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Transition pathways for a UK low-carbon electricity system: Comparing scenarios and technology implications

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ABSTRACT

The United Kingdom (UK) has placed itself on a transition towards a low-carbon economy and society, through the imposition of a goal of reducing its 'greenhouse' gas emissions by 80% by 2050. A set of three low-carbon '*Transition Pathways*' were developed to examine the influence of different governance arrangements on achieving a low-carbon future. They focus on the power sector, including the potential for increasing use of low-carbon electricity for heating and transport. These transition pathways were developed by starting from narrative storylines regarding different governance framings, drawing on interviews and workshops with stakeholders and analysis of historical analogies. Here the quantified pathways are compared and contrasted with the main scenarios developed in the UK Government's 2011 *Carbon Plan*. This can aid an informed debate on the technical feasibility and social acceptability of realising transition pathways for decarbonising the UK energy sector by 2050. The contribution of these pathways to meeting Britain's energy and carbon reduction goals are therefore evaluated on a 'whole systems' basis, including the implications of 'upstream emissions' arising from the 'fuel supply chain' ahead of power generators themselves.

1. Introduction

1.1. Background

The United Kingdom (UK) has set itself on a transition to a low carbon economy and society, through the imposition of a goal, under the 2008 *Climate Change Act* [1], of reducing its 'greenhouse gas' (GHG) emissions by 80% by 2050 (against a 1990 baseline) and the creation of an institutional framework in order to secure this target. Much attention has been given to long-term scenarios and pathways for the reduction of carbon emissions from the electricity system, because there exist a range of options for decarbonising electricity generation and supply. Technological options also exist for the use of low-carbon electricity for heating and transport (as well as other energy services). This type of pathway and scenario analysis is therefore useful to enable 'actors' to reflect on how current energy system decision-making relates to the potential for achieving long-term energy and carbon reduction goals [2]. In the present contribution, a set of low-carbon electricity pathways developed under a research project (supported by Research Councils UK and, initially jointly, by *E.On UK*: the integrated energy company) are compared and contrasted with 'official' pathways developed by the UK *Department for Energy and Climate Change* (DECC) for the UK Government's *Carbon Plan* [3]. This *Carbon Plan*, produced in 2011, set out measures for reducing the GHG emissions from the UK by 50% by the period 2023-27 (from 1990 levels), on a pathway to reducing emissions by 80% by 2050, as required under the 2008 *Climate Change Act* [1]. The UK Government is due to produce an updated plan in 2017, setting out further measures for reducing emissions by 57% by the period 2028-32.

The low-carbon '*Transition Pathways*' were developed by the authors and their colleagues [4,5] to examine the influence of different governance arrangements on potential pathways. They follow the main scenarios developed by the UK Government's independent *Committee on Climate Change* (CCC) and DECC, in that they also focus on low-carbon electrification as the key first step in the transformation of the UK energy system needed to meet the 80% carbon reduction target for 2050. However, unlike these scenarios, the *Transition Pathways* were developed by starting from narrative storylines around the potential

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consequences of different governance framings, drawing on interviews and workshops with stakeholders and analysis of historical analogies [6]. An iterative process of technical elaboration between social science and engineering researchers, informed by energy system modelling, was then followed to produce a quantification of the narrative for each pathway [7,8], as described in Foxon [9] and Robertson et al. [10]. This yielded a way of examining the potential influence of qualitative social and institutional and technological changes on the development of low-carbon pathways [11].

1.2. The transitions approach

The *Transition Pathways* analysed here drew on a Dutch transitions approach or transitions theory that has influenced their national policy on promoting energy system transitions [12–15], and stimulated historical case studies [16], including applications to the Dutch electricity system [17,18]. It has been used to examine the dynamic interaction of technological and social factors at different levels [19,20], and has generated significant international policy and research interest [4,5,9,11,21–24]. This analytical framework is typically coupled with a *multi-level perspective* (MLP) for analysing socio-technical transitions, based on co-evolution at and between three levels [21,22]: *niche innovations, socio-technical regimes,* and *macro-landscape pressures* (see, for example, Fig. 1 [4]). The *landscape* represents the broader political, social and cultural values and institutions that form the deep structural relationships of a society and only change slowly [11]. The *socio-technical regime* reflects the prevailing set of routines or practices used by *actors*, which create and reinforce a particular technological system [25]. In contrast, the existing *regime* is thought of as generating incremental innovation, whilst radical innovations are generated in *niches* [11,21,22]. The latter are spaces that are at least partially insulated from normal market selection in the regime. *Niches* provide places for learning processes to occur, and space to build up the social networks that support innovations, such as supply chains and user-producer relationships. Winskel [26] observed that major system changes often arise from developments within the existing regime, rather than from radical innovations at niche-level. He believes that it would be of greater value to analyse the regime-level dynamics. The representation of MLP niche-regime interactions might then be improved by the adoption of ideas and methods stemming from other fields, such as 'strategic management research' [26].

The transitions theory or socio-technical approach is not without its critics [27–33]. Although Shove and Walker [28] recognised the value of sustainable transitions management for stimulating change towards predefined beneficial goals, they argued that analyses based on the MLP typically have an over-simplified view of the social realm, being rooted in 'innovation studies' [26]. In a response, Rotmans and Kemp [29] noted that it is an approach that has been used in the Netherlands in particular (see also [12–15,17,18]) to aid the achievement of better futures. Transitions management helps secure incremental system improvements and innovations within the planning framework; often in the face of complexity and uncertainty. Indeed, Grubler [33] drew on 'real world', historical energy transitions in order to highlight the long duration of transitions (many decades) and their slow rates of change, the importance of energy end-uses as drivers of change, and the distinctive patterns needed for the scale-up of technological solutions. But even Grubler [33] provided cautionary tales. He suggested that low-carbon transitions require persistence and continuity of policies, their alignment (e.g., regarding fossil fuel subsidies), and balanced innovation portfolios (e.g., public sector R & D investment and niche market incentives). Geels and Schot [27] developed a more detailed typology of transition pathways, focused on refinements to the MLP, in response to critiques and insights in the academic literature [28–30] that were followed-up by Geels [31,32]. Although many successful transition paths reflect a sequence of events [27], they are not automatic or deterministic. Many of the pathways may not, in reality, turn out to have a pure format [27,31,32], and shifts between them can result in those exhibiting mixed characteristics.

An initial theoretical analysis of past and possible future decarbonisation pathways for the UK [34] showed the potential for the application of the transitions approach in Britain. Shackley and Green [34] identified a number of key socio-technical factors that would influence future pathways in terms of policy drivers for change. They also argued in favour of policy learning and experimentation in a similar manner to Winskel [26]. A number of studies have applied the MLP for a comparative analysis of low-carbon electricity transitions in, for example, Germany, the Netherlands and the UK [35,36]. Laes et al. [35] selected these countries as exemplars of the deployment of renewable energy technologies (RET), of a transition management framework [12–14,18], and of legislative commitment to climate change mitigation [1] respectively. They identified best governance practices, e.g., creating communities of interest, target setting to link long-term strategies with shorter-term (energy or carbon) budgets, and the adoption of policy incentives. Geels et al. [36] built on the revised typology of

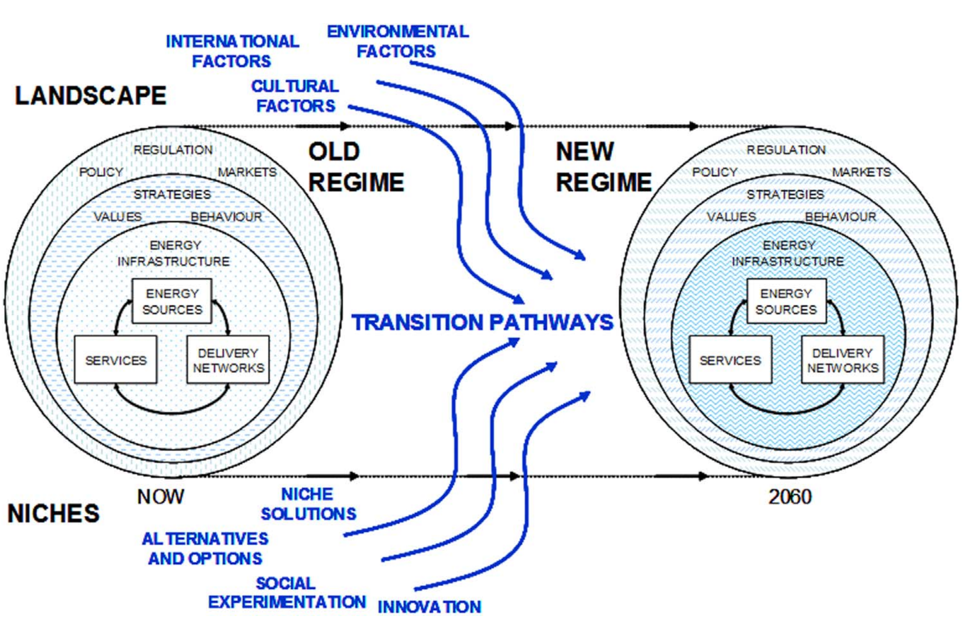

Fig. 1. Possible '*Transition Pathways*' and the factors that influence them. (Source: The Transition Pathways Consortium [4]).