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Long-term scenarios for reaching climate targets and energy security in UK

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ABSTRACT

The construction and subsequent analysis of scenarios using energy systems models is an essential tool in energy policy making. This paper presents two descriptive scenarios for the development of the UK energy system to 2050, using four subsequent decadal time-slices. The two scenarios, K_Scenario and Z_Scenario, were modelled with the use of the Department of Energy and Climate Change (DECC) 2050 Pathways Calculator. K_Scenario is a scenario in which the use fossil fuels with carbon capture and storage (CCS) are prominent in the power sector, while Z_Scenario focuses on the development of renewables with energy storage and nuclear power. Both scenarios seek to achieve the UK's legally binding target of an 80% reduction in GHG emissions from 1990 levels by 2050. Abatement is achieved through numerous developments in each of the scenarios, including the development and use of shale gas, hydrogen, additional wind and solar deployment, the expansion of bioenergy and use of carbon capture and storage (CCS). These developments must be driven by policies designed to pursue dramatic decarbonisation.

1. Introduction

The development of a low-carbon energy system, coupled with security, reliability and affordability of supply is of crucial importance if we are to produce a substantial reduction in greenhouse gas emissions in the United Kingdom and elsewhere. In recent decades, the UK has emphasised the use of coal, nuclear energy and natural gas in electricity generation. However, rapid and significant changes are beginning to occur. Ofgem, the UK's energy regulator, has stated that the statistical probability of severe power blackouts in the UK would increase to almost one in 12 years by 2015 compared to the present rate of one in 47 years, an impact resulting from the decommissioning of power plants owing both to EU legislation (principally the Large Combustion Plant Directive), and the expiry of operating lifetimes. Over the coming decade, a total of 20% of the UK's existing electricity capacity is expected to come offline (Wintour & Inman, 2013). Without new capacity rapidly coming on-line to replace such capacity, the issue of security of supply will exacerbate rapidly. North Sea oil and gas reserves are in decline (a reduction of 82 Mtoe was experienced between 1995 and 2011, UK Government, 2013b), producing an unstable and increasingly expensive energy market in the UK (Simms, 2013).

However, the recent discovery of potentially vast reserves of shale gas may satisfy demand over the short to medium term – although geological, economic and environmental issues compound to produce uncertainties surrounding the potential for this resource. Progress is being made, however. In June 2013, negotiations between the Government and the UK Onshore Operators Group resulted in a new charter for the shale gas extraction industry (Harris, 2013).

Within this context of change and uncertainty, and while considering the grand challenges of energy supply reliability, affordability, and climate change (the Energy Trilemma, WEC, 2012), the UK must transform its energy sector to meet the legally binding 80% reduction of GHG emissions by 2050, from 1990 levels – as codified by the 2008 Climate Change Act UK Government (2008). Despite expected difficulties in the future, positive developments are already occurring. A decrease of 9 Mtoe in total final energy consumption occurred between 1990 and 2011, a consequence of changes in consumption patterns, a reduction in demand due to the economic recession, and active energy-related policies (DECC, 2012).

The first comprehensive UK strategy to tackle climate change came in 2000 with the UK's Climate Change Programme, put in place to meet the UK's commitments under the Kyoto Protocol. This was followed by the 2007 Energy White Paper, the 2008 Climate Change Act (discussed above), the 2009 Low Carbon Transition Plan, and most recently, the 2011 Carbon Plan. The 2007 Energy White

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Paper recognised that the UK will require approximately 30–35 GW of new electricity generation capacity by 2030. The UK 'Low Carbon Transition Plan' details the potential actions to be taken to cut CO_2 emissions by 34% by 2020 (from 1990 levels); including the generation of 40% of electricity from low carbon sources by 2020. The 2013 Energy Act introduces measures to facilitate the generation of 30% of its electricity from renewables by 2020.

There are four main policy landscapes, with a number of instruments in each, with different objectives and mechanisms to achieve carbon emission targets. These can be categorised as follows:

- *Energy efficiency & energy consumption*, which alongside instruments such as the Climate Change Agreements (CCAs), along with the EU Emissions Trading System (EU-ETS) and CRC Energy Efficiency Scheme (originally the Carbon Reduction Commitment), the Climate Change Levy (CCL), Climate Change Agreements (CCAs) and Green Deal and Energy Companies Obligation (ECO), significantly overlap with primary instruments;
- *Carbon pricing* which includes policies that price CO_2; such as the EU Emissions Trading System (EU-ETS) and CRC Energy Efficiency Scheme (originally the Carbon Reduction Commitment), the Climate Change Levy (CCL))
- *Promotion of renewable energy*, which includes the Renewables Obligation (RO (and Contracts for Difference (CfDs)), feed-in-tariffs and the Renewable Transport Fuel Obligation (RTFO), along with the EU-ETS and CCL as key instruments;
- *The non-carbon dioxide GHGs*, which includes the Landfill Tax and the agriculture industry's GHG Action Plan as the primary instruments.

These landscapes together broadly encourage the deployment of renewables across all installation sizes in electricity, heat and transport, and by any sector of society. Many of these have cross-landscape interaction, and therefore they cannot be separated entirely. Many of the instruments in place, including the RO, FITs, RHI, Green Deal, ECO and RTFO do not relate to GHGs directly. Therefore, to different extends the UK climate policy mix covers all sectors of the economy either directly or indirectly, albeit with highly varied levels of attention and stringency.

In order to satisfy the ambition for energy system decarbonisation in the UK, two alternative descriptive scenarios have been developed, with different combinations of energy resources to satisfy the UK's energy demand (Spataru, 2013). The two alternative scenarios have been modelled with the use of the DECC 2050 Pathways Calculator, which produces several key outputs including energy demand (by sector), energy supply (by fuel) and GHG emissions.

A number of previous studies have examined various scenarios for the UK, further explored in the next section. However, such analysis often focuses only on the electricity sector, rather than the wider energy system. Moreover, according to literature, there is not much research focussed on exploring the combination of different options, such as shale gas, biogas and hydrogen integration.

2. Overview of existing energy scenarios

The literature provides several studies producing energy system scenarios, focussed on varied spatial and temporal scales. Global energy scenarios have international relevance and are usually very complex as they integrate a great number of assumptions while covering a broad range of stakeholder groups.

A list of recent studies from inter-governmental, non-governmental institutions and the industry may be found in Appendix B. These reports cover a projection time horizon from 2020 to 2050, were developed with different criteria and produce often very different results. All seek through energy system modelling approaches to describe the long-term picture of the energy sector while focusing on the future role of different energy resources. The reports published annually by the IEA (Energy Technology Perspectives and World Energy Outlook) present scenarios that reflect views of the world in order to compare extremely diverse projections, indicating pathways towards sustainability. Non-governmental organisations such as Greenpeace and the World Energy Council (WEC) have developed studies with forecasts based on 'sustainable' practices, considering interdependencies between the environment and the economy. Studies conducted by industry, such as ExxonMobil in 2013 and BP in 2014, often focus less on environmental policies and emphasise the illustration of different statistics in order to project a single picture of the future energy system. Studies produce by energy companies such as Statoil and Shell suggest conventional and 'alternative' views of the world based on wide range of technologies, policies and economic indicators around the globe. On the other hand, Bloomberg (2013) focuses principally on renewable energy deployment for three different scenarios.

Although most global scenario studies disaggregate results for the Europe area, several studies have been developed for the European continent exclusively, examining 2020, 2030 and 2050 targets. The main studies were produced by or for the European Commission, such as the "European energy and transport – Trends to 2030" series published in 2003, 2005, 2007 and 2009, with the latest version in 2013 expanding its projection horizon to 2050 (European Commission, 2013). The EU Commission reports are based on the PRIMES model and present projections under current policies, with most presenting a single such scenario. The European Commission also published a Roadmap for the EU energy system by 2050, which examined five different pathways to decarbonisation, plus a reference case, projecting the impact of existing policies. Each scenario considers varied technologies development and policy choices, producing scenarios with different emphasis on either enhanced renewables, low levels of nuclear, energy efficiency, etc. The European Renewable Energy Council (EREC) developed a special report suggesting a scenario for a 100% renewable energy system for Europe. Additionally, EREC together with WWF in 2010 prepared another scenario study with three extremely different cases ranging from a future energy sector with slight emissions declines, to an almost net zero carbon future. The National Technical University of Athens (NTU) released an individual study in 2007 with four scenarios for 2050, however they are not comparable with those presented in the 2005 and 2007 reports by the EU (Capros, Mantzos, Kouvaritakis, & Panos, 2007). University College London (UCL) also presented a decarbonisation study with six scenarios projected to 2050 (Barrett, 2007; Spataru and Barrett, 2012). As 2050 targets are clearly stated, the majority of these studies set their projection horizon at 2050, however many focused on developments to 2020 or 2030 only. For example, a scenario published by Ecofys in 2012, and two scenarios produced by ENTSOE. Finally, EWEA (EWEA, 2011) published a number of reports with the most recent being released in 2011 presenting the penetration of various renewables in the energy system by 2020 under the 20-20-20 targets.

In order to explore in detail the scenarios for the UK energy system under the EU and national targets a review of several detailed UK scenario studies was conducted. The purpose of this review was to compare and assess the different assumptions used and approaches taken, along with the outputs generated. According to Rotmans et al. (2000), the two key categories of energy scenarios are backcasting, which begin from a desired end point or target and work backwards to a previous situation and forecasting studies, which examine a future result of different hypothesises developed from an earlier (usually current) starting point. The majority of older UK energy scenarios belong to the latter category (Berkhout