# Technical annex: Analysis of drought resilience

**July 2018**

NATIONAL INFRASTRUCTURE COMMISSION

# The size of the problem

Water is essential to people, the economy and the environment. In England,[1] water abstracted from rivers and aquifers is regulated by the Environment Agency. The vast majority of freshwater abstracted in England is used to produce drinking water and for industry (figure 1).

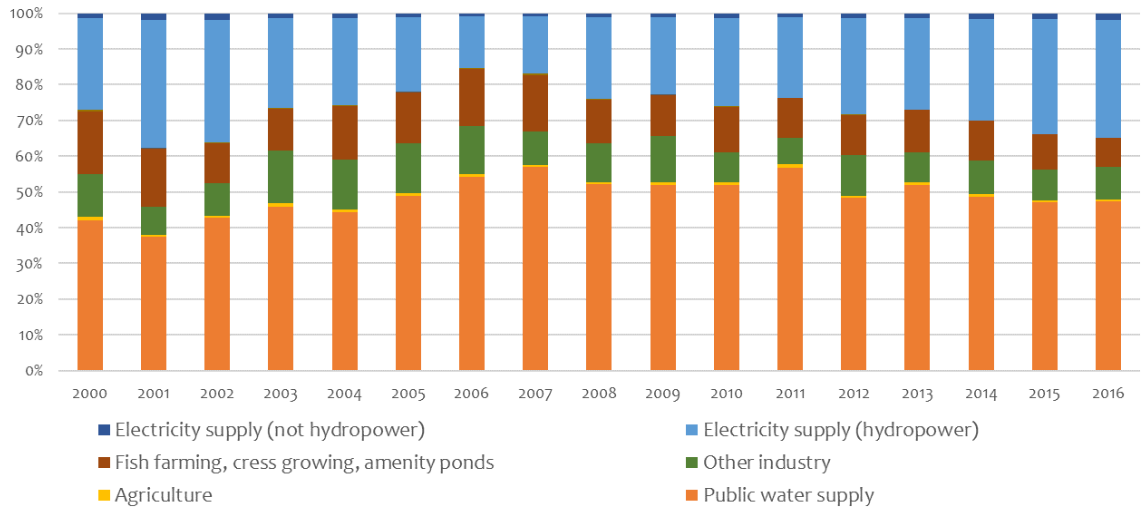


**Figure 1: Freshwater use in England**[2]

Almost half (47 per cent) of the abstraction goes to the public water supply. Water UK in 2016[3] highlighted the challenge of meeting public demand for water during periods of low rainfall. These drought events are increasing in frequency and severity due to climate change, with population growth adding to the challenge. Other abstractors also contribute to the pressure on water resources, although to a lesser extent. Whilst the energy sector accounts for 35 per cent of the freshwater abstraction, most of this (95 per cent) is used for hydropower generation, thus it is not taken away from the environment. Water demand for other types of energy generation would increase only if there is a substantial uptake of carbon capture and storage,[4] and even in this case it would only result in low volumes (a few percentage points) compared with total freshwater use.[5]

The Environment Agency is tasked with ensuring that there is enough water to sustain the environment and the life of waterbodies, supporting water quality and recharge of aquifers. The Environment Agency revises abstraction limits periodically, issuing "sustainability reductions" where necessary. Currently the ecosystems of at least one in 10 rivers and more than a third of groundwater bodies in England are under pressure due to water abstraction.[6]

The UK Climate Change Risk Assessment 2017[7] identified a risk to industry from abstraction reform and reduced water availability. This would only materialise if public demand for water is met by increasing abstraction. Managing public demand and creating additional resources to supply water even in periods of droughts, whilst maintaining sustainable abstraction limits, should ensure that there is also sufficient water for industry, as well as for the environment. Thus this analysis focuses on public water supply, starting with an independent assessment of the size of the problem.

The Commission calculated future water balances under a range of droughts using the National Infrastructure Systems Model (NISMOD),[8] developed by the Infrastructure Transitions Research Consortium. The analysis assumed no further action beyond those listed in the previous round of Water Resources Management Plans (2014). The baseline demand was assumed to be in line with Water UK's "Business as Usual" scenario, under different scenarios of population growth, climate change and drought.

- **Population growth**
    - Low – ONS 2014-based low migration population projection
    - High – ONS 2014-based high fertility population projection
- **Climate Change**
    - Central – medium emission Future Flows,[9] average water balance scenario
    - Dry – medium emissions Future Flows, with less water in the South East
- **Drought** – drought of different probabilities of occurrence were simulated into the two Future Flows scenarios by the Water UK Long Term Planning Framework project.
    - 1 per cent annual chance, corresponding to 1 in 4 probability of occurrence by 2050
    - 0.5 per cent, corresponding to 1 in 7 probability of occurrence by 2050
    - 0.2 per cent annual chance or 1 in 17 probability of occurrence by 2050

The above variables were combined to calculate the supply-demand balance at a company, regional and national scale in England to look at the widest range of results.

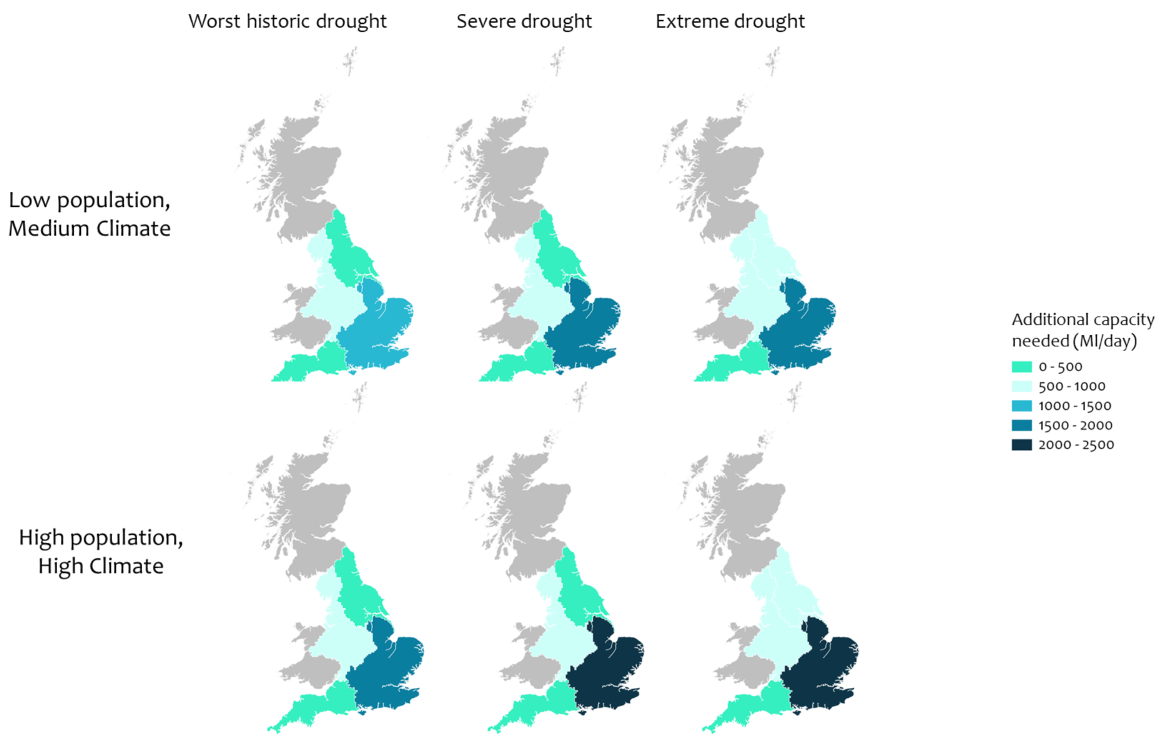


**Figure 2: Additional water capacity needed in England in case of drought under population and climate scenarios**[10]

Six water companies, serving almost 40 per cent of the English population, would experience water deficits during a drought that has a one in four chance of occurring at least once between now and 2050, and ten companies (serving almost 60 per cent of households) during a drought with a one in seven chance of occurring between now and 2050 (figure 2).

Water companies are required to plan for droughts, but these include imposing emergency restrictions – effectively cutting-off supplies to homes and businesses – which are unlikely to be publicly or politically acceptable. It is more likely that emergency action would be taken to sustain near normal supplies for as long as possible. This might include tankering water across the country and removing unsustainable amounts of water from the environment. Most options would incur very high costs and some would result in severe environmental damage and risks to public health.

The Commission calculated the capacity needed to provide water to supply households in periods of drought using the NISMOD model. The capacity calculated represents the additional volume of water needed in each company to respond to drier conditions, beyond that already available within a company (i.e. assuming that internal transfers and investments to maintain or enhance existing capacity take place). It is also assumed that, during these events, some additional capacity is provided by measures that reduce demand but do not restrict essential household water use, such as hosepipe bans and restrictions to some businesses. The calculated capacity needed accounts for interventions in place up to 2020, thus includes those identified in the previous round of

Water Resource Management Plans (2014), but excludes additional interventions proposed in the latest draft plans.

In the previous planning cycle companies assessed sufficient water to maintain household supplies during an event comparable with the worst drought experienced by the company. This "worst historic drought" roughly corresponds to an event with a 1 per cent annual chance of occurring. Maintaining this existing level of resilience to 2050, in the face of population and climate pressures, would require additional demand management and supply for 2,700-3,000 Ml/day (depending on climate and population scenarios).

Over and above this, the Commission estimated that England could face a shortage of between 600 and 800 Ml/day in a severe drought with a 0.5 per cent probability and between 800 and 1,100 Ml/day in a more extreme drought with a 0.2 per cent probability (figure 3).

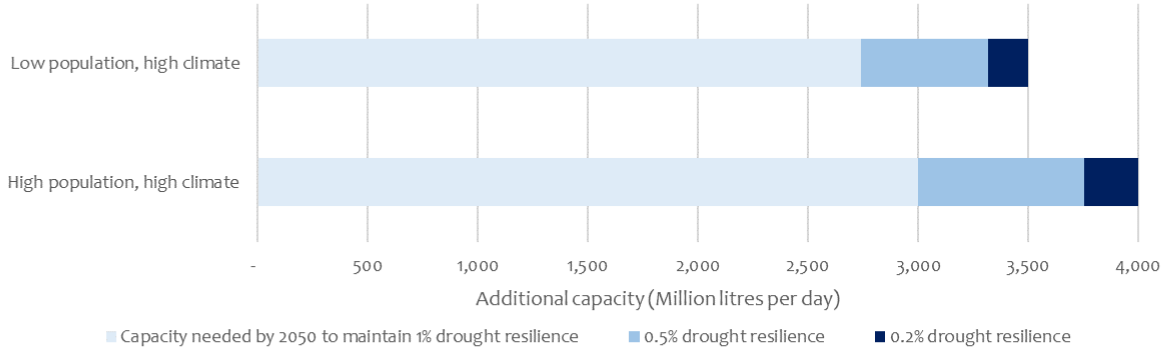


**Figure 3: Water capacity needed**[11]

# Establishing an appropriate level of drought resilience

To establish the appropriate level of resilience for England, the cost of providing new infrastructure and of reducing water demand and leakage (the "resilience cost") has been compared to the cost of deploying emergency drought interventions.

The Commission calculated the cost of emergency interventions based on analysis by Atkins.[12] The analysis estimated the costs of supplying water during drought to avoid imposing emergency restrictions to businesses and households on essential use (i.e. rota cuts). It was assumed that every water company is resilient, and will maintain its resilience, to a drought with 1 per cent annual chance of occurrence. Thus, the costs were calculated as marginal costs compared to a 1 per cent drought. The total costs between 2020 and 2050 of implementing emergency measures to provide household water supply during a 0.5 per cent drought, weighted by the occurrence probability, range between £13 and £16 billion, depending on the assumed climate and population growth (figure 4). The total costs over the same period of implementing emergency measures against a 0.2 per cent drought range between £21 billion and £27 billion.

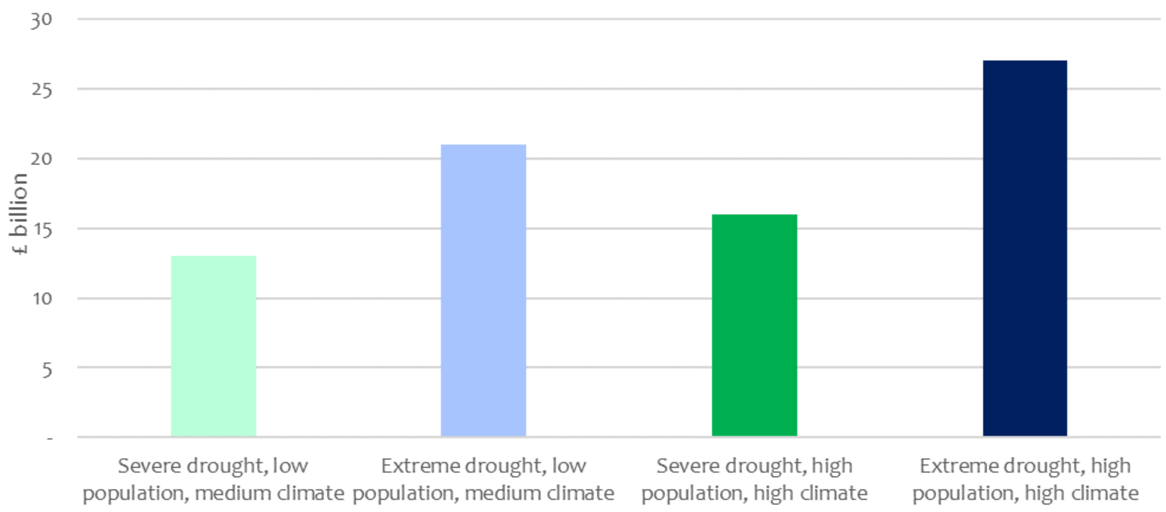


**Figure 4: Costs for the period 2020-2050 of supplying emergency measures to provide household water supply during a drought[13]**

*Note: Costs are on a present value basis (2018 prices) weighted by the occurrence probability*

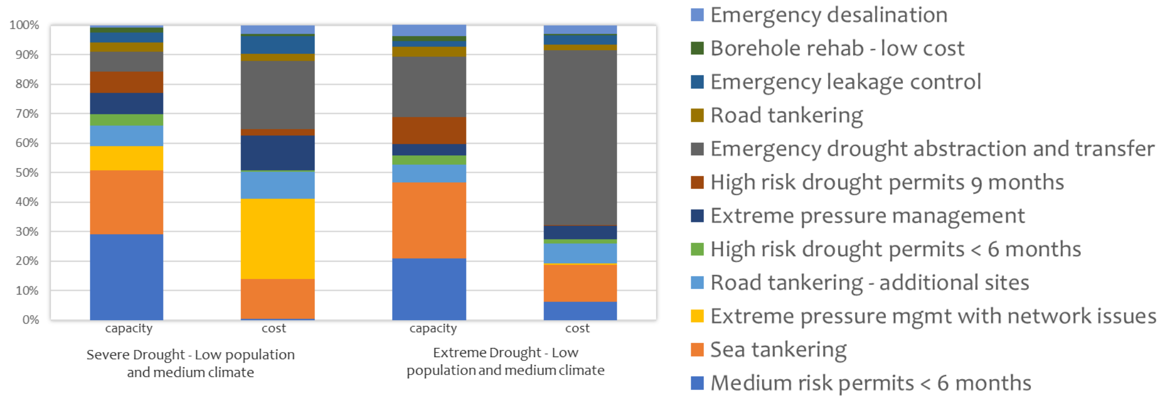


**Figure 5: Proportion of the total capacity provided by different emergency measures and corresponding costs[14]**

The analysis also shows that to ensure supply during drought, some costs must be borne in advance of any event occurring. These include the provision of basic connection infrastructure that cannot be constructed in the short timeframe of a drought. On the other hand, extended drought permits can help tackle the deficit during mild drought, but create risks to the environment and might reduce the availability of water to industry. The costs of responding to a mild drought through emergency measures are thus lower when the deficit is met mainly through cheaper but potentially higher-impact measures. The costs increase steeply with the need for more permanent infrastructure to meet the deficit quickly, such as connecting pipes to transfer additional abstracted water ("Emergency abstraction and transfer" in figure 5) or emergency desalination plants. These interventions make responding to a more extreme drought very expensive which explains why, despite the lower likelihood of a more extreme (0.2 per cent) drought occurring, the weighted present value costs are considerably higher.

The short-term emergency costs of providing water during a drought, weighted by their probability of occurrence in the 2020 to 2050 period, are directly comparable with the whole-life costs of building long-term resilience to an equivalent event. Figure 6 shows the comparison between these two costs, including those of maintaining the current level of drought resilience through proactive long-term measures to manage demand and provide additional supply through infrastructure.[15]

The results show that at a national level, the cost of responding to a drought emergency are consistently higher than those of building long-term resilience to the same event (figure 6).

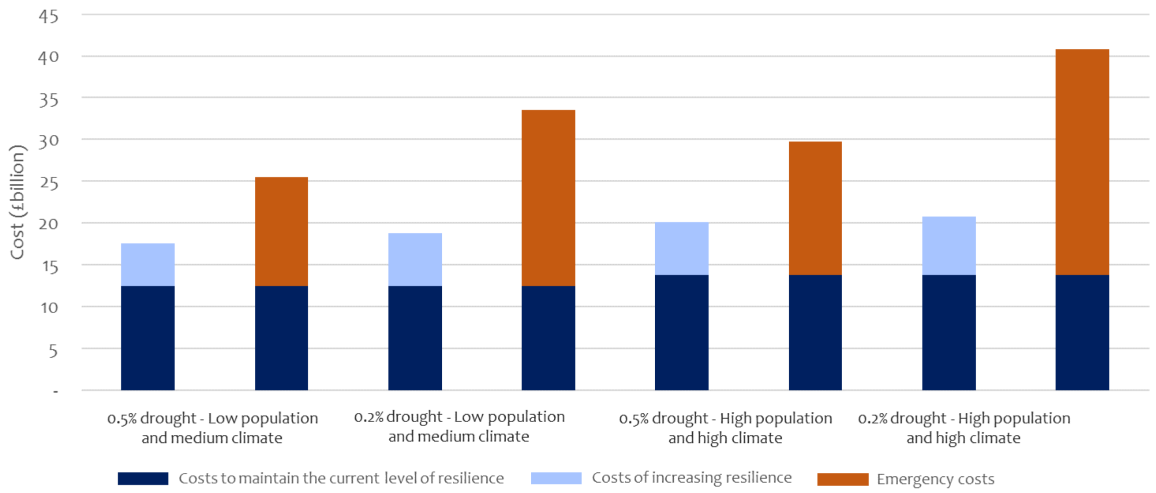


**Figure 6: Comparison between emergency costs and resilience costs[16]**

# A twin track approach to tackling the risk of drought

This section describes the analysis of demand management (reducing consumption and leakage) and infrastructure options to balance costs, benefits and risks.

## Reducing consumption

Increasing the water efficiency of appliances can save considerable amounts of water. For example, modern dual flush toilets use about half of the water compared with traditional ones, standard showers use about one third the water of a bath, and aerated shower heads further reduce water use.[17] Behaviours are also important, for example showering for one minute less each day can save about 3,000 litres of water per year saving £7 on energy and £12 on water bills.[18] Campaigning and public engagement also play an important role[19] and water labelling would allow consumers to make informed decisions.[20]

Current efficiency initiatives are likely to result in savings of about 400 Ml/day by 2050[21] and new technology would increase this to 600 Ml/day over the same period, in line with the Commission's "central technology" scenario.[22] There is strong evidence that charging by volume leads to more efficient water use. Standard meters can reduce average consumption by 15 per cent and smart meters[23] by 17 per cent.[24] Smart meters also enable better identification of leaks, help customers understand their consumption, and allow companies to quickly identify and target those struggling to pay their bills.[25]

Water companies can only impose volume based charges for new homes or occupiers, where households use large quantities of water (e.g. power showers or swimming pools) or in areas classified as seriously water stressed. Despite the constraints, companies are increasing metering and bills for unmetered customers would go up. Three water companies out of 18 should have near universal metering by 2030, and a further two by 2035.

Universal metering would reduce average water bills but some customers would end up paying more than they do now. Large families may be worse off with a meter[26] but this is consistent with the fact that they consume more water. Universal metering by Southern Water showed a reduction in the average water bill of £6 per year. More than half of households likely to have a lower income saw a reduction in their bill (partly related to reductions in consumption). However the average (mean) bill for households likely to have a lower income rose by around £10 per year. This implies that losses for those households that did pay more outweighed savings among the households that paid less, even though there were more of the latter group.[27] Assistance for lower income households that might be worse off with metering is therefore likely to be most effective if it is well targeted. [28]

Water companies have a statutory duty to assist vulnerable customers.[29] Smart metering can help companies identify households with the highest water consumption, who might struggle to pay their bills. Smart meters could also enable variable tariffs (recognised in the energy sector as helpful for vulnerable consumers[30]) and more regular and transparent billing (which helps households to budget[31]).

Overall, water bills are not seen as burdensome by customers and stakeholder discussions indicate a generally positive attitude toward metering as observed by Consumer Council for Water research. Companies will therefore need to work with their customers and support them when rolling out compulsory metering.[32]

Commission analysis of the potential benefits of metering compared a baseline of continuing at the current rate of meter roll-out with near universal conventional and smart metering by 2030 and 2035. The total amount of water that would be saved in each year ranges from 400 to 800 Ml/day (figure 7).

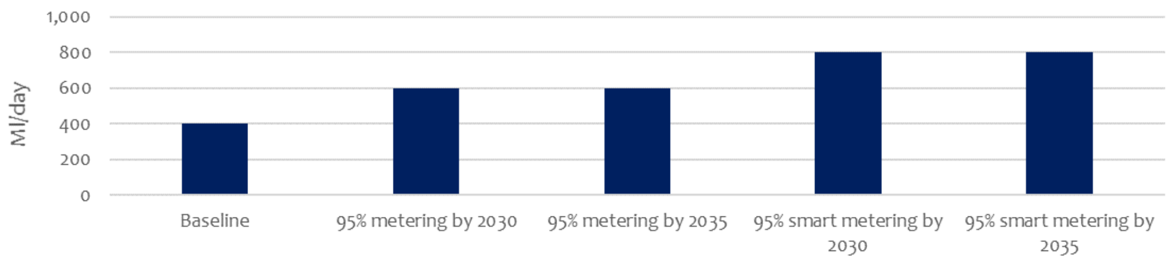


**Figure 7: Water saved in 2050 under different metering options**[33]

Figure 8 shows the total and marginal costs and benefits of these options. Costs include installation, operation, replacement and carbon costs. Benefits include avoided energy (from treating and pumping as well as household energy use) and the avoided cost of infrastructure. These results suggest that, if the wider benefits are considered, quicker and more comprehensive smart metering should result in savings and is at worst cost neutral.

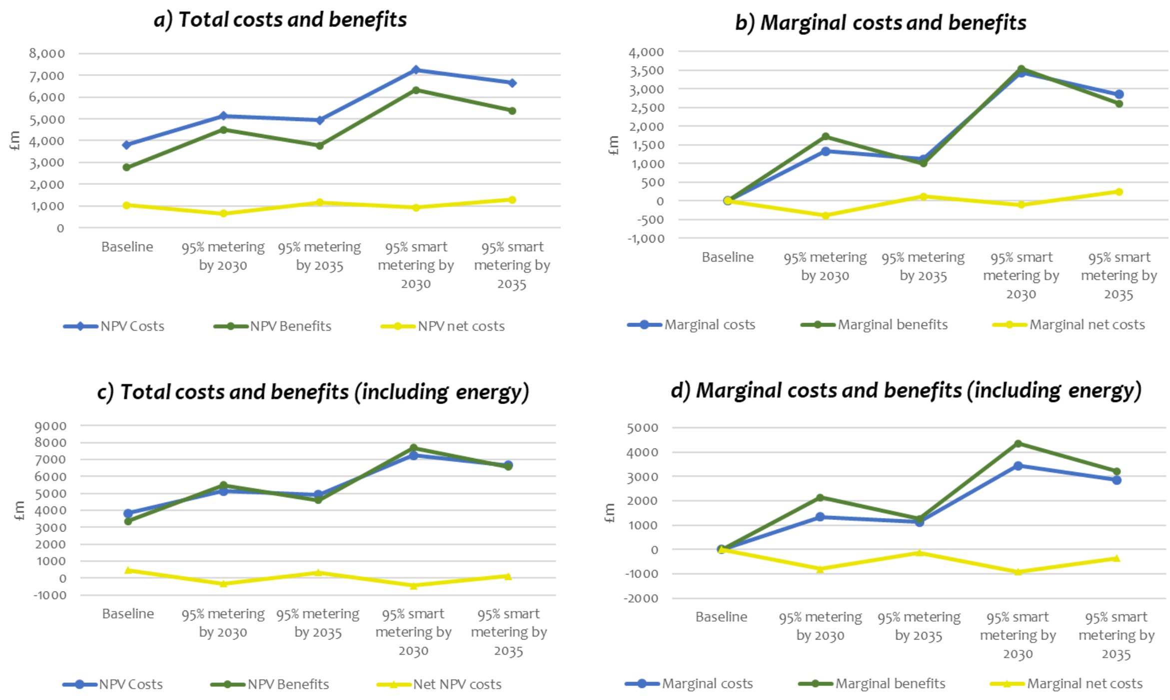


**Figure 8: Costs and benefits of metering policies**[34]

There is also evidence that a faster and better planned transition to universal metering could unlock efficiencies and allow for more extensive engagement to help prepare customers.[35] Systematic metering should also help to identify and address water leakage,[36] target financial assistance at those households most in need and provide benefits in all regions in England regardless of the level of water stress.

Increasing efficiency savings to 600 Ml/day by 2050 and near universal smart metering would reduce average (measured and unmeasured) water consumption in England from the current 141 to 118 litres per person per day, similar to Water UK's most ambitious ("extended" and "enhanced") pathways.[37]

## Leakage

About 20 per cent of the water abstracted from the environment is lost through leakage. Water companies reduced leakage considerably in the late 1990s, but since 2000 levels have stabilised, possibly because decisions were based on a "sustainable economic level of leakage". For Price Review 2019, Ofwat has changed the approach, requiring water companies to consider reduction of at least 15 per cent from the 2020 level, or to the level of the best performing companies (upper quartile, in terms of litres/person/day). There are financial incentives to encourage water companies to reduce leakage.[38]

The Consumer Council for Water reports that leakage is one of the highest concerns for customers,[39] and that companies' performance in managing leakage can have a big impact on their attitude to water saving, as well as their perceptions of water companies. However, reducing leakage levels is expensive, and fewer than a third of the water companies have included a 15 per cent leakage reduction by 2025 in their draft planning tables.[40]

Commission analysis considered the cost effectiveness of different leakage reduction levels. The costs of leakage reduction are uncertain, so the Commission used 'high' and 'low' estimates based on research by Water UK and UK Water Industry Research, the water industry's research body.[41]

These costs were compared with those of providing additional infrastructure to achieve the same level of drought resilience. Figure 9 shows the total costs of providing resilience to a 0.5 per cent probability drought, combining different levels of leakage reduction with additional supply infrastructure and enhanced efficiency and demand reduction (proxied by the cost of extending metering). Additional benefits from leakage reduction, in particular environmental benefits from reduced abstractions, can be substantial but are not quantified in this analysis.

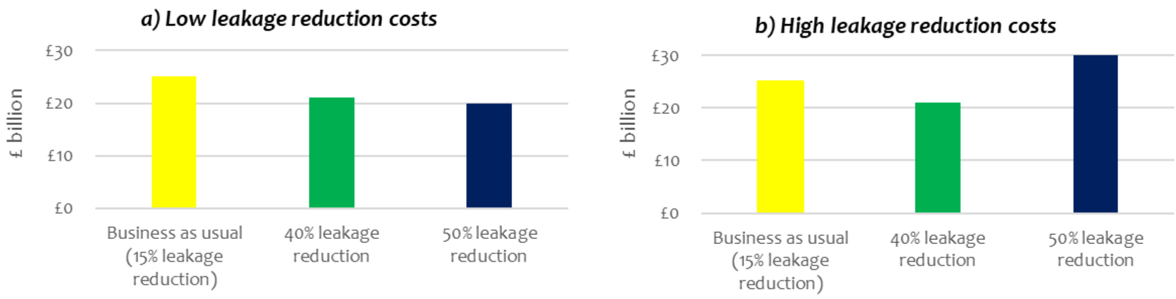


**Figure 9: Comparison of the costs of achieving resilience to a 0.5 per cent drought including different leakage reduction policies[42]**

## Supply infrastructure

To meet the Commission's recommendations, 1,300 Ml/day of additional supply infrastructure would be needed.

A range of different types of infrastructure can be used to increase water supply and factors such as the volume of water needed, versatility, cost and environmental impact influence the choice:

- reservoirs have significant capital costs and are generally most cost-effective when large volumes of water are needed. They can also bring environmental benefits (providing habitats for birds and aquatic species), as well as recreational benefits. However, they take up large land areas and can disrupt local communities, especially during construction. Reservoirs must be planned well before they are needed, as it takes around ten years from the decision to build to being able to use the water supplied
- transfers can move water from areas with surplus to those where it is needed, using pipeline and pumping stations. In some cases existing infrastructure, rivers or canals could be used to move water. Costs depend on the distance and topography: long or complex transfers can be energy intensive although Victorian transfers still supply Birmingham and Liverpool from Wales using gravity. There are risks from

contamination by pollutants, algae, pathogens or invasive species. A transfer network would also allow other assets, including reservoirs, to be built further away from the areas of highest demand, where land may be more easily available

- other options to store water, such as aquifer and surface water storages, are usually less capital intensive but each scheme can only provide a limited volume of water
- additional water supply can also be obtained by treating non-potable sources, including sea and waste water. Desalination has the advantage of an effectively unlimited resource, but is very energy intensive and produces highly polluting waste. The potential for re-use (treating waste water to a potable level) is limited by the availability of suitable waste water and public acceptability, but it is less energy intensive than desalination

The best approach is likely to involve a combination of these options and the industry is well placed to determine the exact mix. The exception is water transfers. A range of studies have all found a positive cost-benefit case for greater transfers and water trading. [43] However, transfers currently only make up a small proportion of total supply (about 4 per cent). This is likely because the incentives in the current system make a strategic transfer network difficult, meaning that the decision needs to be made at a different level.

The Commission modelled two different mixes of water supply infrastructure[44]:

- storage (i.e. non-transfer) infrastructure alone
- a mix of infrastructure in which transfers are used as far as practical and the remaining capacity is provided through storage infrastructure

Although precise costs are uncertain, the costs of a combination of a network of transfers, making up one-third to half of the resources needed, with storage infrastructure are comparable with those of non-transfer infrastructure (figure 10).

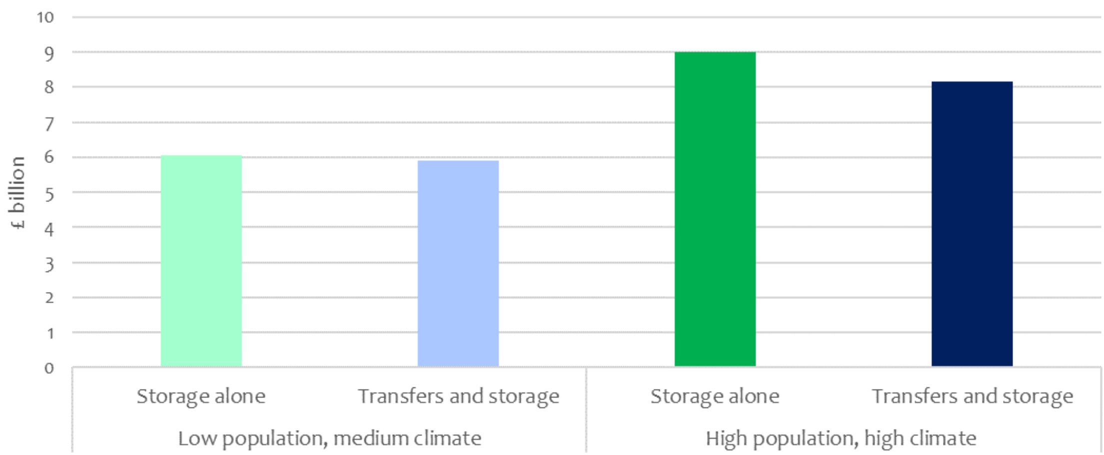


**Figure 10: Cost of supplying water via transfers and storage infrastructure vs storage alone[45]**

# End notes

---

[1] This study covers England only, but includes the areas of Wales that provide water to Water Companies whose customers are mostly located in England.
[2] Environment Agency (2018), ENV15 - Water abstraction tables for England
[3] Water UK (2016), Water resources long-term planning framework
[4] Byers et al. (2014), Electricity generation and cooling water use: UK pathways to 2050
[5] Environment Agency (2015), Water supply and resilience and infrastructure
[6] Brown et al. (2016), UK Climate Change Risk Assessment Evidence Report: Chapter 3, Natural Environment and Natural Assets
[7] Surminski et al. (2016), UK Climate Change Risk Assessment Evidence Report: Chapter 6, Business and Industry
[8] Hall et al. (2016), The Future of National Infrastructure. A System-of-Systems Approach
[9] The Future Flow hydrology dataset was created by the Centre for Ecology and Hydrology (CEH) and contains different scenarios of future river flows under climate change conditions. Accessed at: https://www.ceh.ac.uk/services/future-flows-maps-and-datasets
[10] Source: Commission calculations, based on data from Water UK, water companies and the Environment Agency and using the NISMOD model developed by the Infrastructure Transitions Research Consortium
[11] Source: Commission calculations, based on data from Water UK, water companies and the Environment Agency and using the NISMOD model developed by the Infrastructure Transitions Research Consortium
[12] Atkins for the National Infrastructure Commission (2018), Analysis of the cost of emergency response options during a drought
[13] Source: Commission calculations, based on analysis by Atkins
[14] Source: Commission calculations, based on analysis by Atkins
[15] The cost of responding to a drought emergency are made up by the cost of maintaining 1 per cent level of resilience to 2050 plus the emergency costs only as shown in figure 4. The long-term resilience costs include costs of leakage reduction, demand management and infrastructure excluding intra-company transfers and small interventions needed to maintain existing capacity
[16] Source: Commission calculations and analysis, using input from Atkins, Infrastructure Transitions Research Consortium and Regulatory Economics
[17] waterwise.org.uk/save-water/
[18] energysavingtrust.org.uk/home-energy-efficiency/energy-saving-quick-wins
[19] Consumer Council for Water (2017), Water saving: helping customers to see the big picture
[20] Water Label (2015), The European Water Label Industry Scheme
[21] Water UK (2016), Water resources long-term planning framework, "business as usual" scenario.
[22] National Infrastructure Commission (2017) Congestion, Capacity, Carbon: priorities for national infrastructure - Modelling Annex
[23] Smart meters measure and feedback consumption data remotely at the chosen time interval
[24] Based on expert consultation, and averaging values in literature including Sonderlund et al. (2014), Using Smart Meters for Household Water Consumption Feedback, Procedia Engineering 89, 990 – 997; Ornaghi and Tonin, The Effects of the Universal Metering Programme on Water Consumption, Welfare and Equity (accessed at: https://www.southampton.ac.uk/economics/research/discussion_papers/year/2018/1801-the-effects-of-the-universal-metering-programme-on-water-consumption.page); evidence provided by Thames Water, Anglian Water and Severn Trent water.
[25] Pericly and Jenkins (2015), Smart meters and domestic water usage, FR/R0023
[26] Priestley and Rutherford (2016), House of Commons Briefing Paper Number CBP06596 Water bills-affordability and support for household customers.

[27] Ornaghi and Tonin, The Effects of the Universal Metering Programme on Water Consumption, Welfare and Equity (accessed at: https://www.southampton.ac.uk/economics/research/discussion_papers/year/2018/1801-the-effects-of-the-universal-metering-programme-on-water-consumption.page) and Consumer Council for Water (2016), Beneath the surface: customers' experience on universal metering
[28] The Consumer Council for Water reports that in England and Wales, current social tariff schemes could support around half a million households, compared with the reported 3 million households that do not consider their bills to be affordable. Smart metering will allow companies to better identify these customers but it is unclear if existing measures are sufficient to help all who need it, regardless of any metering policy.
[29] Water Industry (Charges) (Vulnerable Groups) Regulations 1999
[30] Ofgem (2017), Distributional impact of time of use tariffs of gas and electricity markets and Consumer Council for Water 2017 and CCP (2017), Price and Behavioural Signals to Encourage Water Conservation
[31] Consumer Council for Water (2016), Staying afloat: addressing customer vulnerability in the water sector
[32] ccwater.org.uk/priorities/your-priorities/working-to-support-customers/compulsory-metering/
[33] Source: Commission calculations
[34] Commission calculations using input Regulatory Economics Ltd.
[35] Walker, A. (2009), The Independent Review of Charging for Household Water and Sewage Services and Angling Trust, WWF-UK and others (2011), Fairness on Tap, making the case for metering
[36] For example, Berger et al. (2016), Exploring the Energy Benefits of Advanced Water Metering, LBNL 1005988
[37] For 2040, Water UK's "business as usual" scenario forecasts per capita consumption of 129 l/person/day, 121 l/person/day are forecasted in the "extended" scenario and 116 l/person/day in the "enhanced" scenario for 2040
[38] Ofwat (2018), Price Review 2019 methodology
[39] Consumer Council for Water (2016), Water, water everywhere?
[40] Although half of the companies declare the intention of reaching 15 per cent reduction by 2025 in their draft planning document (January 2018).
[41] Water UK (2016), Water resources long-term planning framework and UKWIR (2011) Long term leakage goals, Report No 11/WM/08/44
[42] Source: Commission calculations and analysis, using input from Infrastructure Transitions Research Consortium and Regulatory Economics
[43] Deloitte (2015), Water trading – scope, benefits and options; Cave(2009) Independent Review of Competition and Innovation in Water Markets; Ofwat (2010) A study on the potential benefits of upstream markets in the water sector in England and Wales; Ernst and Young (2011), Changing course through water trading
[45] Regulatory Economics for the National Infrastructure Commission (2018), Analysis of the costs of water resource management options to enhance drought resilience
[44] The costs of supply infrastructure were calculated within the NISMOD model by using the cost curves developed by Regulatory Economics, see Regulatory Economics for the National Infrastructure Commission (2018), Analysis of the costs of water resource management options to enhance drought resilience
[45] Source: Commission calculations and analysis, using input from Infrastructure Transitions Research Consortium and Regulatory Economics