Mathematics (STEM) subjects (Bird 2009); and setting up community partnerships or 'low carbon coalitions' between Further and Higher Education institutions and clean-energy businesses (HM Government 2009: 82).

According to the UK government, equipping the workforce with low-carbon skills and know-how will be 'a determining factor in... [its] ability to attract low carbon investment, successfully commercialise low carbon technologies, and innovate within companies' (HM Government 2009:78). One might therefore assume that for all governments, an extensive skills-base will not only be crucial in ensuring the growth of low-carbon industries domestically, but will also play a role in determining the extent to which they can secure a stake of and be competitive in the global market for clean energy products and services.

At the same time, skills-based training and related ALMP's will be of particular importance as part of a wider package of 'adjustment policies' to support those negatively affected by a low-carbon transition, particularly former employees in carbon intensive industries and supplier firms. Whilst income support and health care benefits (Brinkley *et al*. 2008) may provide temporary reprieve for the unemployed, on-the-job training opportunities are vital to ensure that they have the best chances of finding work in low-energy sectors (UNEP 2008). According to Cleary and Kopicki (2009) the occupational job distribution of a typical low-carbon energy firm differs relatively little from that of a company that manufactures other products. Consequently, with the right additional training, many workers should be able to effectively transfer their existing skills to new low-carbon jobs (Cleary and Kopicki 2009). Provided that time and investment is devoted to developing human capital, a low-carbon transition therefore can be a 'just transition' (UNEP 2008).

[14] In the US, it has recently been reported that many wind, solar and other alternative energy companies have had to cancel projects and cut back on workers as a result of credit markets freezing and venture capital evaporating' (*Guardian*, 11 August 2009).

At the international level, achieving a 'just transition' implies that the economic benefits of low-carbon innovation and transformation should, as far as possible, be equally distributed between countries. Since countries are at different stages of development in addressing climate change and some have more mature domestic renewable markets and industrial capacity than others, it is highly likely that job opportunities in clean-energy industries will vary from country to country in different areas of the supply chain, according to existing capacity and expertise.[15] Regulatory mechanisms to ensure that firms operating in clean-energy supply chains conform to international standards (for example on labour and the quality of products) may also help ensure fairness in accessing markets (cf. Kaplinsky and Morris 2003). Furthermore, international financing and technological assistance from advanced economies will also be necessary in order to ensure that developing countries can reap the employment opportunities of low-carbon innovation and development (White and Walsh 2008b).

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[15] For example, in the off-shore wind industry, some commentators argue that the UKs 'greatest opportunity' to maximise job growth potential appears to be 'in manufacturing specific components that draw on existing skills and knowledge base in the offshore oil and gas sector, for example, manufacturing foundations and towers' (Bird 2009: 7).

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