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Decarbonising electricity supply: Is climate change mitigation going to be carried out at the expense of other environmental impacts?

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ABSTRACT

As nations face the need to decarbonise their energy supply, there is a risk that attention will be focused solely on carbon and climate change, potentially at the expense of other environmental impacts. To explore the trade-offs between climate change mitigation and other environmental impacts, this work focuses on electricity and considers a number of scenarios up to 2070 in a UK context with different carbon reduction targets and electricity demand to estimate the related life cycle environmental impacts. In total, 16 scenarios are discussed, incorporating fossil-fuel technologies with and without carbon capture and storage, nuclear power and a range of renewable options. A freely available model – Electricity Technologies Life Cycle Assessment (ETLCA) – developed by the authors has been used for these purposes. The results suggest that decarbonisation of electricity supply to meet carbon targets would lead to a reduction in the majority of the life cycle impacts by 2070. The exceptions to this are depletion of elements which would increase by 4–145 times and health impacts from radiation which would increase two- to four-fold if nuclear power were used. Ozone layer depletion would also go up in the short-term by between 2.5–3.7 times. If energy demand continued to grow, three other impacts would also increase while trying to meet the carbon targets: human toxicity (two times), photochemical smog (12%) and terrestrial eco-toxicity (2.3 times). These findings demonstrate the importance of considering a broader range of environmental impacts alongside climate change to avoid decarbonising the economy at the expense of other environmental impacts.

Keywords: Climate change; Decarbonisation; Electricity; Environmental impacts; Life cycle assessment; Scenario analysis

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1. Introduction

Carbon reduction targets have become a common element of national policy around the globe. Currently they are disparate in ambition, ranging from The Maldives' target for carbon neutrality by 2020 to China's aim of reducing carbon intensity (per unit GDP) rather than absolute emissions (Ecofys and Climate Analytics, 2014). However, decarbonisation has become a well-established goal and the energy sector has been a popular focus owing to its contribution to greenhouse gas (GHG) emissions: in 2010, electricity and heat together constituted the largest source of CO_2 emissions globally at 41% of the total (IEA, 2012). Consequently, much debate and scenario analysis has been devoted to ways in which energy sector emissions might be reduced (see for, example, IEA (2013b) and Pehnt (2006)).

The UK provides a good example of a nation with ambitious carbon targets in need of an energy sector transforma-

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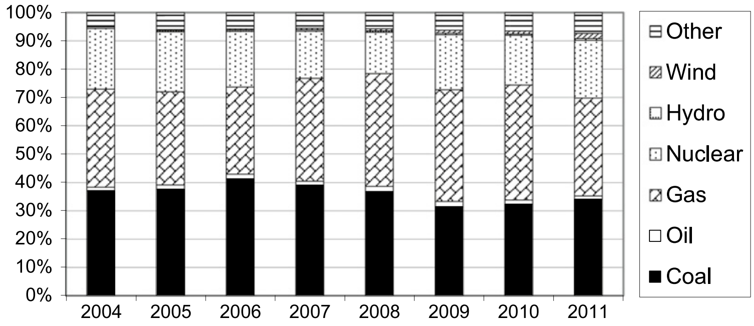

Fig. 1 – Fuel mix for UK electricity generation from 2004–2011 (based on data from DECC (2013b)).

tion. A 2050 carbon target has been set in law in the Climate Change Act (2008) requiring the nation as a whole to reduce GHG emissions by 80% relative to 1990. To meet this target, all sectors will have to increase substantially their use of low-carbon technologies. A number of studies have considered how this could potentially be achieved through scenario analysis, particularly addressing electricity supply (Tyndall Centre, 2005; DECC, 2011a; Ekins et al., 2013): the electricity sector is thought to have the greatest potential to reduce emissions and to bear reductions that would otherwise be required of sectors in which fossil fuels are harder to substitute (for example, transport and heat). As shown in Fig. 1, 65%–85% of electricity in the UK has been provided by fossil fuels in recent years (DECC, 2013b), with nuclear providing 15%–20% and renewables 5%–10%; the balance (typically 1%–3%) is imported, largely from France (DECC, 2013a).

However, while the focus remains on reducing GHG emissions, there is a risk that climate change mitigation may be carried out at the expense of other environmental impacts, such as acidification, eutrophication, ozone layer depletion and toxicity. It is therefore important that any such trade-offs be identified early on, before irreversible decisions are made. It is also essential that the impacts be considered on a life cycle basis to avoid 'leakage' from one life cycle stage – or a region – to another. Currently, global and national policies related to climate change and energy focus solely on direct carbon emissions, i.e. emissions at the point of energy generation. This omission of life cycle thinking in environmental policy has been acknowledged by several authors in the debate over consumer-oriented versus producer-oriented emissions accounting (Peters and Hertwich, 2008a,b; Hertwich and Peters, 2009; Davis and Caldeira, 2010; Davis et al., 2011; Skelton et al., 2011). In short, while policy approaches such as the Kyoto Protocol and its successors attempt to limit emissions within geographical boundaries, a globalised market compels us to consider imports and exports as well: with a producer-oriented approach, a country can decrease its national emissions by curtailing domestic industry and importing more goods from abroad, in turn stimulating foreign industrial emissions and resulting in a net zero global decrease. In many such cases, the reality is a net increase in emissions because the exporting country has a more environmentally-harmful energy system; this has been the case for many developed countries, including the UK, which have effectively exported emissions to China and other emerging markets (Davis and Caldeira, 2010). The same has been demonstrated for water consumption (Steen-Olsen et al., 2012). Life cycle assessment-based approaches avoid this problem by considering whole supply chains and accounting for impacts at both the producer and consumer sides.

In light of the above, this work sets out to explore the life cycle environmental implications of decarbonising electricity supply using scenario analysis and considering the time horizon up to 2070. In total, 16 scenarios are considered, comprising 49 technology options, from fossil-fuel with and without carbon capture and storage (CCS), to nuclear to renewables. A freely available model – Electricity Technologies Life Cycle Assessment (ETLCA) – developed by the authors has been used for these purposes (Kouloumpis et al., 2012). As an illustration of possible consequences for other environmental impacts of electricity decarbonisation, the analysis is carried out in the UK context but similar findings would hold elsewhere. A life cycle approach is applied throughout, using life cycle assessment (LCA) to estimate the environmental impacts. As far as the authors are aware, this is the first study of its kind for the UK electricity sector combining a life cycle approach and scenario analysis. Elsewhere, there have been a few such studies in the electricity sector, notably for Germany (Pehnt, 2006), South Africa (Heinrich et al., 2007) as well as Europe and Africa (Viebahn et al., 2011).

The following section details the methodology developed and applied in this work, including the description of electricity technologies and scenarios. The results are presented and discussed in Section 3 and conclusions are drawn in Section 4, together with recommendations for future work.

2. Methodology

As illustrated in Fig. 2, the methodology integral to the ETLCA model involves the following steps:

1. choice and specification of electricity technologies, both those used currently and those expected to be used in the future;
2. definition of scenarios based on different carbon targets and possible future electricity mixes;
3. estimation of direct carbon emissions for each scenario and electricity mix to ensure that the defined carbon targets are met;
4. estimation of life cycle environmental impacts for each scenario based on the chosen electricity mixes;
5. comparison of scenarios in terms of environmental impacts; and
6. identification of the trade-offs between carbon reductions and other environmental impacts.

The process begins with the selection and characterisation of technologies that are appropriate for a particular country or region. The ETLCA model comprises 12 main technology types, spanning fossil, nuclear and renewable options; each type is split further into different size, capacity, design,

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