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Water use of the UK thermal electricity generation fleet by 2050: Part 2 quantifying the problem

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ABSTRACT

The increasing demand for energy is expected to predominantly be met from a global expansion of water intensive thermal electricity generation. Most countries will in future have less freshwater available when inevitability the cost of thermal generation depends on water availability. A country's future energy costs will directly affect its future global competiveness. Many studies have identified that the solution to the UK's future energy policy's mismatch between thermal generation and freshwater availability is for the UK to make greater use of its seawater resource. The fact the UK with a long learning curve of successful nuclear coastal generation is not progressing coastal generation more enthusiastically raises fundamental policy questions. This paper considers the issues involved. A methodology is developed to assess how the UK's electricity generation portfolio will change in terms of the technologies adopted, and their cost, as access to seawater is varied under Q70 and Q95 freshwater conditions. It was found the emphasis UK energy policy gives to the competing demands of low cost electricity generation and environmental protection will have significant impacts on the cost and make-up of the UK's future electricity generation portfolio.

1. Introduction

The water–energy nexus' importance in global affairs is that available energy is the driver of global wealth, this in turn makes it a precursor of the world population's economic wellbeing. However, energy production depends on the availability of large amounts of freshwater (UN WWAP, 2015). Conversely it has been estimated that for many countries electricity demand accounts for up to 40% of the total operating cost of their water and wastewater utilities (UN WWAP, 2015, Van Den Berg and Danilenko, 2011).

The International Energy Agency (2012) reports that the global water use for energy production in 2010 is some 15% of the world's total yearly freshwater withdrawals, second only to agriculture. Worldwide many thermal power stations are already unable to withdraw the freshwater they require in the summer. This is a situation made worse by the increasing effects of climate change and population growth (Miletto, 2015; Wong and Johnston, 2014). EIA (2013) predicts world energy demand will grow by 56% from 2010 to 2035 with fossil fuels and nuclear generation still being the major providers. Under current policies it is claimed this growth will increase the global energy water withdrawal by 36% by 2035 (International Energy Agency, 2012).

While a reduction in water withdrawal for thermal generation is possible by using alternative cooling systems this inevitably incurs higher capital costs and losses in plant efficiency. Another trade-off required when deploying less water intensive cooling methods is while they reduce withdrawal demand they incur greater water consumption, with net increases in global energy water consumption of over 80% suggested due to this (International Energy Agency, 2012). In freshwater stressed areas this reduces the water available to other downstream users. Another means of power station cooling is the use of seawater, which for countries like Japan, Korea, Australia, and the UK has been accepted as providing an abundant and secure cooling water resource.

The UK energy system is in a state of transition with ageing energy infrastructure needing to be replaced in a way that in the future provides an energy system that is secure, affordable and decarbonised. There are many organisations involved in this and there is a wealth of literature on the subject, some unfortunately often record the difficult process that this has become (Ginige et al., 2012; Ngar-yin Mah and Hills, 2014; Poortinga et al., 2014).

One casualty is the water- energy nexus; with societal, environmental and electricity generation policy arguments being made on the basis of the immediate environmental concern, rather than the more

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distant consequences inflicted upon the future secure and affordable generation objective. The UK energy transition is not just about replacing outdated plant, there is also a need to increase generation from 384 TW h (MacLeay et al., 2011) to a possible 610 TW h/annum by 2050 (HM Government, 2011a). The UK Government's Carbon Plan sees this growth coming largely from an expansion of thermal generation (HM Government, 2011a), which requires more cooling water when, particularly in future summers, the intelligence suggests there will be less (Environment Agency, 2011; Wade et al., 2013).

The UK, with no load centre being more than 70 miles from the coast, has since 1956 established a successful nuclear coastal generation provenance which at its peak was generating over 25% of the UK's electricity (World Nuclear Association, 2016; Bolton, 2013). With less freshwater being predicted, and taking into account a fifty year learning curve of coastal thermal generation, a policy to build the new thermal generation required near the coast would seem to be the obvious option. In the global context, the fact the UK with its long experience of successful coastal generation is not progressing coastal generation more enthusiastically makes this an interesting case study. A number of studies have modelled the future water demand of the UK power sector (Byers et al., 2014; Gasparino, 2012; Murrant et al., 2015; Schoonbaert, 2012). There is agreement that if thermal generation were to be the means of the UK meeting its 2050 predicted generation then there would likely be a considerable mismatch between the onshore cooling water needed and that available. The common identified solution is for the UK to make greater use of its seawater resource. However, the matter remains complex as although the freshwater and seawater environmental issues are well known, unfortunately neither can be argued with the requisite financial facts to hand.

A body tasked with informing the UK's energy transition to 2050 by accelerating the development of low carbon technologies is the Energy Technologies Institute (ETI) formed in 2007 (Heaton, 2014). To this end, the ETI developed the Energy System Modelling Environment (ESME) model which identified cost and emission optimised investment opportunities by modelling the future UK energy system. Unlike other models, ESME can deliver not only national outcomes but can relate UK national results to UK regional results (see Section 3.1). ESME has since been used by the Committee on Climate Change (CCC) for their review of carbon budgets, and by the Department for Energy & Climate Change (DECC) when developing the Carbon Plan (CCC, 2013; HM Government, 2011a). This paper aims to adapt ESME to explore how, at the regional level, the availability of seawater for cooling under future (2030 and 2050) freshwater conditions impacts the generation costs and technology mix of the UK energy system. This will then better inform UK policymakers when making future UK energy policy decisions.

2. UK water and energy policy background

2.1. Water over-abstraction in the UK

The UK Government first addressed the shortage of freshwater through a series of publications, the foremost being the 'Water for Life' White Paper (DEFRA, 2011). Precipitated by Cave (2009) the need for the white paper was confirmed by two further studies. Firstly, the Environment Agency (2011) argued that due to over-abstraction, the majority of the UK's freshwater water-bodies no longer had fully functioning ecosystems. Secondly, OFWAT (the UK's Water Services Regulation Authority) and Environment Agency (2011), warned there would be increasingly less freshwater to meet the greater demand of an increased population that would put even more pressure, on even more ecosystems. This led to the Government committing to introduce *"a reformed water abstraction regime resilient to the challenges of climate change and population growth and which will better protect the environment"* (DEFRA, 2011).

The DEFRA (2011) approach to protecting UK ecosystems from over-abstraction was set out in the Government White Paper "The Natural Choice" (HM Government, 2011b). OFWAT (2011) with the task of initiating the reform required identified that seawater abstraction and discharge was an issue stating "*changes in seawater temperature could adversely affect maritime biodiversity*."

The Environment Agency (2011) over-abstraction case was based on its Catchment Abstraction Management Strategy (CAMS) that gauged for each UK water catchment how much water, after protecting the environment, was available for abstraction. On this basis Environment Agency (2011) concluded additional abstraction of freshwater for cooling water could not be relied upon in the future for large areas of England and Wales. The environmental flow for catchment protection is policed by the EU Water Framework Directive (Directive 2000/60/EC), Habitats Directive (Council Directive 92/43/ECC) and Environmental Flow Indicators, (Collins et al., 2012; Morris et al., 2014; Environment Agency, 2013c).

Both OFWAT and Environment Agency (2011) accepted the problem of over-abstraction and resultant future reduced freshwater availability case. The primary reason for the over-abstraction was that abstraction licences were issued believing there was surplus water which with time had now proved incorrect. Hence, both the Water Resources Act 1991 (HM Government, 1991), and the Water Act 2003 (HM Government, 2003), had allowed the issuing of unsustainable abstraction licences. The conclusion of OFWAT and Environment Agency (2011) was that reforming abstraction will inevitably reduce the volumes licensed for abstraction. However, it was accepted that despite less summer rainfall and higher summer temperatures, power stations would need more cooling water. The solution offered was that energy generators should invest more in technology that does not require water for cooling. However, this takes no account of the higher costs, and additional emissions penalties incurred, when using alternatives to water for power station cooling (Murrant et al., 2015; Turnpenny et al., 2010).

This advice is also contrary to the opinion that the use of saline water for power station cooling water would resolve any lack of freshwater issues (see Section 2.2). DEFRA's instructions to OFWAT on tackling over-abstraction was succinct (DEFRA, 2013a). OFWAT should achieve the reform through its regulatory functions with the management of ecosystems being consistent with their environmental wellbeing as prescribed by HM Government (2011b). Ultimately, the environmental argument was the damage to the UK's ecosystem was neither being recognised, nor being attributed. The societal case was that this damage would eventually have to be acknowledged and would then subsequently increase household and business energy charges. Environment Agency (2013c) suggested restoring sustainable abstraction should be based on the Environment Agency's Environmental Flow Indicator strategy, and in future water abstraction licences should not be regarded as being inviolate. The detail as to how the UK Government proposed to meet its commitment to reform the water abstraction management system in England and Wales was set out in a consultation paper (DEFRA, 2013b).

2.2. Water abstraction of the electricity sector

DEFRA (2011) acknowledged, when it came to licensed abstraction, electricity generation is unique in being the largest abstractor. It accepted the new UK infrastructure rebuild necessary to meet an increased generation demand, and the new legally-binding emission targets all suggested the demand for water may increase. The position of electricity generators would therefore be assessed as a study undertaken by the Government, the Environment Agency and the power sector.

This study's publication (Environment Agency, 2013b), coincided with the reformed abstraction consultation (DEFRA, 2013b). After considering four UKCP09 Regional Climate Model simulations applied to future electricity demand the view was power stations would in