EPI WATER

Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

WP3 EX-POST Case studies

Payment by the drop: The move to water metering in England and Wales

Deliverable no.: D3.1 - Review reports
15 December 2011

Grant Agreement no. 265213

FP7 Environment (Including Climate Change)

COOPERATION

Deliverable Title	D3.1 - Review reports
Filename	Payment by the drop: The move to water metering in England and Wales
Authors	David Zetland and Hans-Peter Weikard (Wageningen University)
Date	15 Dec 11

Prepared under contract from the European Commission
Grant Agreement no. 265213
FP7 Environment (including Climate Change)

Start of the project:	01/01/2011
Duration:	36 months
Project coordinator organisation:	FEEM

Deliverable title:	Review reports
Deliverable no. :	D3.1

Due date of deliverable:	Month 11
Actual submission date:	Month 12

Dissemination level

X	PU	Public
	PP	Restricted to other programme participants (including the Commission Services)
	RE	Restricted to a group specified by the consortium (including the Commission Services)
	CO	Confidential, only for members of the consortium (including the Commission Services)

Deliverable status version control

Version	data	Author
1.0	1-Nov-11	David Zetland and Hans-Peter Weikard (Wageningen University)
1.1	15 Dec 11	David Zetland and Hans-Peter Weikard (Wageningen University)

Executive Summary

Definition of the analysed EPI and purpose

Volumetric water pricing, as an Economic Policy Instrument (EPI), is different from non-volumetric pricing in several aspects. First, volumetric pricing reduces the quantity of water demanded because payments for water rise with use – unlike the case of fixed pricing in which water service – at high or low volumes – costs the same to every household. Second, volumetric pricing makes it easier to create a direct link between costs and benefits, making it easier to charge heavier users a larger share of water system costs. Finally, volumetric pricing, by requiring measurement of water use, makes it easier to understand where water goes in a distribution system – whether to high demand customers, low demand customers, or leaks that are expensive in terms of lost water and the costs incurred in sourcing, treating and moving the water through the system before it's lost.

In this case study, we examine the implementation of residential volumetric pricing in England and Wales through the most basic delivery mechanism: a water meter.[1] For convenience, we will use "EPI" to refer to either water metering or volumetric pricing, taking them as synonymous.

Introduction

Meters are necessary (but not sufficient) for allocating costs in proportion to use and identifying leaks that contribute to environmental stress and increase the cost of running a water system. The combination of meters and sufficiently high charges for volumetric use can encourage customers to use less water more efficiently. Volumetric water pricing reduces demand (by linking payments to consumption) but it also makes it easier to charge users according to their consumption ("economically fair") and incentivize leak repair within homes.

England and Wales had adequate water supplies and supply infrastructure for most of the twentieth century, but water stress has increased under two influences: demand has increased under the twin forces of greater population and an expansion of lifestyle uses of water; supply has decreased as "available" waters (net of environmental base flows) have shrunk. Although scarcity can be addressed by reducing demand (consumption and leaks) or increasing supply (via, e.g., desalination), there is more emphasis on reducing demand in England and Wales.[2]

---

[1] We do not examine non-residential water metering or the design of volumetric water tariffs.

[2] See Ofwat (2011a) for demand-side activities.

The 1989 privatization of England's water companies neither alleviated these pressures nor created an automatic response. That's because volumetric pricing requires water meters that were not widely used in England and Wales. The privatization bill allowed companies to compel consumers to adopt meters and set a year 2000 deadline for replacing charges based on rateable value (RV, or the value of a house) with charges based on consumption volumes (Walker 2009).[3] This was a big goal since only 3 % of residential customers had meters in 1992-3 (Ofwat 2006). Although the year 2000 goal was not met, metering penetration continued to increase. Forty per cent of households are now metered (Defra 2011).

Legislative setting and economic background

The Water Industry Act 1999 sets metering policy for England and Wales. It gives households the right to opt for a meter ("optants") or continue to be billed on RV. Metering is often mandatory for businesses (not examined in this case study), new homes, homes with a change in occupant, homes with characteristics that correspond to high water use (e.g., lawn sprinklers), and homes in officially "water stressed." areas; see Ofwat (2011) for more details.

From an economic perspective, water meters add costs (installation and reporting) while possibly reducing revenues (through the fall in demand). These factors, together, suggest that metered customers will see some combination of higher fixed and variable charges for water. Against these costs come the benefits of reducing water stress (via falling demand and leaks) and reducing the need for investments in new water supplies. Meters also make it possible to charge customers based on their water consumption. This distributional aspect -- combined with a concern for "affordable" water, spreading the meter installation cost among other metered customers, and unwinding some cross-subsidies at the center of RV pricing -- means that the most interesting economics of water meters involve changes to the mix of costs and benefits among various groups of consumers.

Likewise, it's difficult to separate out the costs and benefits of meters in comparison to other methods of reducing demand (via public education campaigns or installation of high-efficiency water appliances, for example). Meters can act as complements as well as substitutes to these measures. The relative cost-effectiveness of these programs is difficult to measure when they are part of a a general trend, e.g., a "water conservation ethic" that is part of increasing environmental awareness or high-efficiency appliances that come to market due to technological advance.

[3] The move from RV to meters was also part of a Thatcher-era trend of replacing funding of government services lump sum property taxes with user fees.

Brief description of results and impacts of the proposed EPI

The impact of water meters on water scarcity and stressed environments is yet unknown. Their effect on leakage and consumption is broadly positive, i.e., leakage is falling via a combination of incentives to reduce leaks and an easier way of identifying their location while consumption is falling among optants who can now be rewarded – through lower bills – for using less-than-average quantities of water.[4]

The distributional impacts of water meters are not as easy to characterize. On the one hand, there are those who argue – from theory or passion – that meters are unfair to poor families that use a lot of water. On the other hand, there are those who argue that meters make it possible to pay for infrastructure repairs in proportion to use and give stronger incentives to reduce demand. These perspectives drive arguments over metering implementation, i.e., whether to emphasize social, environmental or economic criteria.

Conclusions and lessons learnt

The roll-out of water meters to residential water customers in England and Wales has advanced on mostly positive terms. Policies targeted at unwinding some cross subsidies, gradually implementing metering, targeting metering to water stressed areas, and ensuring that volumetric pricing does not cause undue harm to the poor have been pragmatically successful in maintaining public approval while taking cost-effective steps towards sustainable water management in England and Wales.

.

[4] "Network meters" have had a measurable effect on reducing leaks within "district meter areas;" the effect of household meters on leaks is harder to measure because it's unclear when demand reductions are the result of changes in behavior or repairing leaks.

Table of Contents

1 EPI Background

The UK is perhaps the least metered country in the EU. According to Walker (2009, p 71), the Water Industry Act of 1999 (WIA99) set the current framework for metering, but metering legislation dates back to 1989, when companies could compel customers to accept meters (usually on new houses). The 1989 legislation also formalized the conversion from water service charges based on "Rateable Value" (of the home, or RV) to charges based on metered consumption or unmetered service.

Unmetered charges based on the average consumption of non-metered customers are increasing the adoption of meters, as voluntary exodus of low-consumption customers to metered service raises average consumption and thus the cost of service for unmetered customers.

The Prescribed Conditions Regulations of 1999 allow water companies in "official" areas of water stress to compel adoption of water meters on customers. About 40 % of the unmetered households in England and Wales are serviced by 12 companies in water stressed areas; of these; four are pushing for compulsory metering and another five are considering it.[5] The government's top estimate for metering penetration is 92.7 % of households by the end of the installation program (EA, 2008a).[6]

From a political perspective, the move to metering initiated in WIA91 has been pushed along by the need to meet Water Framework Directive goals of environmental health via polluter pays and full cost recovery (WFD 2000).

The Department for Environment, Food and Rural Affairs (Defra), its subsidiary, the Environment Agency (EA), and the Water Services Regulation Authority (Ofwat, a non-ministerial government department) are responsible for, respectively, authority to require or charge for meters, metering locations (e.g., water stressed areas), and implementing metering. The Consumer Council for Water (CCfW) represents consumer interests.

Ofwat provides regulatory support to water companies seeking to use meters by allowing water companies to charge more to metered households (reflecting the cost of the meter), even as they are allowed to charge more to non-metered customers who – as a group – have a higher average water use than metered customers. The goal is to "level the field" in terms of charges per unit of water (the discussion of the

[5] According to Ofwat (undated, but reflecting latest information), there are currently 34 companies providing water services; 21 are large. Companies change their names, merge, etc., over the time period covered by literature in this case study.

[6] See Tables 3.1 and 4.1 in EA (2008a), respectively for metering plans and metering penetration in water stressed areas.

"differential" in section 3.3 spells out these ideas) as low use customers opt to use meters.

Why use meters?

The driving force for meters is decreasing water abundance. In areas of water scarcity, meters are popular when they provide the cheapest means of reducing demand and identifying leakage. Customers can be required to use meters if the Environment Agency determines than an area is under "water stress." Customers can also choose to have water meters installed; they often do so as a means of lowering their bills – they do not want to continue subsidizing other customers who have higher-than-average water consumption.

Meters as an EPI are aimed at improving the reliability of water systems (infrastructure repair and renewal) and water supplies (for economic and environmental uses), each in the fairest way possible, i.e., by allocating water services and costs in proportion to metered consumption.

Meters reduce water consumption by imposing a price on use as well as creating the potential to impose higher prices for "excessive use" in a time of scarcity. (These price signals must be high enough to be relevant to decision-makers.) Meters help reduce leakage within houses (because leaks are now costly) as well as making it easier to measure and reduce system leaks. Meters are also useful for "fairly" allocating costs according to water use.

Water companies may prefer to avoid meters that increase the cost of billing and customer service and introduce greater revenue volatility, but they may prefer installing meters to repair leaking networks if the cost of meters can be added to their capital base (from which Ofwat calculates their "permissible" financial returns) while leak repairs are often treated as non-recurring expenses.

Meters have the advantage of being simple to install and understand. Some people do not like the way that meters call attention to personal water use – versus leaving the responsibility for water shortages with the community or water company. There was also widespread concern over the cost of installing and servicing meters for poor people who use a lot of water and the creation of perverse incentives, i.e., for water companies to encourage people to use more water (Jenkins 2006).[7]

How water meters work

Meters deliver information necessary to address water scarcity in England and Wales. They make it easier to measure system losses, allocate operating, maintenance and capital costs according to use, and improve water-use efficiency.

[7] These issues have been addressed via, respectively, the WaterSure program and Ofwat's "revenue correction mechanism."

Public water companies have been investing in their networks since the privatizations of 1989, but the WFD has called attention to and increased pressure for solutions to water quality and quantity problems that increasing affluence and population have magnified. That said, the high correlation between affluence and water stress means that it is easier to raise the money necessary to repair aging and leaking infrastructure.

Ofwat (2006) says that "optants" can choose to have a meter "free at point of installation" (the cost is installation is covered by surcharges on the bills of by all metered customers) under WIA99. Customers can "go off the meter" within the first 12 months if they dislike the result. Companies are not required to install meters when installation is too expensive.

Meters may be mandatory in water stressed areas (first trigged in 2006 by Folkestone and Dover); homes with sprinklers, large baths, reverse-osmosis units and/or auto-filled pool; new construction; or change of occupancy. Non-domestic users are already metered. Remaining unmetered customers pay according to an "assessed charges" that depends on property type, occupancy and/or average local consumption.

The effects of meters

The 1989-92 Isle of Wight field trials found a 20 % reduction in system demand, a figure that was allocated half to demand reduction and half to leakage reduction (EA 2008a). Peak demands also fell (perhaps those demands represented voluntary behavior).

Average users with meters can use the same volume of water without facing financial penalties. Above-average users have higher bills rise (that they can ignore). Price-sensitive customers who change their "techniques and technology" pay less for water consumption, but can incur time and money costs. Most costs (turning off the tap while brushing teeth) are trivial; others (repairing a leaking pipe) are more significant.

Meter revenues (like non-metered revenues) are used to either maintain or renew water systems. Meters are also associated with reducing demand, which makes them attractive for use in water-stressed regions. These two effects interact more than they would in unmetered service areas where revenues and behavior are not connected.

In their initial stage, water companies pay for meters and receive lower revenues (metered tariffs are set at a level sufficient to generate the same revenue with no change in behavior; consumers who use less therefore pay lower bills). Ofwat has implemented a "revenue correction mechanism" to discourage water companies from incentivizing customers to use more (metered) water. Unmetered customers, on the other hand, are likely to pay more as meters are adopted, as Ofwat wants to both charge them for greater (assumed) water use and encourage them to choose meters.

Meters internalize some externalities, since metered households pay for the water they use (the externality they generate). Such a structure has not kept people from claiming that externalities are "the water company's fault," since the water company is in charge of leak repairs, sourcing new water, etc.

Adverse impacts of meters

The main economic barrier to adopting water meters is the high cost of installation, which is (nominally) borne by the water company. The main philosophical barriers (Jenkins 2006, CIEH 2008 and Staddon 2008) are opposition to charging for a "human right," opposition to reducing demand (compared to "finding" more water), fear that water companies will profit from meters, worry that they will not profit enough with meters, and scepticism that meters will do anything to address water stress.

The primary direct worry – the bill for metered water will be higher for poorer households than it was when bills were based on RV -- has been addressed in several ways. First, there is the emphasis on sharing the cost of metering among all customers – thereby avoiding a liquidity constraint that might appear if a household had to pay up front for meter installation. Second, there is the WaterSure (WS) program that gives payments to families with three or more dependent children or a sick child. Third, there is the right to return to unmetered billing (via RV), which gives customers the option of undoing a move that they may regret (this option will not be in place for long). Finally, there is the benefit of volumetric tariffs that are calculated to deliver the same bill to an average customer with a meter as one without a meter. This calibration means that a customer with a meter who uses less than average volumes will pay less for water service.

Secondary worries are that metered households will not use less water (no environmental benefit) and that there are other, cheaper ways to reduce water use (e.g., water conservation education). The former objection only holds if water is too cheap for consumers to conserve; the latter objection is a distraction from the fact that meters make many other water conservation techniques possible. Education, for example, does not work very well without some idea of how much water one is using.

2 Characterisation of the case study area

England and Wales are historically known for their water abundance, but increasing demand has put water supplies under stress that has, in turn, impacted environmental water flows. In this section, we describe these basic factors.

Water supply and demand

Water supply is a function of local precipitation, surface flows and groundwater resources; see EA (undated A) for monthly hydrological reports.

The total amount of water abstracted from all sources in England and Wales in 2006/07 averaged almost 60,000 megalitres per day (MLD), or about half the 130,000 MLD allowed to 21,500 licenses (EA 2011). EA (undated B) reports abstractions.

The proportion of total abstractions derived from **non-tidal surface waters** has declined from almost 60 % in 2000/01 to just less than 50 % in 2006/07. "Water companies abstract almost half of the total amount taken from non-tidal (i.e. fresh) waters in England and Wales, but return over 70 % as treated effluent which, unless it is discharged to the marine environment, enhances river flows" EA (2008, p. 7). The top four industries using non-tidal surface water (accounting for nearly all abstractions) are public water supply, electricity, other industry and fish farming (EA 2008, Fig 3f).

Abstraction from **groundwater** has remained fairly constant over that time, at around 10 % of the total. Over three quarters of the total abstracted groundwater is used for public water supply; groundwater supplies about one third of mains drinking water in England and around 3 % in Wales. The Southern water company (in England's South East) gets 74% of its supply from groundwater (EA 2006, Figure 6).

The amount abstracted from **tidal waters** has increased over the period with most used to support electricity generation (EA 2008, p. 7).

Eight per cent of England and Wales is built up area; 51 % of their 151,000 km^2 is grassland or agriculture.

People generally prefer to live in areas with less precipitation, but water demand is a function of population density and GDP per capita. England has 50 million people in 130,000 km^2 (population density of 383 people per km^2). Wales has 3 million people in 21,000 km^2 (population density of 65 people per km^2) (Neuralmap 2010). Population density is highest around London; the highest rate of population growth is northeast of London in the water-stressed Anglian watershed (Easton 2008). GDP per capita is correlated with population density, i.e., highest around London.

Per capita consumption varies by region, but it's lower when people pay according to measured water use (EA, 2009, Fig 1.9). This result may be biased by the fact that people who tend to use less water opt to have meters; see Map 1.

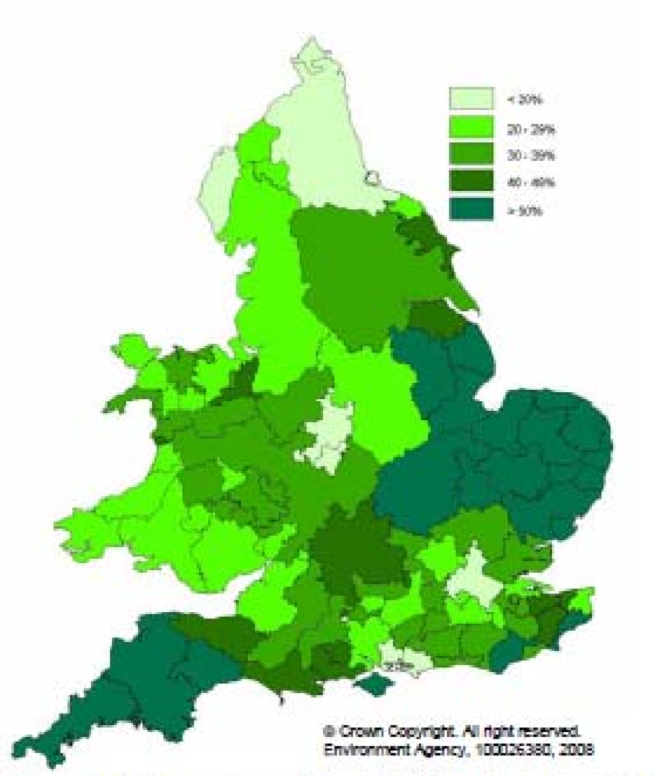
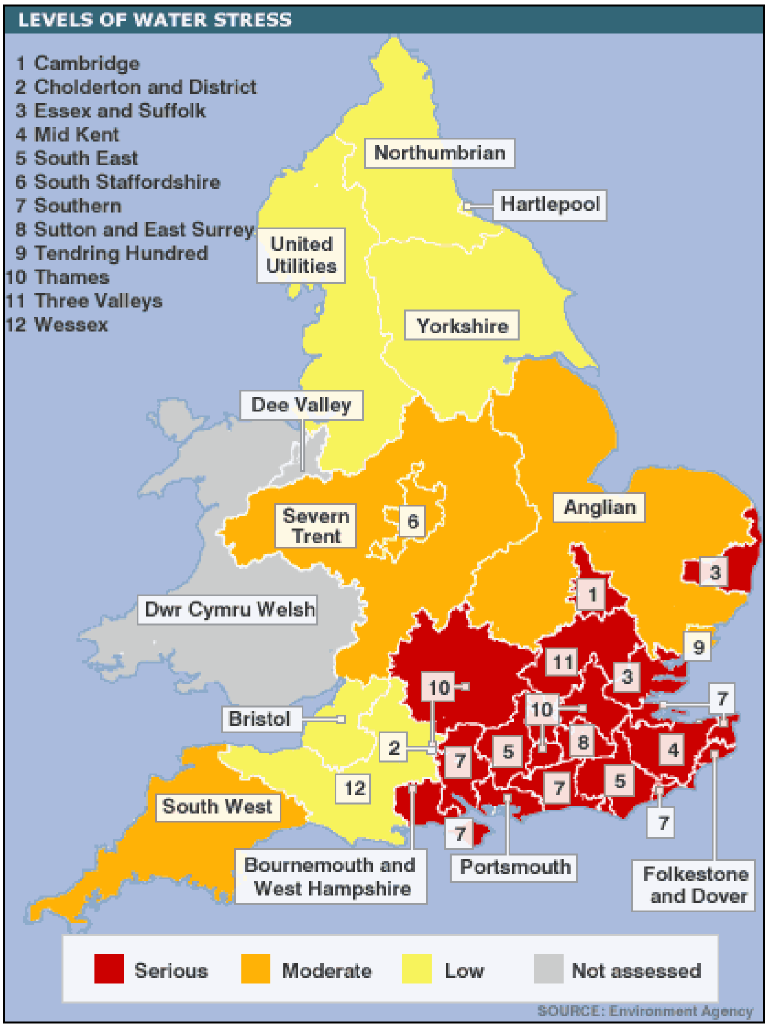


Figure 4f Proportion of households metered in 2008

Map 1: Meter penetration in England and Wales. **Source**: EA (2008, figure 4f)

Water stress and scarcity

Water scarcity results from reductions in supplies due to climate change (changing precipitation patterns and higher temperatures) and demand from public water companies. Hydrology varies across England and Wales, with more precipitation in the north and west. Water resources are stressed in southeast England (see Map 2), where water exploitation and stress resembles the situation in Spain and Italy (EA 2009).



Map 2: Water stress and water companies in England and Wales. **Source**: BBC (2007)

Defra's WFD status reports for river basins in water stressed areas confirm the story; see Table 1. These poor numbers are a major factor behind the drive to install water meters as a means of reducing demand and improving system efficiency (lower leaks reduce abstraction needs).

Table 1: WFD water condition for river basin district in water-stressed areas.

River basin district	Surface water in poor status (%)	Groundwater in poor status (%)
Anglian	82	35
Severn	71	25
South East	81	67
Thames	77	65

Source: EA (2009a)

3 Assessment Criteria

3.1 Environmental outcomes

Public water supplies accounted for about half of 2006-7 withdrawals of about 35,000 ML per day (EA 2008). These withdrawals mean that residential consumption is roughly 150 liters per capita per day (lcd) in England.

The ecological status of water resources is linked to water meters in the sense that water companies in "water stressed" areas are more likely to request permission to require water meters of their residential customers (or be told to use them). That said, there is no strong reporting connection between the implementation of water meters and ecological health, perhaps due to a (pragmatic) knowledge of the many factors affecting water resources in an area and the (bureaucratic) problem of connecting water consumption reports filed with Ofwat to water health reports prepared by the Environment Agency.

Changes in behaviour due to the EPI

EA (2009) proposes that near-universal metering (up from 40 % today) will result in 2030 consumption of 130 lcd.[8] EA (2009, esp. fig 1.9) shows per capita consumption is lower for households with meters than in households without meters, but those statistics are somewhat flattered by the fact that many people with meters are optants who already used less water before they had meters installed. That said, consumption also falls when an "average" household is metered. NAO (2007) reports that demand drops by 9-21 % for optants and 10-15 % for compulsory meters. This effect holds income and population constant, but an increase in either factor will increase per capita and total demand, respectively. Likewise, an increase in network efficiency (lower leaks) can reduce the demand for water, leaving more water in place in groundwater, rivers, and so on.

[8] The 130 lcd goal does not consider price incentives.

Changes in pressures on water resources and ecosystem status

It's too early to tell if there were any material changes in the conditions of water resources due to population growth (more people, each using less water), environmental supply and demand for water, demand from non-household sectors, exogenous changes in residential demand for water, or the impact of this EPI on residential demand. EA (Undated A, B & C) report current environmental water conditions, but the health of these systems has not improved dramatically.

We know that newly-metered customers might cut their demand by reducing their use or plugging leaks. We also know that meters – by clarifying where leaks exist in the network – also made it easier for water companies to find and repair leaks. These assumed benefits may be offset by what appears to be a lack of controls on new (and metered) demand resulting from additional land development.

Environmental cost-benefit assessment

Walker (2009, p. 207) discusses the cash cost of saving water against the benefits ("cost savings") for the environment, carbon emissions and operating costs, i.e., the cost of saving one cubic metre of water by installing meters ranges from 40p to £3.80, with a central estimate of £1.50 in the short term and £0.80 in the longer term. Against these costs are total cost savings of 80p to £1.30 per cubic metre. This number includes the benefits of lower carbon emissions, lower operating costs and a "placeholder value" of 50p per cubic metre value of extra water in the environment. These numbers suggest that metering is not the cheapest action (stopping at current metering levels is), but they are cheaper than finding additional supplies (see Table 2) and may be an integral to addressing water stress, as required by domestic and EU regulations.

3.2 Economic Assessment Criteria

In England and Wales, meters are the preferred alternative to a status quo of no meters plus regulations on water use and/or water use efficiency (EA, 2008a). Although both Jenkins (2006) and Staddon (2008) claim that regulations and/or high-efficiency products save water at a lower cost, both fail to consider the lack of incentive to save water when customers are not on meters (why install an efficient toilet – even if it's "free" – when your water bill will not only stay the same but increase-- to pay for "free" toilets?). Meters are also necessary precursors to using price incentives, detecting leaks and/or allocating the cost of repairing leaks.[9]

[9] Weak price incentives may not result in any change in behavior. Many businesses, for example, have not reduced their water consumption to save money – either because they are not in the habit of watching water costs or find the benefits of change to be insufficient Envirowise (2009).

Meters are the least cost alternative compared to additional supplies (see Table 2), but not necessarily when compared to voluntary demand reductions, some high-efficiency products, or regulations. The trouble with those demand-side responses is that they are not seen as fair (the benefits from voluntary reductions can be offset by others increasing their use), which increases social friction.

Table 2: The cost of meters vs. new supplies.

Option	Range of costs (pence per cubic metre)
Near-universal (90%) metering	140-160
Groundwater development	100-500
Surface water development	100-500
New reservoir	300-1000
Desalination plant	400-800

Source: EA (2009, Table 4.1)

Most people who voluntarily switched to meters at rates calibrated based on average unmetered consumption saw their bills fall because (1) they were already using less than average, (2) they used less when on meters and/or (3) they moved from a water service charge based on RV to one based on metered use. The winners and losers from metering are discussed in Section 3.3

From a financial perspective, meters did not increase revenues or cost recovery because, first, they only reallocate costs from light to heavy water users, and second, because optants using meters pay less if they reduce their water use. Since this outcome is expected, water companies are allowed to increase their revenues from non-metered customers.

Customers without meters were not paying in proportion to their water use, which was unknown. Customers paid based on RV, occupancy, etc. There was little incentive to use less water. The gradual roll-out of meters has allowed low water users to stop subsidizing heavier users as well as reveal their consumption (a fair trade for them). Meters also incentivize customers to fix leaks in their homes. According to EA (2008a), supply pipe leakage in externally-metered households is about half the level of unmetered or internally-metered households (customers repair pipes when they are paying for the leaked water AND can detect the leak).

NAO (2007) notes how meters help consumers reduce consumption but worries that companies may promote usage as a means of increasing revenues. NAO suggests a cap on revenues (similar to the idea of "decoupling" consumption from revenue), but this fear may be unwarranted. The opposite idea – that companies have an incentive to reduce leaks when their customers are unmetered – fails if companies are not allowed to recover repair costs.[10]

Water meters increase economic efficiency in water use and payment for water services, in comparison to the alternatives of telling people how much water they can use (command and control regulation) or RV-based charges that have nothing to do with water use or the cost of service. That said, meters may increase social inequality by replacing "payment according to ability" with "payment according to use," which means that unmetered customers and metered heavy users pay more; see Section 3.3.

Although meters are more expensive to install, maintain and monitor than unmetered services (see Figure 1), they are necessary if one wants to use volumetric pricing to recover costs and/or reduce demand in proportion to use of water services. Future projections anticipate that on-going costs will fall as customers and water companies get used to meters. Installation costs would also fall if meters are installed for entire areas instead of optant by optant; Walker (2009) suggests a 20-50% reduction in installation costs. Ofwat (2011) calculates the net benefits of moving to meters via optant enrollments to 90% penetration by 2050 (business as usual) to be GBP -1.2 billion, i.e., a net cost compared to stopping at the current level of metering. This calculation includes significant benefits from reduced carbon emissions that result when lower water demand reduces the need for water heating. In comparison to this BAU scenario there is the "faster roll out" scenario that costs GBP 200 million *less*, i.e., only GBP -1.0 billion. Ofwat (2011) shows that rollout to 90% penetration by 2030 produces the greatest net benefits (*given* that meters must be rolled out) but the government will decide which option to implement.

[10] The "Distribution System Improvement Charge (DSIC) was first implemented in Pennsylvania in approximately 1996 and allows for rate increases, outside of a general rate proceeding, for non-revenue producing investments to replace aging infrastructure." DSIC charges are collected over several years on expenses that may occur over several years.

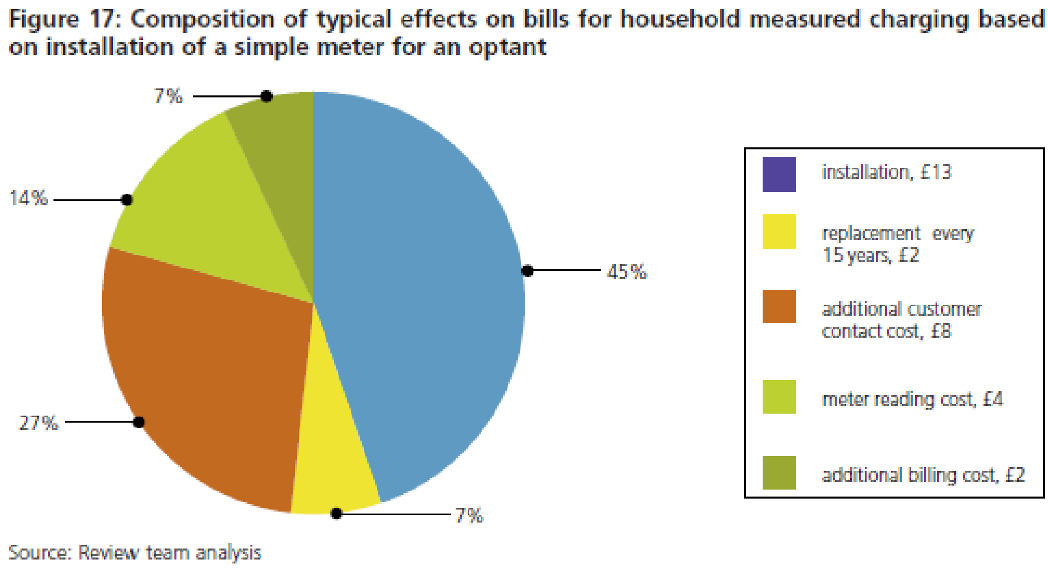


Figure 1: Breakdown of annual meter cost. **Source:** Walker (2009, Figure 17).

These costs and benefits do not include the benefit from meters (as opposed to command and control) of reducing risk, which comes in three forms. First, there is the short term reduction of demand (a "level" effect) and long term reduction in the growth of demand (a "slope" effect) that frees capacity and reduces the need to find additional supplies. Second is customers' greater awareness of their water use, which can therefore be reduced more quickly when necessary. Finally, meters reduce risk by allowing water companies to understand their customers' water consumption and respond with tools to reduce demand, e.g., changes in water tariff structures (EA 2008a).

3.3 Distributional Effects and Social Equity

Residential water meters do not have a direct distributional impact on businesses that use water (they are already metered). There is some small impact within water companies from the move to meters, most obviously in the additional work required of existing and new employees who install and support meters. Since they are paid for this work, we will ignore potential distribution effects on water companies and their employees. Instead, we concentrate on the impact of meters on residential customers. Although we did not conduct interviews for this ex-post desk review case study, we were able to use existing studies to understand the real (and claimed) impact of metering on households.

Before we go to those studies, it helps to discuss the main distributional driver – the move from billing based on RV to billing based on water consumption.

Ofwat uses a "differential test" to ensure that unmetered customers, as a group, pay the same *unit* price for water as metered customers, while allowing metered customers' bills to reflect the additional cost of meters (the differential).[11] That said, water bills for unmetered customers will be higher if they use more water,[12] and they will definitely be higher if billing switches from a low-RV to average consumption for average unmetered customers. Note the dynamics at work here: Meter adoption by low-use, high-RV customers lowers their bills while raising the average consumption of unmetered customers. The resulting increase in their bills gives remaining unmetered customers with the next-lowest consumption an incentive to switch to meters. That process – the snowball effect described in Oliver (1985) – should continue until the only remaining unmetered customers are the heaviest users. (Actual switching rates are neither so fast nor so ordered, due to inertia and miscalculations, respectively.)

These changes in the pattern of charging for water has had **psychological and financial impacts** on water consumers. Some of these impacts has been exaggerated, as when customers conflate higher metering charges with reports of system leakage in their area (leaks change total costs but meters change who pays those costs), hope that "someone else" or "profits" can cover costs, or worry that meters will force them to pay for their use or consider how much water they are using (the reason for meters, not a side effect). Besides these responses from customers who do not have or want meters, CCFW (2006) also reports that customers *with* meters (about 25 % of their survey response) were happy with them. These results are mirrored by MVA (2006), which reports concerns with higher water bills from high consumption, lower water bills from lower consumption, and some inconsistencies in beliefs (e.g., people predicting they will use more water *with* a meter). Many customers feared meters as an excuse to raise prices in general (also in Doward 2011). Most customers without meters couldn't be bothered to get them; some didn't want them due to cost of privacy concerns. As with CCFW (2006), customers preferred subsidies for saving water (e.g., rebates on water saving appliances) or regulation of water use (e.g., hosepipe bans) instead of paying by volume.

CIEH (2008) directly disputes the fairness of metered water pricing, since economically fair (paying for consumption) conflicts with socially fair (paying in line with income and/or headcount). CIEH reports that 10.7 % of all households and 36.9 % of households in the lowest income quintile were spending more than 3 % of income on (metered and unmetered) water in 2009-2010. Doward (2011) reports that 15% of metered customers saw a GBP 100 increase in annual water bills, and 25 % of the poorest customers saw their bills rise by GBP 50 or more, but fails to report what

[11] The differential was £34 per household for 2003-04; it averaged £37 – rates vary by company -- in 2009 -2010 (Ofwat 2009).

[12] Demand is lower due to the combination of optants switching because they tend to use less water and the demand reduction that most people make when they are volumetrically metered.

happened with other customers (presumably, their bills fell). Some customers wanted to keep RV-based billing because they were subsidized by people in high-value homes.[13]

Some of these households were helped by subsidy checks or moving to metered water, but others were not. One big problem has been take up of the "WaterSure" (WS) subsidy by eligible households (6 % in 2007-08). Walker (2009) concludes that metering is the fairest way to allocate costs when water is scarce but recommends greater financial aid for poorer customers, via an expansion of WS and lump sum payment to customers in the South West who have paid for post-1989 investments that the government had failed to make prior to privatization. Defra (2011) responds to Walker and CIEH with its own statistics on spending (p. 10: "Twenty-three per cent of households in England and Wales currently spend more than 3 % of their income (after housing costs) on water and sewerage bills and 11 % currently spend more than 5 %") and WS (31,200 households enrolled, 40 % due to medical conditions and 60% due to 3+ children). Defra suggests expanding WS to as many as 700,000 additional households and looking into a financial adjustment for South West customers.

From a **health perspective**, meters have a positive impact when they lower system leakage (since leaks can allow contamination into drinking water) but a negative impact if people use less water for personal hygiene. CIEH (2008) worries about the impact of volumetric charges on low-income customers, citing "water poverty" to now be a question of financial "access" rather than the old problem of "infrastructure access."

Meters also make it easier to **educate the public** and water users on the value of water in the home and environment, since they create an explicit connection between water and money (value). In theory, meters will also have a direct and positive impact on the environment, as they reduce overall demand for water and thus the need to extract more water from natural sources. This impact will be partially offset by a reduction in system leaks that return water to natural sources, but those leaks are not necessarily in places where additional water will improve environmental conditions.

The process of implementing metering has improved regulator and water company **engagement with customers** who are now paying according to their use instead of just paying a flat fee (or tax) that does not vary. Engagement takes more effort on all sides, but it allows other matters (e.g., water quality or customer service) to be discussed. Charges based on metering is also seen as more "fair" than charges based

[13] Barraque (2011) examines submeters in formerly master-metered buildings in France and concludes that they do not improve equity because indoor use is inelastic and customer bills go up with the cost of additional hardware and meter reading. Barraque considers it "socially fair" to charge according to house value (RV).

on RV, as it switches the perception from water being a good provided in unlimited quantities and paid for by taxes to water being a commodity that customers pay for. The old cross-subsidy from people with high-RV homes to people who use a lot of water is unwinding, reducing the social tension associated with these subsidies, i.e., people paying more money so others can use more water.[14] The discussion has now moved to most people paying for what they use (without impacting others), with a small number of people (3+ children, etc.) receiving support for their use.

3.4 Institutions

The UK is a wet place with a history of entrepreneurial water ventures (everything from canals, to water supplies, to steam engines). As a nation with strong local loyalties, most water and sewerage was provided by locally controlled public companies. Increasing environmental and population pressures made it difficult to run operations that wasted water and polluted the environment. EU membership creates outside pressure for action to improve the quality and quantity of water in the environment as well as bring distribution systems up to higher standards.

The UK has three different systems of water provision. Residential water service in Northern Ireland is "free" and subsidized by the central government (as is the case in the Republic of Ireland). Scottish water is also a public company but its customers pay for their service. Relative to England, these countries within the UK are sparsely inhabited and abundantly watered. Water and sewerage services in England and Wales were privatized in 1989, towards the end of the Thatcher Era. This pattern of private/public is probably due to a combination of local autonomy (Thatcher couldn't tell the Scots what to do), urgent pressure for investment in England and Wales, and the potential to operate at a profit.

Privatization increased the drive for consolidation and efficiency that was already underway. Private firms have an easier time investing in system repairs and upgrades, knowing that they can pass their costs to customers. Meters make it easier to allocate these costs in proportion to use. Public companies have a harder time charging at all (N Ireland) or in proportion to use (most customers in Scotland do not have meters; they pay for water based on their council tax bill).

Rapid population growth, economic activity and heterogeneous communities make it easier to install meters and charge customers for what they use – as opposed to "sharing" the cost with other people in the community. EA (2009) emphasizes reforming legacy management institutions to reflect current conditions (e.g., abstractions, leakage, inter-sectorial exchanges, demand, etc.). "The UK is almost unique among developed countries in that most households are not metered" [p. 50].

[14] Tsenga Tabi (2011) reports that only 39% of UK water customers consider a GBP 2 cross-subsidy to be acceptable

Old and leaky distribution networks – many dating from the Victorian era -- also increased the pressure for meters. The government didn't want to pay, and customers wanted to shift costs to heavy water users. NAO (2007) says that meters are good for finding leakage and notes that some leakage is "economic" relative to repair costs. EA (2009, p 55-6) reports that most water companies are operating at, or below, their "economic level of leakage" (ELL)," but supports "Ofwat's move to setting targets based on a 'sustainable economic level of leakage' (SELL), which requires water companies to take account of the social and environmental costs and benefits of leakage management." SELL is lower than ELL due to the environmental (water stress) and social (repairing leaks helps customers accept scarcity pricing, meters, etc.) costs of leakage. Figure 2 shows how leakage has changed over the years (leakage at Thames Water is highly publicized).

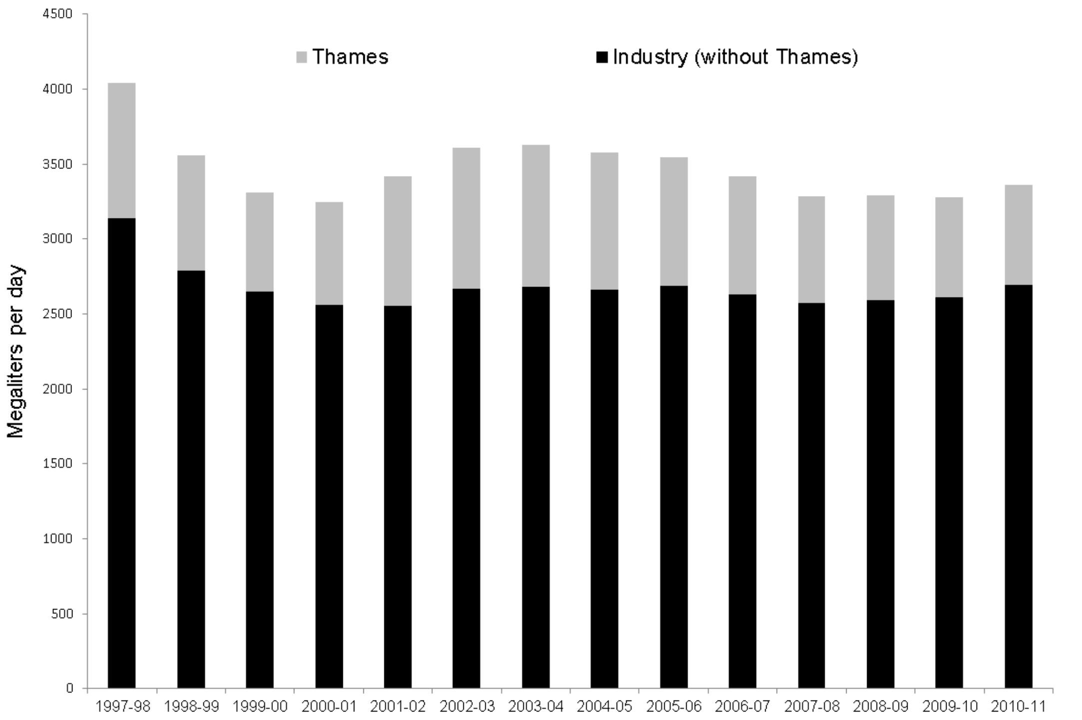


Figure 2: Leakage in England and Wales. **Source**: Paul Hope, Ofwat

Total leakage has fallen from 5,112 Ml/d in 1994-95 to 3,362Ml/d in 2010-11, or by about one-third (Ofwat 2010a). This reduction by 12 % of total system flows should not be used to estimate the percentage of total system leaks (i.e., 12 % less implies that 23 % is still leaking) because the total changes with prevailing weather conditions while leaks do not. The lack of correlation can make leakage performance appear much better or worse regardless of whether total leakage has actually gone up or down.

Water companies, consumers, regulators and politicians mostly agree that meters are the fairest way to charge for water service, address leaks and pay for upgrades. A minority that disagrees on the entire idea of payment for water has been ignored;

their worries about the burden of paying for water on the poor have been partially addressed (Walker 2009, Defra 2011).[15]

Meters have changed the distribution of costs and benefits among households but only modified the institution of paying for water. They have piggybacked on earlier efforts to meter electricity and natural gas. Adoption has been sped up by their "free" aspect (the cost is added to everyone's bill) and the financial benefits for low-consumption and/or high RV customers who switch to meters.

3.5 Policy Implementability

The rollout of meters was facilitated by the (largely) voluntary nature of choosing to have a meter, public discussions and surveys by Ofwat and water companies, the EA's role in declaring water stressed areas, cooperation among Ofwat, EA and water companies, and a broad social acceptance of "you pay for what you use" volumetric charges (EEA 2008a). Rollout was impeded by people who preferred regulation, a shortage of installation personnel, and rebellion against higher charges for poorer households (NAO 2007; Defra 2011). Cooperation among various parties was essential in optimizing the costs for metering in terms of regulations, installation and operation.

These costs were not minimized in recognition of the need for acceptance by customers (who ultimately pay for meters) and implementation that needed to reflect local infrastructure and water scarcity conditions; see Table 2. In most regions, metering is voluntary – customers can request that meters be fitted. Companies are also not required to fit "free" meters when customers have complex piping. Companies can impose meters if the Environment Agency declares its service area "water stressed." Nine companies are in water stressed areas; four have announced compulsory metering (EA 2008a).

---

[15] Staddon (2008), e.g., worries that meters will turn water into a commodity, reduce the public's concern about managing their "common pool" asset, and ends with a plea for unmetered water to support the "social basis of modern political society."

Table 3: Meter penetration for household and non-household customers.

Company	Household meters (%)	Non household meters (%)	Total proportion of billed properties metered (%)
Anglian	57.2	87.8	59.2
Bournemouth	45.6	93.7	49.6
Cambridge	57.0	89.9	59.7
Essex and Suffolk	39.4	92.7	42.3
Folkestone and Dover	51.5	84.6	53.9
Mid Kent	37.9	92.5	42.7
Portsmouth	7.9	87.3	13.0
South East	33.3	87.1	37.3
Southern	33.0	80.5	36.0
Sutton & East Surrey	23.2	85.3	26.9
Thames	23.1	87.5	27.0
Three Valleys	30.3	84.2	33.0
TOTAL Water stressed	34.3	87.1	37.6
Bristol	26.6	81.0	30.7
Dee Valley	41.4	91.6	45.0
Dwr Cymru	24.9	89.7	30.0
Northumbrian	15.6	84.0	19.4
Severn Trent	27.6	93.1	31.6
South Staffs	18.7	86.6	22.5
South West	55.4	88.9	58.7
Tendring Hundred	65.9	97.6	67.8
United Utilities	21.3	89.6	25.6
Wessex	37.3	86.7	42.1
Yorkshire	31.0	86.7	34.6
TOTAL rest	27.3	88.9	31.4
TOTAL all	**30.3**	**88.2**	**34.1**

Source: EA (2008a, Appendix 2)

The lag between use of the EPI and its impact is quite small. That's because customers understand how meters work and ask for meters. Most complaints have come from activists and academics (Jenkins 2006, MVA 2006, CIEH 2008 and Stoddard 2008). That said, some customers saw their bills rise while most cut their use (Doward 2011).

The main adjustment since WIA99 has been an increased emphasis on affordability. Walker (2009) reaffirms the problem of expensive water service in the South West (a hangover from 1989's privatization of under-capitalized assets) and affordability. Defra (2011) addresses both of these problems with partial solutions (financial transfers to the South West; greater emphasis on subsidies to households) even while rejecting broader aid as "unaffordable."

Regional or sectorial acceptance of meters varies. Businesses have accepted water metering as another cost. Residents in water-rich areas do not want to (indirectly) pay for meters when water bodies are in good health. Perhaps the biggest opposition to meters comes from South West customers facing higher bills connected to infrastructure investments. The impact on poor people of this move to higher bills – on average – is magnified by the move from RV to meters. Poorer people are thus more likely to pay a larger share of a larger total revenue; see Section 3.3 for more on public participation on the rollout.

That said, opposition to meters has been reduced by their voluntary nature, the understanding that higher bills for unmetered customers are the result of unwinding cross-subsidies, and (limited) assistance with water bills.[16]

Some opposition is illogical. Some customers, e.g., prefer that companies repair leaks instead of switching to meters, but they forget that water bills must rise to pay for leak repairs. Others oppose "for profit" water companies, *per se*, worrying that they will use meters to make more money by encouraging greater consumption of metered water; see NAO (2007) in Section 3.2. Some of this opposition is fed by the public discussion of meters, leaks and finances in the press – a discussion that does not always follow the rules of logic, law or economics.

Luckily, these public discussions are augmented by periodic reports (e.g., Walker 2009) and discussions prepared by various stakeholder groups. Ongoing cooperation and consultation between Ofwat and the EA (via, e.g., formal and informal questions and responses) are mostly productive, given that they agree on metering as a means for allocating costs and improving efficiency; see EA 2008a).[17]

The impact of other policies on water metering has been fairly limited; see Table 4.

[16] Water companies that have problems collecting payment (partially due to a prohibition on disconnection for non-payment) anticipate larger problems if meters increase bills for customers already facing high water bills.

[17] The allocation of water abstractions (or cutbacks) between farmers and water companies may be more contentious, but those discussions are not part of the implementation of water meters.

Table 4: ***Assessment of the interaction between the EPI with other relevant policies***

EPI Policy Objective: Reduce volume of households water consumption in England and Wales		
Other sectorial policies	Objectives of sectorial policies	Synergies and Barriers
Common Agricultural Policy	No impact	0 CAP affects agricultural water use.
EU Energy policy	Reduce energy consumption	+ carbon-savings goal makes it easier to press for meters that will reduce water pumping and (hot) water consumption; see Ofwat (2011).
WFD	Reduce water stress	++ increased pressure for meters as a means of reducing water consumption and system leaks.

Notes: + represents a positive synergy between the objectives of the EPI and the other policy; 3 levels: + (low positive interaction),++ (medium),+++ (high positive interaction)

3.6 Transaction Costs

The transaction costs (TCs) from metering are not mentioned by name, but they are mentioned in terms of the cost of rolling out and using metering. Most roll-out costs are in terms of time spent on consultations, e.g., Walker (2009). Figure 1 shows estimated costs per customer per year.

Metering as an EPI was introduced with low TCs due to existing familiarity with metering gas and electricity (institutional characteristics). WIA99 gave customers the right to be charged for their water consumption instead of RV. As noted above, meters merely provide the means to introduce the real EPI – volumetric water pricing.

It's difficult to measure the man-months behind the inclusion of the right to metering in WIA99. That law had several components, many of them in response to lessons learned since WIA91. It appears that lobbying costs were minor, as government, water companies and many consumers supported the *option* to move to meters.

Monitoring and enforcement costs are estimated to cost at GBP14 per customer per year. Volumetric billing is relatively easy to implement within existing billing departments. Implementation costs were low because most meters are being installed under voluntary (optants) or appropriate (new construction or water stress) circumstances – with the knowledge that *something* had to be done. Most expansion at water companies took place in customer service. Meter installation could be done thorough outsourcing or with internal manpower. The move to compulsory metering (or meters in new housing developments) would require higher staffing levels, but lower the installation cost per customer.[18]

3.7 Uncertainty

The objective of the EPI is specified clearly, but its impact was not very easy to quantify. Metering is one response of many in reducing water stress in England. Stress can be measured (vs. historic water levels and flows) but the impact of various actions cannot be directly attributed, since their interactions and timings are difficult to understand from an ecological perspective.[19] The target for "results" appears to be 2015. The clear target – moving residential consumption from 150 LCD to 130 LCD – does not have too much significance if it's not accompanied by a fall in leakage and population growth. Total demand is what matters.

The EPI's environmental objective was to reduce water stress. This objective is clearly stated but difficult to measure due to the influence of other factors on water stress. Metering, as an EPI, does not come with a consumption target (an outcome) but a metering penetration target (an output) of "all economically feasible houses." The vague outcome can be explained by the existence of multiple factors affecting water supply in an area. There is no uncertainty in metering penetration statistics -- only the rate of penetration. Annex II: Pedigree matrix

Table 5 (in Annex II) describes the pedigree of these data sources.

4 Conclusions

This case study of the expansion of residential water metering in England and Wales provides a useful description of the multiple, interacting impacts of an economic policy instrument: volumetric charges of water use, facilitated via the delivery channel of water meters. The EPI makes it possible to link the costs and benefits of water use in the minds of water users who pay for water in proportion to their use. Meters also facilitate system repairs by making it easier to locate leaks. These behavioral and engineering impacts then lead to environmental impacts, via reductions in demand for water extractions.

As noted in Section 3.2, metering is expected to have a net cost of GBP 1 billion, but this cost must be incurred if the UK is going to meet its domestic and WFD obligations of returning its surface- and groundwaters to ecological health.

---

[18] The average cost (materials and labor) of installing an optant or COM (Change of occupancy) meter is about £180. This cost would be 20% lower for compulsory meters (EA 2008a; Walker 2009).

[19] See EA (undated A) for monthly and weekly water situation reports.

Meters are widely accepted as a means of charging for use, but their implementation involves transaction costs (relative to the status quo of no meters). These costs come from installing meters, establishing systems for volumetric billing and then monitoring and billing customers for the water they consume. Although these costs may be necessary in terms of meeting WFD concerns, they are also necessary for managing resources, growth and the environment in the UK's most densely-populated – and water stressed – regions.

The most interesting and most sensitive dimension of the move to meters is the way that volumetric pricing changes the distribution of costs and benefits from water service. The old system of billing based on rateable value (of one's house) meant that people in higher-RV houses and light water users paid more than their share of the costs of water service, effectively subsidizing people living in cheaper houses and heavy water users. Although some people supported this subsidy, arguing that poorer people should pay less for water that is a "social good," it makes more sense to help the poor with direct income supports and charge for water service based strictly on its commodity nature. Agreement on this point among government, regulators and investor-owned water companies has made it politically easier to promote metering. The voluntary – and semi-subsidized – program for installing meters in residences has made them more acceptable to customers. These subsidies (allocating the cost of installing a meter among all customers and setting tariffs to reduce bills for metered customers who use less water than average) look sustainable, in the sense that they are shared among water users and adjust as the share of metered customers increases.

4.1 Lessons learned

The implementation of volumetric water charges (the EPI) via a delivery mechanism of water meters has been successful in England and Wales. This success is based on the emphasis on pragmatism over dogmatism in installing meters and the degree to which responses to meters have aligned with predictions.

The environmental impacts of meters are difficult to know, given that numerous factors affect environmental water supplies. That said, meters are necessary for monitoring and influencing the impact of water use on environmental waters. Against this benefit, there are economic costs to moving to meters. Most of these costs (and the transaction costs that go with them) are fixed, but they are minimized due to England's institutional acceptance of "paying for what you get." The largest impact of meters is through their alteration of the distribution of payments for water services among different classes of water users, but this re-distribution is acceptable to the degree that people are willing to see water as a commodity to be purchased instead of a public service that should be provided according to human needs. The relatively smooth implementation of this EPI is less due to brilliant design and execution (meters were supposed to hit full coverage in 2000) than periodic and pragmatic readjustments to cope with logistical, social and political issues. It may be better to successfully implement meters over forty years than fail in a shorter time.

4.2 Enabling / Disabling Factors

Uncertainty assessment: We have HIGH confidence in the validity of findings in this case study, due to the existence of excellent data and analysis on the reasons behind – and implementation of – water metering in England and Wales.

Key enabling factors: Public acceptance of metering and a pragmatic implementation.

Key disabling factors: Complicated (costly) installations of meters in places that were not designed to accept them and opposition to charging for water as a service.

5 References

Barraqué, Bernard (2011). "Is individual metering socially sustainable? The case of multifamily housing in France" *Water Alternatives* 4(2): 223-244.

BBC (2007). Water metering plans put forward. 30 Jan. (http://news.bbc.co.uk/2/hi/uk_news/england/6314091.stm) accessed 1 Nov 2011.

CIEH (2008). *Water charging: a submission to the independent Review of Household Charging and Metering for Water and Sewerage Services*. The Chartered Institute of Environmental Health, London. (http://www.cieh.org/uploadedFiles/Core/Policy/CIEH_consultation_responses/Water_charging_review_Dec08.pdf) accessed 1 Nov 2011.

CCFW (2006). *Using Water Wisely: A deliberative consultation.* Commissioned by Consumer Council for Water. Opinion Leader, London.

Defra (2011). *Affordable water: a consultation on the Government's proposals following the Walker Review of Charging*. Department for Environment, Food and Rural Affairs, London. (http://www.defra.gov.uk/consult/files/110405-walker-consult-condoc.pdf) accessed 1 Nov 2011.

Doward, Jamie and Ledwith, Mario (2011). "Seasonal water metering is seen as a con by consumers, study finds." *The Guardian.*

EA (2006). *Underground, under threat - The state of groundwater in England and Wales*. Environment Agency, Bristol. (http://publications.environment-agency.gov.uk/pdf/GEHO0906BLDB-E-E.pdf) accessed 1 Nov 2011.

EA (2008). *Water resources in England and Wales - current state and future pressures*. Environment Agency, Bristol. (http://publications.environment-agency.gov.uk/PDF/GEHO1208BPAS-E-E.pdf) accessed 1 Nov 2011.

EA (2008a). *The costs & benefits of moving to full water metering. Science Report – SC070016/SR1 (WP2)*. Environment Agency, Bristol.

EA (2009). *Water for people and the environment Water Resources Strategy for England and Wales*. Environment Agency, Bristol. (http://publications.environment-agency.gov.uk/PDF/GEHO0309BPKX-E-E.pdf) accessed 1 Nov 2011.

EA (2009a). River Basin Management Plan, South East River Basin District Annex A: Current state of waters. Environment Agency, Bristol. (http://www.environment-agency.gov.uk/research/planning/33106.aspx) accessed 1 Nov 2011.

EA (2011). Water abstraction metering. Environment Agency, Bristol. (http://www.environment-agency.gov.uk/static/documents/Business/Abstraction_metering_briefing_220211.pdf) accessed 1 Nov 2011.

EA (undated A). *Water Situation for England and Wales* (http://tinyurl.com/EPI-UK1) accessed 1 Nov 2011.

EA (undated B). *Water abstraction* (http://tinyurl.com/EPI-UK2) accessed 1 Nov 2011.

EA (undated C). *Managing and protecting groundwater*. (http://tinyurl.com/EPI-UK3) accessed 1 Nov 2011.

Envirowise (2009). UK Businesses sitting on untapped cost saving of around £10million per day. Press release. (http://envirowise.wrap.org.uk/uk/Press-Office/Press-Releases/UK-Press-Releases/UK-Businesses-sitting-on-untapped-cost-saving-of-around-10million-per-day.html) accessed 10 Dec 2011.

IPCC (2010). *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties. Working paper. (http://www.ipcc-wg2.gov/meetings/CGCs/Uncertainties-GN_IPCCbrochure_lo.pdf) accessed 1 Nov 2011.

Jenkins (2006). "Water metering: In search of more critical debate." Working paper. Dept of Life Sciences. University of Hertfordshire, Hatfield.

MVA (2006), *Quantitative research to determine consumers' attitudes to water use and water conservation*. Report for Consumer Council for Water In Association With WRc. mvaconsultancy, Woking.

NAO (2007). *Ofwat – Meeting the demand for water*. ISBN: 9780102944181. National Audit Office, London.

Neuralmap (2010). population density England. (http://www.neuralmap.com/archives/population-density-england/) accessed 1 Nov 2011.

Ofwat (2004). *Measured/Unmeasured Tariff Differential: Conclusions. RD 02/04* (http://www.ofwat.gov.uk/regulating/charges/ltr_rd0204_measunmeastardif) accessed 1 Nov 2011.

Ofwat (2006). *Water metering: position paper*. Water Services Regulation Authority, Birmingham.

Ofwat (2009). *Metered/unmetered household tariff differential 2009-10*. Water Services Regulation Authority, Birmingham.

(www.ofwat.gov.uk/content?id=6f960438-5a8b-11de-9c48-61095c6650c6) accessed 1 Nov 2011.

Ofwat (2010). *Household water customers 2010-11*. Water Services Regulation Authority, Birmingham. (www.ofwat.gov.uk/regulating/reporting/rpt_tar_2010-11hhwatcust.xls) accessed 1 Nov 2011.

Ofwat (2010a). *Waste not, want not– making the best use of our water*. Water Services Regulation Authority, Birmingham. (http://www.ofwat.gov.uk/publications/focusreports/prs_inf_demand.pdf) accessed 1 Dec 2011.

Ofwat (2011). *Exploring the costs and benefits of faster, more systematic water metering in England and Wales*. Water Services Regulation Authority, Birmingham. (http://www.ofwat.gov.uk/future/customers/metering/pap_tec201110metering.pdf) accessed 1 Nov 2011.

Ofwat (2011a). *Push, pull, nudge – how can we help customers save water, energy and money?* Water Services Regulation Authority, Birmingham. (http://www.ofwat.gov.uk/publications/focusreports/prs_web1103pushpullnudge) accessed 25 Nov 2011.

Ofwat (undated). Water companies. Water Services Regulation Authority, Birmingham. (http://www.ofwat.gov.uk/industryoverview/today/watercompanies) accessed 1 Nov 2011.

Oliver, Pamela E. et al. (1985) "A Theory of the Critical Mass I: Interdependence, Group Heterogeneity and the Production of Collective Action." *American Journal of Sociology* 91(3): 522--556.

Staddon (2008). "Do water meters reduce domestic consumption? A summary of available literature." Working paper. Dept of Geography and Environmental Management, University of the West of England, Bristol.

Tsanga Tabi, M. (2011). Implementing human right to water in Europe: lessons from French and British experiences. CEMAGREF working paper.

Walker (2009). *The Independent Review of Charging for Household Water and Sewerage Services*. Department for Environment, Food and Rural Affairs, London. (http://www.defra.gov.uk/publications/files/pb13336-walker-water-review-091205.pdf) accessed 1 Nov 2011.

WFD (2000). Water Framework Directive, formally known as Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. (http://europa.eu/legislation_summaries/agriculture/environment/l28002b_en.htm) accessed 1 Nov 2011.

WIA (1999). Water Industry Act 1999. Office of Public sector Information. (http://www.water.org.uk/home/policy/positions/legislation) accessed 1 Nov 2011.

6 Annexes

Annex I: Abbreviations and glossary

LCD: Liters per capita per day

Optant A residential customer who opts to have a meter installed.

RV: Rateable value – based on the taxable value of a residence.

WIA91: Water Industry Act 1991

WIA99: Water Industry Act 1999; see WIA (1999)

WS: WaterSure – A program of reduced water and sewer charges for households on benefits who have three or more children or one sick child.

Annex II: Pedigree matrix

Table 5: Pedigree matrix for performance of metering with respect to targets (IPCC 2010)

	Environmental outcomes	Economic costs	Distributional effects
Target	reduce water stress	at low cost	without undue duress to the poor
Proxy	3	4	3
Empirical	3	3	3
Method	3	3	3

Source: Author estimations.

Annex III: Acknowledgments

This report is the result of discussions between all partners in the EPI consortium, with particular assistance from Carlos M. Gómez (IMDEA), Colin Green (MU), Jennifer Möller-Gulland (Ecologic), Davide Viaggi (UNIBO), and Christophe Viavattene (MU). We are especially grateful for the useful comments and corrections made by Paul Hope of Ofwat. The authors own the opinions and remaining errors in this paper.