Water use and electricity generation

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Water is important to the generation of electricity in England and Wales, but England's water resources are facing increasing pressures from climate change and population growth. We summarise the current position and future issues for thermal and hydroelectric generation for those with an interest in water and energy.

Why water is important to electricity generation

- England and Wales currently rely on electricity produced by thermal generation. Thermoelectric power plants boil water to create steam, which spin turbines to generate electricity. This heat comes predominantly from burning fuel or the splitting of atoms in a nuclear (fission) reactor. Once steam has passed through a turbine, it is condensed before being reused to produce more electricity. Cooling water is used as a heat removal device absorbing the waste heat.
- Water isn't essential to cooling but it is extremely effective and can be convenient. Water can absorb more heat than air and lead to improved thermal efficiency. This means more electricity can be produced per unit of fuel burnt, which results in reduced Carbon Dioxide (CO_2) emissions, waste and by products and a reduced cost of production.
- The UK[1] is committed to meeting 15% of its energy demand from renewable sources by 2020. Small scale hydropower has a small but important part to play. Hydropower currently contributes 2.5%[2] of the UK's total electricity generated (1% of which is generated in England and Wales). Water is essential in hydroelectric generation where it is used to feed the hydroelectric turbines and generators which produce electricity.
- Investors require confidence that a power station has reliable access to sufficient quantities of water throughout its life before committing to investment for new plant, retro-fits and upgrades.

How much water is used and what influences this water use

- The electricity generation sector is by far the largest licensed abstractor of water (from all sources) of all sectors, including Public Water Supply. It is licensed to abstract over half of all freshwater licensed. In practice however, it takes around a third of this with the majority of the water abstracted from tidal sources.
- 5% of the freshwater abstracted by the sector is used for thermal generation and 95% for hydropower[3]. Of the 5% used in thermal generation, at least half is returned to the environment.
- A fifth of the electricity generated in England and Wales in 2011 was generated by thermal plant (excluding nuclear) which used this 5% of freshwater for cooling. Even though a relatively small amount, this water is extremely important for meeting the UK's demand for electricity. 30% of all electricity generated using freshwater is generated by power stations in the Trent and Derwent catchment.
- Power stations use different technologies for cooling. Generally speaking, subject to water resource availability and environmental impacts, there is a preferred hierarchy of cooling technologies (Best Available Technology) from once through (best thermal efficiency), wet tower cooling (mid ranking

1 http://ec.europa.eu/energy/renewables/index_en.htm

2 Electricity generation and supply figures for Scotland, Wales, Northern Ireland and England, 2004 to 2011, DECC, December 2012

3 ABSTAT, Environment Agency, 2011

thermal efficiency) to air cooling (lowest thermal efficiency). The different cooling technologies use water in different ways:

Once through (direct) cooling

- Water is abstracted from an estuary or the open sea. It is pumped to a cooling water circuit where it cools the turbine water, and is subsequently returned back to the environment at a higher temperature. It uses by far the greatest gross volumes of water but with very little lost or consumed[4] in the process (less than 1%).
- This is the least complex, most thermally efficient and often cheapest option. All nuclear generation is on the coast and uses once through cooling.

Tower and hybrid (indirect) cooling

- Cooling towers facilitate evaporation of water to remove waste heat. Water is pumped to the cooling tower. As it falls down through the tower it comes into contact with air. This process results in some evaporation but the remaining water condenses and collects in a basin at the base of the tower where it is fed back into the system and reused in the circuit. Cooling is facilitated through natural convection or mechanical fans.
- A short natural draught tower which includes mechanical fans to enhance the air flow is referred to as a 'hybrid' tower.
- Tower cooling uses less water than once through cooling but has the highest consumptive demand of all cooling technologies. Around a third (coal tower) to almost half (Gas, Combined cycle gas turbine, hybrid tower[5]) of the water abstracted from the environment is lost to the atmosphere through evaporation. Tower cooling is typically from 0.5% to 2% less efficient than direct cooling[6].

Figure 1 – This image shows Heysham's nuclear reactor 2 which uses once through cooling technology

Figure 2 – This image shows Didcot A, a dual fired power station which used tower cooling when operational. It closed in March 2013

Dry/Air cooling

- Small amounts of water are used in dry cooling. This type of cooling uses fully closed re-circulating water circuits from which there is no intentional loss. The heat generated is transferred to the atmosphere as hot air.
- Air cooling is 2% to 3% less efficient than direct cooling[4].

- The sector's water use at a national level is influenced by a number of factors:

4 Consumption is calculated as the sum of water abstracted minus the sum of water discharged

5 Based on existing UK plant and therefore excluding Nuclear tower

6 Cooling water options for the new generation of Nuclear Power Stations in the UK, Environment Agency, SC070015/SR3 - https://publications.environment-agency.gov.uk/ms/CJnPHc

- Power plant location – The availability of water at the specific location must be considered reliable and the sensitivity of the water to receive the cooling water discharge is a vital consideration in site specific design. Old power station sites tend to be redeveloped due to already established infrastructure and connections to the National Grid.
- The fuel type and cooling technology – Different combinations use varying quantities of water. The choice of cooling technology is considered at plant siting, design and permitting stage when it is assessed for its impact on habitats and water quality. Optimizing water use at a given site involves considering the balance between water use and its consequences on, for example, the water environment, choice of materials, use of chemicals, own energy use, re-cycling and re-use opportunities. It's not usually feasible to change the cooling technology for an existing plant.
- Age of plant – In general, the thermal efficiency of a plant degrades slightly over time leading to an increase in water demand per unit of energy produced. As a plant ages it begins to compete with more modern, often more efficient plant and its commercial operation may change, for example, to operate at lower load. Changes in commercial operation lead to changes in water used per unit energy produced.
- Wider market conditions - Electricity demand and market conditions vary and affect an individual plant's commercial operation. This leads to changes in the amount of water used per unit of electricity produced and the total used in a year.

- Power stations can use different sources of water for cooling; freshwater, waste, mains, estuarine or salt water. Once built they have a very limited ability to flex between different sources of supply.

How and why the environmental impacts are managed

- Environmental impacts are managed through the planning and environmental permitting process and the abstraction licensing system.
- Impacts on rivers and groundwater need to be managed so that there is sufficient water for people, businesses and the environment of a sufficient quality. The environmental significance of a given volume of water used depends on the specifics of the individual power plant, its operation and the local circumstances.
- Careful consideration needs to be given to the balance between maximising energy efficiency, reducing CO_2 emissions and balancing the environmental impact. This is done through regulation including the Industrial Emissions Directive, the Habitats Directive, the Water Framework Directive and Eels Regulations. The permitting process manages environmental impacts and the abstraction licensing system establishes how much water can be taken whilst ensuring the abstraction does not compromise the environment or deny other valid users. There are a range of environmental issues associated with electricity generation which if not carefully managed could lead to:
  - Reduced water flow and levels;
  - Cooling water return temperatures above an acceptable level to the receiving waters;
  - The release of chemical substances above an acceptable level to the environment;
  - Organisms drawn into the water intakes, impinged on screens and entrapped or entrained.
- Hydropower abstracts and returns all water used to the freshwater source, albeit further down the river. Hydropower schemes can be complex and need to be designed and managed carefully to avoid unacceptable impacts on communities and the river environment. For example, changes to a river can increase the risk of flooding and have significant impacts on wildlife.
- Once through (direct) cooling is the most common cooling technique on our estuaries, due to the size of the water bodies and the large tidal range which provide efficient heat dispersal. These locations are more sensitive than open coastal sites. They are important nursery grounds for many fish species and act as migration corridors. They are also more sensitive to summer heat build-up and the large intertidal areas absorb solar radiation. Coastal sites do not suffer the same thermal capacity limits as estuaries, and provided that cooling water discharge outfalls are carefully sited, the environmental impacts are managed.

- Only a few licences for electricity generation have Hands off flow restrictions[7]. If these restrictions were applied to those power stations across different catchments and all triggered at the same time, this could have an impact on the sector's ability to meet electricity demand.
- Water resources are currently under pressure. Already a quarter of water bodies in England and 7% of water bodies in Wales will provide a reliable source of water for new consumptive abstraction for less than 30% of the time[8].
- Less than 5% of generation in England and Wales in 2011 was generated by thermal plant supported by rivers where there is insufficient water for the environment and abstraction.
- These pressures are likely to increase as a result of climate change, population growth and increased demand for water.

Future shape of the electricity generation sector

- There are a number of factors that will, or have the potential to, affect the characteristics of the electricity sector over the coming years:
  - Electricity Market Reform (EMR)[9] - will deliver greener energy and reliable supplies that the country needs, at the lowest possible cost. It will transform the UK electricity sector to enable low-carbon generation to compete with conventional, fossil fuel generation.
  - The Industrial Emissions Directive (IED)[10] - streamlines a number of Directives (including the Large Combustion Plant Directive), and will implement new stricter requirements on the emissions from fossil-fuel power stations. Some of our existing power stations will need to close by 2016 and possibly others by 2023.
  - Abstraction Reform - Our abstraction licensing system was designed more than 50 years ago for a world with less environmental protection, with less demand for water and without climate change. It is not suitable to meet the challenges of the future. We are supporting the Department for Environment, Food and Rural Affairs (Defra) with the reform of the current system and the electricity generation sector are advising on the development and assessment of options for reform.
- In addition the Department of Energy and Climate Change (DECC) have set ambitious UK targets for reducing greenhouse gas emissions. This may mean that Carbon Capture and Storage (CCS) technology is fitted to fossil fuel power stations and this could increase their water use by 44-140%[11]. Depending where these CCS plant are located this could put additional pressure on water resources.
- The use of unconventional gas such as shale gas and coal bed methane is being explored in the UK. Extracting these gases requires water but the volume is small compared with other water users. However, the issue is around the availability of water at the relevant location.
- Together with Defra, DECC and the electricity generation sector, we have modelled the electricity sector's future water demand[12]. The results show a very uncertain future for water demand but demonstrate an overall trend of increasing total demand. Projections for future freshwater demand are more variable and could increase or decrease depending on the future electricity generation mix (including the uptake of CCS), future location and the cooling technology used.
- We have explored the availability and reliability of water now and in the future, based on different climate change, environmental and socio economic scenarios. Our analysis[13] includes water demand projections for different sectors and is available here - https://brand.environment-agency.gov.uk/mb/5OHfl

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7 A specified river flow or level at which abstraction must stop to protect the environment and other abstractors' access to water

8 The case for change – current and future water availability, Environment Agency, December 2011, http://publications.environment-agency.gov.uk/pdf/GEHO1111BVEP-E-E.pdf

9 https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform

10 http://www.environment-agency.gov.uk/business/145770.aspx

11 Water demand for Carbon Capture and Storage (CCS), Parsons Brinkerhoff, November 2012 - available on request by emailing aidan.whitfield@environment-agency.gov.uk

12 Forecasting future water demand of the electricity generation sector, report available soon

13 Current and future water availability - addendum. A refresh of the Case for Change analysis, Environment Agency, December 2013 - https://brand.environment-agency.gov.uk/mb/5OHfl