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**National Pathways to Low
Carbon Emission Economies**
Innovation Policies for Decarbonizing and
Unlocking

Edited by Kurt Hübner

tax, though Canada has (yet again) promised a national carbon price in 2019. Neither country has national regulations for the emission sources most critical to their success: upstream oil production in Canada, and power plants in the USA.

The Canadian and US cases are not only similar, but deeply intertwined. To date, economic interdependence has deterred actions to launch a transition to a low carbon economy. The smaller, and thus more vulnerable, of the two trading partners, Canada, has gone to great lengths to harmonize its international negotiating positions and domestic policies with those of the USA.

In the face of weak policies, observed emission trends to date largely reflect market forces. The impact of innovation is a central question in this project. While *policy* innovation has been in short supply, the impact of *technological* innovation on the carbon intensity of the US and Canadian economies is evident – yet mixed. On the one hand, increasing energy efficiency has facilitated a partial uncoupling of economic growth and greenhouse gas emissions in many sectors in both countries. More recently, the advent of fracking has prompted a quiet revolution in US energy, prompting significant emissions reductions as the USA has shifted its electricity sector from coal toward natural gas, a lower if not low carbon path. On the other hand, the same technology is having the opposite effect in Canada, where increasing reliance on unconventional oil reserves is yielding an emissions growth.

Even in the USA, technological innovation alone cannot be counted on to prompt a transition to a low carbon economy. To the extent that a shift from coal to gas in the USA has been driven by market forces, it has already occurred. Absent additional measures, US emissions are expected to level off. There is thus no substitute for policy innovation to direct markets toward a low carbon economy. While that represents a challenge for North American liberal market economies that traditionally have been steered with the lightest of touches, it is much needed and long overdue.

Tragically, the Trump administration rejects the reality of human-caused climate change and is actively dismantling regulations devised by their predecessors. While many US states will fight a rearguard action to limit damage, the USA has chosen a dangerous path for its own economy and for the planet.

Canada, in contrast, is in a mixed position. The current government continues to promote expansion of oil exports, but is also pursuing a slate of praiseworthy policies to reduce emissions in other sectors. Canada has reaffirmed its commitment to the Paris Agreement despite the USA's withdrawal. These signs are undoubtedly promising, but with three decades of hindsight, success is far from assured. Although Canada ratified the Kyoto Protocol after the USA had already withdrawn, that action turned out to be largely symbolic. In the face of formidable pressure from carbon-intensive industries and their provincial defenders, Canada's domestic climate policies have never significantly diverged from those of the USA. They must do so now.

3 Transition to a low carbon economy in the United Kingdom

A case of liberal capitalism?

Alexander Ebner

Introduction

This chapter explores the political-economic process for the transition to a low carbon economy in the United Kingdom. Historically, the United Kingdom has pioneered fossil-fuelled industrialisation, going through distinct periods and phases of industrial change. These have resulted in the formation of the current post-industrial type of economy with an extended financial services sector. The varieties of capitalism (VoC) perspective portrays the United Kingdom as a liberal market economy (LME), characterised by a pattern of predominantly market-based coordination in the operations of firms and their institutional environment. The following chapter explores British capitalism's low carbon transition by addressing the matter of industrial change and technological innovation given these underlying actor constellations and policy strategies.

The first section takes stock of the United Kingdom's decarbonisation profile, by addressing its patterns of greenhouse gas and carbon emissions. The second section outlines the British variety of capitalism in terms of a liberal type of market economy. The third section discusses the related institutional setting and performance of the British innovation system in support of a low carbon transition. The fourth section outlines strategies and policies driving this transition and the fifth discusses the underlying actor constellations and coalitions. The conclusion elucidates how the British path to a low carbon economy involves strong governmental components to accompany market-based governance, which highlights the hybrid elements in the British variety of liberal capitalism.

Profiles of carbon emissions in the United Kingdom

The path towards a low carbon economy in the United Kingdom is exemplified by its institutional foundations of legally binding emission targets: using 1990 as the base year, the 2008 Climate Change Act demands an 80 per cent reduction in greenhouse gas emissions by 2050; the Low Carbon Transition Plan from 2009 outlines a target for a 30 per cent share of renewable

electricity by 2020 and an almost complete decarbonisation of electricity by 2030 (Geels *et al.* 2016). The redesign of the energy system that is necessary to reach the decarbonisation targets of the Climate Change Act, includes the expansion of renewables and the phasing out of coal (Staffell 2017: 463n). In light of these ambitious targets, which reach beyond those of the Kyoto protocol and Paris Agreement, British performance in reducing carbon emissions has shown positive results. The decrease in carbon emissions and the parallel improvement in energy efficiency, are both said to be caused by favourable changes in industrial and energy structures, framed by specific policies in support of a low carbon economy (Burck *et al.* 2013). Furthermore, econometric evidence on the effects of the reduction in carbon emissions suggests that this has been achieved with largely positive effects on economic growth and employment (Pollitt *et al.* 2013).

Figure 3.1b outlines the United Kingdom's greenhouse gas emissions performance since 1990. Greenhouse gas emissions were reduced by 36.1 per cent between 1990 and 2015; a pattern that represents a success, and actually outperforms the average reductions in the EU 28 economies, as well as besting most OECD economies during the same time period (see Figure 3.1a). The reductions in carbon and energy intensities have actually outweighed the impact of economic growth since the 1990s. In disaggregating greenhouse gas emissions, the most striking performance was delivered in the non-carbon dioxide gas domain, as a small number of industrial installations accounted for nearly all of these emissions and their subsequent reduction

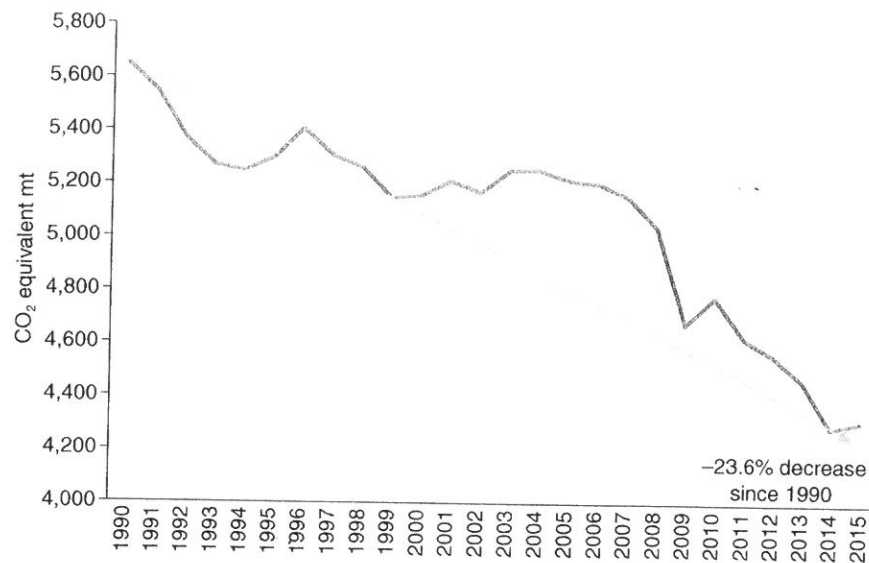


Figure 3.1a EU GHG emissions.

Source: UNFCCC Data Interface, 2017.

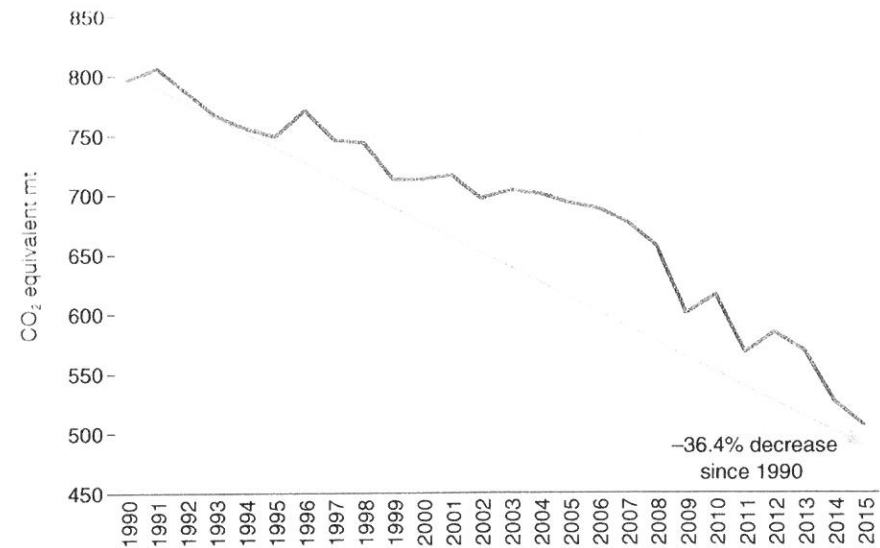


Figure 3.1b UK GHG emissions.

Source: UNFCCC Data Interface, 2017.

(Bowen and Rydge 2011: 6). The economic downturn in the late 2000s seems to have catalysed a further decline in greenhouse gas and carbon dioxide emissions, resulting in a faster average rate of decline per head between 2005 and 2009, driven by a fall in the growth of GDP per capita, along with a fall in both carbon intensity and energy intensity of output (Bowen and Rydge 2011: 8). In addition, the observed reduction in carbon emissions since 2012 is said to be due to falling coal consumption, thus reflecting structural changes in the prevailing energy mix (Staffell 2017: 472). In summary, despite fluctuations in annual emissions performance, the overall trend of decreasing emission levels has persisted as one of the most relevant contributions to the transition towards a low carbon economy (DECC 2013c: 2). This promising performance in the reduction of greenhouse gas and carbon emissions points to the fact that, for 2016, more than half the electricity in Britain was generated from low carbon resources, which includes renewables, domestic nuclear, and French nuclear and hydro imports (Wilson and Staffell 2017).

Figure 3.2 provides an overview of British greenhouse gas emissions by their source, as recorded since 1990. It underlines the high share of the energy sector in total emissions (which is standard for most countries), while the role of manufacturing industries remains comparatively small. This is in line with structural changes in the industrial sector, based on a drive towards a service economy. Emissions reductions by sector between 1990 and 2015

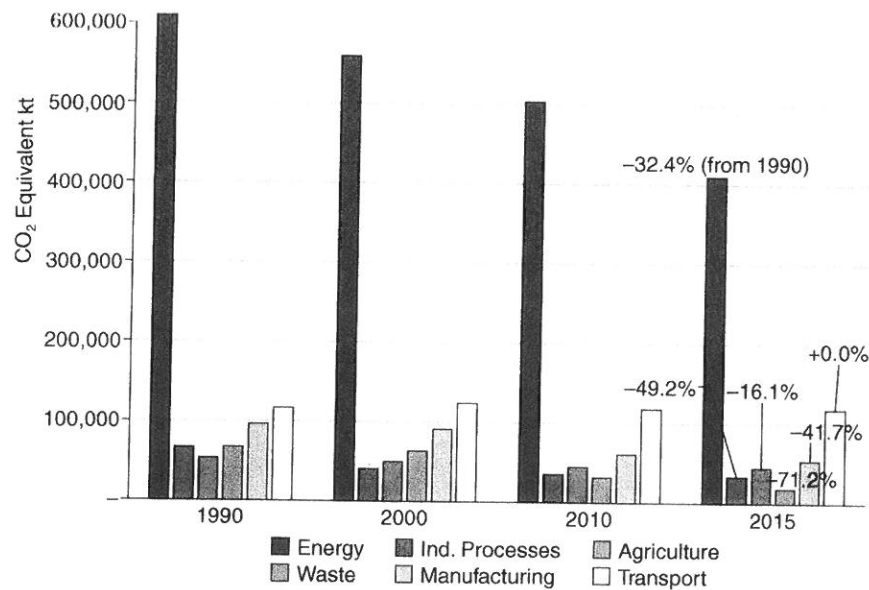


Figure 3.2 GHG emissions by sector.

Source UNFCCC Data Interface, 2017.

proceeded as follows: the energy sector decreased its emissions by about 32 per cent during the 25 years under scrutiny; the agriculture sector by 16 per cent; manufacturing industries and construction by 42 per cent; and industrial processes and product use, including waste, by almost 50 per cent and 71 per cent respectively; the transport sector kept its emissions fairly level throughout the period, following slight increases during the 1990s. With regard to the overall mix of sources of greenhouse gas emissions, however, a downward trend in emission levels is obvious (UNFCCC 2017b). Furthermore, there are decreases in emissions from the residential sector recorded during the most recent decade with a drop by 20 per cent in 2010 alone (DECC 2013c: 6). This decrease in residential emissions reflects temporary influences, such as temperature swings, but it also stands for the overall reduction in demand for electricity, actual modes of residential gas use, and greater use of nuclear power for the purpose of low carbon electricity generation (DECC 2013c).

The British fuel mix provides further evidence on the specific energy base of the United Kingdom. Indeed, the mix of fuel from domestic electricity suppliers has been going through some obvious structural change in recent years. Coal has lost its leading position in the electricity generation mix, gas and nuclear have slightly expanded their shares, while renewables have exhibited impressive growth. This pattern of substituting coal for gas was already

visible in the context of a 'dash for gas' during the 1990s, based on short lead times, low capital costs, quick returns on investment, new gas finds and low international gas prices. Coal was therefore under constant cost and price pressures that would contribute to its politically framed, later phasing out (DBEIS 2017; DECC 2013b). It is worth noting that the share of energy from coal has been relatively small compared to other European and OECD economies; a pattern that can be explained as an effect of the politically enforced de-industrialisation processes of the 1980s and 1990s, which predominantly hit coal-based heavy industry. The current policy of phasing out coal as a means of decarbonisation builds on these structural specificities. A further specificity relates to current British plans to promote the utilisation of nuclear energy in the fuel mix, which can build on widespread political support including from labour unions.

Electricity capacity dynamics provide a telling illustration of this decarbonisation process. The fossil fuel capacity fell from 65 GW to 45 GW between 2011 and 2016, whereas renewables expanded from 2 GW to 27 GW. In line with these tendencies, the share of fossil fuels within the electricity supply fell from 83 per cent in January 2009 to 45 per cent by December 2015. The share of nuclear remained consistent at around 20 per cent, and renewables – including gas, biomass, wind, and solar – increased from 4 per cent to 25 per cent. By the end of 2015 wind had overtaken coal's share in the electricity supply. At the same time, electricity imports grew from almost zero to 7 per cent of the total (Staffell 2017: 467n). A further look at the dynamics of electricity generation underlines the pattern of coal collapsing and renewables expanding. In the UK, excluding Northern Ireland, coal held a 9.3 per cent share of electricity generated in 2016, down from over 40 per cent in 2012. At the same time, wind produced a 10.2 per cent proportion of electricity, followed by solar with 3.2 per cent (Wilson and Staffell 2017). This outstanding performance by wind power also reflects the fact that the United Kingdom is the windiest country in Europe and therefore possesses environmental conditions that are conducive to wind energy. Accordingly, the United Kingdom persistently takes one of the top spots when it comes to the new deployment of wind power facilities in Europe (Global Wind Energy Council 2012).

Figure 3.3 depicts data on electricity generation from renewable energy sources as a percentage of gross electricity usage between 2004 and 2015. In 2004 this share was at 3.5 per cent, which dramatically increased more than six-fold to 22.3 per cent in 2015. The corresponding level for 2015 in the EU economies was already 28.8 per cent at this point. In a similar manner, energy from renewables has been experiencing a solid take-off during the 1990s and 2000s; the contribution from renewable energy to total primary energy supply has risen from 0.5 per cent in 1990 to 3.1 per cent in 2009, paralleled by a share in electricity generation which has risen from 1.8 per cent to 6.7 per cent between 1990 and 2009. Still, the contribution of renewables has so far remained comparatively low relative to other OECD economies (Bowen and Rydge 2011: 12–13).

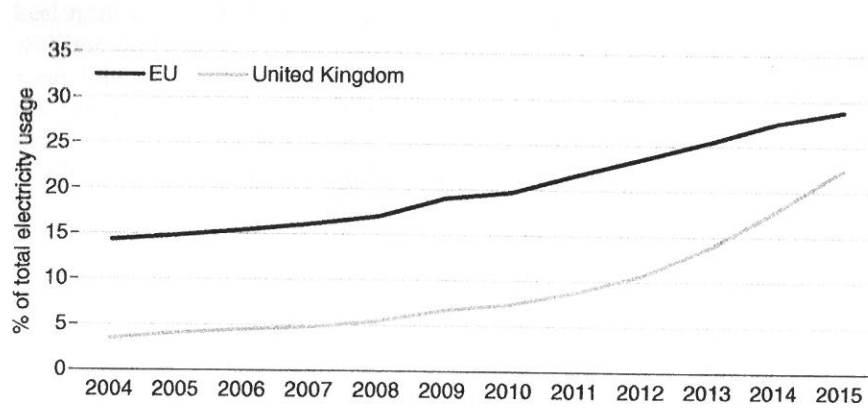


Figure 3.3 Share of renewable energy in electricity.

Source: Eurostat, 2017.

Figure 3.4b provides an overview of the United Kingdom's primary energy consumption from 1990 to 2015. It shows swings of generally increasing consumption during the 1990s and 2000s, followed by levels that only markedly decrease from the mid-2000s. Primary energy consumption only settles below the 1990 standard after the early 2010s. However, the same cyclical pattern of primary energy consumption also holds for the EU 28 economies, as can be seen in Figure 3.4a.

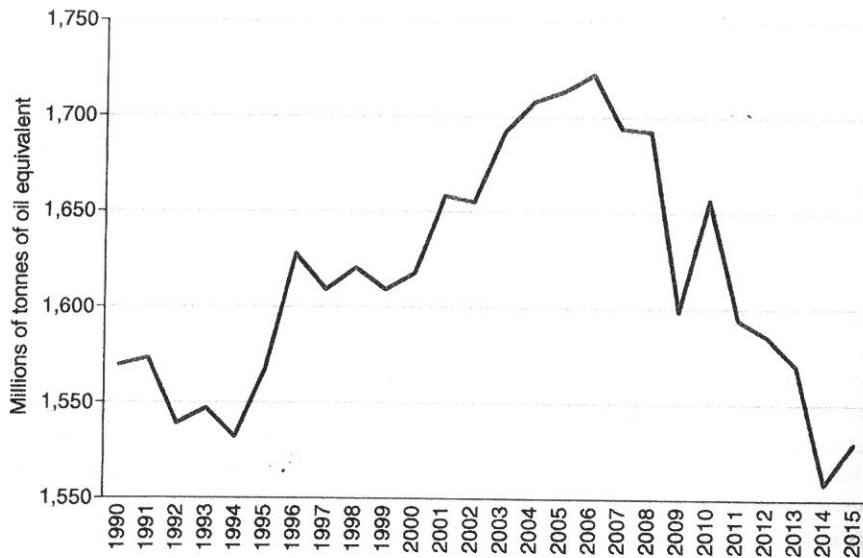


Figure 3.4a EU primary energy consumption.

Source: Eurostat, 2017.

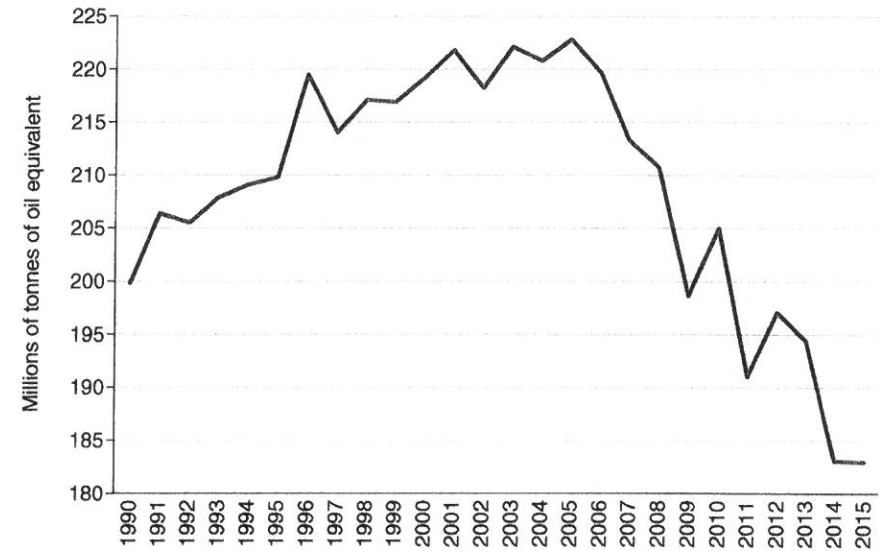


Figure 3.4b UK primary energy consumption.

Source: Eurostat, 2017.

Figure 3.5 outlines the dynamism of resource productivity in the United Kingdom between 2000 and 2013. Given the key role resource productivity plays in resource-friendly ecological transformation, the British metrics are quite impressive, with a resource productivity increase of 71 per cent between 2000 and 2016; a performance that dramatically exceeds that of the EU economies.

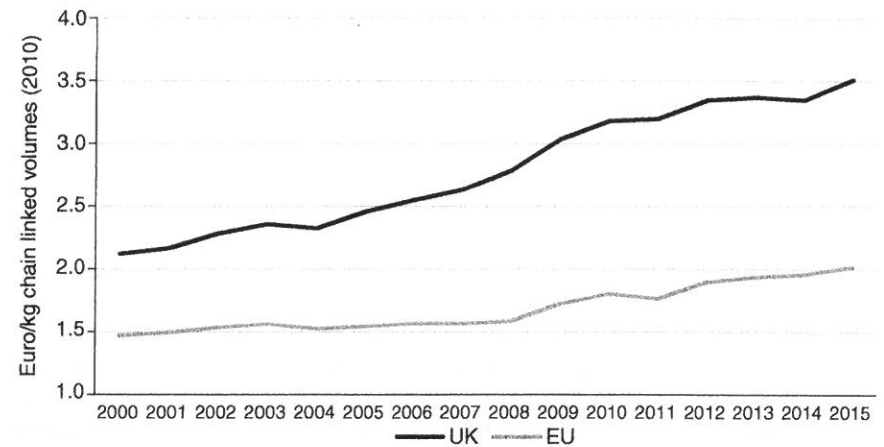


Figure 3.5 Resource productivity.

Source: Eurostat, 2017.

However, the low carbon transition of the British economy also needs to be assessed with regard to import and export dimensions. Available data indicate that the import side of energy supply has been prevailing over exports in recent years with a net import dependency of 43 per cent, a fossil fuel dependency of 87.3 per cent and a low carbon share of 11.9 per cent in 2012. While net import dependency has thus risen by almost 20 per cent in recent years, fossil fuel dependency has shrunk from over 90 per cent in 2010 to just under 83 per cent in 2013 – data which underline the steady turn away from coal (DECC 2013b: 9–10). This shift in the energy foundation is also constitutive for the British position in the European Union's emissions trading system. In this setting, the United Kingdom has been a net seller of emission allowances (DECC 2013c).

The geographic heterogeneity of carbon emissions can be seen by exploring disaggregated emission activities at regional and local authority levels, and in particular sectors and industries, which tend to have evolved into industrial agglomerations in certain regional and local settings. Indeed, changes in greenhouse gas emissions between 2005 and 2011 reflect the spatial concentration of industrial activities. Traditional manufacturing industries are expected to be most prominently affected by emission reduction efforts. During 2005 to 2011 the highest percentage change in greenhouse gas emissions was a 30 per cent decrease in the North East of England (known for its large industrial installations). The region that showed the least progress in decreasing emissions was Northern Ireland, with a decrease of 8 per cent. Northern Ireland is also one of the less developed industrial regions in the UK. Wales and Scotland both exhibit similar percentages of emissions reduction with 11 per cent and 12 per cent respectively. More pronounced is the reduction performance of the North West of England and Yorkshire with 18 per cent, the South East of England with 17 per cent, the East and West Midlands with 16 per cent and 15 per cent, and the Greater London area with 14 per cent. In effect, in 2011 the South East of England remained the region with the highest level of emissions, amounting to 54,634kt CO₂, followed by North West England with 49,043kt CO₂ and Yorkshire with 43,382kt CO₂. In terms of the industrial specificity of these greenhouse gas emissions, the biggest share of emissions was generated by industry and commercial electricity, followed by household domestic electricity and diesel railways (DECC 2013a).

In exploring the inherent dynamics and development of the British economy's carbon emission profile, we will have a closer look at the prevailing institutional framework. This framework coordinates economic transactions in terms of production and consumption, with institutional scaffolds that underlie the low carbon transition being shaped by government activities, and even cultural dispositions that allow for the reconstruction of distinctly national types of capitalism. In the case of the United Kingdom, this national type of capitalism has been commonly perceived as a liberal model, based on competitive market processes for firms and industries, framed by the legal

governance mechanisms of a regulatory state. Accordingly, viewed from the VoC perspective, the British transition towards a low carbon economy is expected to be based on market-compatible fiscal and legal frameworks that set incentives for firms to decrease their emission activities. However, the British variety of capitalism's prevailing institutional setting is much more complex than the simplistic traditional VoC LME might suggest.

The British variety of capitalism

From the perspective of the VoC approach, the United Kingdom is typically characterised as an ideal LME, which exhibits a dominant pattern of market coordination through investment in transferable assets (Hall and Soskice 2001). Its common qualities involve market-oriented characteristics in the major sub-systems of corporate governance, industrial relations, skill formation, education and training, finance, technology transfer, innovation and polity. The system of corporate governance echoes the logic of financial markets, as it is marked by an orientation towards shareholders that combines the prevalence of short-term financial resources with publicly assessable market monitoring. This puts high performance pressures on discretionary management. Industrial relations exhibit a market-oriented form of wage formation, with decentralised wage bargaining and few barriers to workforce turnover. Skill formation proceeds largely on the job, without a formal apprenticeship system for vocational skills. This implies a less relevant role for unions in the qualification of these skills. The market-based financial system undergirds the strategic importance of financial markets. These are linked to managerial concerns with shareholder value, market capitalisation, and competitive markets for corporate control. Technology transfer proceeds in terms of a competitive mode of standardisation and market-based mechanisms. The related innovation regime tends to favour radical technological innovations that disrupt established routines and paradigms. This innovation environment provides competitive advantages during periods of changing techno-economic paradigms, with a strong bent for entrepreneurial initiatives. All of this is flanked by a political system that operates as a liberal regulatory state with parliamentary sovereignty and centralised governance mechanisms, driving policies that maintain the primacy of market-based incentives in the regulation of economic affairs (Casper and Kettler 2001: 14).

Based on the patterns of the prevailing sub-systems, and the complementarities between them, comparative institutional advantages sustain the technological and industrial specialisation of firms in the different VoC approaches. Thus, firms in LMEs are expected to realise advantages by generating more radical and disruptive innovations, due to the flexible institutional setting in which they are nested. Therefore, the liberal model may reign supreme in times of rapid and comprehensive change, especially in terms of paradigmatic technologies on an international scale. This is because adaptive flexibility in the institutional domain becomes key in maintaining industrial competitiveness

(Hall and Soskice 2001: 38–41; Soskice 1994). The transition to a low carbon economy poses a distinct challenge for each country's prevailing capitalist variety. From the VoC analytical perspective therefore, one can expect the transition path for the UK to be shaped by the specific systemic institutional complementarities, and industrial specialisations, that constitute a LME (Hall and Soskice 2003).

Recent discussions in the comparative capitalisms domain understand complementarities as an outcome of evolving institutions, which are subject to institutional recombination and change. Accordingly, institutional diversity needs to be viewed as the common state of institutional co-evolution of capitalist varieties, resulting both from internal forces, such as sectoral and regional specificities, and from external impetuses, such as international regulatory regimes and foreign investment activities (Lane and Wood 2009). Implications for a conceptual assessment of institutional change are straightforward: a wide scope for institutional hybridisation may take place, which changes the quality of complementarities by adding ever new institutional components. Speaking of hybridisation then, implies dealing with deviations from empirically grounded ideal types, and thus allows for an adequate understanding of capitalist diversity (Crouch 2005). The political dimension of this process is reflected by a hybridisation of state-market relations, which is shaped by the diversity of interest groups and their organisational patterns across all domains of society (Hancké *et al.* 2007).

Historically, the British variety of capitalism evolved with Britain as the hotbed of industrialisation during the nineteenth century, serving as a 'workshop of the world' that would generate major technological innovation, and promote liberal standards of free trade and market competition under the rule of law. At the same time, London evolved as the major financial centre of the world economy, with a reach far beyond that of the division of labour within the British Empire. These pioneering efforts at industrialisation and the formation of modern industrial capitalism, might explain why the economic impact of British capitalism remained remarkably strong all the way through the twentieth century (Dore *et al.* 1999). The underlying trajectory of economic performance, however, reveals further specificities and allows us to revisit Britain's institutional diversity. Following economic reconstruction during the post-war era, the British economy regained industrial strength in its internationally competitive industries, such as automotive, aerospace and pharmaceuticals. This continued until the 1970s, when the impact of industrial restructuring in traditional heavy industries met with macro-economic turbulence in unemployment and inflation. The onset of Thatcherism in the political domain and its deregulation strategies, pushed structural change towards services, with financial services being an especially prominent example. Ever since, the British economy has been shaped by a rapid drive towards the tertiary sector, although those core activities in manufacturing accompanied by the rise of new science-based industries, such as biotechnology, still prevail (Booth

2001). These changes in the industrial environment are also reflected in the evolution of British capitalism.

In effect, Britain's LME model has been subject to comprehensive reconfigurations that have affected its diverse institutional forms and layers (Crouch *et al.* 2009). Major institutional changes were promoted in a political system characterised by a strong government, based on parliamentary sovereignty and centralised governmental capacities. The voting system favours single-party governments with strong legislative capabilities that are able to support potentially disruptive policies (Wood 2010: 259). In fact, some of the liberal character of the British variety of capitalism was contested by the Labour government during the post-War era, in effect introducing elements of non-market coordination to domains such as labour rights and welfare services, while also expanding the public sector. Remnants of corporatism would even expand during the 1960s and 1970s and business associations and labour unions were even involved in price and income regulation efforts, as promoted by the Conservative Heath government in the early 1970s (Moran 2009: 42–45). Labour governments also tried to strengthen market coordination in the 1970s. Subsequently, major components of the liberal model have been reintroduced, initiated by the reforms of the Conservative Thatcher government in 1979. This included rolling back non-market coordination in areas such as corporate governance, industrial relations and financial markets. As a result, the role of government in the economy at large was redefined by pressing for an extension of state autonomy in economic governance (Howell 2007). These deregulation and privatisation efforts propelled the UK to within striking distance of the idealised LME (Wood 2001).

Crucially, the liberal reform programmes of the late 1970s and 1980s provided further incentives for the expansion of an already strongly liberalised and economically potent financial system. The bias towards financial markets has reinforced the short-term competitive strategies of firms, allowing for constant pressure on returns and profitability (Fioretos 2011: 221). This set of market-oriented incentives spurs radical technological innovation in new industries, because it allows for a more comprehensive reallocation of resources, while simultaneously furthering cost and price competition in established industries (Vitols 2001). However, the combined economic and societal range of these financial markets also needs to be taken into account. For instance, investment and pension funds in the UK hold almost half of all available shareholdings, which is far greater than corresponding numbers in coordinated market economies (Crouch *et al.* 2009). These basic orientations towards a liberal model also prevailed with the shift towards New Labour. The Blair government kept a commitment to these liberal market positions, although some coordinated elements were introduced, such as state involvement in skills upgrading and retraining of the workforce and a more union-friendly outlook in industrial relations (Coates 1999). Regional devolution created further manoeuvring room for regional policy experiments with non-liberal coordination patterns, such as networking and associational

governance. The regional authorities in Wales and Scotland in particular would utilise these options in deviating from the hegemonic liberal model at the national level (Moran 2009; Morgan 2007; Amin, Cameron and Hudson 2002).

From a VoC perspective, the decarbonisation of the economy involves a restructuring of institutional complementarities in line with industrial and technological specialisation. This restructuring is driven by strategic coalitions of change and can also be obstructed by adverse coalitions that would like to maintain the status quo, or at least slow down the process of transformation. In terms of the prevailing discourses on the transition towards a low carbon economy, it has been argued that the United Kingdom is stuck between a market competition and governmental control ideology, thus exhibiting a politically entrenched contradictory rationale, which may impede further transitory progress (Keay 2016). A key problem in this regard is therefore the unlocking of path dependence by means of collective action, in both the economic and political systems (see Hübner in Chapter 1; Altenburg and Pegels 2012). Beyond these policy elements, the material driving force of a low carbon transition can be traced to new products, production processes and modes of energy supply, that is, in the domain of technological innovation. In addressing the relationship between institutions and innovation in distinct VoC, it may be argued that the prevailing institutional complementarities also shape the institutional architecture of the related national innovation system (Hübner 2009; Ebner 1999).

Low carbon innovation in the British innovation system

The VoC perspective claims that LMEs exhibit advantages in radical innovation, especially in high-tech industries. This claim derives from the prevailing set of institutional complementarities among the main sub-systems in the institutional environment of business firms (Hall and Soskice 2001). Empirical explorations of OECD economies during the 1990s and early 2000s have largely confirmed the prediction that LMEs tend to specialise in high-tech exports; although aspects of internal diversity and technological dynamics within these classifications need to be taken into account (Schneider and Păunescu 2012). In the case of the United Kingdom, this is exemplified by debates on the advent of biotechnology as an industrial and technological field. Biotechnology is marked by a deep science base with strong university–industry linkages and sustained patterns of entrepreneurial start-up activities, all of which seem to be successful in the context of LMEs (Casper and Murray 2004; Taylor 2004). The British innovation system's institutional setting is distinguished by a pattern of university-related research activities, with an emphasis on research and development (R&D) cooperation. This is most prominently seen in high-tech sectors that are characterised by entrepreneurial activities, such as biotechnology. Empirical evidence shows that, when

compared to other European economies, the United Kingdom is distinguished by both the breadth and intensity of university–industry interaction in its science-based industries (D'Este and Patel 2007). Indeed, the British innovation system has been ranked second in an international comparison for university–industry collaboration in R&D by the World Economic Forum. The UK also stands out in terms of R&D funding from abroad, and in scientific output as measured by scientific citations (BIS 2012).

The revealed technological advantage metric provides further insight to this pattern of specialisation. This metric counts the national share in world patents of a certain good, divided by its total share in world patents. During the late 1990s, the British pattern of revealed technological advantage highlighted competencies in pharmaceuticals, chemicals and aerospace (Tylecote and Visintin 2008: 258–259). Accordingly, when it comes to the industrial specialisation of innovation efforts, science-based industries stand out – these include biotechnology, biosciences, pharmaceuticals, defence, aerospace and automobiles. This bias in industrial innovation is accompanied by the eminent role of financial markets in the provision of venture capital (Leijten *et al.* 2012). However, this pattern of industrial and technological specialisation goes along with a comparatively narrow path of R&D operations in the British innovation system. The gross domestic expenditure on R&D/gross domestic product (GERD/GDP) ratio for the United Kingdom has been operating way below the 2 per cent threshold throughout the 2000s – with comparatively high shares of publicly funded and enacted R&D. This GERD/GDP ratio is slightly below the EU average and significantly below global economic powerhouses such as Japan and the United States. The British GERD/GDP profile has also remained below the OECD median value on both the input and output (patenting activities) side (OECD 2012b). With regard to the sectoral performance of R&D activities, the available data show that more than 60 per cent of all R&D in 2010 was carried out by private sector business, 27 per cent in higher education, 9 per cent in government, and the rest in non-profit organisations. In terms of a comparative perspective within the OECD, the British R&D profile underlines the gigantic role of higher education in R&D (OECD 2010c). Thus, public involvement in R&D remains comparatively high in the LME of the United Kingdom. A pattern that may reflect such factors as the short-term market orientation of the private sector, as well as gargantuan uncertainty in science-based innovation that constrains, or even prevents, private sector initiatives with their distinct rationale of investment. The large contribution of higher education to the R&D performance of the British economy is also noteworthy, involving both private and public institutions. It reflects the role of universities as pillars of a British national innovation system that is increasingly oriented towards science-based university–industry relations, with strong market linkages (Mikler and Harrison 2012: 191).

Among the challenges facing the British innovation system is the paucity of privately financed industrial R&D investment, which remains comparatively

low according to OECD measures. Other hurdles comprise the maintenance of public funding of the national science base in times of fiscal austerity, the promotion of an adequate supply of venture capital and the ongoing supply of human capital in science and technology. The latter reflects the comparatively low share of science and technology occupations in total employment (OECD 2012a; Cunningham and Sveinsdottir 2012: 12). Knowledge-based entrepreneurship in emerging science-based industrial fields, such as biotechnology, requires an adequate supply of manpower, thus reiterating the long-standing need for extended public-private interactions between firms, universities and government when it comes to strategic efforts in high-level education and training (Casper and Kettler 2001).

The governance and policy dimensions of these distinct innovation and industrial change profiles in the United Kingdom are straightforward. First, the market-based coordination patterns of LMEs as in the United Kingdom tend to rely more prominently on formal regulations and government activities in science and technology. These are meant to promote radical technological change in line with the logic of market competition. In official expositions therefore, the private sector is said to be in the lead, while government facilitates and provides adequate institutional conditions for technological innovation in promising industrial fields, such as renewable energy (DECC 2011a: 12). Accordingly, when it comes to ecologically oriented types of innovation, market signals are dominant in carrying out technological change. Activities of consumer initiatives and related interest groups from civil society remain attached to this market logic, as they aim to alter market signals and related market incentives for innovation (Mikler 2009, 2011). Thus, as the British innovation system and its contribution to the transition towards a low carbon economy indicate, the actual relationship between institutions, innovation and ecological sustainability is quite complex, but the core of the system still clearly reflects a market orientation.

The institutional scaffold of the United Kingdom's national innovation system is constituted by interactions between firms, universities, research organisations, industry associations, unions, political and administrative organs, as well as diverse actors in complementary policy areas such as research, education and finance. The coordination of these interactions combines the competitive dynamics of markets with extensive legal frameworks provided by government. In this setting, a key policy player in the governmental domain has been the Department for Business, Innovation and Skills, which was responsible for several related policy areas, such as technological innovation and intellectual property rights, along with science, research and higher education. It had also overseen the Government Office for Science and housed the Council for Science and Technology with its advisory functions for government. In July 2016 however, it was merged with the Department of Energy and Climate Change to form the new Department for Business, Energy and Industrial Strategy. This measure by the Conservative May government is not necessarily a downgrade. It could possibly be a device

for a more integrated industry-oriented climate policy that frames the public support for low carbon innovation (Hepburn and Teytelboym 2017). An important public body has been the Technology Strategy Board, a former advisory body within the Department of Trade and Industry, which had evolved into the United Kingdom's premier innovation agency. It was recently reorganised and renamed InnovateUK. It is now labelled as an executive non-departmental public body that is sponsored by the new Department for Business, Energy and Industrial Strategy. In the past, it had developed several innovation programmes to stimulate technological change. One example is the low carbon vehicles innovation platform, which promotes R&D in low carbon automobile technologies (Technology Strategy Board 2013). A complementing organisation is the Small Business Research Initiative, which offers assistance to entrepreneurial start-ups and small and medium-sized enterprises, in the commercialisation of their innovative products by providing lead customers from the public sector (SBRI 2013). These concerns with commercial viability have also been relevant for new bodies created to support low carbon innovation during the 2000s, these include the UK Energy Research Centre and the Energy Technologies Institute (International Energy Agency 2015).

The former Technology Strategy Board also co-initiated the N8 Industry Innovation Forum, along with the Higher Education Funding Council for England and the N8 Research Partnership. These bring together the leading research-intensive universities and global firms involved with UK R&D, including AstraZeneca, Croda, National Nuclear Laboratory, Procter and Gamble, Reckitt Benckiser, Siemens, Smith and Nephew and Unilever. The Industry Innovation Forum supports linkages among these key players in the national innovation system, by creating collaborations between the established research base and industry (N8 Research Partnership 2013). A further programme in this domain is the UK Research Partnership Investment Fund, which provides financial support to higher education research facilities. It was set up by the Higher Education Funding Council for England in 2012, with a total of £300 million in funds for 22 university projects. It also attracted additional private funds in the process (HEFCE 2013). This strategic thrust to further university-industry relations is shared by sector-specific Research Councils, which are publicly funded research agencies, each providing their own particular funding and support opportunities. The Research Councils UK energy programme is responsible for research on global competitiveness in energy security, affordability and sustainability (Research Councils UK 2013). A related component of these efforts since 2007 is the formation of Innovation and Knowledge Centres, funded by the Engineering and Physical Sciences Research Council, in a comprehensive university and business collaboration initiative (EPSRC 2013). The private non-profit sector also contributes to the British innovation system with activities of the Wellcome Trust in life sciences as a case in point (Leijten *et al.* 2012). A major venture capital fund – initially sponsored by the former Department for Business

Innovation and Skills, the Department of Health and the Department of Energy and Climate Change – has aided technological innovation efforts. This fund, the UK Innovation Investment Fund, promotes venture capital investment in high-tech SMEs and entrepreneurial start-ups. In 2009 Hermes Private Equity and the European Investment Fund were selected as fund-of-fund managers for this fund – which is actually the largest European technology venture capital fund, as well as being a public fund (BIS 2009). Therefore, the finance-innovation nexus in the British innovation system involves shares of public venture capital, and this reflects the persistent involvement of government in the national innovation system.

In view of these innovation profiles, the actual performance of the British innovation system in the low carbon transition is rather ambivalent. In 2011, expenditure on R&D in the fields of energy and environment only comprised 3.2 per cent of total public R&D expenditures, which remains rather low globally. R&D spending in energy-related industries has actually declined over the past 20 years in relation to GDP, with the British government lagging behind other major OECD economies in terms of spending on energy R&D. The more recent resurgence in government R&D is largely due to spending on renewable energy R&D, whereas government funding for clean energy R&D remains underrepresented (Bowen and Rydge 2011: 14).

Similar patterns hold for the output side of low carbon innovation. Although the United Kingdom was ranked high in ‘clean’ innovation global patent submissions during the 1990s and 2000s, with British patents experiencing sustained growth, its position slipped slightly in the latter period. In addition, their number is still way below the patenting efforts of other leading economies. While the United Kingdom remains a leader in marine energy innovation, its international ranking declined in batteries, electric and hybrid vehicles, nuclear, methane, heating, solar, fuel injection and waste. However, these tendencies are not only the result of a relatively underperforming British innovation system but they also seem to be due to higher growth in patenting activity in emerging economies such as South Korea (Bowen and Rydge 2011: 15). At the same time, British green technology patents have shown a low degree of specialisation throughout the 2000s. The UK’s proportion of world patents for environmental management is 4.8 per cent, it is 4.6 per cent for energy generation, 2.9 per cent for transportation, and 2.6 per cent for emissions mitigation technology (OECD 2012a: 69). The sub-field of clean energy patenting comprises the patenting of activities in technologies such as solar, wind, carbon capture and storage, hydro, geothermal, biofuels and the integrated gasification combined cycle. In this particular sub-field, the British share of global clean energy technology patents between 1988 and 2007 was 3.6 per cent, while the in the EU that share was 32 per cent. Also, in this particular sub-field, the United Kingdom exhibits a revealed technological advantage below 1 – that is, no significant advantage at all. In line with this pattern, British numbers of patent applications filed under the Patent Cooperation Treaty for energy generation from renewable and non-fossil

sources in 2010 were much lower than those of other leading OECD economies (Veugelers 2011: 4–5).

Accordingly, comparative technology advantages of the UK in green innovation from 1988 to 2011 were most prominent in the fields of wind, hydro, biofuels, and carbon capture and storage (Veugelers 2011). In OECD rankings the United Kingdom holds the sixth place in patents for clean energy technologies; in the hydro/machine domain the UK is ranked fourth, in biofuels fifth, in carbon capture and storage fifth, and in integrated gasification combined cycle fourth (OECD 2012b). These advantages are related to distinct industrial fields. The most advanced green innovation sectors in the United Kingdom are actually in ‘pharmaceuticals, medicinal chemicals, etc.’ with a green innovation score of 1.8 and a revealed comparative advantage score of 1.9. In comparison ‘measuring/testing/navigating appliances, etc.’ held a green innovation score of 1.0 and a revealed comparative advantage score of 1.6 in 2012 (Fankhauser *et al.* 2012).

When it comes to venture capital and private equity in financing low carbon technology innovation, the leading economy in this field is the United States. USA investment volumes are almost eight times higher than those generated in the United Kingdom, which is ranked second globally. However, the latter still accounts for related financial operations, which are more than two times greater than the EU average. In fact, along with tidal and wave, biomass, wind and others, carbon finance has evolved as a major low carbon growth sector (BIS 2010). In line with this pattern, the United Kingdom was by far the biggest European investor in renewables in 2015 and 2016, largely a consequence of offshore wind projects. It accounted for almost double the amount of investment of second place Germany (FS-UNEP 2017: 25). In general, energy efficient and low carbon technologies and services, and other renewables, take the largest share of green venture capital and private equity finance, with a particular focus on wind energy. This contrasts with Continental European economies that only hold minor shares in financial services for low carbon transition, which reflects their less market-oriented and more bank-based financial systems (McCrone *et al.* 2013). However, a major step towards the institutional hybridisation of the British variety of capitalism and its national innovation system has been made with the establishment of the Green Investment Bank. This bank is part of the public sector and finances investment activities in projects that contribute to government environmental and sustainability targets (Green Investment Bank 2012). This comes close to the model of a government-owned development bank supporting low carbon innovation; in any case, it can be seen as a major contribution to the moulding of a new financial infrastructure for ‘low carbon entrepreneurs’, who are set to promote innovative new enterprises with significant effects on the technology landscape (Carbon Trust and Shell 2013). Yet, promoting the dynamism of the low carbon transition requires much more than just the support of entrepreneurship and innovation. It also implies efforts in unlocking path-dependent institutional structures of the established energy systems.

Strategies and policies in the United Kingdom's low carbon transition

The British transformation path towards a low carbon economy is based on the impact of both incumbent firms and actors that promote the established large-scale energy system, involving both cooperation and struggle between industry and government (Geels 2014). The corresponding environmental policy style has been portrayed as pragmatic, with government partnering and consulting with industry. In contrast, environmental groups find it difficult to access governmental decision-making (Bailey 2007). This pattern is driven by a centralised political system that is most accessible to incumbent interests, while small parties like the Greens are disadvantaged. A predominant liberal ideology of market competition and cost efficiency, and comparatively weak structures of environmental organisations in civil society also characterise the British political system. While policies in favour of renewables have become more pronounced since the late 2000s, the basic orientation towards a coalition between government and established utilities remains strong. In effect, renewable electricity technologies in the United Kingdom are mainly related to large-scale centralised modes of deployment, as represented by onshore and offshore wind farms and the biomass conversion of coal power stations. In addition, nuclear power and carbon capture and storage systems add to the prevalence of large-scale varieties of low carbon electricity generation. Indeed, the dominant regime for lighting, heating and power services is still a system of centralised technologies with large-scale transmission and distribution frameworks. Recent policy efforts in support of renewables, such as the Community Energy Strategy, are meant to complement the established large-scale systems. The formation of a low carbon economy means that both this large-scale centralised energy system and its dominant market logic are under pressure from transitional forces. These forces encompass new technologies and transmission mechanisms that allow for decentralisation and small-scale operations, as well as new institutional and cultural patterns of non-market coordination that relate to these alternatives (Geels *et al.* 2016).

Historically, the post-war nationalisation of the electricity supply industry led to a lock-in of a highly centralised, monopolistic and large-scale energy generation system, involving fuel-based technologies and national grid networks. Thus, the energy component of the public sector expanded from the 1950s, run by the Central Electricity Generating Board. However, after the liberalisation and privatisation of the energy sector that was completed in the 1990s, which also involved the abolition of the Department of Energy in 1992, the market logic of competitive efficiency has been dominant. Yet a centralised system has, in fact, prevailed. An oligopolistic market structure emerged with six large vertically integrated firms. The expansion of this market logic has also been paralleled by government activities in support of an adequate market framework (Foxon 2013). Britain's centralised energy system prevents local deviation and niche competition, which are key factors

in the promotion of renewables in other, more decentralised, European systems. Unlocking these path dependencies thus stands for a key aspect of policy strategies in the low carbon transition of the United Kingdom (Simmie *et al.* 2014).

As outlined above, a key issue regarding the role of market competition in low carbon transition is the *oligopolistic* market structure of the British energy supply. In fact, 'big six' energy companies dominate the United Kingdom's supply structure, operating three-quarters of British electricity generation, while facilitating over 90 per cent of electricity supply in the British retail market. The leading player among these 'big six' is EDF Energy, a subsidiary of Électricité de France, the major state-owned French energy company. It is followed by Scottish and Southern Energy SSE. Other players are RWE power, a British subsidiary of Germany energy supplier RWE, Centrica British Gas, E.on UK, the British subsidiary of German company E.on, and Spanish company Iberdrola/Scottish Power (New Power Consulting 2011). Data on the carbon intensity and fuel mix of these energy suppliers in the United Kingdom serve as a reminder of the ramifications of nuclear energy in the British energy mix. EDF energy is the biggest supplier of nuclear energy in the United Kingdom and operates with the lowest carbon intensity at 280 gCO₂/kwh. In contrast, E.on UK operates with a negligible share of nuclear energy and therefore has the highest carbon intensity of the major firms at 543 gCO₂/kwh (Friends of the Earth 2011). In a dynamic view, EDF energy has made some major advances in low carbon activities. These are chiefly due to the acquisition of nuclear power plants, which have contributed to a massive reduction of the company's carbon intensity (ElectricityInfo 2013). Corresponding evaluations of carbon savings of the major energy suppliers tend to highlight their overall compliance with official reduction targets, although further improvements are deemed indispensable by the authorities (OFGEM 2013).

Policy efforts in support of the British economy's low carbon transition may be labelled market-oriented, quite in line with the prevailing liberal variety of capitalism and its bias towards market coordination of firms and arm's length regulation by government. Most domestic policies in the United Kingdom that target decarbonisation of the economy use price signals that set incentives for firms and households to adjust their behaviour in a cost-effective manner. Examples are tradable quota markets, as implemented in the form of a Renewables Obligation, and price-based instruments, such as the Climate Change Levy. There are also market regulations in support of specific mandatory actions, such as the labelling requirements for energy efficiency. As a matter of fact, legal measures that are related to programmatic governmental projections play a key role in the British approach to decarbonisation policy, this has become apparent since the late 2000s. An example is the Climate Change Act from 2008, which gave statutory force to carbon reduction budgets, accompanied by the Committee on Climate Change with distinct statutory responsibilities in the management of these carbon budgets (Bowen and Rydge 2011: 16).

Further hybridising mechanisms have emerged that transcend the logic of market coordination by infusing a rationale of governmental involvement. The influence of the public sector in the domain of green finance is a case in point, as outlined above. Transnational governmental influences in the corporate setting of the energy sector may also be addressed at this point. In conceptual terms then, this hybridisation of market and non-market coordination reflects long-standing historical processes in the recombination of governance mechanisms. These shape the institutional architecture of capitalist varieties (Crouch 2005). That being said, the institutional core of British capitalism still remains dedicated to the rationale of market coordination, which was constructed and installed in its current shape by the policy reforms of the 1970s. When it came to the energy sector, these liberal reform efforts involved privatisation in coal, gas and electricity, as well as a liberalisation of the energy market framed by complex regulatory efforts. It is fair to say that these privatisation and liberalisation processes in the energy sector, which paralleled the politically enforced decline of Britain's emission-intensive coal and steel industries during the 1980s, have shaped subsequent efforts in the transition towards a low carbon economy.

The political processes underlying British decarbonisation policies have been shaped by distinct actors and coalitions from across the political spectrum. Until the mid-2000s, the agenda of climate change mitigation was of secondary importance, not least because during the 1990s the United Kingdom was already making some progress in the reduction of greenhouse gas emissions. This reduction was an unintended consequence of the Thatcher government's privatisation of the electricity sector, which resulted in the replacement of coal-fired power stations with gas-fired plants. The instrument of non-fossil fuel obligations was introduced in 1990 as a means to support both nuclear energy and renewables, combined with an auction system that was marred by information asymmetries and benefitted incumbent firms and actors. In fact, the Conservative liberalisation and privatisation programs that were initiated by the Thatcher and Major governments kept a focus on price-regulated market competition and a business-related refocusing of governmental energy policy. This was symbolically institutionalised by the dissolution of the Department of Energy and the transfer of energy policy to the Department of Trade and Industry, in tandem with the establishment of the new regulatory agency Ofgem (Geels *et al.* 2016).

Blair's Labour government, installed in 1997, became a major force in the design and implementation of the low carbon agenda. It actively negotiated the Kyoto Protocol, yet – following extensive consultations with energy providers, industry and experts – it managed to go beyond the Kyoto targets. It also established a Climate Change Programme and introduced related initiatives, such as the Climate Change Levy as a downstream tax on commercial energy consumption. Crucially, Climate Change Agreements with industry would allow for major reductions, in exchange for the commitment to legally binding reduction targets. Furthermore, the Renewables Obligation

instrument was taken to the fore in order to encourage electricity generation from renewable sources (DETR 2000). The latter was designed as a market-based instrument that would accompany the established emissions trading market mechanism, which had been settled in the context of an UK Emissions Trading Scheme. Under the Renewable Obligations scheme, utilities would need to meet renewable electricity targets by either producing electricity from renewables themselves, by buying certificates from other electricity generators or by paying a penalty. Again, as in the case of the non-fossil fuel obligations, this mechanism exhibited an inherent bias towards favouring well established and experienced incumbents (Geels *et al.* 2016; Bailey 2007).

However, Blair's actual government activities were largely void of further decarbonisation actions; an aspect that was repeatedly criticised by the opposition. More ambitious governmental activities were hindered by organised interest groups. For instance, the proposal of the Climate Change Levy in 1999 initially met with hostile criticism by organised business interests. A year later, public discontent with increasing fuel prices resulted in organised militant protests led by hauliers' and farmers' organisations (Carter 2008). All of this contributed to delegitimising taxation as an environmental and climate policy. Instead, the government reverted back to the view that carbon markets, as exemplified by the European Union's Emissions Trading Scheme, were the best means of reducing carbon emissions. Intragovernmental conflicts between a less market-oriented policy approach pursued by the Department of Environment, Food and Rural Affairs and adherents of market efficiency in the Treasury, the Department for Trade and Industry and the Department for Transport were decisively solved in favour of the market (Lorenzoni *et al.* 2008).

Brown's Labour government pressed more emphatically for the transition towards a low carbon economy, while being engaged in political competition over the environmental affairs mantle with the Conservative and Liberal Democrat opposition in parliament, framed by green interest groups across civil society. Brown's government established a new Department of Energy and Climate Change in 2008, paralleling the introduction of the Climate Change Act with its ambitious emission targets to implement the emission targets of the Kyoto Protocol. This initiative made the United Kingdom a pioneer in building a credible, legally binding framework for achieving clear targets in the reduction of greenhouse gases. These amounted to a 34 per cent reduction in greenhouse gas emissions by 2020 from 1990 levels, and an 80 per cent reduction in emissions by 2050 from 1990 levels. These targets were to be framed by quinquennial carbon budgets that set the trajectory towards these targets, overseen by a formally independent Climate Change Committee. At the same time, the European Union's targets on renewables were accepted, with 15 per cent of all energy to be generated from renewable sources by 2020. Therefore, the United Kingdom became the first country to operate within a legal framework to tackle the problem of emissions and establish an institutional setting for governing the required adaptations

(Dreblow *et al.* 2013). Moreover, the 2009 Low Carbon Transition Plan presented an almost complete decarbonisation of electricity by 2030, including the expanded use of the renewals obligations for large-scale electricity generation, which had been in place since 2002, as well as feed-in tariffs for small-scale renewable electricity generation from 2010 onwards. This was accompanied by strategic investment in renewables, carbon capture and storage, grid capacity, transportation and storage in sustainable infrastructure, along with related R&D. The streamlined regulation and planning of marine, offshore wind and nuclear power were combined with market-oriented mechanisms of decarbonisation. These involved up-front financing of energy efficiency, internalised through energy bills and supplemented by clean energy cash-back schemes (DECC 2009). Crucially, energy supply and utilisation reform would also include the phasing out of coal, in effect making the United Kingdom the first country to commit to a coal phase out. In so doing, maintaining a decade-old trend of replacing coal with gas, and later on with renewables. Indeed, in addition to the economic pressures on coal, its decline was sped up by political means, such as the Large Combustion Plant Directive and then the Industrial Emissions Directive (Staffell 2017: 463n). Thus, in a historically unique political move, a Labour government would initiate the shut out of coal from the energy mix – finalising the decline of British coal, which had formed a major social basis of the Labour Party in prior decades.

The 2010 elections that resulted in a power shift from Labour to a Conservative–Liberal coalition government were marked by significant concerns with climate change across the political spectrum. Labour's 2010 election manifesto focused explicitly on the transition to a low carbon economy as a key challenge of future governments (Labour Party 2010). At the same time Cameron's Conservative Party had already developed a distinct political brand in terms of 'greening' the economy. The British Conservatives only became visibly interested in environmental affairs in 2005, under Cameron's leadership. This caused the climate change mitigation and emissions reduction agenda to join the mainstream of political debate. This was further intensified by green lobby organisations, such as Friends of the Earth, with their agenda of channelling environmental concerns into legal measures (Carter 2008). Also, since the mid-2000s, the British business community has become more open to tackling environmental issues within the confines of market regulations. The mitigation of climate change has increasingly been viewed as a new field of business opportunities in terms of improving energy efficiency, new green technologies and emissions trading schemes. The low carbon initiative of the Corporate Leaders Group – which formed in 2005 and includes major British corporations such as Shell, Tesco, Unilever and Vodafone – exemplifies this point. The Confederation of British Industry, the United Kingdom's major employers' organisation, would soon set up a task force on climate change that should contribute to the communication of related policy proposals (Strong 2010).

The Conservative Party's 2010 election manifesto combined the call for a reduction of greenhouse gases, with the goal of increasing the competitiveness of British firms in global markets for low carbon technology. Corresponding key projects included the establishment of the Green Investment Bank, meant to leverage private sector capital to finance new green technology start-up enterprises (Conservative Party 2010). In even more sweeping terms, the Liberal Democrat election manifesto emphasised environmental issues regarding climate change and the transition towards a low carbon economy, underlining a green political profile (Liberal Democrats 2010). Accordingly, the Cameron coalition government of Conservatives and Liberal Democrats took off with a distinct pledge to strengthen efforts in mitigating climate change and promoting energy efficiency, in so doing actually pushing for a more interventionist approach. This was done in terms of feed-in tariffs and new emission standards, despite increasingly vocal opposition from interest groups in industry and finance. Indeed, the coalition government continued the established low carbon strategy. Including, among other measures: furthering distinct Energy Acts; accepting the fourth carbon budget through to 2027; creating the Green Investment Bank; establishing a Green Deal for domestic energy efficiency; promoting smart meters in all homes across the nation; and reforming electricity markets. The latter was done in a manner aimed at encouraging companies to do more long-term investment in low carbon energy generation (Carter 2014: 423–424; Foxon 2013: 15). These electricity market reforms were meant to promote a system of feed-in tariffs with different contracts for large-scale renewables and nuclear from 2014 onwards, introducing fixed prices for energy generators along with market price oriented compensation for energy suppliers. Emissions performance standards should limit carbon emissions from new fossil fuel power plants, while long-term contracts are set to provide a high degree of revenue certainty to investors in low carbon generation domains, such as renewables, nuclear and carbon capture and storage (DECC 2011a, 2011b, 2012). Additionally, tendering is promoted as a possible means to mitigate the security of supply risk, in line with European market conditions (Meeus *et al.* 2012).

Crucially, nuclear power remained a debated topic in the politics of low carbon transition during the 2000s. In the coalition government, which initially proposed a major thrust towards decarbonisation, the Conservatives acknowledged the opposition of the Liberal Democrats on the nuclear issue, yet Cameron soon confirmed that the new government's strategic orientation should allow for the construction of new nuclear power plants. This is in keeping with the prevailing fuel mix – and also quite in line with the positions of previous Labour governments (Cabinet Office 2010). Therefore, the 2008 White Paper on Nuclear Power proposed that innovations might allow for the 'eco-friendly' inclusion of the nuclear sector in the low carbon economy strategy. Indeed, nuclear energy is increasingly seen as a relatively clean technology, which is likely to make an important contribution to the

energy sector's long-term decarbonisation. The military-political aspects of nuclear capacities also play a key role in this discourse, as is discussed below (Bowen and Rydge 2011: 26). This pro-nuclear stance has not been altered by the international impact of the Fukushima incident. Fukushima may have increased perceived dangers in comparative risk assessments when examining low carbon transition options, yet without damaging the generally positive standing of nuclear energy in the British energy mix (Rhys 2013). In fact, the Conservative Cameron and May governments have voiced continued political support for nuclear power as an energy source. Also, the building of new nuclear power plants is clearly an option for the future. In 2015 the Conservative government announced the construction of new nuclear reactors that should contribute to the low carbon energy system of the future (Pemberton 2017).

However, the matter of climate change mitigation and low carbon transition has recently become the subject of some serious conflict within British politics. While the cross-party consensus on energy and climate policies has largely been sustained, growing divisions within the Conservative Party have turned climate change into an increasingly partisan issue. For instance, the Conservative position on the environment involves cautious support of fracking, while becoming ever more critical of the subsidy-based promotion of onshore wind power and other types of renewable energy sources. During the Liberal-Conservative coalition government, environmental debates were reflected in controversies between the government's economic and environmental affairs departments. Both departments were stacked with Conservative and Liberal Democrat leadership personnel, and repeatedly communicated conflicting policy strategies on these issues, despite belonging to the same administration (Macalister and Harvey 2013). This burgeoning stance towards low carbon policies reflects growing discontent among Conservatives on the economic costs of emissions reduction, which allegedly pose an increasingly unbearable burden on businesses and their competitive performance. Thus, the promotion of subsidies for offshore oil and gas exploration has become a debated topic, while the legally binding definition of decarbonisation targets remains controversial (Carter 2014: 429-430).

In actuality, recent reforms under Conservative leadership have involved feed-in tariff auctions, which provide a competitive market mechanism to counterbalance price distortions; a policy motive that has become ever more pronounced since the Conservatives took over again in 2015. However, with Prime Minister May in charge, the Conservative government seems set to maintain the low carbon agenda of previous governments. A government proposal from November 2015 aims to deliver on the phase-out of unabated coal use by 2025. As coal use is at a historic low, with major coal plants closing, the remaining ones being over-aged, and electricity generation from solar surpassing coal for the first time, it seems as though the Conservatives may be ready to put the finishing touches to the complete phase-out of coal (Littlecott 2016). Still, this does not imply full-blown policy continuity with

recent Conservative governments, for the level of support for renewables has been revised. In particular, support for onshore wind and solar photovoltaic has largely been withdrawn in an effort to push the agenda of market-based competitive pressures as key forces in moulding the energy mix (Geels *et al.* 2016). Most specifically then, British low carbon policies signal that renewables might expand, as long as they are driven by markets, whereas nuclear remains a politically charged (and government subsidised) component of the energy mix – while coal is phased out at last (Keay 2016: 248n).

The upsurge of critiques against low carbon transition strategies in the United Kingdom, however, are not only an echo of business interests fighting regulatory measures that may drive up costs and endanger competitive advantages, but these positions also represent substantial criticisms of the efficacy of the implemented policy strategies. A common denominator for both proponents and detractors on energy and climate policies in the United Kingdom, is provided by the insight that the economy's low carbon transition is in need of a solid legal basis that credibly commits government. Given its long-term nature, strategies for decarbonisation may face time inconsistency problems as governments may be tempted to postpone difficult measures. In this respect, the combination of long-term commitments enshrined in law with statutory short-term targets have been singled out as the most promising way forward (Fankhauser *et al.* 2012). Also, the strategic orientation towards credible long-term commitments may in fact encourage the development of new low carbon technologies, as firms prepare for tougher carbon reduction targets and thus channel resources into related technological innovations. Nonetheless, critics of this market-oriented, law-based approach highlight the persistent problem of uncertainty regarding cost-benefit patterns in the decarbonisation of the economy, including with respect to related technological innovations that should serve as the drivers of a low carbon transition.

First of all, the feed-in tariff model that is set to be employed in the United Kingdom means that energy generators are to be paid the difference between the contract reference price and the electricity market price. Allegedly, this measure reduces uncertainty, stabilises expectations and promotes transparent cost calculations in a turbulent technological setting. It has been argued that this model, which resembles pioneering German regulations, is more effective at increasing the share of renewables than the previously adopted approach of renewable obligations (Mitchell *et al.* 2006; Foxon *et al.* 2005). Still, the cost challenges related to the support of new energy industries, such as solar, remain largely unresolved. Levels and directions of subsidising the renewables sector seem to be uncoordinated across industries and technologies, which breeds uncertainty for investors. Moreover, energy and climate change policies seem to overlap, leading to a relatively complex policy regime that differs between business sectors and individual firms. All of this is paralleled by disparities in carbon prices across industries and fuel types – with particularly high price differentials observed between electricity and other fuels, as well as between high and low energy-intensive companies (Bassi *et al.* 2013).

These problems may reflect the overall structure of low carbon policies, for legal frameworks such as the Climate Change Act start by setting mandatory targets from which actual policy strategies are derived. The ultimate process of policy-making is massively influenced by interventions from interest groups. Governance and feasibility problems concerning the extent of decarbonisation and emissions reduction are prevalent in such a complex economic, social and political experiment as the transition to a low carbon economy (Pielke 2009).

Rent-seeking, as well as the stifling of competition and innovation, are critical concerns with price regulation and subsidies. It has been pointed out that feed-in tariffs will also be implemented for nuclear energy, which means that the British government will negotiate long-term contracts for the supply of nuclear energy at the guaranteed price using the feed-in tariff mechanism. This price regulation implies that nuclear power is going to be subsidised on a major scale, regardless of cost and efficiency considerations. A major cost concern that should be addressed is the long-term social cost of nuclear energy (Toke 2011). Additionally, the regulation of nuclear energy industries is among the most politicised in the energy sector. This can be seen in the fact that a major corporate player in the British energy supply – and in nuclear energy – is EDF energy, whose parent company is state-owned French company EDF. In effect, subsidising nuclear energy equals subsidising a foreign government-run enterprise through domestic fiscal resources; resembling a transnational transfer of financial resources that transcends the logic of market competition and its regulation (Theurer 2013).

These issues once again hint at a diversity of economic and political relations that transcends the British image of a LME, and pinpoint direct governmental influences on business affairs, which even reaches the transnational level. In this manner, the transition towards a low carbon economy is subject to governance mechanisms and bargaining relations that are settled well beyond the confines of the nation-state – and thus also beyond the strict limits of national models of capitalism. Transnational and – in the case of the European Union – supranational interactions clearly are of great import. Yet these political-economic interactions increase the complexity of policy-making and, in doing so, invite extended rent-seeking activities of organised interest groups, which push for an agenda of special regulatory treatment and subsidies. Of course, the resulting policies suffer from inconsistency and thus damage the case for long-range strategies and decarbonisation policies. These aspects of rent-seeking and policy inconsistency become ever more complicated once the regional policy level is considered. Strategies for the promotion of a low carbon economy in Scotland and Wales involve regional and urban low carbon energy projects, with these locales possessing their own ambitious carbon agendas. The Scottish regional government in particular uses its competences to further regional economic development in the context of a comprehensive green growth agenda. This is set to transform the Scottish economy into a green regional economy with the goal of 80 per cent

of energy consumption emanating from renewables by 2020 (Leijten *et al.* 2012). The recent Scottish referendum serves as a reminder that regional policy concerns, and their underlying deviations from the hegemonic national model of capitalism, remain highly relevant in ongoing policy discourses. As the Scottish exit from the United Kingdom was prevented by a rather narrow majority, regional varieties of transition paths towards a low carbon economy are set to persist. In this regard, the UK case of transition shows similarities with the Canadian case (Harrison, Chapter 2).

Actors and coalitions in the United Kingdom's low carbon transition

Understanding low carbon economy policy efforts requires the re-examination of institutional actors and processes that transcend party politics and governmental affairs. As outlined above in the case of Labour's doomed fiscal approach to the low carbon transition, it is a fact that policy strategies remain subject to institutional constraints. These include policy networks that are dominated by organised business interests, while systematically excluding environmental NGOs and other civil society actors. This may hint at a basic lack of voice when it comes to the communication of environmental concerns within political systems; an aspect that is aggravated by a British electoral system that has stymied the emergence of the Green Party as a political force in the United Kingdom. However, changes in UK climate politics since the mid-2000s reflect a comprehensive reorientation of business interests and political actors. This is based on the persistent activities of environmental interest groups and is framed by wider international, as well as regional, attention to this issue. The temporary alliance between Cameron's Conservative Party and the Friends of the Earth NGO provides a most relevant example of this political agenda and strategy revamping in the context of a comprehensive societal change of perceptions of environmental affairs (Carter 2014: 430–431).

When it comes to the actual operation of the transition towards a low carbon economy, the interactions between businesses and their institutional environments are the most important, involving actors and coalitions from the domain of business associations and labour unions. It is standard reasoning in the VoC framework that the role of associational governance is less relevant in LMEs, such as the United Kingdom, than in relational and associational types of capitalism, such as Germany (Mikler 2009: 105; see also Ebner, Chapter 5). A case in point is the governance-related role of voluntary agreements by business in the political-economic setting of the United Kingdom. They may be quite prominent with regard to corporate commitments to report energy use and emissions, which have nonetheless been subject to legal regulations, yet less so regarding an articulation of associational governance with clear-cut voluntary action. Still, business associations can play a major role in the introduction of low carbon technologies in certain strategically

relevant industries, where they take part in the formation of the knowledge base for technology adoption. A fitting example is provided by RenewableUK (formerly known as the British Wind Energy Association), which is the leading renewable energy association in the United Kingdom and focuses on wind and marine energy. Remarkably, collaborative efforts between government and RenewableUK include a Renewables Training Network that assists 77,500 workers in dealing with the prevalent skills gap in the British renewable energy industry (RenewableUK 2014). In this way, it contributes to associational efforts in skills formation as a prerequisite for expanding the supply of renewables. Of course, labour unions also have a stake in the promotion of a low carbon economy at the firm and industry levels.

However, the asymmetrical distribution of business opportunities and economic costs arising from the low carbon transition across firms and industries amounts to a distinct pattern of industrial change, which breeds attitudes of ambivalence among some towards the envisaged low carbon economy. In fact, this ambivalence has largely prevailed in the various business associations and communities that are also involved in the recent Conservative criticism of low carbon initiatives. The Confederation of British Industry, which is the United Kingdom's leading employer federation, promotes a course of 'green growth', which maintains that energy security and affordability need to be tackled through exploring new business opportunities in working towards a low carbon transition. Yet inter-industry differences in energy intensity require specific decarbonisation strategies and targets that fit both the domestic and international competitive situations of firms in each sector, and thus allows for a level playing field with manageable long-term commitments. A stable market framework that promotes competition within the energy sector while prioritising energy affordability is an indispensable basis for further low carbon initiatives (CBI 2012). Low carbon economy ambivalence also applies to British unions, which are historically an active part of the Labour Party and thus have quite an outspoken institutional position in policy-making. The Trade Unions Congress supports renewable energy as a means of low carbon transition. In particular, it demands feed-in tariffs to encourage the sustained use of renewable energy and a corresponding shift in the energy mix towards renewables. However, the remaining coal industries are not completely out of the picture as the TUC has argued that coal and gas should become more environmentally friendly through new technologies such as carbon capture and storage. Reaching technologically viable 'clean' coal has thus been an overarching strategic motive, which contradicts the policy of phasing out coal. Moreover, there is a clear-cut promotion of the building of new nuclear power stations to further reduce carbon emissions, which means that for the TUC nuclear energy is set to remain within the domestic energy mix (TUC 2013).

This aspect of maintaining a reliance on nuclear energy underlines the confrontation of economic and political interests and ideas in the making of a low carbon economy (Hubbard 2014). All the way through the 1990s

providers of nuclear power were under constant economic pressure, even though British Energy took over major nuclear plants in 1996. However, despite preceding debates on the social and ecological costs of nuclear energy, policy-makers reverted to promoting the nuclear industry during the 2000s. The 2008 White Paper on Nuclear Power outlined a renewal of the nuclear sector that was met by rather fragmented resistance from environmental groups. While building new nuclear power plants remains an uncertain venture, the British government has been willing to grant subsidies for these endeavours (Geels *et al.* 2016). In 2015 the government announced the subsidised construction of two European-designed nuclear reactors, partly financed by Chinese utility companies. This announcement was largely perceived as a top-down decision without civic participation, thus corroborating the impression that the governance of nuclear energy remains subject to a specific mode of policy design and implementation that lacks basic democratic-deliberative credentials (Pemberton 2017). The question is, why does the British government proceed with such a clear commitment to nuclear power? This strategic thrust is against a global trend of moving away from nuclear. Also, the British nuclear industry has held a rather low proportion of electricity production, exhibited a low degree of innovativeness and has a negligible share of world markets. In these metrics it differs markedly from its German counterpart, which is subject to a national phase-out policy. This British nuclear sector context may be explained by ideological factors relating to military affairs, in particular with regard to the maintenance of nuclear submarine capabilities, which are at the heart of the UK's status as an international political-military power (Cox *et al.* 2016).

The corresponding actors and coalitions that shape the British path towards a low carbon economy can be characterised as follows. Main political supporters of a low carbon agenda are smaller political parties, namely the Green Party, which holds influence primarily when it comes to policy discourse and less with regard to actual administrative capacity, as well as the Liberal Democrats, which have emerged as a third political force in parliament and have consistently promoted low carbon concerns, including when in the former coalition government. The environmental orientation at the regional level should be mentioned, in particular with the Scottish National Party. The Labour and Conservative parties are more ambivalent however. Blair's Labour government introduced the low carbon economy agenda to British politics, involving highly controversial fiscal measures in its support. Yet it was Brown's Labour government that promoted the most relevant legal frameworks and regulatory instruments. At the same time, Labour underlined the need for combining environmental and business concerns into a 'green' growth and innovation model for the British economy. Revamped coal and nuclear energy were to be part of the diversified energy mix. Yet this combination of business and environmental concerns was persistently subject to inter-departmental policy conflicts. These would set proponents of market-breaking measures in the Department of Environment, Food and Rural

Affairs against adherents of market-making and shaping solutions in the Treasury, the Department for Trade and Industry, and the Department for Transport. The Conservative Party then reinvented itself under Cameron's leadership as a political force with a clear-cut environmental agenda, in so doing revamping an approach that aimed to use markets as coordination mechanisms in support of a low carbon economy. This reinvention of the Conservatives was pursued in temporary alliances with civil society actors, in particular with Friends of the Earth. Industry associations also played a major role in the making of low carbon alliances. The Confederation of British Industry, with its task force on climate change, plays a supportive role on this point. This mirrors activities from within the managerial business elite, such as the low carbon initiative of the Corporate Leaders Group, accompanied by industry-specific associations such as RenewableUK in the wind and marine energy sector. On the union side, the Trade Union Congress is quite clear in its support of the low carbon transition and applies a comprehensive cross-industrial approach that involves both 'clean' coal and nuclear energy.

Actors and alliances that are set to slow down or even abolish the transition towards a low carbon economy are most prominently active within the Conservative Party. While business-related public protest against early Labour efforts to promote low carbon policies by fiscal means have led to an abolishment of this policy strategy, current debates address business concerns with the economic costs of low carbon policies. These argue that ambitious national regulations may negatively affect the competitiveness of British industry, and put a monetary burden on domestic energy users and consumers. It may be underlined, however, that the dominant discourse on aligning business and environmental concerns was originally pushed by Blair's New Labour during the late 1990s. In this manner, the Confederation of British Industry also plays a key role in communicating the need for policies that are simultaneously market compatible and business friendly. This, together with persistent concerns with energy security, might actually slow down the transition process towards a low carbon economy.

Whether the recent political turbulence regarding the British exit from the European Union impacts the United Kingdom's low carbon transition in a positive or negative manner is still subject to debate and further observation. The advocacy of 'Brexit' during the referendum campaign did not coincide with specific political positions on decarbonisation. Brexit support came from Conservatives and right-wing forces that sympathised with climate change denial, while more radical environmental elements of the Labour Party's left flank, and other leftist groups who support interventionist climate change policies, also backed the Brexit decision. Apart from these diffuse political constellations, it remains true that the United Kingdom is the only major European economy with legally binding emissions targets that are actually more ambitious than those pronounced by the European Union. This situation is not affected by Brexit. Also, EU directives that would need to be

Trading Scheme. Indeed, as the United Kingdom has been pushing forward and transcending EU regulations with more ambitious goals, even under Conservative governments, a post-Brexit climate policy roll-back seems improbable (Staffell 2017: 474). More significant for the low carbon transition of the British economy may be the impact of Brexit on the national innovation system. For instance, the loss of funds for low carbon energy innovation as encapsulated in EU schemes such as Horizon 2020 need to be considered. Moreover, 'green' funding by means of EU Structural and Regional Funds are at stake and funding by the European Investment Bank may become inaccessible (Hepburn and Teytelboym 2017). This may result in a further intensification of market-based innovation efforts combined with a further extension of 'green' finance in the domain of venture capital, quite in line with the basic structures of the complex interdependencies of the British model of capitalism.

Conclusion

The United Kingdom follows a distinct trajectory in the transition towards a low carbon economy, which combines political-administrative features, such as carbon budgets, with legal frameworks for market regulation and the public support of low carbon innovation. In effect, these measures have promoted a comparatively successful effort at the reduction of greenhouse gas and carbon emissions, based on a rapid phase-out of coal, the expansion of renewables, and the persistence of nuclear in the energy system. Also, in the case of the United Kingdom, technological innovation is the key variable in the process of low carbon transition. The corresponding national innovation system is part of an institutional setting that may be labelled a LME from the viewpoint of the VoC perspective. Its market-oriented policy focus, with its logic of arm's length regulation, is inherently combined with hybrid elements that introduce aspects of non-market governance modes. An example is the UK Innovation Investment Fund, a public fund that promotes investment in new high-tech enterprises and which is among the largest European technology venture capital funds. An accentuated role of government can also be traced to the nuclear energy domain.

In the United Kingdom, as in other OECD economies, the transition mechanisms to a low carbon economy are subject to debates on the feasibility of emission targets, energy supply security and the efficiency of market regulations in the face of counter-productive rent-seeking. It remains a key challenge to mediate these concerns, which have recently gained in political weight, with the ongoing need to implement already established targets towards further carbon reduction. The Brexit referendum decision to leave the European Union adds to the complexity of these issues, as it affects the institutional and financial core of the British innovation system – quite apart from its unforeseeable impact on the future position of the United Kingdom in the global division of labour. At this point, it is evident once more that the

institutional substance of the British VoC rests on the political construction and regulation of market coordination. This political rationale and its concern with the performance of markets is an indispensable element of the British type of LME; an assessment that is well illustrated by its contested transition towards a low carbon economy.

4 Climate change politics in Japan in the aftermath of the Fukushima nuclear crisis

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Introduction¹

Japan is one of the world's largest emitters of greenhouse gases, accounting for about 3.4 percent of global CO₂ emissions in 2014 (World Bank 2017b). As the host of the climate conference at which the Kyoto Protocol was reached, Japan has been a relatively strong supporter of global action on climate change. Under the Kyoto Protocol, Japan committed to reducing its greenhouse gas emissions by 6 percent of 1990 levels by 2012. Making use of the Kyoto flexibility mechanisms, Japan met its target. At the Copenhagen climate negotiations in 2009, Japan committed to reduce its greenhouse gas emissions by 25 percent below 1990 levels by 2020, a stronger target than the EU's commitment to a 20 percent reduction over the same time frame. Behind this ambitious target were plans for a wide-scale expansion of nuclear energy and further improvements in the country's already strong energy efficiency performance. These plans were, however, abruptly abandoned as a result of the March 11, 2011, triple disaster of an earthquake, a tsunami, and nuclear meltdowns that crippled the Fukushima Daiichi nuclear facility and eventually led to a near total shut down of the country's nuclear facilities. At the time of the Fukushima nuclear accident, Japan obtained over a quarter of its electricity from nuclear energy. Six years after, Japan obtained less than 2 percent of its electricity from nuclear energy, as the process of restarting nuclear power plants has been slow.

The Japanese people rallied together after the triple disaster and combined their efforts in what is the single most impressive energy-saving initiative any country has conducted in recent memory. As a result, substantial reductions in electricity demand were achieved. Nevertheless, the government was forced to abandon its ambitious greenhouse gas emission reduction targets. Carbon dioxide emissions have since risen dramatically as the electricity demand that was previously being met by nuclear energy has had to be replaced by other sources, primarily coal, oil, and natural gas (see Figure 4.1). In 2013, despite the impressive energy-saving initiatives, Japan's carbon dioxide emissions were 10 percent higher than in 1990. At the 2013 climate negotiations in Warsaw, Japan announced it was abandoning its Copenhagen 25 percent emissions reduction pledge and would no longer use 1990 as its