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Developing Resilience to England's future droughts:

Time for Cap and Trade?

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Abstract

Much of England is seriously water stressed and future droughts will present major challenges to the water industry if socially and economically damaging supply restrictions are to be avoided. Demand management is seen as a key mechanism for alleviating water stress, yet there are no truly effective incentives to encourage widespread adoption of the behavioural and technological demand management practices available. Water pricing could promote conservation, but on its own it is an inefficient tool for dealing with short term restriction in water supply. Raising prices over the short term in response to a drought is likely to be ineffectual in lowering demand sufficiently; conversely, maintaining high prices over the long term implies costs to the consumer which are needlessly high most of the time. We propose a system for developing resilience to drought in highly water stressed areas, based on a cap and trade (C&T) model. The system would represent a significant innovation in England's water market. However, international experience shows that C&T is successful in other sectors, and need not be overly complex. Here, we open the debate on how a C&T system might work in England.

Keywords

Drought resilience, water scarcity, water resource trading, demand management, TWUC.

1. Introduction

Despite its importance, England lacks a permanently secure water supply. Rising demand, coupled with climate change and the prospect of drought, means that periodically water becomes a scarce resource. England has experienced drought over the last 40 years (Environment Agency, 2012a), including the dry winter of 1975 and hot dry summer of 1976 when nationally water was rationed via standpipes; the 1989-90 drought which impacted on groundwater and led to spray irrigation restrictions in East England; the 1995-96 Pennine drought where road tankers transferred water from Northumbria to some Yorkshire reservoirs; the 2005-07 drought where restrictions were imposed on 15 million people in SE England; and in both 2010 and 2011, when the driest springs ever recorded in the north west and east respectively led to further restrictions.

Water companies learnt from these experiences (e.g. distribution networks are more connected, although disconnects between companies largely remain). However, measures introduced to deal with past droughts may be insufficient to deal with future drought, influenced by climate change. For 23 UK water regions Rahiz and New (2013) analysed drought characteristics of ensemble projections made using the Meteorological Office Hadley Centre regional climate model. They found profound increases in drought intensity, duration and extent for the 2050s and 2080s, with more winter (wet season) drought, particularly in the south where water resources are already stressed but the population is growing - in absolute terms England currently has the greatest population growth in the EU (ONS 2013). Whilst water is clearly a very important resource, and often a commodity, its value varies in time, space and by activity - i.e. by who is using it, for what, where, and when. It is variously essential for life, critical for some economic activities but only useful for others, whilst some is wasted. In general the marginal utility derived from water use is typically very high at low levels of consumption, whilst there is often a very low marginal utility at high rates of use. Under scarcity, this is inefficient from a societal welfare perspective, as more utility could be derived by a better allocation of the resource in space, over time, and by use, and between users who value the water differently.

This situation is readily seen in the case of UK drought orders which allow the regulator to place restrictions on ‘non-essential’ uses, those having a lower marginal utility (Environment Agency, 2012a). Thus commercial car washes are suspended recognising the higher marginal benefit of supplying water for, say household use, over keeping our cars clean. Similarly, drought permits allow relaxation of abstraction limits, allowing utilities to take water normally reserved for ecological support functions, so as to maintain public supply. This recognises the higher marginal utility people associate with meeting their basic water needs, over that they gain from protecting the environment. It is ironic of course, that regulators issue drought permits when environmental water requirements are greatest. Environmental impacts of recent UK droughts include fish deaths, reduced breeding of wading birds and outbreaks of poisonous blue-green algae. Reducing compensation flows from reservoirs that support ecological requirements adds complexity to drought decision making (and releases prior to recognition of a drought development will in retrospect be seen as a loss of resource). Such failures are permitted under Article 1 (section 4.6) of the EU Water Framework Directive which allows temporary non-compliance with good ecological status objectives during times of drought, so long as such conditions ‘could not reasonably be foreseen’. This is a phrase open to interpretation, but its seems reasonable given mounting evidence (Burke *et al.*, 2010; Rahiz and New, 2013) to expect that future droughts may be more extreme, thus in effect the directive argues for drought planning rather than crisis management.

Water is essentially a non-substitutable resource, especially in the short term, when it is difficult to switch quickly to an alternative source. Thus under scarcity conservation campaigns encourage a change in behaviour (shower not bath, turning tap off when brushing teeth etc.), activities that people would like to engage in (e.g. garden watering) are restricted, and in extremis water may be rationed via street standpipes. The less extreme conservation campaigns may change water use behaviour during drought and deliver demand reductions (Queensland Water Commission, 2010), but imply a loss of welfare as customers would prefer to consume more. This is illustrated by Fielding *et al.*, (2013) who used smart meters to provide water conservation advice in a study of 221 households in Queensland. They found that different forms of water conservation advice (general, tailored to households, tailored with feedback) all reduced demand compared with a control, but that within a year savings had dissipated and water use had returned in all cases to pre intervention levels, despite customers paying on a volumetric basis. Such an outcome has also been reported by a UK water plc. (at a meeting under Chatham House rules) for all interventions it had tried.

Voluntary behavioural change has a role in demand management but appears a weak instrument reliant upon voluntary restriction and acceptance of reduced levels of service. More effective demand management implies raising prices significantly, and/or embedding the fixed conservation practices offered by technological change (e.g. low flush toilets, replacing high use appliances and fittings, installing rainwater harvesting or grey water recycling, or altering production processes and product designs to reduce water requirements) (Butler and Memon, 2006). Metering is often perceived to be a demand management tool, but in England, people opting to switch to a metered supply are self-selected and in the majority of cases do so because they believe they are low water users.

Furthermore some water companies, recognising the bad press suffered by energy companies for not guiding customers to the lowest tariff, are seeking to identify all those customers they believe to be low water users likely to benefit from a metered tariff.

Numerous instruments can reduce demand but their effectiveness under a prolonged drought is questionable, given their constraints (Table 1). A recent UK water industry summit concluded that current conservation measures could soften the impact of a prolonged drought, but were insufficient to deal with a prolonged drought, and that alternative approaches that promote a package of measures, including the use of dynamic tariffs, was needed (St George, 2013:p5).

TABLE 1 ABOUT HERE

Most countries with high rates of metering use a uniform block tariff (where the unit price is independent of volume consumed) or increasingly an inclining block tariff (IBT) which is assumed to discourage 'wasteful' use, by adopting a low or zero price for an initial block of 'essential' water use, with higher prices for subsequent blocks (Worthington and Hoffman 2007; Crase *et al.*, 2007; Herrington, 2007). IBT's are also supported on social equity grounds as revenue from higher tier blocks offsets the low cost of the initial block. However, IBTs have been criticised on both philosophical and operational grounds.

Zetland (2011:p39) advises caution with respect to IBTs as in well-functioning markets we do not see companies raising unit prices as quantity purchased increases, and because they suppress demand via cost, not scarcity or value. Conceptually simple, IBTs actually represent a complex billing structure where the number, size and price of blocks must be set precisely to match the local context; however, regulators have been unable to provide guidance on how to do this, because IBTs often depart from marginal cost pricing

(NWC, 2008) whilst the average or marginal prices under an IBT are themselves exceedingly difficult to determine (Boland and Whittington, 2000).

IBTs are also criticised for being ineffective in suppressing demand. Low users receive the wrong price signal, so use more than they would otherwise do, whilst the relatively price inelastic nature of water (Worthington and Hoffman 2007) means that narrow blocks with very substantial rises in price are required to supress demand. Australia's National Water Commission (NWC, 2008) concluded IBTs were not very effective in influencing consumption as the cost impact of reaching higher tiers is not evident in time to respond. Recent UK trials of IBTs have also so far found them to be relatively ineffective in prompting behavioural change (Environment Agency, 2013a). This is particularly salient in the context of tackling acute scarcity under drought (Monteiro and Roseta-Palma, 2011).

IBTs are also criticised on grounds of cost recovery, as low users pay below cost price; use at higher tiers may cross-subsidise these costs but the tariff structure may need to be steeply raked to do so, thus making revenue unstable and unpredictable (Crase *et al.*, 2007). Additionally, IBTs do not protect low income households, one of their chief attractions in principle. In practice, low income households tend to be larger on average, and the initial low cost blocks are thus used sooner, putting the household into the higher price blocks (Dahan and Nisan 2007; OECD 2009; NWC 2008). This problem can be rectified using per capita pricing but household occupancy data needed to do this is rarely available, hence utilities assume conservative (high) occupancy rates that mean pricing is inefficient (Zetland, 2011). The difficulty with per capita pricing (and recognition that low income households tend to have the least resource efficient homes) led the UK parliament to reject the use of IBTs in the domestic energy market (House of Commons, 2013). Thus whilst there are merits to IBTs there are evidently difficulties that brings into conflict the fundamental equity, efficiency and affordability goals of sustainable water allocation. Alternatives to the uniform block tariff are being explored in the UK, and rather than focus solely on the IBT, it seems timely to debate a wider range of structures to manage demand.

We argue that demand management via pricing alone is unlikely to be a successful in dealing with ephemeral, yet acute scarcity. Consumers, domestic and commercial, will be able to respond to price rises by investing in more water efficient appliances, technology and processes. However, for the market as a whole, such investment decisions come in response to long term cost drivers. Over the short term, when a drought hits, most customers will be unable to invest in technological demand management in time due to a lack of capacity to implement appropriate measures, or a lack of capacity in the business sector providing water conservation goods and services - the market cannot respond adequately to drought induced scarcity prices. So, pricing alone does not seem able to deliver a degree of resilience to weather a major drought or succession of droughts.

Supply side measures, including investment in storage and enhanced distribution network connectivity can raise water security. These, together with existing demand management measures have largely been effective in averting major restrictions to date, but also face difficulties. New reservoirs are unpopular and take decades to get through the planning system, desalination implies large carbon emissions, and there are limits to which leakage can be economically controlled or distribution network efficiency enhanced, particularly as droughts are expected to become spatially more extensive (Rahiz and New, 2013) so water companies may not have supplies to share. Strategic supply side developments designed to add resilience and reduce risk from drought implies investment that may become harder to deliver as customer acceptability of, and willingness to pay for, proposed expenditures becomes more explicitly embedded in the price review process (OFWAT, 2013). That said, customer views on what they seek from a water company has provided evidence that a safe reliable water supply is a fundamental customer requirement.

There is then concern that the conventional responses to water stress, as well as the wider application of pricing that will come with growth in metering, will prove inadequate in the long run, particularly given the uncertainty that climate change brings. Whilst the UK water industry is geared to coping with a dry winter, and can weather a two dry winter sequence albeit with restrictions and significant impacts (Environment Agency, 2012b), it is unlikely that we could cope with a three dry winter sequence without large areas facing severe shortages requiring draconian cuts (St George, 2013:p5). This was recognised by Caroline Spelman who as Environment Secretary raised the possibility of standpipes in the street if the country is hit by three dry winter in a row (Telegraph, 2012). Although a national drought plan exists (Environment Agency, 2012b), the plan does not plan *for* drought but plans a reaction *within* the drought specifying what options become available within a drought and who communicates with whom. Valuable as far as it goes it is nevertheless reactive and does not proactively defend against future drought.

Here, we suggest a water resource management system based on the Cap and Trade (C&T) concept. It offers potential to overcome the problems discussed above, delivering resilience against drought, by driving effective demand management amongst consumers, and so supporting a more cost-efficient investment in supply side measures. The system would act to better incentivise a package of demand management measures, which the water industry recognises is needed to hedge against the ‘Black Swans’ of future droughts

(St George, 2013). Our intention here is not to present a detailed scheme but to initiate debate on the relative merits of a C&T system for water stressed parts of England, so as to deliver resilience to drought.

2. Cap and Trade

C&T is an economic instrument that tackles common pool resource problems. The best known applications address emissions to air or water; a market is created in the assimilative capacity of the receiving environment, and users (emitters) of that capacity acquire an allowance (emission credits) that permits them to emit. Credits are allocated in various ways, by auction and by historical use are common, although other means exist. Users who emit below their allowance can sell surplus credits to those who need to emit more than their credit allowance permits. Over the long term, the emission credits market encourages investment in emission reduction technology, and innovation. The regulator can lower the cap over time to drive a continual reduction in emissions. The UK participates in such a system for carbon, via the EU emission trading scheme (DECC, 2013). The scheme, introduced in 2005, has delivered modest emission reductions so far because of a low unit price following an initial over allocation of carbon credits (Ellerman and Buchner, 2008) but proponents anticipate that Phase III (2013-2020) will deliver more significant reductions (in excess of 1% per annum) now that the infrastructure and market are established. The refusal of MEPs to back plans to delay the release of ETS credits is however expected to see the persistence of low carbon prices within the scheme (IEMA, 2013).

Other systems are operating very successfully. The longest running C&T scheme is for acidifying gases, where the market involves all the large emitters in 27 states in NE USA. This EPA regulated scheme has seen emissions of SO_2 fall 60% and NO_x by 65% since the cap was imposed (1990 and 1995 respectively) (US EPA, no date). In England, Yorkshire Water Ltd have explored a real time river integration system (rtRiveri), making more efficient use of a rivers pollutant assimilative capacity by discharging a greater share of effluent at time of peak flow. However, a scheme in Australia's Hunter Valley has taken this approach much further. Here, problematic saline discharges from mining and power generation have been managed on a similar temporally dynamic (hourly) basis linked to river flow, but with total permissible salt discharges to river capped, with a market in emission credits. This scheme has lowered salt levels in the Hunter river below target levels despite a drier than average period, making water suitable for agricultural irrigation again (DEC, 2006). A US C&T scheme addresses point and diffuse source water pollutants under the National Pollution Discharge Elimination Scheme (US EPA, 2007). These established systems are delivering substantive environmental benefits, often with emission reductions greater than originally sought, as emitters are incentivised to find innovative ways of reducing emissions, so that they can sell unused credits.

C&T schemes are not limited to emissions. In fisheries, the strategy of simply restricting the total allowable catch (TAC), proved unsuccessful as it encouraged individual fishers to over invest in large vessels so they could harvest as much as possible before the quota was reached. However, a TAC (a cap) allied with an individual transferable quota (ITQ), a share of the quota that can be traded between fishers allows the relatively more efficient fishers to purchase rights from those who are less efficient, thus lowering overall capital cost, whilst staying within the environmental capacity. Such a scheme started in 1986 in New Zealand and has since been adopted in other fisheries around the world (Anderson, 1995).

Singapore's Vehicle Quota System is another example (LTA, 2013). For each vehicle owned, a Certificate of Entitlement (COE) must be held. These can be purchased at a twice monthly internet auction, but the total number available is capped, and COE’s (and their cars) must be retired after ten years. This has acted to reduce congestion, energy use and emissions (as newer vehicles with cleaner technology are introduced more quickly) and has made public transport alternatives economically more viable (Olszewski, 2007). C&T schemes have also been discussed with respect to energy. A tradable fuel economy scheme has been proposed for US car manufacturers (NRC, 2001: 90-93), whilst in the UK, the feasibility of Tradable Energy Quota’s (TEQ’s),which builds on Hillman and Fawcett’s (2004) work on the Personal Carbon Allowance, has been the subject of a recent parliamentary feasibility appraisal (Fleming and Chamberlin, 2011).

Water trading is already possible in England, where since 2001 holders of water rights can trade some or all of their abstraction licence, although in practice few trades have occurred (Synovate UK, 2008). The practice allows a licence holder to sell rights to any surplus supply, so more efficient use of the total resource can be made. However, this is unlikely to foster greatly increased resilience to drought, as the trade encourages the more efficient spatial distribution of water, rather than its conservation. A water trading system also exists in Australia promoted by the National Water Commission (NWC), facilitating water redistribution from areas of surplus to deficit. However, there is evidently a lack of infrastructure to allow transfers to take place, and the scheme similarly promotes efficient spatial distribution, rather than demand management (as the trading is between abstraction rights holders, not consumers). The NWC also recognises that water rights trading *per se* does not amount to effective drought planning (Hamstead *et al.*, 2008: xvi).

3. A Water Cap and Trade System for England?

Our view is that a C&T system has potential to bring about a step change in England's resilience to drought, with added benefits in non-drought years. In contrast to the schemes discussed above, we extend membership to all consumers, rather than simply abstractors, in a similar manner to that proposed for TEQs (Fleming and Chamberlin, 2011) as our prime motivation is to promote demand management in consumers, rather than a more efficient spatial distribution of abstraction rights. This is important, because whilst an efficient spatial allocation of water leads to a more even allocation of 'headroom' (supply less demand) it will not deliver the added headroom required to weather a prolonged drought. Below we consider how such a water C&T system might operate.

3.1 The Cap

The cap and its geography are defined. The cap is the maximum permitted to be abstracted within a region per year. The region must reflect physical geography so a river basin could be suitable, but in practice company distribution networks would better define the linkage of sources and customers. Additionally, the institutional arrangements required by a water C&T system would likely mean that water company areas are the defined C&T market areas. A complication to defining the cap area will arise if England's water industry is restructured along the lines of the energy industry. This would most likely see separation of customer services (essentially the billing function) from the engineering dominated, supply and waste management. A closer parallel to the energy sector would see further separation of the distribution network from the sources and treatment. While there is occasional debate on the separation of water supply and waste disposal this would seem counter to all the benefits of an integrated system and to act to reduce the benefits of real time integration between the engineering system and natural environment. Here, we assume that the retail function - selling water services to the customer - might at some future point be independent of the wholesale function - the provision of the goods and services since many companies have already made this separation by having contracted out billing. We assume no further sectoral segmentation.

The cap is set to reflect the total abstraction required for a low supply period. Initially this might be a 1 in 25 year return period 'drought'. This relatively undemanding cap would give time for users to become familiar with the system (and perhaps phase different sectors in over time), and invest in water conservation (technology and water conservation behaviour). An undemanding cap would be unable to fully address a more serious drought, should it occur, although greater resilience to it would be developed. Subsequently the cap could be lowered to defend against more serious droughts, thus developing greater long term security of supply / resilience and promoting responses to demographic and climatic change forecasts. Conversely, a cap could also be raised to reflect any added resource made available from supply infrastructure investment (including resources secured from neighbouring regions via water trading arrangements as discussed in section 2).

3.2 Scheme membership

Everyone is enrolled. To work effectively, the scheme must be mandatory for all consumers. To encourage water conservation behaviour, the scheme must incentivise the water user, who is best placed to implement demand management, rather than an 'upstream intermediary', such as the supplying water utility. If the scheme only involved intermediaries, there would be insufficient agents to develop a competitive market (and potentially, given the regional nature of the scheme set out in 3.1, only one). Note that although water rights trading has been operational in the UK for over a decade, very few trades between institutions have been made, and on average, trades take 6-18 months to implement (Synovate UK, 2008).

Whilst all consumers must participate in the scheme, sectors (e.g. commercial, domestic) could be phased in to ease implementation. This would require a sector specific cap to be set, apportioned according to historical use of that sector. Once all sectors were within the scheme, then trading across, not just within sectors would be possible to maximise conservation opportunities. The only consumers exempt from the scheme would be those (households, businesses) with a private supply, but their abstraction would be accounted for when setting the cap. We assume the substantial cost of obtaining a private supply (e.g. drilling a borehole) will dissuade most customers from exempting themselves from the system by developing a private supply. However, new private supply development already requires authorisation of the Environment Agency if minimum abstraction thresholds are exceeded, hence there is regulation in place which could be amended to force enrolment of new abstraction into the C&T system.

3.3 Paying for Water: Bills and TWUCs

All members are metered. For a water C&T system to work well, there is a requirement to have accurate records of consumption thus all customers must be on a metered supply (although see the online appendix for possible application to non-metered customers). Currently, no water company meters all its customers, and nationally, meter uptake is only around 42% (but with considerable regional variation). However, the Water Industry (Prescribed Conditions) Regulations 1999, gives the power to compulsorily meter all customers. The main qualifying condition for compulsory metering *and* a volumetric charge (which a C&T system implies) is that the company area is ‘seriously water stressed’, considering current and projected demand and supply (Table 2 shows qualifying water companies). As climate changes and/or projected demand increases, more areas may become ‘seriously stressed’. It is exactly this high water stress that a C&T system is designed to alleviate. Note that some utilities have already embarked on universal metering; Southern Water’s programme, began in 2010, should be complete in 2015. Other companies, even those outside areas deemed to be water stressed, are reviewing the multiple benefits of an ordered expansion of metering towards a near universal metered customer base (McDonald and Boden, 2012).

TABLE 2 ABOUT HERE

Currently metered water customer bills comprise fixed charges (e.g. for surface water drainage, pipe/sewer infrastructure), and variable charges (based on volume of water supplied/wastewater disposed). Under a C&T scheme this customer billing process would be unchanged, except in respect of one significant addition. When a customer pays their bill, they must also surrender a series of **Tradable Water Unit Certificates** (TWUCs) along with the financial remittance for the fixed and variable charges. Each TWUC surrendered accounts for 1000 litres of water, and is retired after surrender. A two person household with an average per capita demand of 137 litres per day would have an annual demand of 100,000 litres, and hence over the course of four quarterly bills would be required to surrender 100 TWUCs along with their financial payment. The electronic infrastructure for doing this is already available, and government feasibility studies of the more complex Tradable Energy Quota system indicate this is quite practical (Lane *et al.*, 2008).

TWUCs exist as unique digital reference numbers, held in a customer’s TWUC account, and could represent multiples of the base unit (10m^3, 20m^3 etc.). At the inception of the scheme each customer (household, business etc.) would be given an initial allocation by the C&T body (e.g. water utility, overseen by the regulator), which is intended to be sufficient for one year's consumption at current rates. Each quarter, the C&T body tops up the customer's TWUC account with a new supply of TWUCs. The number of TWUCs added each quarter will decline gradually in time, so that the total number of TWUCs allocated in a year represent a volume equivalent to the regional cap.

3.4 Initial Allocation of TWUCs

Initial allocation reflects past use. To begin, TWUCs must be allocated to customers. There are several ways C&T systems do this, including random access (lotteries), first-come first-served, auction, and administrative rules based on eligibility criteria (Tietenberg, 2000). The most widely used have been allocation by auction, and by 'grandfathering', where allocation is based on historical use. An auction has the advantage of raising revenue to invest in environmental protection or remediation, but in the case of water, auctions would likely prove unworkable as: (a) this would be seen to be an additional cost burden for the customer; (b) some customers may consider they have a 'right to supply'; and (c) there is a risk that some customers will secure insufficient TWUCs to cover their current use. An allocation based on measured or estimated historical use is more practical, and is usually the most politically acceptable allocation system, although it has the disadvantage of losing auction revenue and any hypothecated investment. Measures to ensure access for new entrants are also required for common pool resources making grandfathering unpopular for some schemes. However, in our system new entrants would access water just as they do now, but would obtain TWUCs, not from the C&T body, but via an open market (see 3.6 and section 5).

The larger and potentially more water inefficient customers also receive a larger allocation, so to some extent historical allocation rewards past inefficiency. There is also a danger that, knowing that TWUCs are to be allocated based on historical use, customers would waste water to drive up their reference demand. This would be averted by establishing the historical annual use for a year prior to the scheme being announced.

3.5 Descent to Cap

Customers gradually receive fewer free TWUCs. The total number of TWUCs available in any one year is fixed, set with reference to the cap, the supply estimated to be reliably available in a drought year. Initially, the number of TWUCs on offer will be well above the cap, as the total number of TWUCs is set with reference to historical water use. However, each year the total volume of water addressed by the TWUCs will be reduced creating a pressure to drive down demand. The total volume reduction could be achieved by maintaining the total number of TWUCs in the system and lowering the volumetric value of each TWUC (1000, 980 litres, 960 litres etc.) so that customers must purchase more TWUCs than before, or reduce demand. However, maintaining a constant TWUC volume of 1000 litres, and reducing the total number of certificates on offer would be more understandable, and means a constant volume is retained regardless of TWUC age.

The need to surrender TWUCs will raise a customer's awareness of their consumption, and in many, it will change behaviour. This occurs as over time the C&T body reduce the number of new TWUCs being released into the system, to bring the total water volume represented by the annual release of TWUCs, in line with the regional drought abstraction cap. Customers must submit TWUCs that cover their volumetric water use, and as the number of free TWUCs added to a customer's account each quarter reduces, they will experience pressure to reduce demand, or purchase additional TWUCs on the open market (see 3.6 below), which similarly exerts a downward pressure on consumption.

The rate at which the number of TWUCs released each year falls will need to be determined. If it is too slow, then resilience against drought will not develop quickly enough; if it is too fast, then there may be insufficient supporting capacity in the water conservation industry (conservation advisors, equipment, installers etc.) to enable customers to make the transition.

A periodic review of the cap would be advisable. If risks associated with climate change rise, and there is an expectation that drought frequency, intensity, extent or duration increases, then there is a case to lower the cap. Conversely, if additional water resources can be reliably secured (greater storage, transfer), then the cap could be raised.

Because TWUCs are allocated on the basis of historical water use, there is a potential inequity in the system, as the more inefficient users receive a greater initial allocation of TWUCs. This could be addressed by reducing TWUCs proportionately, rather than absolutely – thus a 5% reduction in TWUC allocation would require a greater absolute water saving from a large user, than a small user.

3.6 TWUC trading

Efficient behaviour is rewarded. The rate of customer engagement with the C&T system will vary. Some will engage quickly, others will choose to ignore the scheme for as long as possible. Both are likely, and such behaviour is accommodated in the TWUC trading element of the system. All customers will still receive the normal free quarterly allocation of TWUCs (scaled according to the fall in the cap), but a customer whose demand falls will find they have an annual surplus of TWUCs. Conversely a customer whose demand does not fall quickly enough, or indeed rises, may find they have insufficient TWUCs to surrender with their bill. At this point, both parties can enter into an open TWUC market, an online system (‘eBay for TWUCs’) operated by the C&T body. Customers would buy/sell the TWUCs at the unit price determined on that trading day, and the financial value (unit price x number of TWUCs traded) would be automatically added/debited to the customers utility bill. If customers short of TWUCs choose not to engage in the market then the transaction would occur automatically on the last day the utility bill is due.

In both commercial and domestic cases, trading incentivises demand reduction, via behavioural means or technology. TWUC vendors reap long term benefits of water conservation behaviour and investment in that they have a lower water bill (as demand has fallen) in addition to revenue gained from selling surplus TWUCs.

3.7 Institutional arrangements

An incremental development of existing arrangements. OFWAT (working with the Environment Agency) would provide regulatory oversight (OFWAT is accountable to parliament but independent of them, and water companies). This would include agreeing caps and their reduction over time, making the initial TWUC allocation, and oversight of the market. Their objective would be to institute a managed transition to a lower demand market, with protection of customer access to water at fair market prices, and an adequate return on investment to the water utility. Note that whilst the system encourages users to consume less, so variable charge revenue to the water utility may decline as a result, there would be less need to invest as heavily in water supply infrastructure intended to secure supplies under a drought (new reservoir, desalination etc.). Thus the C&T system can introduce efficiencies that can reduce costs for the utility, and the customer.

Transaction costs for the scheme need not be high if it operates under existing institutional frameworks. That is, the cap is informed by existing resource management plans developed in conjunction with environmental regulator guidance (e.g. abstraction limits), with billing via the water utility. A business unit would be required to run the TWUC trading website – this role is taken on by the environmental regulator in the emission cases cited above (e.g. the US EPA for the acid gases scheme), but could be operated by the water utility with regulatory oversight, or a new company established to handle the trading.

4. Vignettes: Water Cap and Trade examples

The vignettes below provide some illustrative examples of how the scheme might operate. These examples relate to four participants in the market, commercial companies, residential households, an environmental pressure group, and a water utility.

Example 1. Commercial sector

Chromatec Ltd., a metal finishing business in Oldtown, uses a lot of process water but has never bothered with water conservation much, as it’s a small part of their overall costs. PharmaGen , an international biotech company, operating from new build premises in a business park near Newtown. Both companies operate in the same ‘water region’, ValleyDale where water ‘stress’ is high, and where a number of prolonged dry periods over the last 30 years have caused problems.

The abstraction cap for ValleyDale is X Million m3/ yr. which reflects abstraction that is possible without environmental damage (e.g. ecologically low flow rivers) during a summer month in a 1 in 25 year return period ‘drought’. Historically, water demand in ValleyDale is twice this amount, so the C&T system seeks to cut demand by 50%. It is determined by the regulators that this will be done over 20 years.

Both companies have an allocation of TWUCs based on their past demand (Chromatec Ltd use more water than PharmaGen so were allocated more TWUCs initially, and receive more in the quarterly top up). In the first year neither company pays much attention to the scheme, but by year two both are familiar with the scheme operation and are more water aware. PharmaGen has been growing quickly and its water demand has risen, and they no longer have the TWUCs they need. They consider conservation investment, but decide that the returns are insufficient, so they have a ‘worker water awareness’ campaign in-house, and enter the auction to purchase TWUCs to cover their deficit. Chromatec Ltd do not enter the auction as their TWUCs cover their use.

Several years later, the annual reduction in total TWUCs available, and the consequent fall in quarterly top up, means that Chromatec Ltd have been spending a lot on TWUCs whose market price has been rising. They invest in water conservation processes and technology, based on guidance provided by a growing water conservation industry (technology and advice providers, environmental auditors etc.). They reduce their demand and sell their spare TWUCs to offset some of their conservation investment.

A few year later, the regulator lowers the cap to reflect a 1 in 50 year drought return period, giving greater protection to ValleyDale. Both companies receive fewer TWUCs but Chromatec find this barely affects them due to their prior conservation investment, but PharmaGen decide it’s now cost-effective to retrofit a rainwater harvesting tank and pump to flush the office toilets without using a piped supply.

Example 2. Household sector

The Smiths live in a decent sized flat in BigCity basin, a highly water stressed area. They don’t really think about water much, as they are both working and water is a small part of outgoings. However, over the last two years they have had to enter the TWUC auction several times, and have noticed TWUC prices are rising. When their washing machine breaks down they buy a new one, selecting a highly water efficient device. The following year they have their bathroom remodelled and choose water efficient tap fittings and shower head. They find they have more TWUCs than they need, but can’t be bothered to sell, instead saving them for a ‘non-rainy day’.

The Jones, a family of four, live a few miles away in a detached house with a large garden, and two cars. They have found that since having to purchase TWUCs at the auction they are much more water aware and start to conserve water around the house, and the garden hose is used sparingly. They have an extension built, and decide that they could cost-effectively install a rainwater harvesting system, collecting water from the roof, and storing in a tank in the garden so as to flush the toilets and water the garden in summer. Their bill drops such that they build up a healthy cushion of TWUCs. The two children leave for university, and the Jones’s find they now have a surplus of TWUCs. They gift some to their children and from next year, sell their surplus at the auction.

The Anderson family live in a terraced house without a garden. Their water use has historically been quite low, so they received relatively few TWUCs in the initial allocation. However, their demand has risen quite sharply as Mr Anderson’s mother who has a limiting illness and needs a lot of home care, has moved in with them. Although Mr Anderson’s mother gave him her surplus TWUCs when she moved in, their water bill is higher than it was, and the family don’t have sufficient TWUCs. However, because the family qualify for the water industry ‘Water sure’ scheme, that offers assistance to low income and other households (see section 5 below) they do not need to purchase additional TWUCs, and continue to receive financial support with respect to their bill.

Example 3. The Chalk Rivers Alliance

A national environmental pressure group, the Chalk Rivers Alliance, are concerned about some chalk streams routinely running well below flow requirements needed to maintain a healthy ecosystem. The Chalk Rivers Alliance raise funds nationally through member donations, which are used to purchase TWUCs on the open market for the regions with the at risk chalk rivers. They choose not to allocate the TWUCs to any companies/homes, 'retiring' them from the market. This retirement means there are fewer TWUCs available overall, hence the price rises, further encouraging customers to invest in demand management. The Chalk Rivers Alliance thus speeds the descent to the cap in the region they are most concerned about.

Example 4. The Water Utility

Leakage is a big 'user' of water, and could be excluded from the C&T system, and tackled in its current fashion, via OFWAT targets and 'fines' (restrictions on charging) for non-compliance. However, this does not display leadership in sustainable water management, and the water utility participates in the C&T market as a customer (as a legitimate user, and as one who 'uses' water via leakage). Previous year leakage estimates (OFWAT approved), are used as a basis for allocating TWUCs to the utility. The regulator then requires utilities to pay for use over that addressed by their TWUC allowance, at the market rate. Although this payment goes from and back to the utility the regulator requires that it must be re-invested in improving water security (e.g. leakage control, network connectivity, land management works to increase natural storage and groundwater recharge), and supporting social security programmes such as ‘Water Sure’. The utility also sets up a spin-out business to meet demand for water conservation advice and equipment. Value lost through water theft is also more explicit and the utility invests in a water theft reduction programme.

5. Water Cap and Trade: FAQs

Further work would be needed to develop and implement the C&T system, and initially research would be needed (similar to that for TEQs – see section 6). Below we address some likely initial questions about the basic design and operation of the system.

5.1 Allocation of credits based on historical use.

Will past virtuous conservation behaviour be ‘punished’ by allocating few TWUCs compared to more profligate users? Low users would receive fewer TWUCs, but would not be required to reduce demand as quickly as bigger users as the cap falls. We anticipate that a minimum TWUC allocation would be made, so that very low users (e.g. house construction to Code for Sustainable Homes level 5-6) with confirmed historic use at or below a specified level (e.g. at the equivalent cap level) would immediately receive more TWUCs than they need. These could be sold to generate an income.

What period is used to determine the historical water use and hence the initial TWUC allocation? A billing year or years, for a period before the scheme becomes widely known, so as to avoid false inflation of initial allocation. For users with only a part year record, an annual record would be reconstructed using a scaling formulae agreed with the regulator.

Shouldn’t initial allocations be based on observed use under drought conditions? No. Initial allocations are a best reflection of current use, and the subsequent TWUC top up rate would fall to deliver a descent to the drought year cap over a period of years or decades. Under drought there is suppressed demand, where people would use more water to raise welfare if they could, whereas under C&T they would have attained the desired welfare by modifying water use behaviour. Additionally, we also have poor information on actual water use under drought, with which to inform a drought sensitive allocation process.

Must household TWUC allocation be based on historical use? This is the preferred method as it relates most directly to actual use. In principle, TWUCs could be allocated on the historic use of a particular house type/size, with above average users getting fewer TWUCs than needed and so incentivised to be efficient, whilst below average consumers have TWUCs to sell, and so seek to continue to be efficient to maintain revenue.

5.2 Moving house /premises

What happens when people move home / company premises? Customers have a TWUC account for their household or business, not the property – i.e. "people use water not buildings". If you have a TWUC surplus, say from downsizing home, then you can sell them, if you move and find you have fewer TWUCs than needed you may have to buy extra (or invest in water efficiency). Water efficient buildings will attract a seller's premium and will be a marketing feature.

What happens when someone moves into newly constructed premises that have no water use history? The occupants will have a TWUC account to draw on to settle the utility bill as normal. The C&T body will not put new TWUCs into a new occupiers account (as this would require reduction in TWUCs elsewhere), so any TWUC deficit must be covered by purchase on the open market. Developers may do this on behalf of purchasers as a sales incentive. A C&T system will more quickly grow demand for new buildings that are more efficient than average (e.g. high level CSH homes or BREEAM rated commercial buildings).

5.3 Changing customer base

What happens with new customers who have not previously had a TWUC account? People moving from a non-C&T region (within or beyond England), or forming new households (young adults, divorcees etc.) may not have a TWUC account. They would need to open an account with the C&T body, and obtain TWUCs; these can be bought on the open market, provided by an employer, or gifted to them (e.g. from parents). People moving from one C&T area to another would sell their TWUCs for the region they are leaving, and buy new ones for the destination region. Over the long term (decades), these demographic changes further drive a transition such that consumers would obtain all the TWUCs they need from the open market, not the quarterly free top up.

What happens when people die, emigrate or their business closes? TWUCs that are no longer required, but have not expired, are assets. These can be gifted, inherited or claimed by creditors. If not required by the recipient, they can be sold, and will last until their original expiration date (see 5.5). Over years the number of customers receiving a quarterly TWUC allocation from the utility will fall, and the C&T body can make this released share available via the open market, rather than via the water utility quarterly allocation (based on the grandfathered initial allocation).

5.4 Application to rental households

Recent changes to billing legislation make application of the scheme to the rental sector feasible. Rental properties account for a third of homes in the UK, evenly split between private and social renting, and historically account for about 80% of household water debt (disconnection for non-payment has been illegal since 1999). The 2012 FWA puts a legal obligation on landlords to provide tenant's personal details to the water utility, and makes them legally responsible for unpaid bills if they do not. Thus the mechanism for tracing tenants, allocating liability and recovering costs can be used for TWUCs (or their fees) as well as conventional charges. Those in social rented housing may currently pay for water as part of a single rental fee paid to the landlord (e.g. a local authority). In this case, water conservation could be promoted by introducing a requirement for tenants to supply sufficient TWUCs to cover their water use (or that above a pre-determined cap), and/or by the landlord enabling conservation via upgrading to water efficient fittings and appliances

5.5 TWUC 'retirement'

How long do TWUCs last? Once surrendered, the TWUC expires. It must be surrendered within a set number of years, say five, after which it expires, thus ensuring demand conservation measures are continually incentivised in the market. Customers could be automatically alerted to upcoming expiration so old TWUCs could be used or sold.

What if environmental groups retire all the TWUCs? This is extremely unlikely, as there will be millions of TWUCs (over a billion if all highly stressed areas participated) with a high collective worth (millions of pounds). Retiring TWUCs reduces their supply, so raised prices will also prevent NGOs from excessive retirement. It is improbable to expect that an NGO will outcompete homes and businesses for all the required TWUCs.

5.6 Private supplies and emergency use

Won't existing consumers on a private supply be penalised? No. Current private supplies would be exempt from the scheme, although their use would be taken into account in calculating the cap (all private supplies require an abstraction licence from the Environment Agency). Applications for new licences may need to be more heavily regulated (e.g. demonstrate no viable alternative to a private supply). to prevent companies developing a private supply to avoid the C&T system.

How would large users such as farmers or golf courses investing in on-site water storage be affected? Capturing and storing more water on-site (e.g. extensive RWH, or local impoundments) means drawing on existing sources less, so you may have TWUCs to bank. On-site storage is water conservation that the C&T system promotes, as it encourages less reliance on local abstraction or piped supply. If any abstraction rights were surrendered these would be removed from the cap, but in practice surrender is unlikely as rights holders could gain an income from the TWUCs that retired abstraction represents.

What about emergency use, such as fire-fighting? Emergency uses would be exempt but an estimate of their use would be made and subtracted from the drought year secure supply, leaving the cap for distribution. The estimate would specifically need to consider drought year requirements (e.g. it allows for greater usage due to moorland fire fighting).

5.7 Equity and debt

Won't some customers struggle to meet their basic water needs? It is important that needs are met, and households with high need plus low ability to purchase TWUCs are not penalised. Water utilities are not permitted to cut off the supply to any consumer who does not pay their bill. This situation would continue, with water debts handled under the C&T system just as they are now.

What help would be available to households potentially facing 'water poverty'? A range of schemes currently exist to help low income households. These include a range of payment options (e.g. spreading the bill), trust fund/charitable payments (company pays some of the bill), and 'Water Direct' (households in arrears and on benefits have bills paid via social security). 'Water Sure' targets low income high need users, where qualifying households (on benefits with three or more dependent children, or on benefits and suffering from a medical condition involving large uses of water) have their bills capped. Such schemes could be extended to cover the purchase of any additional TWUCs required. Households who struggle to pay water bills, but are able to engage in conservation behaviour (e.g. they have no atypically high need for water, say for medical reasons), would benefit financially as their conservation may enable them to sell surplus TWUCs.

Can the system help alleviate water debt? The system would not fundamentally change how water companies address customers in debt (deserving households would still receive help with their bills, others would be subject to current debt collection procedures). The system is not designed to reduce debt, but works in the right direction (and is arguably a better industry response to debt than exists now) as households reducing consumption below their allowance can sell their surplus, water utilities purchasing TWUCs to cover leakage above that agreed with the regulator could have the expenditure hypothecated to service water debt (e.g. via the Water Sure scheme), whilst ultimately the water resource system will be more resilient to drought reducing need for supply side investment whose costs would otherwise be passed on to customers in higher bills.

5.8 Scheme extent

Should low water stress areas, such as the north of England bother with this system? No areas are immune from drought. Drought planning occurs for all regions, with yield estimates under drought able to inform the cap. This process reflects water resource projections that address climate change, with the cap set to hedge against future risk, rather than being based solely on past observations of supply, an imperfect guide to the future. Lower stress areas would have a higher cap, so the descent to the cap would be more gradual, and the traded price of TWUCs lower, but operation of a C&T system would deliver greater resilience. The system also incentivises development in areas where resource capacity is high, and discourages it where resources are highly stressed. Under current legislation, only regions in the south of England are classed as seriously stressed and hence readily able to meter all customers. Thus it is reasonable to expect that a C&T system might be introduced in the south first, and later extended to other regions. Note that levels of distribution network connectivity are also likely to be lower in 'water rich' areas; for example one UK water company in a low stress area has seven communities of over 100,000 people each, that are supplied from a single source and so vulnerable to localised drought (as well as failure in infrastructure).

Will water utilities be able to trade? Yes. A water utility in a water rich area may supply a neighbouring water company using inter-regional connections. In undertaking to provide an agreed volume to a neighbouring company (inset agreement), the volume is removed / added from the respective regions resource estimates when calculating the cap. Fewer TWUCs may then be available for purchase in the supplying region (if it operates a scheme), but there will be revenue benefits to the supplying region and its customers. The receiving company adds the import to their resource estimate increasing their cap, enabling a more gradual descent to the cap, and deflating TWUC prices on the open market.

5.9 Headroom

Doesn't lowering demand like this mean there is no 'responsive headroom' (supply less demand 'safety net') under drought as people are already engaged in water saving behaviour. Headroom may be reduced, but the system is designed to match demand to drought supply, so less headroom is needed. Reduced consumption via structural change (e.g. water efficient appliances) and temporary behavioural change (e.g. not watering garden, shorter showers) would still be possible for many, although there may be consumer resistance to any encouragement to voluntarily reduce demand, hence it would be beneficial to descend to an appropriately demanding cap sooner rather than later.

6. Conclusion

Whilst 2012 proved an exceptionally wet year, we should remember that England is not getting wetter *per se*, but is experiencing greater extremes. The floods of 2012 came after two dry winters with economic impacts in some areas as serious as they were in the major drought of 1975-6 (Environment Agency, 2012). Whilst flooding has been uppermost in the public conscious lately, we must also plan for those times when the pendulum inevitably swings the other way. Lord Smith, the Environment Agency's chair, reminded us of this pointing to major UK climate extremes, with, in 2012 alone, major rivers such as the Tyne and Ouse both having their lowest and highest flows since records began, whilst a Met Office analysis suggests that the UK could experience a severe short-term drought, of the intensity experienced in 1975-6, once every decade (Burke *et al*., 2010). Rahiz and New (2013) predict that not only will droughts of the latter half of the 21st century be longer and more intense, they are also likely to affect more regions at a time, limiting the extent to which water can be shared to defend against drought. Lord Smith warns that Britain must become more resilient to both flood and drought (Environment Agency, 2013b).

Whilst climate change raises scarcity risk, demographic changes and economic growth are pushing up demand, exacerbating water stress. The population of the Wider South East and East Midlands is forecast to grow 23.2% from 2010-2035 with London growth projected at nearly 30% over this period (ONS, 2012). Longer term projections suggest major growth beyond this period, with England's population reaching 85.2 million in 2110, a 62% increase over the 2010 base (ONS, 2011). Rising water stress risks shortage that would damage economic development (e.g. business activity, restriction on dwellings needed house the necessary workers). Water stress is being taken seriously, but it is doubtful whether current instruments are sufficient to weather a prolonged drought, without major impacts on the economy, well-being, and the environment.

C&T has proved effective in the management of other common pool resources, and we believe that a water C&T system offers the potential to deliver greater resilience against drought than is possible with current water management approaches. The UK Parliament has already considered a C&T system, with respect to energy (TEQs), which it found to be technically feasible, but deferred adoption pending more evidence on its cost-benefit ratio relative to a cheaper upstream system (i.e. up the supply chain from the consumer) (Fleming and Chamberlin, 2011). The economic benefits of TEQs were large, but so were the implementation costs, an estimated £0.7- £2 billion, to be paid from general taxation.

We anticipate that a water C&T system would be more attractive and feasible than this. The scale of implementation is less (it can start for discrete high stress areas, water utilities in the SE) whilst cost savings may be substantial as fewer supply side schemes would be needed. The scheme is also simpler than TEQs (where there are myriad fuels with different greenhouse gas warming potentials), is likely more easily understood by the public, and could be implemented via incremental developments in existing institutional structures (utilities, regulators). Of course, a water C&T system would represent a bold and radical development of water resource management for England, and there is a gulf between concept and practice. An implementation strategy would need to be informed by prior evaluation of the proposal to identify impacts and barriers. This research would require development of a suitable numerical model to, for example, examine impacts of prices, TWUC lifetime, a changing population base and so on. More generally the research could usefully mirror the approach for TEQs, focussing on fit to strategic objectives, technical feasibility, cost-benefit appraisal, distributional impact assessment, and analysis of public acceptability.

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Table 1. Limitations on application and efficacy of demand management interventions

Approach	**Application and assumed benefit**	**Implementation challenges**
Metering (volumetric charging)	Demand reduction, calculated as product of count of metered properties and demand reduction per meter type (dumb, AMR, Smart)	To date, most metered households in England are self-selected low users. Diminishing returns from compulsory enrolment is likely Retrofit metering of older flats difficult. Cost and uncertainty of forecast utility income
Education	Water conservation campaigns raise customer awareness of value of water and lead to reduced demand through behavioural change	Poor evidence of effectiveness over long term. Even under drought, customers may be unwilling to conserve unless water industry leads by example CCW (2006). Overseas studies suggest behaviour change is short lived, even with advice tailored to individual households (Fielding *et al.*, 2013)
Technology	Displacement devices, low flush WCs, low flow fittings, shower timers	Readily removed by householder if perceived to offer poor service. Regulations (Water Supply Fittings 1999, Code for Sustainable Homes) not enforced post occupation
	Water efficient appliances (washing machines and dishwashers)	Purchasers choose white goods primarily on cost and energy efficiency, although water efficiency is a greater consideration in water stressed areas (MVA, 2006)
	Rainwater harvesting and grey water recycling systems	Householder apathy due to installation inconvenience, health concerns (Fewtrell and Kay, 2007), low roof to occupant ratio for flats, complex agreements for multiple occupancy buildings, and (Roebuck *et al.*, 2011) negative financial return Technology ineffective as short term drought response due to market installation capacity
Network management	Mains replacement reduces bursts and leakage	Utilities aim for economic level of leakage (find and fix cost v. value of water saved) set with respect to the long run average price of water, not its (drought) scarcity value
	Pressure reduction reduces bursts and leakage	Costs (e.g. booster pumps for tall buildings) to maintain service level

Table 2. Water Stress in England by Water Company

Water Company	Water Stress Score	Water Stress Classification	Households served 2011-12 ('000's)	Households metered 2011-12 (%)
Essex and Suffolk Water	41	Serious	705.5	51.2
Folkestone and Dover Water (now Veolia Water SE)	41	Serious	69.1	87.8
Southern Water	40	Serious	962.7	60.3
Thames Water	40	Serious	3322.7	30.9
Three Valleys Water (now Veolia Water Central)	40	Serious	1180.2	40.2
Portsmouth Water	39	Serious	282.1	18.9
Sutton and East Surrey Water	39	Serious	256.8	36.1
Cambridge Water	36	Serious	119.2	64.9
South East Water	36	Serious	799.8	49.1
Mid Kent Water (now part of South East Water)	36	Serious	See South East Water	
Bournemouth and West Hampshire (now Sembcorp Water)	34	Serious	183.9	60.9
Anglian Water	34	Serious	1893.1	69.5
South Staffordshire Water	32	Moderate	520.0	27.7
South West Water	31	Moderate	695.8	72.4
Tendring Hundred Water (now Veolia Water East)	31	Moderate	68.7	74.3
Severn Trent Water	29	Moderate	3150.6	36.2
United Utilities	27	Low	2859.0	31.9
Bristol Water	25	Low	467.0	38.2
Northumbrian Water	25	Low	1061.7	25.3
Yorkshire Water	25	Low	1971.0	41.4
Cholderton and District Water	24	Low	0.7	20.5
Wessex Water	22	Low	520.2	51.7

Notes: Water stress data from Environment Agency (2007) where ≤ 28 is low stress, 29-33 is moderate stress, ≥ 34 is serious stress.
Population and metering data from the regulator OFWAT

For on-line appendix:

Non-metered customers

How are non-metered customers addressed? The scheme assumes that all customers are metered and this will likely transpire in high stress regions, and perhaps ultimately all England. Nationally, meter penetration is rising, with about 42% of dwellings metered (52% in high water stress regions) and some companies are working actively towards universal metering. Meters can now be compulsorily fitted to customers in over half the water company areas in England with over 46% of England's households (Table 2), using powers granted by the Water Industry Regulations, 1999. The qualifying condition is that the area is 'seriously water stressed', considering projected demand and supply. As climate changes and/or projected demand increases, more areas may become seriously stressed. It is just these high water stress areas that the C&T system is designed to address.

Compulsory metering is allowed if a water utility can demonstrate it is the most efficient way of securing supplies. Metering is assumed to be an efficient demand management device, but the evidence on this is equivocal (Table 1). A C&T system can deliver greater efficiencies than metering alone, and as it relies on volumetric data to make that efficiency possible, C&T is a justification for compulsory metering. Universal water metering is already a condition of successful agricultural quota systems (2030 WRG, 2013).

Could C&T work with non-metered users? Possibly, although this likely presents complications so if a scheme were to cover non-metered users, it should be designed to encourage meter uptake. Note that water companies can if they wish meter every user (most don't due to cost and customer resistance), thus there is a mechanism for determining how many 'shadow' TWUCs a customer would need if they were billed on a metered basis. Utilities can only levy this volumetric charge if customers are metered and live in a seriously water stressed area, or display high use characteristics (have an automatic garden watering device, a swimming pool, a power shower, >320 litre bath, or a reverse osmosis water softening unit). Thus a mechanism already exists for bringing the presumed highest water users into the C&T system. Water utilities can also compulsorily meter and charge volumetrically on change of ownership of a property (1999 Water Act, section 7) if the new occupiers have not received an unmetered bill, providing another mechanism for bringing unmetered users into the C&T system. Given an average home move of every 10 years, this will in the time scale of one to two decades result in a marked expansion of the metering base. However whilst growing metering in this way would be uncontroversial, it would lose the cost effectiveness benefits of meter installation street by street, region by region, and leave incomplete data for water resource zones thus negating the information and water balance accuracy benefits of a progressive universal metering programme.

How might non-metered users be encouraged to adopt the C&T system? All non-metered customers would operate in 'shadow' market. Data on estimated usage and TWUCs would be included in their quarterly bill, with the aim of encouraging formal entry to the scheme. (i) A customer would receive an allocation of TWUCs based on estimated historic water use. This estimation would be made based on household characteristics – demand forecasts required by the regulator have long used such an approach (Parker and Wilby, 2013), although estimates for individual households will clearly vary in accuracy more than area estimates. (ii) Customers would receive a quarterly top up to their TWUC account, calculated in the same way as for metered customers. (iii) On receipt of a water utility bill, customers would make the normal financial settlement, and their TWUCs would be automatically deducted from their TWUC account (again based on estimated use). As these are shadow TWUCs, the user cannot enter the market to buy/sell them.

This process however, provides a route to encourage water conservation. High users would be advised as such (“your estimated use is X% above the average for people like you in the C&T scheme – please conserve!”; appropriate advice would be offered). Advising a consumer of their environmental performance relative to their neighbours is a more powerful instrument than information strategies that encourage conservation by raising awareness (Steg and Vlek, 2009). The user would also be advised of the cost implications, should metering be made compulsory; their bill would indicate any TWUC shortfall and how much covering this deficit would cost at current rates. Similarly, illustrations of comparable households who have made savings, and the TWUC savings/income generated could be given. Users who believe they use less than their estimated use would be advised that metering would be beneficial, providing savings on both their conventional utility bill, and making them eligible to trade on the TWUC market, generating an income.