

Running out of water and options? An assessment of current drought and water scarcity management options in England and Wales

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Abstract

Droughts are a recurring feature of UK climate. This paper asks what drought and water scarcity management options are currently applied in England and Wales and contrasts it with international literature. This research will also deviate from the standard differentiation of supply versus demand options and present a new classification focussing on different stakeholder groups or overarching water governance issues. This new typology helps identifying weaknesses in current drought and water scarcity management. The literature review shows a tendency towards proactive measures that focus on cross-sectoral collaboration, abstractor groups and valuing water. In contrast, the results for England and Wales, based on an analysis of water companies' Water Resources Management Plans, show that only a limited number of the international available options are applied and that the currently applied options focus on restricting water use in times of drought but focus less on preventing droughts in a larger context of water governance. Thus, to tackle future challenges such as climate change and population growth, water companies and regulators should embrace the introduction of more proactive drought management options.

Keywords

drought; water scarcity, water governance; England; Wales

Supplementary Materials

The following are available at the end of the document: Table S1: Overview analysed Water Resources Management Plans England & Wales (page 20); Table S2: Results analysis English and Welsh water companies' Water Resources Management Plans (pages 22); Table S3: Overview and brief description drought and water scarcity management options (page 62).

Introduction

Successful management of drought and water scarcity requires the availability of a broad array of management options. Drought and water scarcity management options ensure that sufficient water supply is available during a drought or water scarce situation. This article argues that England and Wales lack this broad array of options but instead English and Welsh water companies stick to the regulatory framework of prescribed options and measures. Speight (2015) judges about the UK water sector: “The water industry is notoriously slow to implement change, often embracing tradition and tried-and-true methods for achieving their goals.” In her comparison between the US and the UK water sector Speight concludes that, “b[B]ased on the availability of capital, the UK water companies should be better positioned to implement innovation than publicly funded US utilities. Yet the UK companies need a regulatory driver to justify innovation expenditures within their short payback periods. Ofwat is uniquely positioned to increase spending on innovation and infrastructure replacement, both of which will soon be needed to meet the challenges of increased water demand, high public expectations about service and water quality, and energy efficiency” (Speight, 2015, p. 311). In the context of this research, an innovative drought and water scarcity management option is defined as an option that is not part of the current regulatory framework but as an option that addresses and reflects current trends in water governance such as the multiple uses of water, multi-level governance aspects and a cross-sectoral view on water issues (Gupta, Pahl-Wostl, & Zondervan, 2013; van Loon et al., 2016).

The UK Climate Change Risk Assessment 2017 attributes a “medium magnitude now” but a “high magnitude in future” for the “risk of water shortages in the public water supply, and for agriculture, energy generation and industry, with impacts on freshwater ecology” (Committee on Climate Change Risk Assessment, 2016). The overall assessment is that more action is needed in this area (ibid.). “Drought is a recurring feature of UK climate.” (Marsh, Cole, & Wilby, 2007). The last drought event was between 2010 and 2012 (Met Office, 2013), before that 2004-2006 (Met Office, 2016) and 2003 (Met Office, 2012). Other major drought events occurred in 1995/1996 and 1976 (Marsh et al., 2007). There is no consensus over the definition of drought. Lloyd Hughes (2013) describes it as a “deficit of water relative to normal conditions” and the UK Environment Agency (Environment Agency, 2015a) differentiates between an environmental drought, an agricultural drought and a water supply drought. What is important though is to emphasise that drought is not just a natural event of limited duration, but also a socially constructed event as it can result of social factors such as agriculture, housing and transport policies (Lange & Cook, 2015). Van Loon et al. (2016) explicitly factor in human processes in drought definitions, an issue that so far has been neglected, according to the

authors. Droughts are process specific, local in space, local in time of the year and predicated on the existence of the climatological norm of a process-specific reservoir term (Lloyd-Hughes, 2013). Water scarcity is defined as the result of long-term unsustainable use of water resources, which water managers can influence (Van Loon & Van Lanen, 2013). It is hence human induced and subject to the socio-political and economic context (G. Walker, 2014).

The management of drought and water scarcity in the UK takes place in a governance space (Lange & Cook, 2015) that includes the major actors in UK water governance. In the following however this article will focus on England and Wales, where the major actors are: the Ministry for Environment, Food & Rural Affairs (DEFRA), the Environment Agency (EA), Natural Resources Wales (NRW), Natural England, the Water Regulation Services Regulation Authority (Ofwat), private water companies, the Drinking Water Inspectorate (DWI) and the Consumer Council for Water (CCW). All actors operate within a legal framework that is shaped by legislation and regulations such as for example the European Union Water Framework Directive (EU-WFD) (EC, 2000), the Water Act 2014 (Water Act, 2014), the Water Industry Act 1991 (Water Industry Act, 1991), the European Union Habitats Directive (EEC, 1992) or the EA's Drought Planning Guideline (DEFRA & Environment Agency, 2015; Environment Agency, 2015b). In addition, further actors such as the National Farmers Union, the Rivers Trust, local councils and the UK Irrigation Association have a stake in drought management. A full account of the drought governance space provide Lange & Cook (2015).

In addition to droughts being a recurring feature of UK climate, population growth and increasing water demand are other major pressures the UK water resources face. Thus, drought management options need not only cover aspects of when in a drought but also increase the preparedness for droughts. In other words, proactive measures. Sayers et al. (2017) developed eight golden rules of strategic drought risk management. One rule is to "implement a portfolio of measures to transition towards a drought resilient society." (ibid.) Robins et al. (2017) would like to see the creation of a more water-literate society that will better enable water managers to shift from reactionary, crisis-driven approaches to long-term, agenda-driven plans in line with agreed strategies. This article picks up on these points and will demonstrate that England and Wales have a long way to go with regard to drought and water scarcity management in order to become a drought resilient society and a water-literate society.

This article asks the question what drought and water scarcity management options are currently implemented and applied in the English and Welsh context and juxtapose it with international literature on drought and water scarcity management options. This article will also deviate from the standard differentiation of supply versus demand options in drought and water scarcity management and instead present a classification that for example focusses on

different stakeholder groups or overarching water governance issues such as valuing water. This could potentially help to broaden the array of available options and it could help to shift attention to areas in need when implementing new options and measures. This research is the first to analyse all English and Welsh water companies regarding their Water Resources Management Plans and drought and water scarcity management options. Although limited in focus geographically, this research and especially the newly developed classification of drought and water scarcity management options is potentially useful beyond the English and Welsh case presented here.

Data and Methods

The data presented in this paper originates from two major sources. First, a non-exhaustive national and international literature review of drought and water scarcity management options and second, an analysis of all English and Welsh water companies' Water Resources Management Plans (WRMP). The aim of this approach was to contrast currently implemented drought and water scarcity management options in England and Wales with internationally available options.

The literature review included academic literature but also government documents and grey literature, for instance project reports. The literature review focusses on western, industrialised countries such as the United States, Australia or European Union countries in order to provide comparability with the UK. Although there are countries that are far more affected by drought than those named above for example in Africa (WMO, 2014), they hugely differ in impacts and measures against drought and water scarcity. Literature and documents were searched using ScienceDirect, Scopus and World Wide Web search engines. All literature, documents and project websites were searched to identify drought and water scarcity management options. Papers and documents were selected on the basis of dealing with drought and water scarcity management options and a snowball search using cross-references. The search and review was carried out in spring 2016 but more recent papers and documents were added during the analysis phase if found relevant to the research question. Table 1 presents an overview over the analysed literature and documents.

Table 1. Overview of analysed literature and documents

Academic Literature
Bokal et al., (2014); Farmer, (2012); Garrote et al., (2007); Gleick et al., (2011); Gleick & Heberger, (2012); Gómez Gómez & Pérez Blanco, (2012); Horne, (2016); Ingram &

<p>Malamud-Roam, (2013); Kampragou et al., (2011); Kron et al., (2016); Lange & Cook, (2015); Lorenzo-Lacruz et al., (2010); Marsh et al., (2007); Nelson et al., (2008); Pérez-Urdiales & García-Valiñas, (2016); Priscoli & Hiroki, (2016); Rossi & Cancelliere, (2013); Stakhiv et al., (2016); Stone, (2014); Van Loon & Van Lanen, (2013); Wilhite, (2002); Wilhite et al., (2014); Wilhite et al., (2007); Zetland, (2014); Zetland, (2016)</p>
<p>Government documents and reports</p>
<p>UK:</p> <p>Environment Agency Water Company Drought Plan Guideline (Environment Agency, 2015b)</p> <p>Drought permits and drought orders. Information from the Department of Environment, Food and Rural Affairs, Welsh Assembly Government and the Environment Agency (Department of Environment, Food and Rural Affairs, Welsh Assembly Government, & Environment Agency, 2011)</p> <p>Drought response: our framework for England (Environment Agency, 2015a)</p> <p>Managing Water Abstraction (Environment Agency, 2016)</p> <p>California (United States):</p> <p>California's Drought. Water Conditions & Strategies To Reduce Impacts. Report To The Governor March 30, 2009 (Department of Water Resources & Department of Food And Agriculture, 2009)</p> <p>California Drought Contingency Plan (State of California, Natural Resources Agency, & California Department of Water Resources, 2010)</p> <p>United States:</p> <p>Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis (Vose, Clark, Luce, & Patel-Weynand, 2016)</p> <p>Australia:</p> <p>Water Markets in Australia. A Short History (Australian Government. National Water Commission, 2011)</p> <p>Agricultural Competitiveness White Paper (Australian Government, 2017)</p>
<p>Grey literature (reports, policy briefs)</p>
<p>WMO/GWP. National Drought Management Policy Guidelines: A Template for Action (World Meteorological Organization (WMO) & Global Water Partnership (GWP), 2014)</p> <p>UK:</p> <p>Water resources long term planning 2015-2065 (Water UK, 2016)</p> <p>Markets, water shares and drought: Lessons from Australia What can the water industry in England and Wales learn from Australia's water reform story? (Piure, 2014)</p> <p>Water resources in the Southeast. Progress towards a shared water resources strategy in the South East of England (Critchley & Marshallsay, 2013)</p> <p>California:</p> <p>Allocating California's Water. Directions for Reform (PPIC, 2015)</p> <p>Managing California's Water. From Conflict to Reconciliation (Hanak et al., 2011)</p>

Economic Analysis of the 2015 Drought For California Agriculture (Howitt, MacEwan, Medellin-Azuara, Lund, & Sumner, 2015)
Sustainable Water and Environmental Management in the California Bay-Delta (Committee on Sustainable Water and Environmental Management in the et al., 2012)
Drought research projects
Xerochore (URL: http://www.feem-project.net/xerochore/)
DROP project (URL: https://www.vechtstromen.nl/projecten/projecten/noordwest-europees/kopie-noordwest/)
WATCH project (URL: http://www.eu-watch.org/)
Drought R&SPI (URL: http://www.eu-drought.org/)

The second source is an analysis of all current English and Welsh water companies' Water Resources Management Plans (WRMP). Water companies in England and Wales are important because they “occupy a central, powerful position in the governance space” (Lange & Cook, 2015). Since 1989 all water companies in England are privately owned. Welsh Water, which supplies water to most parts of Wales, is a company that has no shareholders and is run for the benefit of its customers and hence the only exception to the privately owned model. WRMPs are a statutory requirement that water companies write every five years. WRMPs look at supply and demand balances over 25 years and lay out plans how to deliver secure public water supplies. As such they are strategic documents, approved by regulators. Hence, they are an important, credible and valuable source for analysis. Table S1 provides an overview over the analysed WRMPs and Table S2 provides a comprehensive and detailed overview over the results. The analysis searched for drought and water scarcity management options in all WRMPs and considered how water companies ensure sufficient deployable output, strategies on metering, leakage, water efficiency and other key strategies for efficient use or to reduce pollution plus any other noteworthy items that did not fall into these categories. The analysis did not only consider options that are currently implemented and applied but also options which are envisaged for later implementation, since the timeframe of a WRMP is 25 years. WRMPs are strategic documents and were favoured in the analysis over Drought Plans, another statutory requirement. WRMPs are broader in terms of water resources management, outward looking and hence more interesting to answer the research question, whereas Drought Plans are operational plans describing actions necessary to deal with various drought situations. They set out how a water company will continue to meet its duties to supply water during drought periods. However, all water company Drought Plans are based on the Environment Agency's Drought Plan Guideline (cf. Table 1), which was part of the analysis.

The purpose of both, the literature review as well as the analysis of the WRMPs is to first of all highlight the contrast between internationally available drought and water scarcity

management options and currently employed options in England and Wales. Furthermore, the aim of this generic approach is to highlight themes and patterns in drought and water scarcity management options, leading to a new typology of drought and water scarcity management options. Based on this, a further aim was to overcome the traditional differentiation between supply and demand side options. It is argued that this dichotomy falls short of successfully identifying and pointing out deficiencies in drought and water scarcity management options. Table 2 presents a novel typology of drought and water scarcity management options. This typology helps identifying where the emphasis in current drought and water scarcity management lies and it helps pointing out weak points, i.e. areas that could and should potentially be given more attention in the future. In this regard it could also be viewed as a learning tool for water companies and regulators. Beyond the UK context, the typology has potential to act as toolbox for water companies and water authorities. For example, even if costly options such as desalination are not feasible due to financial constraints water companies or regulators might opt for other, less costly options to reduce water consumption such as water efficiency campaigns or handing out water saving devices. Limitations of the typology are discussed in section 4.

Table 2. Typology of drought and water scarcity management options

Criteria	Description
current regulatory framework	This category describes options as prescribed by the current legal and regulatory framework. Examples: drought orders and drought permits
structural approaches / overarching framework	This category reflects overarching measures, i.e. measures that go beyond the individual option and instead aim for networks and collaborations with other sectors for example. Examples: collaboration with other policy sectors such as housing or international legislation
abstractor groups	This addresses options aimed at specific water abstractor groups such as agriculture or large business abstractors (e.g. power sector, paper industry). Examples: irrigation management, agricultural insurance
procedural devices	A procedural device refers to options such as water markets.
distribute water	This category includes options that put emphasis on sharing and transporting water. Examples: bulk water agreements or sharing water

supply side / water creation	This category contains options aiming to provide more water. Examples: water recycling, reservoirs or desalination
metering	Metering is a key option and includes current trends such as smart metering and tariffs.
technology led	This category describes options driven by technology such as deepening a borehole for example.
land use planning	This category refers to option that take a view beyond drought and water scarcity management and integrate it into the wider discussion on land use planning. Examples: restoring wetlands or drought tolerant landscaping
company led	This describes options implemented at the discretion of water companies such as pressure management.
valuing water / water attributes	This category refers to options that stress societal aspects of drought and water scarcity management. Examples: water stewardship or water rights

Results

Water governance is a complex issue and as mentioned in the introduction faces several challenges such as climate change, population growth and linked to that rapid urbanisation. This implies major challenges for water supply, wastewater treatment, flooding and drought policies. Robins et al. (2017) begin their assessment of water policy in the UK, but the statement could also be applied to other nations, by stating that “water resources management is integral to economic, ecological and socio-political sustainability, its management is complex and requires coordination across a range of institutions and stakeholder interests.” Although the management of drought and water scarcity is just one aspect among others in water governance, the above statement is also true just within the sub-field of drought and water scarcity management. The results from the international literature and document review support this view and reveal a broad array of drought and water scarcity management options. There is a clear tendency towards proactive measures that focus on cross-sectoral collaboration such as catchment management, integrating water scarcity into planning or the collaboration of water suppliers with neighbouring policy fields (Farmer, 2012; Hanak et al., 2011; Kampragou et al., 2011; Wilhite, 2002). Other options pay attention to certain abstractor groups

such as farmers and include items such as agricultural insurance, or income support (Nelson et al., 2008). Another set of options puts emphasis on the value of water, for instance water stewardship or the creation of water saving cultures (Farmer, 2012). These options are the way forward in enhancing resilience to the increased risk of drought and water scarcity. Figure 1 presents the results of the literature and document review and is arranged according to the typology introduced in the previous section. It is a non-exhaustive collection of drought and water scarcity management options and Table S3 provides a brief description of each option based on the literature review.

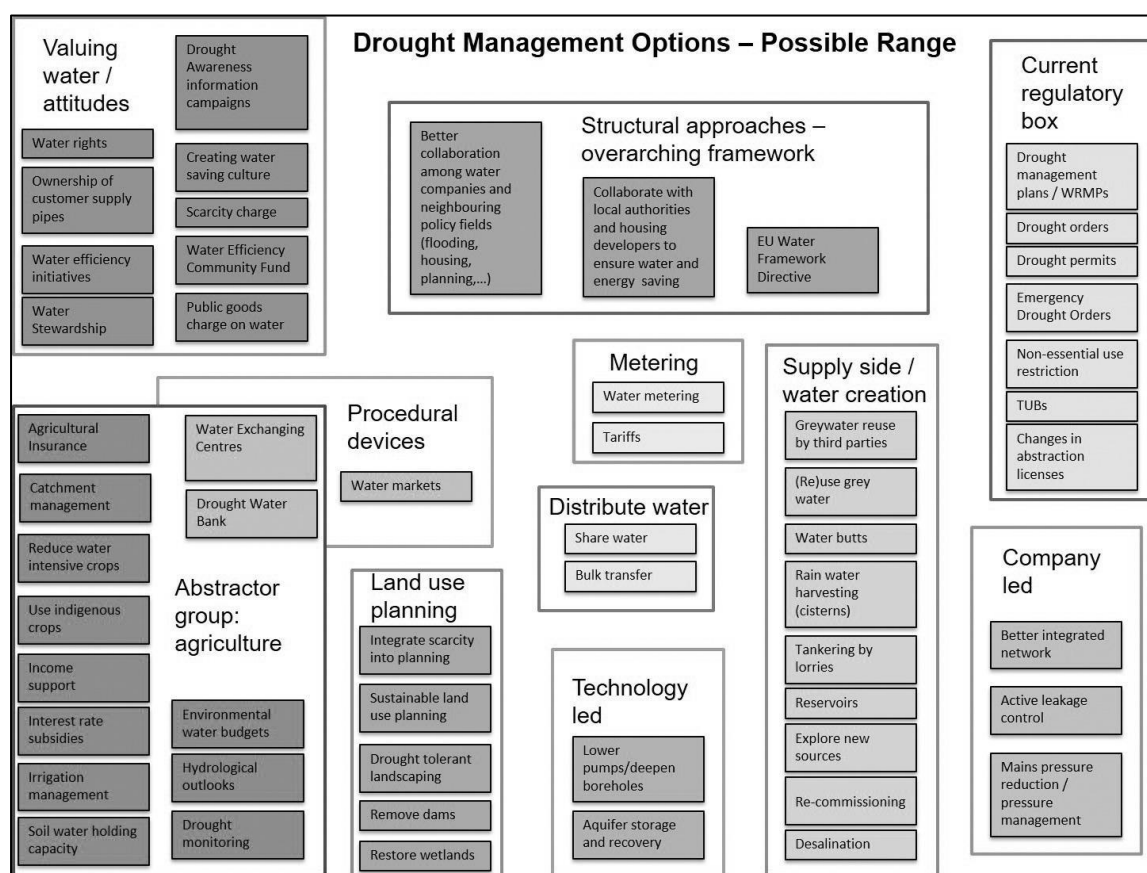


Figure 1. Internationally available drought and water scarcity management options

Against the background of internationally available drought and water scarcity management options the current range of drought and water scarcity management options in England & Wales is presented in Figure 2. All encircled options are either currently applied or the implementation is planned in the future. The analysis is based, as described under “Data and data analysis” on the analysis of WRMPs of all English and Welsh water companies (Table S1) and a detailed overview over the results can be found in table S2. The overview does not reflect how many water companies apply a certain method, hence, even if just one water company has implemented a certain measure it is reflected in the illustration.

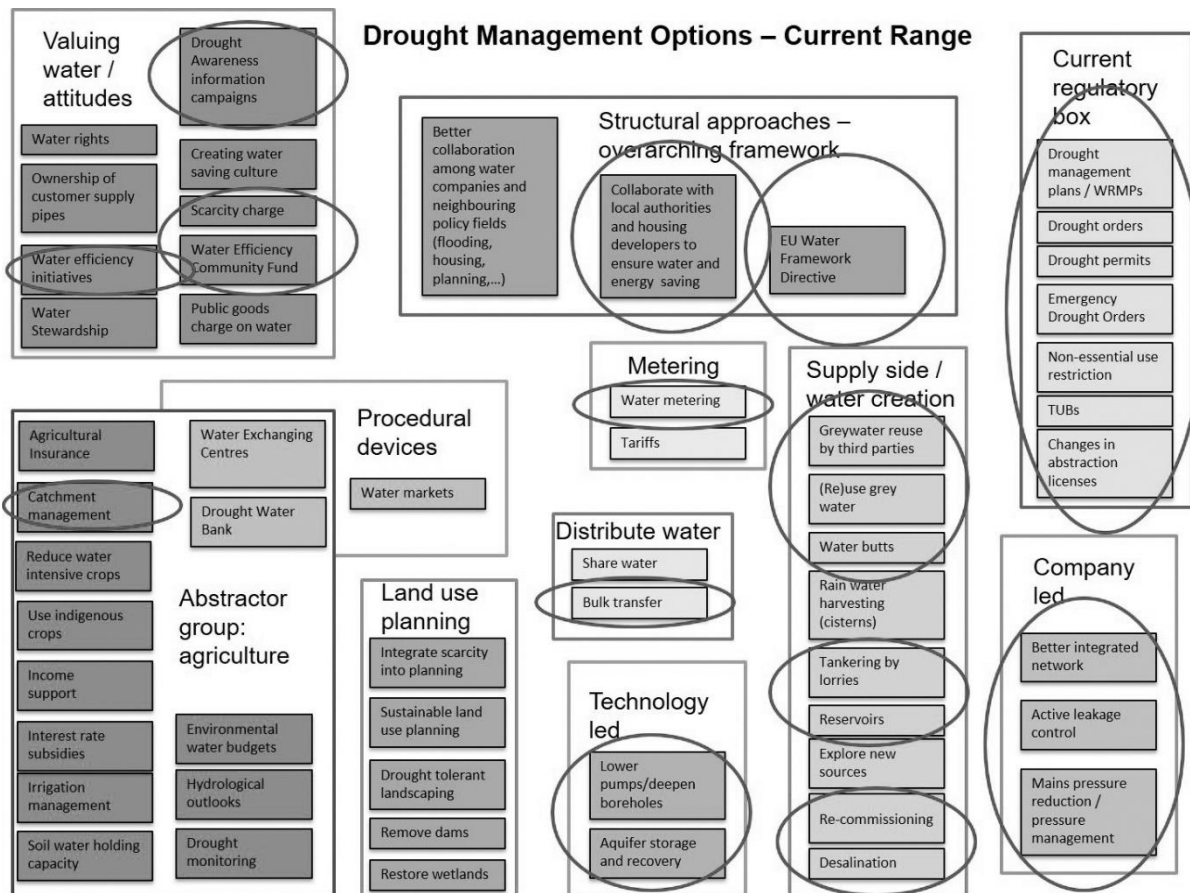


Figure 2. Current range of drought and water scarcity management options in England and Wales (encircled)

The illustration shows that English and Welsh water suppliers are using only a fraction of the options available given that this is an optimistic overview, i.e. as mentioned before options that are foreseen for future implementation, but potentially run the risk of being dropped for the next round of WRMPs, are also included. Figure 2 highlights a tendency towards the current regulatory box and supply side options. Thus, it can be concluded that currently employed drought management options in England and Wales rely significantly on restricting water use in times of drought and are therefore, with the exception of elements of drought plans and WRMPs, potentially too much focused on thinking about water scarcity in the context of actual drought events. Based on the WRMPs analysis, all English and Welsh water companies apply a standard set of options that includes metering, active leakage control or water efficiency campaigns. Apart from options in the “current regulatory box”, these are the options water companies aim for the most, although with varying degrees. For example, metering strategies are influenced by the Environment Agency’s classification of an area as being under “severe water stress” (Environment Agency & Natural Resources Wales, 2013). If an area is classified as “under severe water stress” metering becomes compulsory. All newly built properties are also fitted with a water meter and water companies often opt for meter installation when a

property changes occupancy or they offer for voluntary metering programmes. Hence, meter penetration differs largely across the country or even within water companies different water resources zones. Affinity Water's Southeast region has a meter penetration of 93%, while its Central region has only 42% meter penetration (Affinity Water, 2014). Northumbrian Water currently has a very low meter penetration, 30%, but like other water companies aims to increase metering in the next 25 years (Northumbrian Water, 2014). Besides the options prescribed by the regulatory bodies, a few water companies have either implemented or are contemplating options that go beyond the required. For example, the "water efficiency community fund", which provides the installation of water saving devices in public buildings such as schools (Wessex Water, 2014). Or, the concept of the "scarcity charge" (Southern Water, 2014) that would introduce a higher price to be paid for water which is abstracted from areas where there is less water available. Portsmouth Water (2014) and Cambridge Water (2014) highlight the benefits of grey water (re)use. Efforts to collaborate with other sectors such as the housing or energy sector in order to contribute to overall energy savings are also noteworthy (Essex & Suffolk Water, 2014).

Although the list of drought and water scarcity options currently applied in England and Wales is far from being incomplete or insufficient, contrasting figures 1 and 2 could leave the impression English and Welsh water companies do miss out on options, especially proactive measures, like creating a water saving culture, collaboration with other sectors or sustainable land use planning. However, it is important to say that all water companies undergo a so-called option appraisal stage when they develop their WRMPs, described in the Environment Agency's Guideline: "a water company should decide on the best option for its customers (on the basis of cost and what customers would like) and for the environment (local and global). Deciding which option to choose is known as 'option appraisal' and must include both monetary and non-monetary costs and benefits" (Environment Agency & Natural Resources Wales, 2016). Water companies such as South East Water (2014) provide impressive lists of options during this stage, which in itself contains four steps – from an unconstrained list of options, to a constrained list, followed by feasible and preferred list of options. In the case of South East Water this meant 912 unconstrained options, which were already reduced to 320 in the feasible list of options (ibid.). Usually these are not, as in this case, 912 distinct options, but often variants of one option. For example, the augmentation of a borehole can be described in numerous small increments each resulting in a distinct option. A deeper understanding as to why options fall of the list was not focus of this research but the description of the options appraisal stage by the Environment Agency (see above) might provide a clue, thus being either little willingness to pay by customers or high implementation costs for water companies.

Discussion

The typology for drought and water scarcity management options (table S3, figures 1 & 2) does come with limitations. First, it is a non-exhaustive list. The literature and document review was focussed and geographically limited as explained above. Also, some options are generic, in the sense that they only provide a name for a category of options. A good example is “water efficiency campaigns”, which can be subdivided into many different items such as websites, blogs, school plays, roadshows to name just a few. Second, it reflects the situation in England and Wales, which is most strongly reflected in the “current regulatory box” category. In order to be useful in other contexts it would need to be adapted accordingly. However, for example in a European Union context this would be easily achievable as the Water Framework Directive affects every EU member state. Third, not all of the options are mutually exclusive and there are overlaps. For example, “drought water banks” or “water exchange centres” are predominantly found in the agricultural sector but are procedural devices that may also be applied in other sectors. Another limitation is that not every option can be applied and implemented by every water company due to for example geographical reasons. Desalination might be a viable option for water companies operating at the coast but not for water companies with no access to salt or brackish water. Yet, the idea of the typology is not that every option is adopted but rather that it is seen as toolbox of available options. One goal of this research was to show that the UK water sector limits itself in its selection and application of drought and water scarcity management options and that water companies limit themselves to the regulatory framework and the options prescribed by it. The idea of the developed typology is to demonstrate that other options can be embraced and be taken into account by water companies and regulators. This could support future-proofing the UK water sector against mentioned challenges such as population growth and climate change.

Thus, this novel typology proves effective as it can display weaknesses but also strengths in current drought and water scarcity management in a given jurisdiction. Water companies can use the typology for the same purpose, to identify strengths and weaknesses, hence it could potentially be used to explore areas for future improvement and innovation.

Drought planning by water companies has become a major feature of water resource planning (Cook, 2016). Yet, as the results show, compared to internationally available options for drought and water scarcity management, English and Welsh water companies only apply a fraction of them. They orientate themselves at the regulatory framework, i.e. the options prescribed by the regulatory bodies. Against the background of the UK Climate Change Risk

Assessment 2017, which concluded that more action is needed in the area of public water supply, agriculture, energy and industry (Committee on Climate Change Risk Assessment, 2016), it is worth asking the question whether the current set of options will be enough to tackle future water challenges. This addresses especially the result that currently applied options focus on restricting water use in times of drought but focus less on preventing droughts in a larger context of water governance. However, the UK Water Act 2014 introduced a so-called resilience duty to achieve long-term resilience of water and wastewater systems and service provision. This includes the use of “a range of measures to manage water resources in sustainable ways” [16]. Key features of resilience are diversity and redundancy (Folke, Hahn, Olsson, & Norberg, 2005; B. Walker, Holling, Carpenter, & Kinzig, 2004). Hence, the availability of a diverse set of options is favourable and also opens up opportunities to address drought and water scarcity issues in a different way. Figure 1 can actively contribute to this discussion.

Furthermore, the chapter on the resilience duty says: “(...) increase efficiency in the use of water and reduce demand for water so as to reduce pressure on water resources.” [16] Demand management is more challenging for water companies than supply side options because they have to engage with the socio-political context (G. Walker, 2014). By focussing more on demand management water companies could not only broaden their set of options but by increasing their engagement with the public it could also help building a drought aware society, if not to say water-literate society (Robins et al., 2017), thereby changing the behaviour citizens, and not just water company customers, show towards water.

The majority of UK water companies collaborate among each other through bulk water agreements. So far, only two examples of water company collaboration go beyond this. The Water Resources in the South East Group (WRSE) and Water Resources East Group in Anglia. Both organisations foster the collaboration between water companies, regulators and other stakeholders in the respective regions, but they lack a wider stakeholder inclusion that could bring fresh perspectives into the groups. Thereby they are neglecting recent trends in water research such as the nexus approach (Green et al., 2017; Gupta et al., 2013) or catchment based management (Robins et al., 2017). The same holds true for collaborations with other policy sectors. Flooding, agriculture, forestry and housing are just a few of the many policy fields that are highly interconnected with the water sector and could be given more attention by water companies. However, personal communications with representatives from water companies about the results of this research indicate that future drought and water scarcity management options should reflect current trends in water resources management such as more collaboration among water companies, regulators and stakeholders more strongly.

Conclusion

The paper established an overview over the currently applied drought and water scarcity management options in England Wales and contrasted it with internationally available options based on a literature and document review. The results confirm that English and Welsh water companies adhere to options that are prescribed by the regulatory framework and options that favour the supply side of water resources management. Overall, it can be concluded that drought and water scarcity options in England and Wales are reactive rather than proactive. The paper also established a new typology for drought and water scarcity management options that differs from the usual supply and demand dichotomy. Instead, the typology introduces a new classification that covers aspects such as options according to different abstractor groups, overarching frameworks or valuing water. It was argued that this novel typology could help identifying weak points in current drought and water scarcity management, thereby opening up the opportunity to introduce new options. If drought is a recurring theme of UK climate, then water companies should more actively embrace new options and should also consider going beyond the “willingness to pay”- and “cost-benefit analysis”- horizon in order to tackle future challenges such as climate change, population growth and changing water demand patterns.

English and Welsh water companies are currently preparing the next round of WRMPs and it will be interesting to see in how far they have advanced compared to the current WRMPs with regard to drought and water scarcity management options. However, if the required push for a broader set of options does not come from the water companies themselves maybe it is time for the regulators to step up.

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Conflicts of Interest

The author declares no conflict of interest.

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Supplementary Material

Table S1 Overview analysed Water Resources Management Plans England & Wales

Water Company	Document Title	Source
Affinity Water	Our Plan for Customers & Communities. Final Water Resources Management Plan, 2015-2020	Affinity Water (2014)
Albion Water	Draft Water Resource Management Plan	Albion Water (2016)
Anglian Water	Water Resources Management Plan 2015	Anglian Water (2014)
Bournemouth Water (sembcorp)	Water Resources Management Plan. Final Water Resources Management Plan-2014 Technical Report	(sembcorp Bournemouth Water, 2015) (2015)
Bristol Water	Water Resources Management Plan 2014	Bristol Water (2014)
Cambridge Water (South Staffs Water)	Water Resources Management Plan 2014. Cambridge Region. Main report	Cambridge Water (2014)
Cholderton and District Water	Water Resources Management Plan 2014	Cholderton and District Water (2014)
Dee Valley Water	Water Resources Management Plan December 2013	Dee Valley Water (2013)
Dwr Cymru (Welsh Water)	Final Water Resources Management Plan. Technical report	Welsh Water (2014)
Essex & Suffolk Water (Northumbrian)	Final Water Resources Management Plan 2014	Essex & Suffolk Water (2014)
Hartlepool Water (Anglian Water)	Water Resources Management Plan 2015	Anglian Water (2014)
Northumbrian Water	Final Water Resources Management Plan 2014	Northumbrian Water (2014)
Peel Water Networks	Revised Draft Water Resources Management Plan 2013	Peel Water Networks (2013)
Portsmouth Water	Final Water Resources Management Plan 2014	Portsmouth Water (2014)
Severn Trent	Final Water Resources Management Plan 2014	Severn Trent (2014)
South East Water	Water Resources Management Plan	South East Water (2014)
South Staffs Water	Water Resources Management Plan 2014. Main Report	South Staffs Water (2014)

South West Water	Water Resources Management Plan	South West Water (2014)
Southern Water	Water Resources Management Plan 2015-40. Technical Report	Southern Water (2014)
SSE Water	Water Resources Management Plan (England) 2015 – 2040. SSE Water. Revised Draft Consultation Water Resources Management Plan 2015 – 2040. SSE Water. Draft Consultation	SSE Water (2014a, 2014b)
Sutton and East Surrey Water	Final Water Resources Management Plan. Main Report	Sutton and East Surrey Water (2014)
Thames Water	Final Water Resources Management Plan 2015 - 2040	Thames Water (2014)
United Utilities	Final Water Resources Management Plan. March 2015	United Utilities (2015)
Veolia Water Projects	Water Resources Management Plan. Final Published Report	Veolia Water Projects (2014)
Wessex Water	Final Water Resources Management Plan. Website version	Wessex Water (2014)
Yorkshire Water	Water Resources Management Plan	Yorkshire Water (2014)

Table S2 Results analysis English and Welsh water companies' Water Resources Management Plans

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Affinity Water (Central, East, South East)	Water Only	yes	<ul style="list-style-type: none"> - operational changes (not specified); - improvement in treatment capacity; - jointly owned reservoirs; - impacts of climate change 	<ul style="list-style-type: none"> - Southeast (93%), East (72%), Central (42%); - compulsory metering led to 16% decrease in consumption in the pilot Southeast region; - extensive trial in the Southeast region (smart communication, stepped tariff, retrofit, deferred meter, small area metering) 	<ul style="list-style-type: none"> - pollution risk assessments, - catchment managing to reduce metaldehyde pollution (Metaldehyde Stewardship Group); - water trading 	<ul style="list-style-type: none"> - leakage targets for every region (three); - Active Leakage Control (ALC; detection of non-visible leaks); - automated meter reading; - biannual comparisons for household customers, every three to six months for business customers; - better response during severe weather events 	<ul style="list-style-type: none"> - water efficiency programme; - Education Centre 	- Affinity customers have the highest per capita consumption in the UK

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Albion Water	Local Water and Wastewater			-all supply and demand is metered	- infrastructure improvements			
Anglian Water	Water and Wastewater	yes	- good for the exception of Ruthamford South; - water reuse - water trading - water transfers	- 43% of delivered supplies to measured households (PCC 124l/d); - promoting further metering is being considered; - by 2019/2020 95.1% shall have meters; - switching on demand or change of property	- new winter storage reservoirs; - regional scale aquifer storage and recovery; - water reuse; - desalination (all not necessary now but in the far future and in collaboration with other companies and regions)	- 13% leakage (distribution), 4% (customer supply pipes); - currently cheaper to build new source than to further reduce leakage; - shall be reduced to 93MI/d by 2040 (however not yet clear how achievable)	- maintain leakage level; - Love Every Drop water awareness campaign (value of water); - reduce consumption; - stop pollution; - cut carbon and; - free installation of water saving devices (180,000 free water efficiency audits)	- Anglia is driest region in the UK; - water quality deterioration due to agriculture

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Bournemouth Water (Sembcorp)	Water Only	no (low)	<ul style="list-style-type: none"> - customer demand is decreasing; - maintain continuous supply over the next 25 years 	<ul style="list-style-type: none"> - metering has decreased demand; - currently 62% of household customers are metered, - systematic metering until 2025 	<ul style="list-style-type: none"> - encouraging efficient use 	<ul style="list-style-type: none"> - 5% reduction from current levels by 2020; - leakage reduction through metering and subsequently monitoring 	<ul style="list-style-type: none"> - strategy focussed on metering; - free water efficiency devices; - Waterwise presentations to primary schools; - aiming at behavioural change (newsletter, water bill, education campaign, press releases, exhibitions) 	<ul style="list-style-type: none"> - no ability to store water for later use
Bristol Water	Water Only	no (moderate)		<ul style="list-style-type: none"> - free meter installations; - metering of all non-household customers by 2015 	<ul style="list-style-type: none"> - reduce bulk transfer out of area; - active leakage control; - pressure reduced zones; - subsidised customer supply pipe replacements; - household water efficiency pack; - customer audits; 	<ul style="list-style-type: none"> reduce leakage rate to 49MI/d by 2015; active leakage control 	<ul style="list-style-type: none"> provide appropriate fittings and advice to customers, school lectures, website, press releases, education centre; 	<ul style="list-style-type: none"> - current supply level can be maintained until 2018; - 15% increase in demand by 2045

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
					<ul style="list-style-type: none"> - new reservoir (Cheddar), transfer disused sources to new reservoir; - raw water transfer, - compulsory household water metering; - bulk supply from Wessex Water; - new reservoir (Chew Valley) 			

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Cambridge Water (South Staffs)	Water Only	no (moderate)	<ul style="list-style-type: none"> - work closely with EA; - twin-track strategy - demand management measures and working with other suppliers on trading; - loss in deployable output of 25Ml/d before non-essential use drought order is required 	<ul style="list-style-type: none"> - 87% metered by 2040, 100% by 2050; - company does not use its legal power to meter property upon change of occupancy; - expected 10% reduction in use when metered; - free meter option, - selective metering (reserving the right to install a meter) 	<ul style="list-style-type: none"> - 1 l/d per head per year in reduction as water efficiency aim; - key strategies on metering, leakage control, DO and water efficiency need to be reviewed with regard to growing population; - appraised options: customers supply pipe ownership, collaborating with housing developers and local authorities to ensure reduces water consumption, compulsory metering, reduced leakage target 	<ul style="list-style-type: none"> - maintain current leakage (14Ml/d), - reduce leakage where it is economic to do so; - free leakage tests and repair; - network of district meter areas to monitor leakage; - estimated that customer's pipework is responsible for 25-35% of leakage 	<ul style="list-style-type: none"> - encourage customers to change to metering (leaflets, site-specific advice); - website promotion, - bill inserts, - literature and display stands, - school educational visits, - occupancy change welcome packs, - free water saving devices, - online water save money shop; - water efficiency roadshows; - ad hoc campaigns; - pilot greywater scheme in Cambridge 	<ul style="list-style-type: none"> - 100% supply from groundwater sources; - pressure expected through population growth; - water trading with a local bottled water facility, - are not aware of how many water is taken away illegally on occasion (road sweeping, bin cleaning, car washing)

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Cholderton and District Water	Water Only	no (moderate)		<ul style="list-style-type: none"> - 56% by 2040, currently 31%, - full metering not possible due to high number of Ministry of Defence (MOD) properties who are invoiced in bulk for water use 	<ul style="list-style-type: none"> - bulk supply from a neighbouring company was considered due to high nitrate pollution (negotiation failed though (high prices)), complying with the safe drinking water standard remains a major challenge (nitrate); - catchment management - collaborating with EA, Natural England and other relevant stakeholders 	<ul style="list-style-type: none"> - very high level, 34% reduction planned; - improved leakage detection (monitoring) 	<ul style="list-style-type: none"> - promote water efficiency (including metering), - enclose leaflet to bill, - website 	<ul style="list-style-type: none"> - small area (22 square kilometres, rural, two villages); - groundwater (2 boreholes)

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Dee Valley Water	Water Only	no (moderate)	- no sustainability reductions	- free metering scheme (low level promotion); - about 3% of customers make use of it per year; - hence 80% meter penetration by 2040, - monitoring developments in intelligent metering technology	- promoting water efficiency at local events and school	- free supply side leak repair	- extension of optional metering; - supply pipe leakage control; - free save a flush sachets; - in future: leaflets and water saving devices in cooperation with local housing associations	- 85% from River Dee

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Dwr Cymru (Welsh Water)	Water and Wastewater	no (moderate)	- five deficit zones (measures: water transfer, supplement available flow, license reductions); - water transfers between WRZ	- compulsory metering currently not justified given the costs	- River Usk and Wye Abstraction Management Group	-	- support customers, - education centres, - schools and universities retrofits, - water butts, - water audits and leakage surveys for larger customers, - welcome pack for new meter optants, - pipe lagging campaign to prevent bursts; - working together with large housing associations who can influence their customers, - better (online) information and communication with customers about the benefit of water saving	- only 3% of rainfall is used for public water supply; - reference to ecosystem approach and GWP (Global Water Partnership); - main source: 65 reservoirs; - seems to rely on Welsh government's position

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Essex and Suffolk Water (Northumbrian Water)	Water Only	yes	- study of water use among unmeasured customers (panel)	- different strategies for Essex and Suffolk; - Suffolk: optant only, 64% meter penetration; - Essex: optant only proved unsuccessful therefore change to selective metering (change of occupier), 55% meter penetration; - full metering is desired but ESW wants to ensure customers are satisfied with the		- overcome effects of natural deterioration; - active leakage control, - pressure management, - leakage driven mains improvement	- aimed at behavioural change (good water habits), - retrofitting, - measurements of water saving, - water saving devices, - cistern displacement services, - retrofit audits (H2Eco, followed by ecofit), - self-audits, - water saving kits, - advertising, - shopping centre events; - Little Green Riding Hood programme aimed at primary school children (pantomime), - monthly fact sheets to customers about water saving including comparison of own consumption against the rest of the participants;	- expect less demand despite population increase as result of water efficiency campaign; - between 2006 and 2012 temporary restrictions occurred in neighbouring water supply zones, the effect was a decrease in demand across ESW supply area; - references to home energy efficiency in general

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
				decision, hence options are being explored; - full metering by 2035			<ul style="list-style-type: none"> - research projects; - school audits, - hotel audits; - collaboration with home energy efficiency programme; - water saving product trials, - donating water butts to allotments, - radio campaigns, - website, - newsletter, - billing leaflets; - participation in networks and conferences 	
Hartlepool Water (cf. Anglian Water)	Water Only							

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Northumbria Water	Water and Wastewater	no (moderate)		<ul style="list-style-type: none"> - optant metering until 2025, thereafter selective metering; - 65% meter penetration by 2040, currently 30%; - Berwick WRZ: no further metering promotion planned, metering penetration 29%, optant metering only, no compulsory metering possible due to not being 	- catchment sensitive farming,	<ul style="list-style-type: none"> - capital leakage options are not considered but the following: increasing DMA (District Metering Areas) from 86% to 95%, - pressure management, - leakage-driven mains renewal (not economical); - maintain current SELL level 	<ul style="list-style-type: none"> - based on Essex and Suffolk Water strategies: home audits, retrofits, water kits, Little Green Riding Hood, promotional campaigns; ecofit, behavioural change, H2O gang (primary schools), - Berwick WRZ: whole town approach, addressing all customers throughout the year; - WRAP project for business customers (resource efficiency), - collaboration with other energy saving initiatives 	- problems with nitrates in some areas

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
				an area of severe water stress; - saving are based on Essex experiences: 5% on average of the unmetered consumption and 8% from a selectively metered on change of occupier				

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Peel Water Networks	Local Water and Wastewater		- no sources= no deployable output	- all customers are metered (smart meter)	- company strategy is to be reliable, sustainable and affordable	- very new network (2010), - monitoring, - 2.8% leakage currently (estimated)	- information for customers, - all users are equipped with water saving devices, - website	- legally an "inset appointee"; - supplies part of MediaCity in Salford; - direct treated water import from United Utilities, - hot water for residential users is supplied by a different company who receive cold water from Peel Water Networks, hot water is therefore metered and supplied via a different pipe network

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Portsmouth Water	Water Only	no (moderate)	<ul style="list-style-type: none"> - large list of options (35), - yet no option should be progressed at present as there is no negative AISC (Average Incremental Social Costs) 	<ul style="list-style-type: none"> - optional metering and metering of new properties; - generally low level of metering (21%, 70% expected by 2040), - no change of occupancy metering; - compulsory metering is only an option for shortfall of supplies 	<ul style="list-style-type: none"> - nitrates, pesticides, oil spillages; - nitrates: blending and catchment management; - pesticides: catchment management; - oil spillages: three in the last ten years 	<ul style="list-style-type: none"> - pressure management to find "invisible" leaks, - two free supply pipe repairs per customer 	<ul style="list-style-type: none"> - promotion of metering, - website, - leaflets, - campaigns with environmental NGOs who are known for their water saving, - water saving devices; - Water Efficiency Plan: control of peak demand, control of leakage, reduction of volume of water used for toilet flushing, advice to customers on Water Audits, education of the public on water efficiency, research on the impact of water efficiency initiatives, company has water efficiency officer, collaborates with local authorities, school, networks, since the water bills are the lowest in the country 	<ul style="list-style-type: none"> - lowest water supply charges in England and Wales; - 2004: bulk supply provided to a neighbouring water company as a result of taking a regional view on water resource planning (Water Resources in the South East group (WRSE)); - no significant raw water storage therefore reliant on recharge

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							incentives are low though; - further efficiency through external campaigns (government, neighbouring water companies, target non-domestic customers (audits, communication, real time consumption monitoring)	

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
Severn Trent	Water and Wastewater	no (moderate)	<ul style="list-style-type: none"> - flexible operation of the Strategic Grid (new links and sources), - increasing the capacity of existing sources, - changes to the Wye River and Elan River to fulfil Habitats Directive requirements; - this will reduce DO by the need to reduce unsustainable abstraction; - solution: change 	<ul style="list-style-type: none"> - hope to install 672,000 new meters over the next 25 year, - customer education and awareness of the benefits 	<ul style="list-style-type: none"> - driving leakage down, - water efficiency campaigns, - improve ability to deploy existing sources more flexibly and efficiently, - use water trading to improve resilience, - develop new sources when required, - proactive catchment management, - key strategy (medium-term) is to reduce amount of water taken from environment by making improvements (local) and by providing alternative sources of 	<ul style="list-style-type: none"> - drive leakage down to 6% by 2020, - SELL is at the heart of supply/demand investment plan, - repair all leaks within 24hours, - active find&fix policy, - pressure management, - regular inspections, - reservoir maintenance programme 	<ul style="list-style-type: none"> - accelerate current water efficiency campaigns, - advice and support to all customers to influence behaviour, - school visits, - billing leaflets, - website, - water saving products, - increase links to third parties to form partnerships to deliver water saving messages, - explicit strategy for business customers copying ideas from private customer's water efficiency measure plus: self audit guides, - case studies and best practice 	<ul style="list-style-type: none"> - Challenges they face: - 1) replacing 85 million litres per day that is no longer sustainable abstractable, - 2) meeting the demand for an additional 1.6 million people, - 3) coping with potential low river flows as a result of climate change, - 4) investment into deteriorating assets as network ages; - building strategic links to neighbouring

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
			of operating rules; - for the Strategic Grid: reduce leakage and demand to ensure DO, - Aquifer Storage and Recovery (inject treated water into sealed aquifer and reabstract it when required (drought), - boreholes are currently being tested; - River Worfe flow augmentation		water where necessary; - catchment management strategy (nutrient management, metaldehyde, pesticides, intake management, cryptosporidium risk reduction			water companies; - most water-efficient customers in England and Wales (126l/p/d); - are in the midst of realising that they have to collaborate with local and regional stakeholders (landowners, farmers) to reduce pollution; - improve long term strategic resilience

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
			(requires alternative supply scheme for Telford though); - water level raise at Draycote reservoir					

Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
South East Water	Water Only	yes	<ul style="list-style-type: none"> - forecast says there is insufficient water to meet the demand, - new supply options (water transfers and expanding of existing reservoirs) are number four and five according to customer survey, - Medway License scheme change, - 5 new groundwater sources, - six water 	<ul style="list-style-type: none"> - number one preference for customers, 90% by 2020 		<ul style="list-style-type: none"> - number two preference for customers, - reduction by 10% on company water mains, - reductions expected through metering programme 	<ul style="list-style-type: none"> - key objective is to evaluate and improve ways of managing customer's demand for water, - customer metering programme, - efficiency education and awareness activities; - this shall reduce household consumption by 10% (currently 165l/d/p); - water saving devices are number three preference for customers 	<ul style="list-style-type: none"> - challenges they face: - 1) population and housing growth, - 2) operating in an area with severe water stress, - 3) optimising water sharing with neighbouring water companies, - 4) high reliance on groundwater sources, - 5) uncertainty of climate change impacts, - 6) deliver a plan that is affordable to customers; - WRMP has been

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			transfer schemes, - improving water treatment works, - water re-use schemes, - build new reservoir, increase capacity of existing reservoir, - internal water transfers, - lessen the reliance on groundwater (water re-use), - targeted briefings with affected entities in the development of new resources;					developed in collaboration with Water Resources in the Southeast Group; - Environment Focus Group (key stakeholders from regulators, local planning and local and national interest groups) advised and challenged the WC through the preparation of WRMP; - emphasize merit of collaborating with neighbouring water companies as they see a merit in regional

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			<ul style="list-style-type: none"> - increased local connectivity within WRZ; - highest net importer of drinking water in England and Wales (8%); - set of alternative options 					solutions (future transfer and water sharing options); - 900 unconstrained options initially considered, later reduced to 320 feasible options

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South Staffs Water	Water Only	no (moderate)	<ul style="list-style-type: none"> - no deficit in the supply demand balance; - has highly interconnected supply system; - in critical drought years as Blithfield reservoir levels fall, a sequence of customer demand restrictions are implemented, - supply measures are also implemented but limited to a raw groundwater source and pump- 	<ul style="list-style-type: none"> - increased promotion of metering, 30% now' 73% by 2040, - customers recognize the wider benefits of metering, - free metering, - change of occupier metering, - large consumers (swimming pools), - non-household metering already at 95%; - since they have a supply surplus this 	<ul style="list-style-type: none"> - part of a pilot catchment management project on a tributary to the Severn River (metaldehyde pollution), - upgrade WTW in order to use less chemicals and energy for treatment, will introduce two water surface schemes collaborating with farmers and with the public to reduce nitrates; - large business customer (brewery) has installed inverse osmosis plant 	<ul style="list-style-type: none"> - ALC, - pressure management, - asset management (service pipe renewals, customer supply pipes policy; core tool: DMAs (district meter areas)); - free leak repair scheme; - leakage reduced below SELL only with customer support demonstrated by a willingness to pay for this improved level - however there is no support for such a measure according to surveys 	<ul style="list-style-type: none"> - pcc currently at 132l/h/d, will be further reduced to 120 l/h/d by 2040; - aim: saving 1l/property/day; - since they have supply surplus they will continue their efficiency strategy on the current level, revision with regard to long-term behavioural change; - advice and information to large users, - communication with all customers on saving water, - education of future customers (Blithfield Education Centre), - outreach programme for schools, - participation in collaborative projects, 	<ul style="list-style-type: none"> - don't expect supply demand deficit, therefore no major demand management and resource development measures, - jointly funded WTW with Severn Trent Water; - working with Severn Trent Water on mains connection to provide water in emergencies but also to improve the network's resilience, - company is committed to biodiversity,

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			back scheme, they do not include any drought permits, - borehole maintenance	will continue to be their strategy			<ul style="list-style-type: none"> - greywater recycling (Cambridge area), - working with partners under the Green Deal; - focus group also suggested that not only the water company but also the government should take a greater role in water efficiency education 	<ul style="list-style-type: none"> - embedding a culture of environmental awareness within the workforce and partnership with sustainable projects; - thorough customer research (quantitative and qualitative); - position on metering changed significantly after focus group; - Customer Challenge Group; - expect the overall household occupancies to reduce

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South West Water	Water and Wastewater	no (moderate)	- surplus available in all three WRZ, therefore no need for new reservoir or sources, - no changes to WRP09; - transfers between WRZs instead of developing new sources	- currently 75% (household) and 92% (non-household), - free metering option, - 90% (household) and 95% (non-household) if current strategy is continued, no intention to change metering policy; - generally speaking customers reduce their consumption after installing a meter (financial	- catchment management (five year programme)	- network of DMAs; - pressure management; - supply pipe leakage is reduced on average by 20% (32% non-household) after meter installation; - leakage target is below SELL; - leakage control is based on detection and repair, - increase efficiency of leakage monitoring; - customer supply pipe repair policy; - estimate that 80% of leakage is from supply network and 20% from customer supply pipes; - targeting more areas for	- website, - audits, - conservation helpline, - education material for schools, - events (county shows), - free water saving devices, - online tools for business customers to increase water efficiency, - water use reviews for customers who struggle with bills, - efficiency reviews targeted at the hospitality sector, - help with calculating water use (and subsequently switching to a meter)	- have added overstaying visitors and EU accession country migrant to population forecast (based on research), - estimate that 1.3% of population have private water supply; - expect a drop in average household size; - tourism region therefore seasonal demand patterns; - hotel and catering industry accounts for 18% of non-household consumption,

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				incentive), - based on research, the average reduction as a result of metering is 16.5%; - only SMART meters will allow new tariffs		pressure management, - upgrade infrastructure, - aim to repair leaks within two days		followed by agriculture (15%); - resilience planning has been "business as usual" for many years; - continued collaboration with farmers and those interested in water; - internally water is used conjunctively the WRZs forming a grid

Southern Water	Water and Wastewater	yes	<ul style="list-style-type: none"> - water supply relies on rainfall (winter recharge); - risk of saline intrusion in coastal regions; - number of run-of-river services with no supporting storage to supplement low flows; - these sources are particularly vulnerable to drought; - four surface water reservoirs, which offer the most potential for drought management; - identify key challenges over the next 25 years: stricter laws (sustainability reductions), 	<ul style="list-style-type: none"> - PCC unmetered: 160l/h/d (median), metered: 136 l/h/d (median); - 8% of customers are currently unmetered; - continuation of metering programme is associated with high costs; - tariff options rely on smart water meters, however trial with different tariffs in AMP6 to provide evidence 	<ul style="list-style-type: none"> - working with farmers and landowners to reduce nitrate pollution and build up of sediment 	<ul style="list-style-type: none"> - three main pillars (leakage management strategy): improvement strategies (DMAs, pressure management); - operational leakage activities (repair, monitoring); - asset and data maintenance; - ALC; - 200-strong team of leakbusters 	<ul style="list-style-type: none"> - behaviour change, free advice, - discount on water saving devices, - free water audits to vulnerable customers, - soft and hard measures, - aim: 1l/property/day; - education programmes in schools; - partnership with Waterwise and Energy Saving Trust 	<ul style="list-style-type: none"> - fragmented geographical areas, - shares borders with eight water companies, - ten WRZ some of them interconnected; - 70% of supply come from groundwater, 23% from river abstractions; - extensive stakeholder engagement during the WRMP phase
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		catchment management (working together with farmers and landowners), new housing developments (trend to smaller households), population growth, climate change (weather extremes, changing weather patterns), energy use (running costs of treating water), state of economy (water price), resilient water supply (reduce vulnerability), resilient water sources (metering, reducing leakage, increase efficiency), water transfer and water					
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		<p>trading (regional strategy, WRSE), planning constraints (no increase in abstraction), value of water (scarcity charge);</p> <ul style="list-style-type: none"> - customers prefer a resilient water supply; - internal transfers; - western area: huge supply-demand deficit due to sustainability reductions (new sources, conjunctive use, river augmentation, transfer from Portsmouth Water), - central area: catchment 					
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			management, winter transfer scheme, import from Portsmouth Water, internal pipeline; - eastern area: Medway license variation, water export, internal pipeline; - long-term plans: water re-use (Medway), desalination (Hampshire), aquifer storage and recovery (Sussex), increased transfer to Isle of Wight					
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Water Company	Water Only / Water and Wastewater / Local Water and Wastewater	Area of Severe Water Stress	Ensuring Sufficient Deployable Output (volume of water that can be pumped into supply)	Metering (% of meter penetration and strategies)	Key Strategies (for efficient use / to reduce pollution)	Leakage	Water Efficiency (Campaigns)	Other / Comments
SSE Water (SWALEC in Wales)	Local Water and Wastewater		- SSE has no DO and no storage capacity	- all properties are metered (new housing developments),		- reactive leakage repair, - control via comparison of bulk supply and billed volumes	- welcome pack for each new customer on water saving	- water and sewage provider, - supplies water to 19 water supply areas via bulk supply connection from incumbent's water networks
Sutton and East Surrey Water	Water and Wastewater	yes	- no constraints to supply currently; - increase WTW capacity, - new borehole source, - advanced treatment for a disused source, - improvement to the internal network (connect	- 37% metered (88% non-household); - change of occupier metering; - target for household customers: 61% by 2019/2020, - smart metering will allow variable		- leak detection and repair above company's target; - free supply pipe leak detection and repair scheme, - subsidised supply pipe replacement; - ALC, - DMAs (97% of properties are contained within DMAs),	- audits for non-household customers and large private users (high consumption visits); - water saving devices in the hospitality sector, schools, elderly care homes and households; - billing inserts, - website, - events, - talks, - behavioural change,	- 85% groundwater, 15% river sources; - member of WRSE Group; - large business customer is Gatwick Airport

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			and commission an existing source), - groundwater scheme (UV treatment)	tariffs (trials are carried out; company will wait five more years and consider technology improvements), - Pay As You Save		- new telemetry software for quicker leakage detection and awareness, - pressure management (covers 69% of properties), - reduced metering through leakage	- emphasis on customer education	

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Thames Water	Water and Wastewater	yes	<ul style="list-style-type: none"> - London relies on bulk supplies from other WRZ, - supply demand balances have worsened compared to the draft WRMP version; - only Kennet and Henley Valley remain in surplus, - London: combination of demand reduction and resource development, heavy demand reduction through metering, leakage 	<ul style="list-style-type: none"> - London: progressive metering from 2020 onwards, 70% meter penetration by 2025; - Thames Valley: full household metering scheme from starting 2020, introduction of smart meters and tariffs (2020-2025), - SWOX 92.7% meter penetration by 2030; - SWA 87.7% by 2030; 	<ul style="list-style-type: none"> - customer preferences: leakage reduction, metering, water efficiency 	<ul style="list-style-type: none"> _ London: leakage reduction through: mains replacement, pressure management, ALC, DMAs, aim: 10% reduction between 2015 and 2020 	<ul style="list-style-type: none"> - educational campaigns, - visitor centres, - water saving devices, - behavioural change 	<ul style="list-style-type: none"> - UK's largest water company (13.5 million customers); - supply mainly through surface water abstraction supported by reservoirs (London: 80: surface water (Thames, Lee), 20% groundwater, Thames Valley: 30% surface water, 70% groundwater), - member of WRSE group, - discussing strategic transfers within WRSE group, - regional challenge and need to

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			reduction and water efficiency in the short to medium term period, water trading (surplus due to closure of power station Didcot A), water transfers are also key, wastewater re-use (reverse osmosis) is also favoured to secure water supply in London; - Thames Valley: focus on demand (progressive metering,	- Kennet Valley 93.2% by 2030; - Guildford 86.5% by 2030; - Henley 93.7% by 2030;				collaborate is acknowledged, - see an opportunity for joint implementation of water re-use schemes; - collaboration with WWF on Save Water Swindon

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			efficiency and leakage control), small aquifer storage and recovery scheme in Guilford WRZ to facilitate water transfer to Affinity water, remove network constraints to facilitate treated water transfers; - large water resource scheme will be required in mid-2020s to maintain security of supply in London					

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			(wastewater re-use (though costly and risky), regional water transfers and reservoir storage)					

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United Utilities	Water and Wastewater	no (moderate)	<ul style="list-style-type: none"> - challenging supply area West Cumbria: use spare water from Integrated Resource Zone, - new WTW and pipeline between West Cumbria and Thirlmere Reservoir; - trading water was considered but only if it is beneficial to the customers; - otherwise no supply deficits; - contingency plan if Thirlmere 	<ul style="list-style-type: none"> - free metering, - meter all new households, - meter all non-households, - introduce smart meters where possible, - investigate support for social tariff 		<ul style="list-style-type: none"> - DMAs, - pressure management, - leak detection work force, - free supply pipe repair 	<ul style="list-style-type: none"> - education (primary schools), - free water saving devices, - free advice to business customers (self-auditing); - sponsoring of children's TV character Gabi H2O, - water meter calculators; - billing leaflets, - website, - collaboration with local groups, - attendance at local shows (flower shows etc.); - sponsorship of regional ITV weather forecast; - research into benefits of water efficiency campaigns 	<ul style="list-style-type: none"> - 90% from rivers and reservoirs; - challenging water supply issues in West Cumbria, an important habitat; - affordability is an issues as the supply area is characterised by low income, - supply options in the west are limited due to geographical border; - floating solar farm at Godley Reservoir

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			options fails/becomes undeliverable (local sources, using wastewater)					
Veolia Water Projects Tidworth	Local Water and Wastewater	no (moderate)	- uprate pumps at two boreholes, - "Military Uncertainty Factor" (peak demands = army exercises and lows = block leave, garrison may be increased, hardly predictable as army planning is classified)	- currently 55%, 79% by 2016 (new developments), - Ministry of Defence (MOD) has metered all significant buildings		- DMAs,		- inset appointment for 800 civilian customers, 90 commercial customers in Tidworth (Wiltshire) plus agreement with MOD (up to 6000 personnel), - groundwater supply, - growing demand expected as garrison continues to grow; - exports to Wessex Water,

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								- high nitrates, - reference to flooding
Wessex Water	Water and Wastewater	no (moderate)	- development of integrated grid	- free meter option, - metering at occupier change, - research has shown them that customers use 15% less water when metered	- major challenge: noticed deterioration in the quality of water at some sources (nitrates and pesticides), - result: catchment management approach	- reduction through metering, - DMAs, - pressure management, - free leak repairs	- assistance and advice on wise water use, - water saving devices, - school education campaign, - retrofit scheme, - social housing retrofit scheme, - water efficiency community fund to provide schools, hospitals and councils buildings with water saving devices, - better collaboration with communities (e.g. Transition Towns)	- 75% from boreholes, 25% from reservoirs, - demand surplus, - water trading is considered, - adopted a catchment based approach, - will decommission sources, - liaise with local authorities on population and

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								property projections, - future challenge: expansion of Hinkley Point Power Station
Yorkshire Water	Water and Wastewater	no (moderate)	- supply demand deficit expected from 2018/19 onwards (loss of yield due to climate change); - solution: balance of demand reduction options and development of existing or new assets, includes leakage reduction, use of existing river abstraction	- currently 40%; - optional metering with moderate promotion, - meter penetration by 2039/2040: 60% (80% if new housing is included)		- free supply pipe repair; - ALC	- water saving devices, - retrofits, - behavioural change (website, self-audit (water use calculator), classroom school pack, visitor centres), - water audits for non-household customers	- 45% of supply from reservoirs, 25% from boreholes and 30% from rivers; - no raw water exports, - raw water import from Severn Trent to support supply in Sheffield

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			licence, three groundwater schemes and customer water efficiency; - interconnected grid; - DO in East SWZ is limited by capacity of WTW (however demand is lower than capacity)					

Legend:

DO= Deployable output

PCC= Per capita consumption

WTW=Water treatment works

WRZ= Water Resource Zone

ALC= Active Leakage Control

DMA= District Metering Areas

WRSE= Water Resources in the South East

SELL=Sustainable Economic Level of Leakage

WRMP=Water Resources Management Plan

Table S3 Overview and brief description drought and water scarcity management options

UK current regulatory box	
Drought orders	A drought order, issued by the Secretary of State (DEFRA) or the Welsh Minister, authorises increased abstraction from the environment by water companies or any other abstractor in order to meet statutory duties for public water supply. It can also restrict the demand from commercial water users or limit abstraction by a water company or the EA.
Drought permit	A drought permit, issued by the EA, enables to increase supply of water abstracted from the natural environment.
Drought plan	Drought plans cover the range of actions necessary to deal with various drought situations. They set out how a water company will continue to meet its duties to supply water during drought periods with as little recourse as possible to drought permits or drought orders.
Water Resources Management Plan	WRMPs look 25 years ahead and conform to UK legislation and Environment Agency guidelines to ensure companies have sufficient water to supply the public and maintain adequate water in the environment.
Temporary Use Bans / non-essential use restrictions	Water companies can implement temporary water use restrictions under their own powers. These restrictions are temporary measures that reduce the demand for water and are usually one of the first steps a water company can take to protect its supplies during a drought. The water company does not require any approvals to restrict these uses of water but must run a period of public notice and allow for representations to be made before the restriction comes into force. Examples: watering gardens, cleaning a private motor vehicle
Abstraction licences	Abstraction licences provide abstractors with a licence to take a fixed volume of water
Emergency Drought Orders	Emergency Drought Orders may prohibit or limit the use of water for any purposes a water company considers appropriate. Water is supplied by means of standpipes or water tanks.
Abstractor Group: Agriculture	
Catchment Management	A catchment-based approach looks at activities and issues in the catchment as a whole, rather than considering different aspects separately in different locations. It involves bringing people together from different sectors to identify issues and

	agree priorities for action – and ultimately building local partnerships to put these actions in place.
Soil water holding capacity	One of the main functions of soil is to store moisture and supply it to plants between rainfalls or irrigation. Evaporation from the soil surface, transpiration by plants and deep percolation combine to reduce soil moisture status between water applications. If the water content becomes too low, plants become stressed.
Irrigation management	Irrigation is the artificial exploitation and distribution of water at project level aiming at application of water at field level to agricultural crops in dry areas or in periods of scarce rainfall to assure or improve crop production.
Drought monitoring	Early-warning systems supported by data networks, data sharing, forecasts, SPI, etc.
Agricultural insurance	Agricultural insurance covers yield losses caused by droughts.
Reducing water intensive crops	Reducing water intensive crops means giving preference to crops that use less water in water scarce regions.
Environmental water budgets	Environmental water budgets account for the inputs, outputs, and changes in the amount of water by breaking the water cycle down into components.
Indigenous crops	Indigenous crops have their origin in the area they are grown in.
Income support	An income support scheme provides eligible farmers and their partners who are experiencing financial hardship due to a drought with assistance and support to improve their long-term financial situation. Example: Australia.
Interest rate subsidies	Interest rate subsidies provide business support to farms that were viable in the long term, but were in financial difficulties due to a drought event. Example: Australia.
Hydrological outlooks	Hydrological outlooks are based on observed data and projections and they present the UK water situation for the next 1-3 months and beyond.
Procedural devices	
Water exchanging centres	Water Exchanging Centres offer and demand water use rights in periods of drought. Example: Spain
Drought water bank	Drought Water Banks allow selling and buying of water
Water markets	Water markets provide a more flexible allocation of water. In the Murray-Darling Basin (Australia), the poster child for water markets, water licenses used to be tied to land but water markets allowed to get water you need from someone who already has a license. However, market rules need to reflect hydrological realities.

Distribute water	
Bulk transfer	Bulk transfer is the transfer of raw or treated water between two parties, for example water companies and areas. Bulk transfers are usually subject to contracts between the two parties.
Share water	Sharing water encompasses a wider concept than bulk transfers. Sharing water can mean voluntary sharing of water resources across areas or sharing and (re)using water for different purposes, i.e. irrigation, production processes.
Supply side / water creation	
Grey water reuse by third parties (inset appointees)	In this special case third party suppliers, who for example supply and treat water for a new housing development, invest in greywater reuse schemes thereby decreasing future bulk water transfers from the local statutory water supplier.
(re)use greywater	This process describes the utilisation of treated or untreated water for a variety of purposes. For example, household discharge could be reused for non-potable uses such as watering gardens.
Explore new sources	This includes tapping into aquifers, new river abstraction points, or can go as far as transporting water from geographical distant regions by ship.
Rainwater harvesting	Rainwater harvesting is the accumulation of rainwater for reuse (e.g. irrigation). This includes for example cisterns or collection from roofs.
Reservoirs	Reservoirs are artificially created lakes for storing water. Reservoirs are fed by rivers or glaciers and usually provide drinking water and irrigation water. Reservoirs and dams are also used to generate electricity through hydropower.
Water butts	A water butt or tank is used to collect rainwater runoff usually from rooftops. The collected water can be used for watering gardens for example.
Tankering by lorries	This describes the provision of usually drinking water by means of water tanks in emergency situations.
Desalination	Desalination describes the process of removing salt from saline water (sea water, brackish water) either through thermal desalination or reverse osmosis. Desalination plants are energy intensive and so far in the UK only Thames Water operates a desalination plant for emergency purposes.
Recommissioning	Re-commissioning of sources is the process or reactivating previously closed down boreholes or other abstraction points. This could be the case for example if a groundwater aquifer has recharged.

Technology led	
Aquifer recharge and aquifer storage and recovery	Aquifers storage and recovery is a process to convey water underground. Aquifer recharge replenishes groundwater stored in aquifers. Aquifer storage and recovery is used to store water and reuse it at a later stage.
Lower pumps / deepen boreholes	This option is applied when the groundwater table drops below the level of the well pump.
Company led	
Mains pressure reduction / pressure management	Pressure is the force that pushes water through pipes. Water companies apply pressure management to reduce leakage and thereby reduce the loss of water.
Better integrated network	A better integrated network means improved links between water resource zones. This enables water suppliers to distribute water more efficiently and allocated it to where it is needed.
Active leakage control	Active leakage control aims at prompting detection, localisation and repair of pipe burst, thus reducing possible damages to properties, minimise unplanned works, and reduce the volume of lost water.
Valuing water / water attributes	
Water efficiency campaigns	Water efficiency campaigns aim at reducing water demand. They usually address private household customers but also aim business customers. Water efficiency campaigns use a variety of media - print, audio-visual, social – or take the form of plays, games or roadshows. Another form of water efficiency campaigns is the provision of water saving devices to customers.
Water stewardship	Water stewardship describes the use of water that is based on social equality, sustainability, yet economically beneficial approach. It includes a wide variety of stakeholders and is catchment based.
Water efficiency community fund	A water efficiency community fund provides devices and their installation in schools and other not-for-profit social organisations such as hospitals, councils and local services.
Ownership of customer supply pipelines	The ownership of customer supply pipelines enables water companies to target leakage reduction according to their own strategies and timescales.
Water rights	A water right describes the right to use water from a source (e.g. groundwater, river, etc.).
Scarcity charge	A scarcity charge would mean the price abstractors pay better reflects the environmental impact of water abstraction. If

Creating water saving culture	introduced, a higher price would be paid for water, which is abstracted from areas where there is less water available.
Public goods charge on water	A water saving culture promotes water efficiency and tackles issues of reduced supply and increased demand.
Drought awareness (information campaigns)	A public goods charge for water users funds improvements in water infrastructure and environmental protection and conservation and restoration and research.
	A drought awareness campaign proactively promotes water efficient behaviour before and during a drought. This can take the form of educational measures or tangible items such as providing buckets for rainwater collecting.
Structural approaches / overarching framework	
EU Water Framework Directive	The EU Water Framework Directive is a comprehensive approach to address qualitative and quantitative issues with regard to water. It addresses chemical issues, promotes public participation and requires river basin management plans. The directive's goal is to achieve a good ecological status of all European Union water bodies.
Collaborate with local authorities and housing associations / developers	Collaboration between water companies and local councils and housing developers can make sure that new and refurbished housing benefits from the latest water saving technologies and appliances.
Regional drought preparedness networks	Regional drought preparedness networks allow sharing information, technologies and tools.
Better collaboration among water companies and neighbouring policy sectors (flooding, agriculture, forestry, housing, etc.)	A better collaboration can ensure that policies are aligned and measures in one sector do not contradict measures in another sector. It also raises problem awareness among sectors and its stakeholders.
Metering	
Tariffs	Tariffs are a measure to incentivise efficient water usage. Water tariffs can be volumetric, i.e. metred, or a flat rate. With regard to consumption different model exist, for example increasing block tariffs, where tariffs increase with consumption.
Water metering	Charging customers according to use.
Land use planning	
Restore wetlands	The restoration of a wetland describes the return of an ecosystem to a close approximation of its condition prior to disturbance.
Remove dams	Water stored in reservoirs is subject to evapotranspiration and there are more cost-effective ways to store water available. In

	<p>addition, the removal of a dam can restore a negatively affected ecosystem.</p>
Drought tolerant landscaping	<p>Drought tolerant landscaping takes into account the ecological characteristics of each space. It includes using efficient irrigation, the use of native plants, use of succulents and strategic plant grouping.</p>
Sustainable land use planning	<p>Sustainable land use planning takes into account regional social, ecological and economic characteristics. For example, it takes into account population forecasts and planning is based on preserving the liveability and environmental protection.</p>
Integrate water scarcity in planning	<p>Integrating water scarcity into planning means to acknowledge that water scarcity is part of life in a given area and thus, water scarcity should not be seen as a problem during emergencies but as a constant condition.</p>