A BLUEPRINT FOR

CARBON EMISSIONS REDUCTION

IN THE UK WATER INDUSTRY

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"A Blueprint for Carbon Emissions Reduction in the UK Water Industry" was written by Alastair Chisholm with support from the CIWEM Policy Team and members of CIWEM's technical panels and networks.

Who we are, and what we do

Working for the public benefit for a clean, green and sustainable world, CIWEM (The Chartered Institution of Water and Environmental Management) is the only independent, chartered professional body and registered charity with an integrated approach to environmental, social and cultural issues.

CIWEM:

- Supports thousands of members worldwide in nearly 100 countries
- Is a powerful evidence-based lobbying force in the UK and overseas
- Provides training and professional development opportunities
- Provides a forum for debate through conferences, events and publications
- Works with governments, international organisations, businesses, NGOs, the creative industries and faith groups for a holistic approach to environmental issues
- Develops partnerships with like minded organisations across the world
- Supplies independent advice to governments, academics, the media and the general public
- Brings members from all over the world together under common policy issues
- Inputs directly into European and UN policy development
- Promotes and celebrates excellence through a varied awards portfolio
- Is committed to improving its own environmental performance
- Is the first chartered professional body to have its Environmental Management System accredited to ISO14001 standard

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Executive summary

The UK water industry is a large consumer of energy and emitter of carbon, much of which is associated with the electricity it uses, though it also makes significant direct emissions. As an industry it is also well placed to become a significant generator of renewable energy, mostly through maximising the potential of biogas generation from wastewater biosolids (sewage sludge) through anaerobic digestion.

With the Climate Change Act requiring the UK to reduce its greenhouse gas emissions by 80% by 2050, the water industry, as with the rest of the UK economy, must make a contribution. **A range of factors are critical to considering how big a contribution the industry can make to decarbonisation and how quickly this might happen, including:**

- How far can currently employed processes and technologies be optimised for efficiency?
- How much can demand management measures be employed to reduce the amount of heavily treated water required to be put into supply?
- How much can 'soft engineering' and catchment scale measures contribute to reducing the requirement for energy intensive drinking and wastewater treatment?
- How can more extensive real-time monitoring reduce the need to over-treat wastewater and avoid the risk of failing to meet permit conditions?
- How much renewable energy might the industry be able to generate, in order to offset its consumption of centrally generated electricity?
- How supportive will policymakers and regulators be of water companies passing on the additional costs of decarbonisation to customers?
- How well set up is the industry to drive forward innovation at a sufficient pace to develop new technologies and ways of working, to meet the decarbonisation challenge?

This report considers these questions, amongst others, and offers an analysis of where the main opportunities for carbon emissions reduction lie for the industry. An accurate prediction of the extent and pace of decarbonisation is difficult as there is considerable variation in terms of these between companies and **the pace of change will be influenced considerably by factors such as energy prices, political will and regulatory incentivisation**.

There is widespread awareness of carbon emissions within the water industry, extending to both operational and embodied emissions. The extent of ambition to reduce these is growing and the most ambitious water companies are aspiring to carbon neutrality by 2050, delivered through a combination of energy efficiency, renewable energy generation and purchase of low-carbon grid electricity. **It is important that this ambition is underpinned by a more extensive research and development drive and the sharing of knowledge within the industry** to ensure that early innovation is brought to commercial reality as fast as possible.

There is significant scope for process optimisation to deliver further energy efficiency and therefore emissions savings, in addition to those which have already been secured. Innovations in treatment processes and network optimisation are ongoing, but would benefit from further research.

An important area of emissions reduction is associated with reducing the amount of highly treated water that is required to be put into supply. This will involve using less intensively treated water for purposes where it is not essential as well as improving water efficiency in both the domestic and non-domestic setting, together with educating consumers of the value of water and environmental impacts of profligate use. CIWEM considers that this drive should be underpinned by ambitious targets on average per capita consumption and near-universal metering.

From a policy and regulatory perspective, we are supportive of Ofwat's move to afford companies greater flexibility in how they meet their outcomes and there appears to be progress towards the industry and its regulators taking longer-term challenges into greater consideration.

We believe, however, that carbon emissions reduction should be more actively incentivised. We consider that, to this end, there is scope for a financial incentive mechanism to be worked into Ofwat's Future Price Limits work and believe that the industry could and should be working to reduce its carbon emissions by around 10% per AMP round, against an appropriate baseline. This will not be possible through reductions to the industry's direct emissions alone, thus reduction of indirect emissions, particularly those associated with electricity use, will play a key part.

The water industry is well aware of climate change and its associated challenges, both in terms of adaptation and mitigation. Carbon will become a key currency for the industry between now and 2050. Progress on reducing the carbon footprint of water should reflect the seriousness of these challenges.

Scope of this report

The UK water industry is examining how it will be able to contribute towards the emissions reductions targets established under the Climate Change Act (80% by 2050, 34% by 2020[1]). There are no clear targets of what emissions reductions it should be aiming for and by when. So, what will (and can) the industry's contribution be to the 80% target? Could it even become carbon neutral and can it achieve these changes before 2050?

The impacts of climate change, from droughts to floods, are significant to how the water industry maintains its security of supply and the operational performance of its infrastructure. It is also an energy intensive industry and is therefore exposed to the risks and uncertainties associated with future fossil fuel energy prices. However, it is well placed to hedge against these risks through considerable opportunities to generate its own energy from renewable sources. The Environment Agency[2] states: "*Climate change is a significant additional challenge. However, it may in fact facilitate the development and deployment of new infrastructure, technologies and management systems, which could contribute to the 2050 low-carbon target.*"

This report will examine the challenges and potential measures to achieve carbon emissions reductions and consider what barriers exist (e.g. institutional, regulatory, economic and technical) and how these might be overcome.

Whilst there is considerable opportunity for the water industry to engage with and assist consumers to reduce the energy (and hence emissions) associated with heating and other use of water (which accounts for some 89%[3] of carbon emissions associated with domestic water use), this report does not consider this in detail as the discussions relate far more to the respective roles that may be played by different utilities and other parties and how they will work together with customers to achieve this end. Instead, this report focuses squarely on direct, indirect and 'regulated scope 3' emissions which may be more immediately influenced by companies and how much these may be reduced.

[1] HM Government: Climate Change Act 2008. http://www.legislation.gov.uk/ukpga/2008/27/contents
[2] Environment Agency: Evidence – A Low Carbon Water Industry in 2050. December 2009
[3] Clark, Grant & Thornton. Quantifying the energy and carbon effects of water saving. Environment Agency, Energy Saving Trust, 2009.

1 An overview of the UK water industry and its carbon emissions

Introduction

The Climate Change Act 2008[4] is the first piece of national legislation to tackle climate change with legally binding carbon reduction targets to be introduced by any government in the world. It requires at least an 80% reduction in carbon emissions by 2050, against a 1990 baseline. Achieving this target will require all sectors of the economy and society to reduce their emissions, including the UK's water and sewerage and water-only companies. The targets are ambitious and will require significant ongoing policy and regulatory support in order to be achieved.

The Act contains an interim target of a reduction of at least 34% by 2020. Five-year carbon budgets are set by the Committee on Climate Change (CCC), with three consecutive budgets set at any one time. The present budgets cover 2008-12, 2013-17 and 2018-22. They are intended to ensure that an achievable trajectory towards the final target is maintained. The Government is required to report its policies to meet the budgets to Parliament and the CCC produces annual reports on progress against these, to which the Government must respond. The Government's Stern Review[5] and Carbon Plan[6] provide further drivers.

The water industry directly contributes around 1% of the UK's greenhouse gas (GHG) emissions. This was estimated at 5 million tonnes of greenhouse gases in 2006/7[7]. It is the fourth most energy intensive industry in the UK[8], yet no official emissions reduction targets exist for the water industry. Some water companies have set themselves aspirational targets (Wessex Water has, for example, set itself a target of carbon neutrality across its combined activities[9]). The Carbon Plan[10] proposes that industrial processes, of which the water industry is considered part, might reduce their emissions by 25%, collectively, by 2027 compared to 2008 levels.

A significant proportion of carbon emissions are associated with heating water in the home – between 4 and 5% of the UK's emissions, depending on the source of data. Whilst the carbon implications associated with water heating are very relevant to national decarbonisation, they are out of the direct control of water industry and its regulator, and closely concerned with general domestic energy efficiency. This issue is therefore not covered in any detail within this report although it is recognised that the industry will have a key future role to play in reducing such emissions through helping to reduce per capita consumption of water as well as providing efficiency advice to customers. Other parties will play a role e.g. The Energy Saving Trust, energy utilities and central Government through initiatives such as the Green Deal. This report will instead focus on the more direct emissions by water companies, associated with both their operational and embedded emissions.

[4] http://www.legislation.gov.uk/ukpga/2008/27/contents
[5] HM Treasury and Cabinet Office: Stern Review on the Economics of Climate Change. 2006
[6] Department of Energy & Climate Change: The Carbon Plan: Delivering our low carbon future. December 2011
[7] Environment Agency. The greenhouse gas implications of future water resources options – A briefing note.
[8] Council for Science and Technology. Improving innovation in the water industry: 21st Century challenges and opportunities. March 2009
[9] Wessex Water: Water – the way ahead 2015-2040. Wessex Water's long-term strategy. 2012
[10] HM Government: Carbon Plan: Delivering our low carbon future (Annex B), December 2011

Understanding water company emissions

The key purpose of the UK water industry is to deliver safe drinking water and provide effective wastewater management through the management of a natural cycle, the water cycle, for human and environmental needs. To do this, the industry draws on other resources, notably in construction materials but predominantly energy[11].

The extent to which carbon emissions are measured and subsequently managed within water companies varies quite widely despite the fact that a number have been monitoring carbon since the mid-1990s and the commonly used Carbon Accounting Workbook (CAW) software[12] is now on its third revision. The CAW is used across the industry providing a tool for a standardised approach to carbon accounting and reporting. It has been used since 2008 to assist in reporting operational carbon emissions to Ofwat.

Broadly speaking, carbon emissions from the water industry are (with the exception of fugitive emissions from sludge processing and disposal) largely associated with grid electricity use. This is consumed by a relatively small number of key processes:

- Treating water to a potable standard
- Pumping water around the supply network
- Pumping wastewater (where required) around the sewer network
- Treating wastewater to a standard appropriate for discharge to receiving waters.

In other words, the treatment and pumping of water are the industry's carbon emission culprits. The key reasons for this are that water is a heavy medium to move around and modern methods of water treatment, whilst highly effective, are energy intensive. According to UKWIR[13], on the drinking water supply side of the industry, it is estimated that 65% of energy consumption derives from distribution with only 10% from treatment. On the sewerage side, 60% of energy consumption is associated with treatment, with the remainder attributable to sewerage pumping (25%) and disposal (15%). Typical areas of energy use and carbon emissions are shown in Figure 1.

With increased environmental regulation and higher water quality standards in recent decades, treatment processes have become more high-tech and complex, often with a corresponding rise in energy consumption. Energy use by water companies has risen markedly in the past 20 years, although the rate of increase has slowed over the past decade. Many water company carbon mitigation strategies only stem this increase, rather than reverse it.

Many new treatment processes are sold on the basis of small physical footprint and low capital cost. However, these can often have a high energy usage and therefore in the long term are higher carbon solutions. In comparison, many of the older treatment processes both in water and wastewater treatment are less intensive, with a larger footprint and higher capital cost, but have lower energy requirements. As civil construction has a life in excess of 25 years and mechanical and electrical equipment of 15 years compared to electronic control systems of 5-10 years, it may be that less intensive and manually controlled processes may in fact represent more sustainable solutions, even when their embodied carbon is considered.

The drivers for carbon-intensive treatment are likely to continue in the short to medium term, e.g. with the requirements of European directives such as the Water Framework Directive

[11] Grant et al. Regulation for a Sustainable Water Industry – A positive vision for the future water industry in England and Wales. CIWEM, September 2010

[12] UKWIR. Workbook for Estimating Operational GHG Emissions. 2009

[13] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.

placing increasingly stringent requirements on effluent discharge standards. Opportunities for energy consumption reductions on the operational side are therefore likely to be centred on changes to the carbon intensity of grid-derived electricity, combined with increasing use of on-site renewable energy generation and process optimisation.

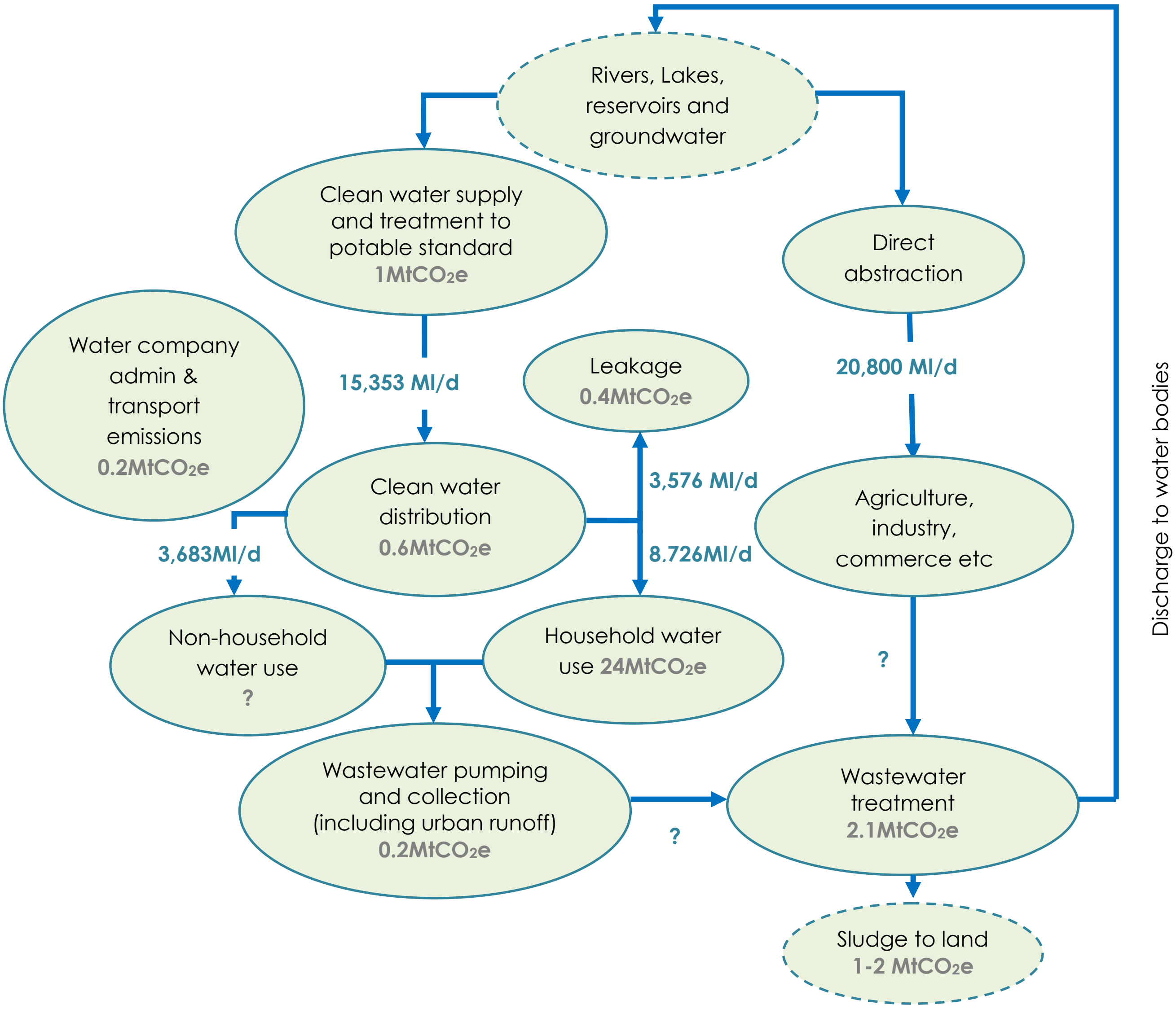

Figure 1: GHG emissions as million tonnes carbon dioxide equivalents[14]

GHG emissions as million tonnes carbon dioxide equivalents, $MtCO_2e$
Water flow figures for 2005/06 in million litres per day, Ml/d (Ofwat)

As the focus on water company emissions intensifies, there is a growing discussion of the unintended emissions implications of some environmental drivers. There is a need for greater innovation and a more holistic approach to managing water to enable the needs of the local and global environments to be met. This is increasingly being recognised by the industry and its economic regulator, Ofwat.

[14] Defra. Future Water – The Government's water strategy for England. February 2008

Economic regulation

In England and Wales price limits are set for five-year periods by the independent economic regulator for water, Ofwat. This process is known as the Periodic Review of Prices. Prices were set most recently in 2009 for 2010-15 (PR09).

Following a price review, the resulting five-year investment programme is known as an Asset Management Plan, or AMP and includes the National Environment Programme that has been drawn up by the Environment Agency. AMP5 refers to the investment period for 2010-2015 – the fifth such period since privatisation of the industry. AMP4 was the preceding period of 2005-2010.

The aim of price reviews is to ensure that customer water bill prices are kept at a reasonable (minimum) level, at the same time allowing for companies to make an adequate return on their capital investment. Ofwat sets its price frameworks on a company-by-company basis, reflecting their business plans and projected revenues and determines a maximum level above which prices may not rise. Ofwat monitors the water companies' efficiency across a wide range of categories e.g. the capability of the network, environmental non-compliances etc, then informs the company whether it is allowed to increase its charges and if so, up to what point. Ofwat balances the level of risk and price it considers acceptable for customers. How a company performed in AMP4 will affect their budget in AMP5.

In previous planning rounds, priorities for Ofwat have included water company levels of service, leakage reduction and other heavily capital expenditure-focused outcomes. Marked improvements in such areas as well as increasing recognition of the role of water companies as managers of the water environment, has seen the focus change somewhat, with a greater emphasis on more holistic, sustainable solutions.

In Scotland, the Quality & Standards (Q&S) planning process defines the investment requirements for Scottish Water. It is an iterative process comprising:

- Ministerial Objectives – summarised in Directions to Scottish Water, setting out specific high level targets to be achieved;
- Business Plan – produced by Scottish Water costing out requirements for the period
- Price Determination – produced by the Water Industry Commission for Scotland
- Technical Expression – a list of projects agreed with Scottish Water

The upcoming investment period is Q&S4 (2015-2027). The current investment period, Q&S3 runs from 2006-2014.

Water resource planning

In addition to the plans required for economic regulation, water companies must also prepare Water Resources Management Plans (WRMPs) with a 25 year planning horizon and submit them to the Environment Agency. A new plan must be produced every five years and they must be reviewed each year in case of change. These set out how companies will manage their water supply and demand balance and have a significant bearing on any future investment that may be required on the resource side, such as development of a new resource or transfer scheme. These plans will therefore have an impact on the carbon emissions of a company. The next round of WRMPs are published in 2014.

Strategic planning

In response to the rather short term nature of economic regulation, compared to the far more strategic approach to Water Resources Planning, Ofwat now (as of 2009) requires water companies to prepare Strategic Direction Statements which look forward at least 25 years. These statements are intended to provide a strategic basis upon which water company business plans are based. It is here that many of the aspirations and principles are established for water companies to reduce their carbon emissions.

A key driver for this appreciation was the growing understanding of the nature and extent of carbon emissions throughout the industry. The ultimate destination is likely to be a water industry that is increasingly positioned as an environmental manager as well as a water services provider.

Other drivers for carbon reduction include the requirement of companies utilising more than 6000MWh of electricity to utilise the CRC Energy Efficiency Scheme (CRC) and to purchase sufficient allowances to cover their annual CO_2 emissions.

The scale and nature of emissions

The emissions from the water industry (consisting of 23 water and sewerage, or water-only companies in the UK) may be broadly divided as two-thirds derived from the operational energy use associated with treatment and pumping of drinking and wastewater (between 65% and 99% of which is attributed to use of grid electricity) with the remaining one-third associated with the embodied carbon emissions relating to infrastructure maintenance and construction.

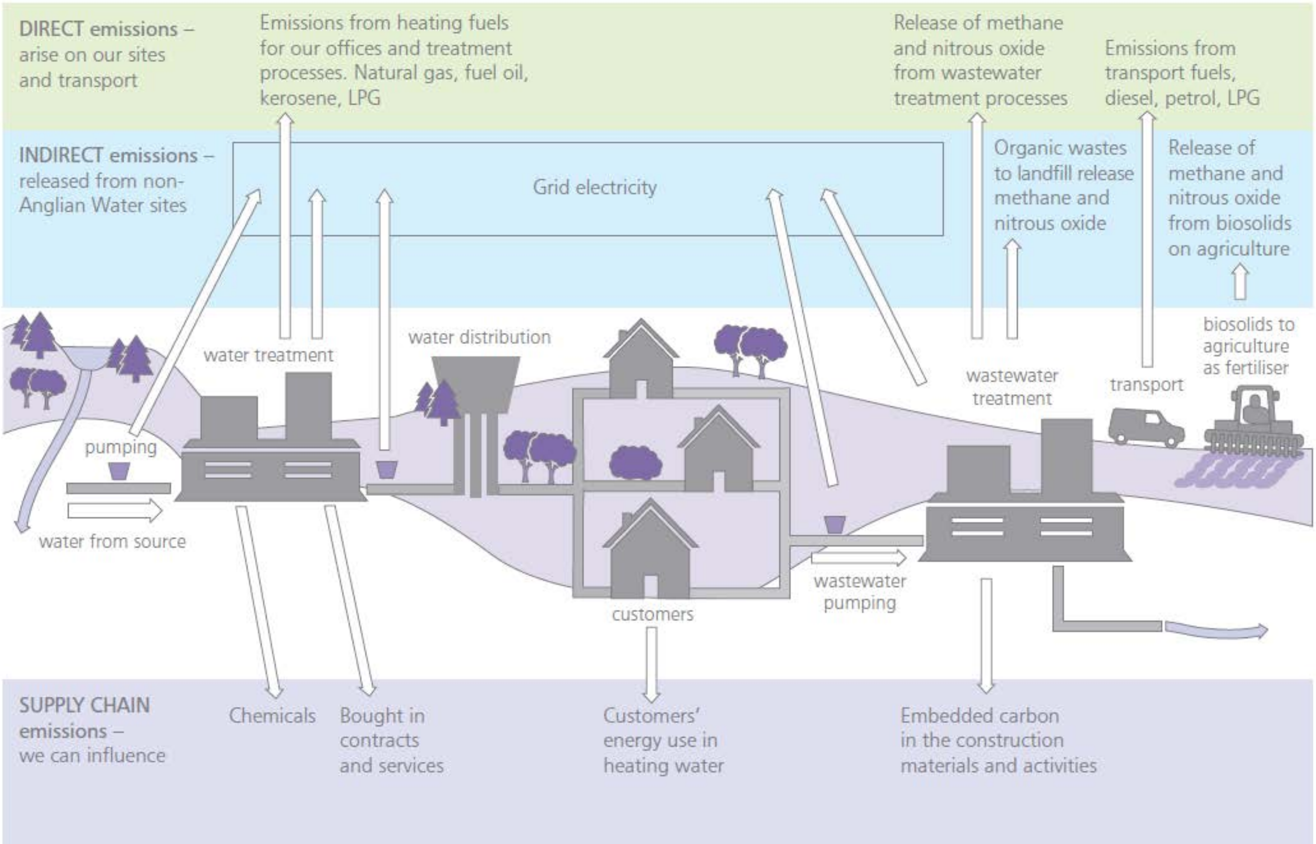

Figure 2: Sources of water and sewerage company CO_2 emissions[15]

Figure 2 illustrates typical sources of emissions for a water and sewerage company. This shows that many of the industry's emissions result from indirect use. This does not mean that indirect emissions cannot be reduced by direct improvement to design, technologies or operational practice, indeed some indirect emissions may be more easily reduced than those that are classified as direct. Table 1 shows how Ofwat classifies emissions and whether or not they are

[15] Anglian Water: Strategic direction statement 2010-2035. 2009

regulated and accounted for. This report will focus primarily on Scope 1, Scope 2 and Regulated Scope 3 emissions as well as embodied carbon.

Emissions are categorised by Ofwat into direct, indirect and supply chain-centric categories as follows (table 1):

Scope 1: Direct emissions	• Emissions from transport owned or leased • Emissions from the companies' own fossil fuel use, e.g. natural gas, kerosene • Methane and nitrous oxide from sewage treatment
Scope 2: Indirect emissions	• Grid electricity used for pumping and treatment of water and sewage • Grid electricity used in owned buildings
Regulated Scope 3: Indirect emissions which are accounted for	• Emissions from contractors and outsourced services • Business-associated transport, on public transport or in private vehicles
Non-regulated Scope 3: Indirect emissions which are not accounted for	• Chemical manufacture • Embedded emissions – from construction and manufacturing activity • Customers' energy use to heat water • Release of methane and nitrous oxide from sludge disposed to landfill and agriculture

Table 1: Categorisation of emissions. Source: Ofwat, 2010[16]

Variations between companies may be a result of a range of factors, according to Ofwat[17], which include:

- Companies' greenhouse gas mitigation and energy efficiency efforts;
- Geography (predominantly pumping head);
- Network configuration; and
- Discharge consents placed on sewage works (potentially requiring differing levels of energy intensive treatments).

These variations aside, as an example of the breakdown of emissions within a water and sewerage company, Anglian Water detail where its emissions occurred in 2006/7, as shown in Table 2. This illustrates that by far the greatest energy use and therefore carbon emissions occur as a result of 'indirect' emissions associated with purchased electricity and greenhouse gas emissions that occur from the application of sewage sludge to land (much of which will be methane, a very potent greenhouse gas, the management of which has to be considered very much in the round because there are very significant nutrient recycling benefits associated with recycling of sludge to land).

Table 42 of the June Return (the submission of which to Ofwat ceased to be required as a regulatory tool in 2011) detailed operational carbon emissions under a range of different categories. These were scope 1, 2 and 3 emissions, as detailed in Table 1, not including those scope 3 emissions 'not accounted for'. It also included data for operational emissions intensity ($kgCO_2e/Ml$ for both water treated and sewage treated) as well as renewable energy generated and provided useful detail on how the water and sewerage companies were already able to generate almost a third of the energy they use operationally, from renewables (almost exclusively electricity generated from sludge processing).

[16] OFWAT: Playing our part – reducing greenhouse gas emissions in the water and sewerage sectors Supporting information. July 2010
[17] OFWAT: Service and delivery – performance of the water companies in England and Wales 2009-10 report Supporting information. 2010

Emission type	CO_2 equivalents (tonnes)	Category
Transport emissions	16,000	Direct
Wastewater process emissions	11,000	Direct
Fuels used at operational sites	10,000	Direct
Sludge treatment process emissions	6,000	Direct
Self-generated renewable electricity	0	Direct
Purchased electricity	253,000	Indirect
Sludge to land emissions	160,000	Indirect
Water sludges to land	2,000	Indirect
Wastewater grit and screenings to landfill	1,000	Indirect
Purchased green electricity	0	Indirect
Total	459,000	

Table 2: Carbon footprint by emission type 2006/7, Anglian Water [18]

Clearly, the decarbonisation of the UK's centralised electricity supply[19] will have a very significant impact upon the water industry's emissions profile. This is likely to have taken place to quite a large extent by 2050, however it should not be relied upon as an entire solution and other measures need to be put in place by water companies to reduce their own emissions, particularly where these relate to emissions other than those derived from electricity use. Ofwat has stated that the industry should not present use of zero-carbon grid electricity as part of its own decarbonisation as such emissions are indirect: *"Purchasing 'greener' energy...is less preferable than reducing emissions directly. This is because the responsibility (and hence benefit) for those reductions really belongs to another organisation. For this reason, reporting requirements do not usually allow the companies to present a reduction in their emissions associated with these types of 'indirect' mitigation."*[20]

Despite this, given the level of electricity consumption by the water industry, an 80% reduction in emissions associated with its activities will simply not be possible without use of low or zero carbon electricity and the contribution that this makes to the overall level of decarbonisation will need to be recognised.

Reducing emissions

Section 2 of this report will look in greater detail at the range of options open to the industry to move along a low-carbon path. An indication of where these other opportunities lie may be illustrated by the following measures identified in Anglian Water's Strategic Direction Statement[21]:

[18] Anglian Water: Strategic direction statement 2010-2035. 2009

[19] HM Government: The Carbon Plan: Delivering our low carbon future. December 2011

[20] OFWAT. Playing our part – reducing greenhouse gas emissions in the water and sewerage sectors. Supporting information. July 2010

[21] Anglian Water: Strategic direction statement 2010-2035. 2009

To reduce our emissions we will:

- Invest in cost-effective renewable power generation and purchase green energy to cover around 75% of our electricity requirement.
- Take full part in the new Carbon Reduction Commitment.
- Work with our customers and suppliers to influence their emissions.
- Reduce water use and increase meter penetration.
- Reduce business mileage.
- Invest in low carbon innovation and technologies.
- Inspire our employees to reduce emissions.

Ofwat's new approach to regulation – a more risk-based and self-regulation principle, now places the onus on water companies to monitor and manage carbon themselves, reporting to Ofwat only using indicators, as shown in Table 3.

Definition of Measure	Measurement of the annual operational GHG emissions of the regulated business.
Obligation	Statutory reporting may be introduced as within the director's report under section 416(4) Companies Act 2006 – section 85 Climate Change Act 2008 requires Defra to introduce regulations or explain by 6 April 2012.
Calculation	Companies report their annual operational net GHG emissions as determined by Defra's 'Guidance on how to measure and report your greenhouse gas emissions' (September 2009). This includes: • only emissions from the regulated business; • only operational emissions; • scope 1 operational emissions that are within the direct management responsibility of the company; • all scope 2 operational emissions; and • scope 3 operational emissions that are within the direct management responsibility of the company.
Target	Companies effectively manage their GHG emissions so that they can deliver their core services in a low-carbon way and to play their part in reducing national GHG emissions where it is economic to do so and in customers' interest.
Frequency	Annually

Table 3: Greenhouse gas emissions environmental impact indicator (Ofwat guidance)[22]

Monitoring and reporting of carbon emissions is of great importance because it facilitates the understanding within companies of their emissions profiles and where the opportunities for reductions lie.

Ofwat requires the carbon emissions of investment options submitted as part of the asset management planning process to be considered as part of the cost-benefit analysis. This requirement was put in place for the PR09 (2009) round of planning: "*companies should investigate all costs and all benefits, including the impacts on society and the environment, of all new investment decisions. A key part of this methodology requires each company to include the shadow price of carbon* [now the non-traded price of carbon] *to take into account the future damage climate change may cause...Each company should understand and expose the whole-life carbon implications of its investment decisions through applying cost-benefit analysis (CBA) in the 2009 price review.*"[23]

Similar toolkits to the CAW have been developed to assist companies in identifying cost effective carbon abatement measures and factoring carbon into cost benefit analysis for

[22] OFWAT. Key performance indicators guidance. March 2012
[23] OFWAT. Preparing for the future – Ofwat's climate change policy statement, 2008

new capital expenditure schemes. After manpower costs, the cost of energy represents the highest operating cost for the industry. It is likely that in the medium to long term, energy costs are only likely to increase so there is a direct benefit to the industry to increase its energy efficiency, which will of course translate to carbon emissions reductions.

Water companies are also required to follow the guidance set out by Defra in its Statement of Obligations[24], which constitute the clearest policy guidance on the issue to water companies: *"Water companies are expected to plan for mitigating and adapting to the impacts of climate change over the next decades... Energy consumption, reducing process emissions and transport efficiency should be considered alongside other aspects of sustainable development in delivering any particular outcome."*

Whilst Ofwat may be moving away from explicit policy requirements of water companies, Defra has this remit and it is incumbent upon water companies to comply with its guidance, as well as incumbent upon Ofwat to approve schemes which feature measures to meet this guidance, provided they can be delivered efficiently and they are in the interests of customers.

Operational and embodied carbon

Much of the 'visible' emissions associated with the water industry relate to operational activities and these form the bulk of emissions from the industry. However, there is growing recognition of the need to consider embodied carbon emissions. Embodied carbon emissions are those associated with initial construction of an asset, coupled with those from asset maintenance and renewal. Combining these with operational emissions allows calculation of whole life carbon cost.

In the regulated water and sewerage sectors, embodied carbon is significant due to their large capital maintenance and construction programmes. Data from the last price review indicates that embodied emissions add another 50% on top of companies' operational emissions. Whilst operational carbon has, to a greater or lesser extent, featured in the mindsets of Water Companies and Ofwat over the last two decades, understanding of embodied carbon is a relatively recent development, with companies only really considering it in any detail since the last price review. Experience of companies including Wessex Water and Anglian Water has indicated that whilst opportunities for reducing operational carbon may be quite limited, there may be some significant gains to be made on the embodied side.

In the case of Anglian Water, these savings have been identified through more detailed consideration and prioritisation of embodied carbon reduction within the design stage of new schemes, combined with active engagement of the supply chain to in turn reduce its own embodied carbon. Anglian Water has set targets for operational carbon reduction of 10% by 2015 against a 2010 emissions baseline. The target for embodied carbon emissions, however, is 50% by 2015. It has also been found that capital expenditure (CapEx) schemes with low embodied emissions are commonly cheaper than more traditional solutions. This runs counter to the conventional wisdom expressed by water companies during PR09. However there is growing evidence that companies can both reduce their embodied carbon whilst at the same time also reduce their costs, though this requires a concerted and innovative effort.

There is a need to consider embodied and operational carbon on a whole life basis, so as to ensure that those solutions with lower embodied carbon do not involve more energy and carbon intensive operations which offset the savings made in construction. This fits well with

[24] Defra. Statement of Obligations: Information for Water and Sewerage Undertakers and Regulators on Statutory Environmental and Drinking Water Provisions Applicable to the Water Sector in England, October 2012

the principle that Ofwat is pursuing, of a move to consider the whole life cost and total expenditure (TotEx) as opposed to separate consideration of CapEx and OpEx).

The clear message emerging is that carbon abatement is now not too high a price to pay and the general principle is that a solution which uses less natural resources is likely to involve less embodied emissions, for obvious reasons. There is less experience within the industry of accurately accounting for embodied emissions, although the accuracy is improving. As with operational carbon, there are tools for doing so, within the suite offered by UKWIR[25].

Economics of carbon mitigation measures

As the price of fossil fuel energy rises over the period to 2050 (as is widely projected, to differing extents across a range of scenarios)[26], the more attractive low carbon solutions across the water industry will become. This driver is likely to be supported by greater use of fiscal incentives, in particular an increasing price attached to carbon emissions which the UK Government[27] predicts could rise to between £106 and £318/tCO_2 by 2050, with its central scenario price at £212/tCO_2. The CCC considers that the price of carbon could rise as high as £500/CO_2 by 2050[28]. With generators passing these additional costs on to consumers, there is likely to be a large incentive to decarbonise an industry particularly reliant on electricity for its operations. There will be a point at which the price of energy and carbon will shift the balance of whole life cost assessments to OpEx-driven rather than CapEx-driven decisions and this is likely to underpin a carbon reduction initiative.

Whilst the emissions associated with electricity use across the industry are 'indirect', the logistical realities of water company operations, with infrastructure spread across the country, mean that connection to grid electricity is essential in most, if not all, situations and high indirect emissions cannot be avoided.

There should, of course, be a strong emphasis on the water industry reducing its direct emissions; but ultimately, given the proportion of water industry emissions associated with grid electricity, the economics of carbon reduction, particularly on the operational side, are inextricably linked to the cost of electricity derived from high or low carbon sources. There is a strong rationale behind recognising the benefits of making best use of low-carbon electricity. As the CCC states; *"There is a very extensive evidence base which shows that economy-wide decarbonisation costs are minimised through early power sector decarbonisation"*[29].

Historically, schemes which sought to minimise carbon emissions were considered prohibitively expensive, however given the strong link between energy consumption and carbon emissions and the significant increases in energy prices over recent years, more energy efficient schemes, as well as those with lower embodied carbon, are increasingly seen to be considerably cheaper than more conventional options. Anglian Water, for example, have achieved considerable cost savings through placing an overt emphasis on carbon reduction from the early design stage[30,31].

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[25] UKWIR - A Framework for Accounting for Embodied Carbon in Water Industry Assets. 2012
[26] Committee on Climate Change. Next steps on electricity market reform – securing the benefits of low carbon investment. May 2013
[27] DECC. A brief guide to the UK carbon valuation methodology for UK policy appraisal. October 2011
[28] Committee on Climate Change. Next steps on electricity market reform – securing the benefits of low carbon investment. May 2013
[29] Ibid
[30] Riley & Stronati. Innovative change driving lower carbon and cost solutions in a collaborative organisation. Water Regulation conference, CIWEM, November 2012
[31] Riley, D. Carbon Management in the water industry. Climate Change in the water sector. CIWEM, November 2011

Figure 3 illustrates, from work undertaken by MWH on marginal abatement costs of a range of technologies employed by the industry, that many of them deliver effective carbon reduction for a relatively low cost. Improvements such as pump efficiency and aeration upgrades appear attractive measures, for example. The acceptability of these costs will be determined by comparison against the non-traded price of carbon and will thus become more attractive as this rises.

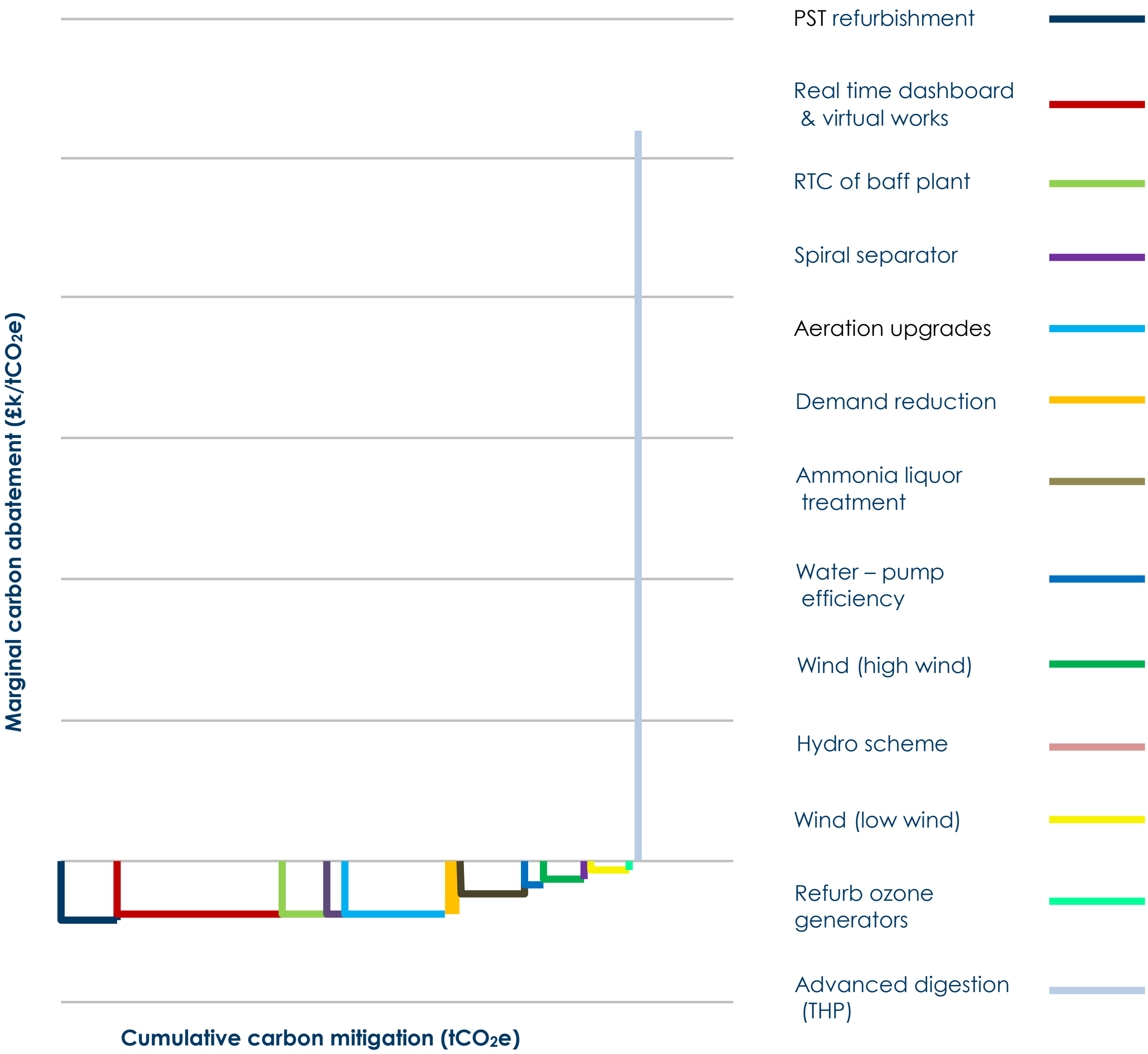

Figure 3. Indicative marginal abatement costs for carbon mitigation options for the water industry, useful for comparing the costs and benefits of options.[32]

Clearly a detailed and committed approach to carbon reduction can deliver results as well as cost savings. This is reliant upon proper embedding of environmental economics into cost assessments, which will be of collective benefit to the industry with companies sharing their experience in relation to this.

[32] Horton, B. Environmental economics in the UK water sector: Development and prospects. CIWEM Conference Water and Environment, April 2013

2 Opportunities for carbon emissions reduction

There is a wide range of improvement, often relating to energy efficiency, which may be instigated (where feasible) across the breadth of water company operations. Depending on factors which differ company to company, these may be applied to varying degrees, but as a broad principle, in common with many industrial processes, beneficial change can be made to a greater or lesser extent on most elements of operation.

The majority of examples and data in this section are taken from the UKWIR report "Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies", 2010[33]. The discussion has been broken up to apply, broadly, to opportunities concerning:

Water resources

Abstraction

Pumping associated with abstraction could be reduced if it were better controlled, using pumps more closely optimised to the required need. However total savings are likely to be small relative to other areas and actions.

Pressure on ecology within water courses from abstraction, assessed by the Environment Agency under the Water Framework Directive, is likely to be an increasing consideration for water companies. During times of low flow, the requirement to mitigate these impacts may require the creation of alternative resource options to account for the need to reduce abstraction to more sustainable levels. Severn Trent, for example, has identified the creation of compensation boreholes close to affected water courses but notes the carbon impact of such schemes. This is an example of local environmental quality measures potentially contradicting broader environmental aims implicit in carbon emissions reduction.

For this reason, it is unlikely that there are many carbon emissions reductions to be achieved associated with abstraction, other than the overall process of putting less water into supply.

Rainwater harvesting

Existing residential Rainwater Harvesting Systems (RWH) are considered by the Environment Agency to be: *"more energy and carbon intensive than alternative water supply and efficiency measures"*[34,35].

On-going research and recent technological innovations in the RWH industry have seen a series of no energy / low energy systems patented. Studies are now underway to quantify the lifecycle costs including CO_2e footprints. Consequently, it is considered likely that low carbon RWH should be widely available within 5-10 years.

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[33] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.
[34] Environment Agency. The use of rainwater harvesting systems: position statement. May 2011
[35] Environment Agency. Energy and carbon implications of rainwater harvesting and greywater recycling. August 2010

Full-scale uptake of these technologies (through new developments and retrofitting) could see significant reductions in the need for potable water delivery by water companies. Memon & Butler (2006)[36], have illustrated that RWH could provide approximately 30% of residential water needs; the typical quantity used in WC's. Furthermore, where roof area and householder perceptions allow, an additional 20% could be saved using rain water in washing machines.

It can therefore be suggested that the wide scale introduction of zero/low CO_2e RWH could see up to 50% savings in the CO_2e footprint required for the operation of potable water networks. More realistic, perhaps, is a scenario in which a reduction in potable water usage of somewhere up to 20% could be envisaged over a 20 year horizon.

Demand management (including metering and smart metering)

Defra has set an average water consumption target of 130 litres per person per day (l/h/d) by 2030, which equates to a little over 1 l/h/d/year in improvement between now and 2030. In some parts of the country, consumption is already below this level, but in others it is still considerably above[37]. The national average is roughly 150 l/h/d[38]. A reduction of average household consumption to 130 l/h/d would result in less water being required to be put into supply and hence deliver an associated carbon saving. It would be desirable to improve consumption widely below this target level; levels in many other EU countries are already at or below this level, some of them considerably (e.g. Germany 121 l/h/d[39] and Belgium 106 l/h/d[40]) so there should be potential to reduce average consumption levels significantly further.

The Code for Sustainable Homes (CSH)[41] sets out average water consumption levels per proposed occupant in new build houses, with a range of 120 l/h/d for Level 1, to 80l/h/d or less for the highest levels (5 and 6). Whilst not statutory, the Code does effectively inform the direction of travel for Building Regulations. Whilst these drivers will not affect existing building stock, the savings are likely to be widely achievable through retrofitting water efficient appliances and fittings.

With developments in water efficient appliances and fittings, water usage and the associated carbon footprints can continue to fall. Options such as the ultra-low flush toilet, could, if widely accepted and implemented, reduce water and energy costs in typical UK properties by around 80%[42]. Public perceptions and market availability remain the key aspects holding back wide scale installation of such options.

The effectiveness of demand management measures will rely heavily on public awareness, education and incentivisation in order to impact on consumer behaviour. Labelling schemes, such as The Water Label[43] would be more effective if made mandatory and minimum water efficiency standards for appliances could be more aggressively encouraged through Building Regulations, in line with higher levels of the CSH. Opportunities for encouraging demand management improvements may be more likely to be taken forward at key times such as on installation of a water meter, change of ownership or on improvement of other areas of a household.

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[36] Memon F. A., Butler D. (2006) Water consumption trends and demand forecasting techniques, *Water Demand Management*, IWA Publishing (2006), pp. 1–26
[37] Defra. Water White Paper: Water for Life. December 2011
[38] http://www.environment-agency.gov.uk/homeandleisure/beinggreen/117266.aspx
[39] https://www.destatis.de/EN/FactsFigures/NationalEconomyEnvironment/Environment/EnvironmentalSurveys/WaterSupplyIndustry/Tables/RateConnectionWaterSupply1991_2010.html
[40] Belgaqua. Livre Bleu. 2005
[41] Department of Communities and Local Government. Code for Sustainable Homes Technical Guide. November 2010.
[42] Memon F. A., Butler D. (2006) Water consumption trends and demand forecasting techniques, *Water Demand Management*, IWA Publishing (2006), pp. 1–26
[43] http://www.water-efficiencylabel.org.uk/home.asp

It should be noted that demand management should not be limited to the domestic setting and non-household water use efficiency could also be more actively encouraged. Much more could be achieved through the Building Regulations. Similar principles to those encouraged via the CSH could be applied to all new or renovated buildings, with non-household users, including heavy industries and energy generators, required to demonstrate that they are fitting and using up to date water efficient systems.

Metering rollout and becoming smart

Central to effective demand management measures is the rapid increase in deployment of water metering. In the context of this report, the ultimate aim of metering is to assist in reducing the amount of potable water put into supply to achieve a carbon saving on the associated treatment and pumping. Further very significant energy and carbon saving could be made through improved awareness and use of hot water in the home. The point must be made that a key method of tackling this water-energy nexus would be through the effective utilisation of smart meters.

The effectiveness of metering as a demand management measure and incentive for improved levels of water use efficiency is well understood and demonstrated. Commonly, average savings on consumption upon fitting of a water meter to a domestic property may be in the region of 15% and 20% on peak levels of use. This is without the use of innovative tariffs, which represent the logical next step for incentivising efficient use of water and discouraging more profligate levels of use, or smart metering.

The Water White Paper[44] states the Government's policy on water metering as that, given varied costs and benefits of metering across the country and company to company, the water companies themselves should determine the "*appropriate local solution in discussion with their customers*", which hardly constitutes a strong signal for water efficiency. It is similarly weak on smart metering, stating that it is "*interested in the potential*" for smart meters to improve network and demand management, but that it again looked to the companies themselves to demonstrate the business case for smart meters, together with their customers. The House of Commons Environment, Food and Rural Affairs Committee[45] described this level of commitment as "*disappointingly weak*" and recommended that metering penetration should reach 80% by 2020, in line with the Walker Review[46].

Widespread metering will allow a far more sophisticated understanding of water use by the user and enable the optimisation of demand management measures such as variable tariffs to ensure best outcomes. A further driver is the need to understand network leakage in more detail, including the identification of customer water supply pipe leaks inside the property boundary (when meters are located at the boundary, which is the most common location and is expected to continue as such). Additionally, charging by volume of water used is commonly appreciated as the fairest method of charging for water, as with other utility services such as gas and electricity.

Under current water company plans, by 2015 half of all homes in England and Wales should be metered, but it is increasingly recognised that near-universal metering will be required if pressures on water supply in the long-term are to be effectively managed. This applies both in terms of management of the resource and also understanding in a clear way the nexus that exists between energy and water use, particularly in the domestic setting. Large-scale, street-by-street installation of meters, rather than a piecemeal approach, is the more efficient way of rolling out widespread metering. It is likely that an increasing number of

[44] Defra. Water White Paper: Water for Life. December 2011
[45] House of Commons EFRA Committee: The Water White Paper. Second report of Session 2012-13. June 2012
[46] Walker, A. The independent review of charging for household water and sewerage services. Final report. Defra, 2009

water companies will seek to take this approach provided they can convince their customer base of the benefits.

The roll-out of smart water meter technology is considered to be some way behind the timescale envisaged for energy meters (2012-2019). Discussion about possible 'piggy-backing' and economies of scale in combined (as far as possible) installation have, in the water context, focused on ensuring that the communications infrastructure is put in place so that smart water meters could connect to the same in-home displays which display energy consumption and use energy utilities' communications infrastructure for the purposes of remote reading (this would allow the use of more complex seasonal or emergency tariffs which require more regular reading).

The benefits of smart meters to water companies lie mainly in their ability to be read remotely and provide more detailed data on usage patterns, leakage and so on. They would facilitate the refinement of demand management options, appropriate to customer usage and deliver the greatest potential for ultimately putting less water into supply whilst still meeting need. In other words, smart meters would refine and improve on the benefits of conventional or so-called 'dumb' meters.

The costs and benefits of smart metering and the evidence requirements required to support the business case for smart metering are being considered by the Ofwat Smart Metering Advisory Group (SMAG) – set up after the Walker Review – which includes the water companies, Defra, DECC, Environment Agency, CCWater, Energy Saving Trust and other interested stakeholders. Trials have been undertaken to test the effectiveness of remote, automatic meter reading communications networks by companies such as Thames Water.

A trial by Wessex Water[47] indicated that arguably the greatest benefit of smart metering was achieved in relation to remote leak detection and reduction of customer supply pipe leaks, as opposed to the real-time visualisation of consumption by the user. Certainly the benefits of in-house displays were doubted and thinking pointed towards the use of existing devices i.e. smart phones, tablets and personal computers for the relaying of consumption data to the customer.

Smart metering is already more commonly available for business consumers who have a particular need to pay detailed attention to their consumption but there has as yet been insufficient evidence presented to Ofwat for smart water metering to become a priority action. Despite this, it would seem counter-intuitive to achieve widespread installation of dumb meters over the next decade, only to replace them with smart equivalents over the course of the next.

According to Parsons et al, "Savings of up to 10% should be achievable by 2020 and at least 20% by 2050."[48]

[47] Wessex Water. Towards Sustainable Water Charging. Conclusions from Wessex Water's trial of alternative charging structures and smart metering. 2012

[48] Parsons et al. Policy brief on carbon sensitive urban water futures. Trust, January 2013

Water treatment and supply

Balance of potable and non-potable water required for treatment

As pressures from various quarters come to bear on water resources (e.g. climate change, population growth and demographic change, sustainability reductions in abstraction arising from WFD requirements), the availability of high quality sources of raw water for treatment to potable standard may become constrained. The higher energy, carbon and cost alternative of treating poorer quality raw water to potable standard could be mitigated by a number of measures including demand management and / or leakage reduction, however another option is the wider use of non-potable water for uses such as irrigation, toilet flushing and industrial use where water is not required to meet a standard for human consumption.

In the domestic or commercial setting this may be achieved through rainwater harvesting or greywater recycling, although there are concerns over mis-connection of pipework, additional costs of fitting dual supplies and ongoing maintenance for the user of the disinfection systems involved[49]. On a larger scale however there is likely to be more potential for such use, e.g. on industrial parks, large social housing development, larger public buildings, for irrigating parks, gardens and agriculture. In large buildings this may be possible through harvesting and recycling but for irrigation or industrial purposes it may be more feasible to use a non-mains water source such as a private borehole or form of storage.

Source control, catchment management

Water company expenditure on meeting drinking water quality standards has approached £40 billion over the past 20 years[50] and standards have risen as a result. Nitrate and pesticide removal and the treatment of colour have contributed to a significant proportion of this investment and have resulted in the construction of energy (and thus carbon) intensive processes within treatment plants (involving operational and embodied carbon). An alternative to this is the prevention (or reduction) of contamination at source through measures upstream in the catchment, which usually involve working in partnership with land users (often in the agricultural sector and involving improved chemical application and land management techniques) to prevent contaminants reaching water courses in the first place. This source control or catchment management approach has been found to be effective in many instances in reducing the need for treatment at the works and can also represent a considerably cheaper solution.

Wessex Water has had great success in reducing raw water metaldehyde (found in slug pellets used by farmers, nurseries etc) levels by communicating with local growers, thereby avoiding highly energy intensive treatment, the efficacy of which may be quite limited. Other pesticides, even occurring slightly above permitted levels may require the deployment of granular activated carbon treatment, often in combination with ozone treatment, both of which are energy intensive processes. The incidence of algal blooms occurring in reservoirs (as a result of nutrient enrichment from runoff from surrounding land) may require increased treatment times under such treatment.

The extent to which source control measures can be put in place to reduce treatment requirements is still being explored by water companies and runs against the industry's previous CapEx bias of building up its asset base. However, increasing numbers of schemes are being put forward in water company business plans as they often have wider benefits, including those relating to water resources, flood risk management and ecological quality. The potential for catchment measures to obviate the need for treatment and hence reduce carbon emissions is increasingly being modelled and understood. This contribution will

[49] CIWEM. Policy Position Statement: Water Quality Issues for Household Water Reuse. September 2009
[50] Water UK. Drinking water quality in the UK progress report. 2010.

depend greatly upon the characteristics of the source catchment and the land management practices occurring within it.

Balancing treatment standards and carbon intensity

Treatment of drinking water commonly goes beyond what is necessary to meet standards set by the regulators. This is considered to be reflective of a cautionary approach within the industry, whereby companies are often setting higher internal standards so that small variations do not result in failure against the regulatory performance requirements.

In considering these issues, there is a distinction to be drawn between parameters that have a health implication and those which do not. For example it may be questioned whether aiming for 95 percentile 10 µg/l manganese concentration is really necessary when the prescribed concentrations or value (PCV) is 50 µg/l? Taste is another parameter to which companies are commonly sensitive because it is something that is commonly identified in customer complaints.

There are already safety factors built into the PCVs set for contaminants, so to strive to achieve significantly lower levels than these arguably represents a waste of energy and carbon associated with over-treatment. Whilst the desire to avoid penalties for failure is understandable, this is a reflection of the general risk-averse nature of the water industry, the slight relaxation of which may assist in the delivery of improved energy and carbon efficiency.

Innovative treatment processes

There are many cases where water companies are putting in place tighter internal water quality standards in order to ensure that risk of failing regulatory requirements is minimised, for example ensuring 10 µg/l manganese at the 95 percentile rather than 25 µg/l. This is resulting in a demand for more manganese removal stages and processes. Scottish Water has had success using a reservoir mixing system to oxidise the manganese before it reaches the works and other companies are also investigating this approach. Whilst the mixers do require energy, other than for very large reservoirs this is small (1 or 2 kW). Considering the embedded and operational carbon associated with a bank of rapid gravity filters or pressure filters, together with use of backwash pumps and blowers as well as potentially avoiding inter-stage pumping, such approaches will deliver carbon savings.

Network optimisation

The water distribution network carries almost 15 billion litres of drinking water per day, through 338,000 km of pipes (enough to reach round the Earth eight times)[51]. Pumping water around the network is a key area of energy use and therefore carbon emissions (UKWIR[52] states that up to around 65% of energy use associated with the drinking water supply side of the industry is associated with conveyance and distribution). This is particularly the case when water is pumped either from aquifers or long distances. Whilst pump design is considered to be a mature science and therefore large scale technological advancements yielding significant energy efficiency savings are unlikely, improvements can be achieved through more closely matching pumps to their duties and it has recently been claimed that savings of 30-50% may be achieved via progressive improvements in distribution[53]. There is also potential to make better use of gravity in some networks.

[51] OFWAT. Delivering sustainable water – OFWAT's Strategy: Water today, water tomorrow. 2010

[52] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.

[53] Parsons et al. Policy brief on carbon sensitive urban water futures. Trust, January 2013

Optimisation of pump combinations can however save appreciable amounts of energy e.g. at Hampton Loade WTW, 9 high-lift drinking water pumps, pumping 215 Ml/day, were optimised to save 20kWh/Ml. Other examples of pump optimisation include United Utilities saving 19.7kWh/Ml at a water distribution pumping station by reducing the frequency of pumps and running these for longer hours to deliver the same volume of water.[54] Whilst intermittent but more intensive pumping, linked to exploitation of cheaper (off peak) electricity tariffs, may reduce operational expenditure, from an energy efficiency perspective, it may be more effective to pump at lower intensity for longer periods of time.

Generally speaking, long-distance transportation of water is highly energy intensive. It is likely to be more energy and carbon efficient to avoid such solutions in favour of more local resources wherever possible. Yet in the context of water resources and drought planning, greater interconnectivity to facilitate longer-distance transfers of water during times of scarcity or other extreme events (broadly, climate change resilience) is being encouraged by Government, Ofwat and the Environment Agency[55].

Hitherto, network optimisation has generally been focused on reducing OpEx but given the high contribution of energy costs to OpEx, efficiency savings will have knock-on emissions reduction benefits. Ofwat[56] is keen to encourage network optimisation, principally as part of its drive to encourage wider water transfer and trading via a more efficient and effective network. As part of its Future Price Limits work, Ofwat has been keen to put in place incentives for network optimisation, but appears to have ruled out any kind of financial incentives in the short term. Ofwat appears keen not to prescribe a recipe for an 'ideal' network, but at this stage to encourage data revelation, sharing of good practice and discovery / innovation. During consultation with water companies on this issue, a number of companies pointed to significant investment to date in network optimisation systems and consequent efficiency savings, expressing doubt at the potential effectiveness of specific direct network optimisation incentives.

Many water companies consider their network optimisation to be focused primarily on their supply networks as opposed to sewerage. Smaller companies expressed concerns to Ofwat that opportunities for optimisation, certainly in terms of configuration, would be constrained by the legacy of inherited infrastructure from before privatisation. A commonly cited driver for network optimisation, alongside efficiency savings was the minimisation of environmental impact so again, emissions reduction would appear to be a beneficiary of this efficiency drive.

Managing leakage

The sustainable or economic level of leakage (SELL) is that at which the costs of providing additional resource is equal to those of leak detection and repair. It is used by Ofwat to define the point at which leakage repair and improvement programmes may be justifiable in companies' investment programmes. The use of the term 'sustainable' in this context is arguably skewed towards economically sustainable (in relation to Ofwat's ambitions to keep water bills low) and it may require a change to the way in which water is priced (potentially including a far more realistic cost of carbon alongside recognition of other externalities, such as the value of water left in a river), before this level is modified and significant additional efforts are made to reduce leakage beyond the currently set targets.

Water companies have acted considerably to reduce leakage between 1995 and 2005. However, outside Thames Water and Southern Water, there has been little progress for the

[54] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.
[55] Environment Agency. The case for change – current and future water availability. 2012.
[56] OFWAT. Network optimisation: Options in setting future price limits in the England and Wales water industry. An independent report prepared for Ofwat by Oxera. August 2012

last 5 years. The last WRMPs showed little further improvement proposed for the future, even on supply pipe leakage. Leakage rates do vary across the country, however, the average rate is still over 20% of that put into supply[57] and there remains considerable opportunity for improvement on this rate through network improvements and pressure management.

There is a clear energy saving, thus carbon abatement benefit, in reducing leakage. Whilst leaked water is never physically lost to the water cycle and will percolate into groundwater, (potentially finding its way back into water courses or aquifers which may then be abstracted), the concern in the context of energy use and carbon emissions is that much of this water has been intensively treated. The flip side to this argument is that mains replacement programmes will often involve significant embodied carbon emissions and the balance between which delivers greater long-term benefit and is most cost effective must be found. If the embodied carbon of new assets is considered, it is also necessary to examine the carbon footprint of the continued operational efforts in finding and fixing leaks, rather than wholesale replacement.

Ofwat's commissioned report on SELL[58] and its integration into water resources planning considered that companies should plan on SELL reducing in the longer-term, but noted inertia and caution resulting from the "*risk aversive nature of water resources planning*". It recommended that regulation would play a role in overcoming this caution, which it considers is bound up in companies being wary of penalties if they plan for lower SELL but in practice fail to deliver it. The report also recommended that as the environmental and social components (or externalities) of SELL were difficult to quantify, the Environment Agency should develop its thinking on the environmental value of water, particularly in relation to the benefits of leakage reduction on a catchment level as well as in relation to carbon, so that this may be better reflected in SELL.

In the context of the Ofwat report, it would be realistic to believe that improvements in SELL should be feasible, given the near-forty year timescale involved. From the emissions perspective, the report recommends that:

- companies should continue to use the existing estimates of carbon based on electricity consumption
- leakage management externalities and carbon costs should be developed by companies using company specific data supplemented with typical values given in this report

Widespread water metering will assist water companies in identifying leakage more effectively as a significant amount of leakage is estimated to occur in customers' privately owned supply pipes[59]. Smart meters will further assist in providing more frequent data readings, or when leak detection functionality can be included in their operation.

Leakage from supply pipes will only be significantly reduced if customer meters are located at the property boundary. This is an issue which has been considered as part of the discussions concerning smart metering, with some arguing that smart meters may be more easily installed within the property, as are those meters for energy supplies. Interpretation of Ofwat 2005-06 leakage report[60] statistics shows average supply pipe leakage of 48 litres/household/day (l/hh/d) for unmetered households, 44 l/hh/d for internally metered households, but only 19 l/hh/d for externally metered households. Component analysis shows that this occurs because of a very small number of leaks with moderate leak flow rates (e.g. 500 l/hour) on underground supply pipes running for a long time. External metering identifies

[57] http://www.ofwat.gov.uk/regulating/reporting/rpt_int_08leakageintro
[58] Strategic Management Consultants. Environment Agency, Ofwat, Defra. Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning. October 2012
[59] CIWEM. Water Supply Pipes Policy Position Statement. 2012
[60] OFWAT. Security of supply, leakage and water efficiency. 2005-06 Report. November 2006

such leaks without active leakage control interventions. Externally metered households in Australia commonly have less than 10 l/hh/d supply pipe leakage, thus even the 19 l/hh/d for externally metered England/Wales households may be an under-estimate of what could be achieved by universal external metering.

Pipe water pressures have now been shown to have a clear relation with leakage, although there is still some disagreement about the degree of leakage reduction that a pressure management project will bring about and whether this reduction will gradually be eroded as the water pipe deteriorates. Pressure control is now widespread in most water companies and a core part of network optimisation, though significant further improvement may be achievable in some areas. The effect on reduction of bursts has been more widely researched outside the UK and the potential for pressure management to reduce energy consumption may be being underestimated and may be worthy of further research in the UK context.

UKWIR estimates that the potential for energy savings for leakage reduction is up to 38%, though it notes that this is likely to vary considerably depending on companies' leak reduction strategies.[61]

Renewable electricity generation from distribution network

There is some scope to generate electricity from the hydraulic flow around the water distribution network, including in and out of treatment works, particularly where these feature a significant change in hydraulic head. Pressure reducing valves (PRVs), control valves and other flow restrictors could be replaced with mini hydro-turbines. There are a range of appropriate locations for such devices; in essence wherever such valves already exist, or at other locations in the network, e.g. inlets to treatment works or in trunk or transfer mains. It is important that the turbines are able to cope with changes in flow and pressure, however they may be readily retrofitted and UKWIR estimates that they could generate between 1,000 and 12,000 MWh of electricity[62], with a corresponding potential offset of carbon from fossil fuel-derived grid electricity.

In practice, generators attached to PRVs and control valves will constitute a useful offset to consumption but are unlikely, even if applied to the thousands of PRVs across the distribution network, to make a great contribution to reducing carbon emissions. Presently, electricity costs are sufficiently low to mean that generators are only installed on such valves where there are particularly large head losses or where locations are sufficiently remote to mean that connection to a mains electricity supply is particularly expensive.

Some larger schemes, where there is sufficient change in head, may be able to contribute considerably more to making treatment works effectively energy neutral. At the same time, a key benefit of hydro-electric power generation is that Ofwat considers it, like sludge-based renewable power, to be sufficiently integrated into appointed water company business that customer bills may be used to help fund the capital investment in such schemes.

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[61] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.
[62] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.

Wastewater sewerage and treatment

Network optimisation and renewal

There is less emphasis placed on network optimisation when it comes to the sewerage network than the water supply network[63]. However, there is a benefit to be achieved from the reduction of infiltration and inflow into sewerage systems due to the direct correlation between this and a reduced requirement for pumping, treatment and disposal. Infiltration is a slow process of percolation through sewage pipes whilst inflow is more directly proportional to rainfall events.

Solutions to infiltration include sewer lining or replacement, however for these to be effective it is also necessary for manholes to be sealed. Such interventions may be most appropriate when sewer condition is poor as they will be capital intensive. More sustainable options include source control of runoff and disconnection of surface water drainage systems, with greater implementation of SuDS, where the potential for this exists.

The potential for energy efficiency savings from reduced infiltration and inflow have been identified as up to 68%. Water from infiltration is considered to account for up to 40% of flow in sewers of good or average condition or approaching 100% in those of poor condition[64]. Network renewal will reduce the incidence of infiltration and inflow, through sewer pipes, manholes and other points of entry. However this is capital intensive and is only recommended in cases of particularly poor sewer condition.

Heat recovery

There is potential to recover heat from wastewater discharged to sewer, with existing heat exchanger technology able to convert its ambient temperature into usable energy before this energy is lost to the surrounding environment. In a domestic context, most of the average 150 l/h/d of water used in the UK home is discharged to the sewer and the temperature of this water is typically around 12-20°C. This technology is applicable for use at various scales, from small scale domestic application able to contribute to water heating, through in-sewer systems more appropriate for use on a community / district / large building scale, up to larger systems for utilisation at treatment works.

Manufacturers claim energy efficiency gains of circa 40%, carbon emission reductions of up to 60%[65], and that the technology may be readily retrofitted to existing sewers (although there are associated requirements for flushing to maintain biofilm growth at less than 20% to maintain system effectiveness). However, the implementation of this technology crosses thresholds between appointed water company business and wider commercial activity, particularly if implemented as an in-sewer option. If employed in treatment works (where heat recovery technologies are typically only utilised as part of combined heat and power units associated with electricity generation from biogas, rather than directly from temperature gradients associated with raw sewage), such obstacles would be less apparent. Low take-up of such technology in the UK implies that its cost-benefit may not be sufficiently attractive, or recognised at present, but it represents a potentially significant opportunity for future energy recovery and emissions reduction in the longer-term, particularly if the other barriers discussed can be reduced.

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[63] OFWAT. Network optimisation: Options in setting future price limits in the England and Wales water industry. An independent report prepared for Ofwat by Oxera. August 2012

[64] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.

[65] http://www.unitracc.com/aktuelles/artikel/recycled-and-reutilised-heat-energy-from-sewer-flows-aids-carbon-reduction-fight

Plant tuning and optimisation

Plant tuning and optimisation of wastewater treatment plant represents a significant opportunity for energy (and therefore cost) saving in one of the most energy intensive parts of water company operations. One of the single most energy intensive operations within wastewater treatment is that of aeration. There is thus significant opportunity for energy saving in activated sludge process (ASP) treatment plant.

Examples of the scale of such savings include the commissioning in 2008 by United Utilities of a new model predictive control (MPC) installation, which delivered a 46% energy consumption saving, equating to 22.8kWh per Ml. This was achieved through optimisation of ASP plant control, predictive load, ammonia and dissolved oxygen control. In 2007, Northumbrian Water achieved a 53.6% saving in an activated sludge plant through plant optimisation to reduce the return activated sludge (RAS) rate. This amounted to a 21.9kWh/Ml saving and an associated daily energy cost reduction from £51.70 to £22.18. Other opportunities may arise in nitrification inhibition. Northumbrian Water again achieved a saving of 114.8 kWh/Ml, through reducing blower power by around 50%[66].

Parsons et al[67] estimate that tuning and optimisation across the wastewater side of the industry could yield efficiency improvements of 10-40% from pumps and other motors; aerobic treatments such as activated sludge, 10-50%; and other general operational improvements, up to 25%, to achieve a reduction in greenhouse gas emissions of 20% of total emissions in the short to medium term. They advise that in the longer term, aerobic processes are likely to need to be replaced by anaerobic processes in order to achieve greater savings.

Efficiency gains in wastewater treatment plants are clearly essential before attention is focused on actually generating renewable energy. Nair[68] states that typically around 50% of the available energy that could be recovered in treatment plants is currently lost. He points to "*an acute misunderstanding of how wastewater treatment plants use energy*" which, alongside fear of permit non-compliance and poor maintenance procedures, mean plants commonly operate well below their efficiency potential. He considers that the most effective and efficient companies will be those that recognise that the best way to reduced operating costs is through maximisation of existing asset performance.

Sludge digestion and biogas optimisation (anaerobic digestion)

Digestion of sludge imparts a moderate energy load on a treatment works, amounting to between 10-15% of total energy consumption[69]. However, anaerobic digestion (AD) does offer the potential to cost effectively generate more than 100% of a large STW's energy supply, in other words, make them energy and carbon neutral or better, selling any surplus energy back to the grid. This existing technology represents the industry's biggest and most readily achievable opportunity to generate renewable energy, through biogas-fuelled combined heat and power (CHP) generators. AD is already widely utilised across the industry, so opportunities to increase the amount of biogas generated will depend on the extent to which this is already undertaken. Potential to expand capacity is also limited by the availability of consistent supplies of feedstock within a relatively short transportation distance from a works, as well as a disposal route for the digestate at the end of the process.

There remains significant potential to both improve the energy efficiency of the process, and to increase the level of biogas production through feedstock and digester biochemistry optimisation. In Arizona, very significant energy savings have been achieved from changing

[66] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.
[67] Parsons et al. Policy brief on carbon sensitive urban water futures. Trust, January 2013
[68] Nair, A. Is energy neutrality possible? The Environment, May 2013
[69] Brandt, Middleton & Wang. Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies. UKWIR, 2010.

mixers from draft tubes with rotating impellors to linear motion mixers. This reduced energy consumption from $11.8w/m^3$ to $1.1w/m^3$ digester volume – a reduction of 93%[70]. Optimisation of biogas yield would enable greater production of biogas for the same level of final digestate disposal (e.g. to land). From a carbon reduction perspective, disposal of digestate via co-firing or incineration with heat recovery (energy from waste) is potentially the lowest carbon disposal route. However, this approach prevents any nutrient recycling benefit associated with sludge to land and will increase the reliance on chemical fertilisers which are themselves often carbon-intensive to produce. From a holistic point of view, CIWEM advocates recycling of digestate to land wherever this is a feasible and cost effective option[71]. There will always need to be a consideration of the wider implications of this approach; for companies with limited agricultural land available for recycling there could result in high levels of tinkering and associated transport costs and emissions, meaning that an alternative route such as thermal recovery may be more appropriate.

Co-digestion

There has long been interest in the potential to co-digest sewage sludge and biodegradable solid waste, such as food waste. This can be beneficial in terms of biogas production; co-digested waste can produce greater amounts of biogas if the feedstock is mixed at a suitable ratio than is achievable by separately digesting the different waste streams. However, whilst the process is technically feasible, there are various obstacles to the widespread expansion of co-digestion: ensuring a consistently high quality and supply of biodegradable solid waste and the discrepancy between the two separate regulatory regimes covering the application to land of digestates from solid waste and sewage sludge[72]. Moreover, investment in digesters on STWs is permitted to be funded through water customer bills, whilst mixing sewage sludge with a new solid waste feedstock not associated with water and sewerage utility services muddies the waters of what is appointed business and what isn't. For this reason some water companies are looking to co-locate AD for separate feeds on their own sites to optimise benefits of existing infrastructure whilst negotiating the regulatory barriers.

From a pragmatic perspective, digesters are already present at STWs, as are vehicle movements and controlled digestate recycling. It is possible to satisfy the requirements of the separate regulations for biowaste and sludge-derived digestate by retrofitting thermal hydrolysis to the process, which could in turn potentially treble the capacities of the existing digesters and increase the biogas from the waste activated sludge portion of the feed, as well as improving the dewatering process. It would also provide one homogenous digestate product for recycling to farmland.

Co-location represents a far less optimal solution to biogas expansion to co-digestion and is being considered by the industry largely because of the way the UK has interpreted EC regulation. Denmark has interpreted the European regulations differently and has been co-digesting sewage sludge and biowaste for many years. Ofwat may now be taking a more favourable view of co-digestion after a strong expression by Government to find solutions to the regulatory obstacles to co-digestion[73], considering a basis for sharing profits between the regulated and non-regulated sides of the companies, which would represent welcome progress.

There are clear opportunities for co-location initiatives away from sewage treatment. Thames Water and energy company 20C have agreed a 20-year partnership to run a 130GWh/yr combined heat and power plant at Thames Water's Beckton Sewage Treatment works, fuelled by 30 tonnes per day of waste fats, oils and grease and solidified fat removed from

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[70] IBID
[71] CIWEM, Policy Position Statement: Wastewater biosolids treatment and use. April 2010
[72] CIWEM. Policy Position Statement: Co-digestion of sewage sludge and waste. June 2011
[73] DECC, DEFRA. Anaerobic Digestion Strategy and Action Plan. 2011

pinch points in London sewers. Thames will purchase 75GWh of the electricity generated, with the remainder to be sold to the national grid. The scheme will improve the amount of self-generated renewable energy by Thames Water from 14% to 20% of its demand.[74] Similar initiatives in other large urban areas are likely to have strong potential, albeit on a smaller scale than that seen in London.

Hydroelectric power

There is some potential to incorporate hydroelectric power generation at treatment works which are able to make use of a sufficient vertical head loss. This need not be large and the most commonly observed example is the installation of two Archimedes Screws at Yorkshire Water's Esholt wastewater treatment works. Here, the turbines are installed in series between the Inlet Works Detritors and new Primary Settlement Tanks. Up to 3,240 litres per second of untreated sewage passes through a 1,800mm diameter pipe to the hydro generating station, producing a maximum of 180kW of electricity. This is used to reduce the imported power demand of the treatment works. Turbines may be readily fitted to foul effluent outfalls and other suitable locations such as treated effluent outfalls where head is sufficient.

Source control

As with certain raw water pollutants on the supply side, catchment management measures are being increasingly employed by water companies to deliver solutions that would otherwise require increased levels of wastewater treatment. Measures put in place with the cooperation or active involvement of land managers such as farmers can be more effective and efficient than end of pipe solutions. Likewise, improved management of water in the urban setting can reduce the impacts of pollution from runoff on both receiving waters and treatment works.

Surface water separation involves the re-routing of surface water (which currently enters combined sewers (CSOs)) into surface water courses, surface water sewers or SuDS systems. Wide scale surface water separation (such as a national programme to replace all combined sewers with dual sewer networks) could see significant operational emissions reductions through reduced pumping of rainwater in combined networks and via reduced energy use at waste water treatment works.

Key barriers to delivering this approach are presented in the short term payback required for capital projects under the existing regulatory regime. In the event that Ofwat released funding for projects with long payback periods (nearer 40 years rather than 5), options for separating existing combined networks may present themselves as cost beneficial. This in turn could allow significant waste water carbon savings to be derived.

Whilst large scale replacement of CSOs would undoubtedly represent a significant financial undertaking, there are many opportunities for smaller scale retrofit of SuDS schemes which could provide considerable multiple benefits and have been proven effective in many parts of the world. In the UK setting, there remains a lack of agreement over the ownership and maintenance of retrofitted green infrastructure but is likely to transfer from water companies to local authorities in the case of SuDS. The general aim should be a national programme to reduce the amount of surface water and infiltration entering existing combined sewers.

Balancing effluent treatment standards and carbon intensity

Permit limits are presently calculated using the full range of river flows, represented in a complete flow duration curve, with the calculations providing to the permit holder the benefit of the dilution provided by the complete mix of high, low and moderate river flows. Environmental agencies, regulators and water companies are often risk averse, particularly

[74] Funding found for fat-fuelled East London CHP plant. ENDS Report 459, May 2013, p. 15

where there are 'no deterioration' clauses in consents. As with drinking water quality standards, water companies may take the approach whereby they set themselves a limit approximately 10% higher than the compliance level set for a parameter in order to allow themselves a safety margin. Whilst this approach may lessen risk, it will also result in additional energy being consumed for potentially needless additional treatment.

This problem may be obviated to a significant extent through source control measures. However, there is potential for increased use of telemetry and real time river flow monitoring, to inform increasing or decreasing levels of treatment depending on the condition of the receiving water, together with more widespread use of seasonal and reactive consents.

There is a need to build evidence from risk-based consenting, based on environmental conditions, at existing treatment works. The Environment Agency[75] and Severn Trent Water are undertaking trials on this approach and modeling them using catchment models with the aim of a more dynamic approach to consenting. Yorkshire Water are undertaking similar work to create a situation whereby all abstraction and discharge consents are dynamically controlled and variable, balanced and centrally controlled. This initiative, named real-time river integration (rtRIVERi), will deliver a significant reduction in energy, chemicals and carbon.

Innovative treatment processes, e.g. reed beds

Greater research and development (R&D) and innovation is needed to provide the necessary technological steps forward to dramatically cut the carbon emissions of the water industry. There are certain sustainable methods of treatment processes employed currently, such as constructed wetlands. Consideration should be given to how much more widely these could be employed.

The use of constructed wetlands for wastewater treatment in the UK has taken place for about 30 years and is typically employed for the treatment of sewage, high strength effluents, contaminated surface and groundwater, leachates and process waters. Their use at larger wastewater treatment works tends to be as a final polishing, tertiary treatment stage. Reed beds have quite a large land footprint, yet are a highly effective, natural and carbon sequestering treatment method.

Other technologies under development for wastewater treatment, which may offer improved efficiency and carbon savings include cold anammox treatment for nitrate removal, aerobic granular sludge technology and direct ultrafiltration. Other approaches include the optimisation of filters and the optimisation of primary sedimentation in order to minimise energy use during secondary treatment as well as improving primary sludge generation and biogas / energy generating potential. These developments offer a prime indicator of the need, in the context of carbon reduction, for R&D and cooperation across the industry to bring new technologies to a commercially workable stage as quickly as possible.

[75] Severn Trent Water – balancing carbon and ecology. http://www.environment-agency.gov.uk/research/planning/121140.aspx

Cross-sectoral opportunities

There are a number of cases of water companies constructing wind turbines on their land to generate electricity, either for direct use on site or for sale to the grid. However, under the present regulatory arrangements, these are not considered part of companies' regulated business and they are unable to invest water bill payments to fund them.

Similarly, with solar photovoltaic (PV) panels rapidly declining in unit cost and electricity from this form of generation due to reach grid parity in the next few years, there is potential for wider deployment of solar PV on building roofs and appropriately located land to offset the energy use at treatment works and other sites.

Other sectoral collaborations could occur between the water and energy sectors. Energy companies could potentially lease appropriately located water company landholdings to site wind turbines, though there may be greater benefit to the water company by owning the turbines themselves.

Some water companies are actively considering co-locating anaerobic digesters for biodegradable municipal waste alongside, but separate to their digesters which are used for sludge digestion. This represents beneficial use of the often large land footprints held by water companies, together with existing expertise and logistical arrangements for vehicle deliveries of feedstock for example. In the case of anaerobic digestion, this approach does not represent the optimum solution from a biogas perspective (which would be likely to be achieved through co-digestion), but does add value and reduce some of the regulatory complexity associated with co-digestion.

Low carbon construction

A number of water companies are now looking very closely at the carbon embodied in the construction of their infrastructure assets and have found ways of reducing this considerably. As detailed in Section 1, savings may be identified through more detailed consideration and prioritisation of embodied carbon reduction within the design stage of new schemes, combined with active engagement with the supply chain to in turn reduce its own embodied carbon. Anglian water has set targets for embodied carbon emissions reduction of 50% by 2015. Schemes with low embodied emissions are commonly cheaper than more traditional solutions.

Digest of key messages

The discussions and examples in this section illustrate that there is considerable scope for carbon saving across the water industry, through a variety of mechanisms, by applying the principles of emissions avoidance, energy and resource efficiency and generation of renewable energy at every level of operation throughout a water company's activities. There is a need for innovative approaches across the industry to improve the integrated management of water, in order to deliver multiple benefits including carbon reductions.

There does not, however, appear to be a requirement for a large technological leap forward in order to achieve the kind of carbon savings proposed (up to 80% by 2050). There is a wide range of existing and developing technologies which, allied to a meticulous attention to detail, data gathering and commitment to carbon reduction wherever assets are subject to maintenance or replacement, have in concert the potential to achieve appreciable emissions reductions. Where shortfalls in a proposed emissions reduction trajectory exist, this may be compensated for through the purchase of zero-carbon grid electricity (as is already proposed in some companies' carbon reduction plans). Even so, there will be clear benefit in increased R&D effort bringing lower carbon technologies, which may achieve savings more quickly and cost effectively, to the fore sooner rather than later.

Due to the variability between water companies in terms of the geographic, demographic and resource characteristics, it was considered unfeasible to estimate likely achievable carbon emissions reductions to each of the operational activities discussed. At the same time, there are some clear messages:

- Given the large energy demand of pumping and treatment of water, there is clear benefit in measures which will require less water required to be put into supply. Widespread (near universal), smart (if possible) metering, demand management and leakage reduction measures will play a key role in achieving this.
- Upstream, catchment-based, soft engineering, source control measures can be effective at obviating the need for treatment of certain substances. Use of these should be maximised, particularly where cost and carbon savings can be delivered alongside multiple and more sustainable outcomes.
- Processes and networks offer continued opportunity for optimisation. Central to this is the capture of improved data, understanding where opportunities exist and putting in place optimisation measures within capital maintenance and improvement programmes.
- There is a need to effectively balance the needs of the local environment and the global environment and examine ways in which consents can be achieved in an effective and dynamic way to safeguard the environment whilst minimising the need to treat water to higher standards than necessary for the avoidance of risk of failure.
- Water companies should seek to make best use of opportunities to generate renewable energy, or to recover energy, in order to offset the energy use and carbon emissions associated with their operations. Opportunities for this are far more prevalent for water and sewerage companies than for water only companies.

3 Synthesis on potential reductions

80% less carbon by 2050: A realistic prospect?

Within the water industry, there are clear areas of high energy use and therefore opportunity for carbon reduction. As stated in section 1, these centre on the treatment and distribution of water. These activities are the *raison d'être* of the water industry, but it may be that in coming decades, with decarbonisation and sustainability becoming an increasing focus for society at large, water companies take on a wider role, integrated with other aspects of peoples' lives as well as with other utilities and industries. UK Trade & Investment set out four key areas where energy use and carbon emissions can be reduced: (1) water saving; (2) reduced operational usage; (3) energy recovery systems and (4) electricity generation to offset usage.[76]

Ainger[77] refers to an impending "perfect storm" for the water industry (see fig. 3), in which a number of drivers are coming together at the present time to force a significant change in the way the water industry delivers its outcomes and its ways of working. Central to this will be a marked increase in the rate of innovation within the industry and it is proposed that a large carbon reduction requirement could be the driver to stimulate this innovation and change within the industry.

Less water available	• Local Environmental Quality > Less abstraction • Climate Change Impacts > less water resources • Population Growth > more water demand
Higher asset costs	• Ageing infrastructure > more assets > more replacement • EU Legislation (WFD etc) > higher standards • Climate change adaptation > resilience, protection • Energy price escalation > higher opex costs
Water price, poverty, finance-ability	• Higher asset cost > higher water prices • Recession, austerity > lower incomes, finance?
Managing climate change	• Reduce carbon emissions fast

Figure 3. Challenges for the water sector – interacting demands. From Ainger, 2012

The discussions in Section 2 indicate that **there are many opportunities for carbon reduction across the range of water company operations.** Many of these centre on energy efficiency

[76] UK Trade & Investment. Water & wastewater: An innovative UK industry. 2012
[77] Ainger, C. Setting the Scene – for Innovation in Water. CIWEM conference on Water and Innovation – Learning from innovators. December 2012.

savings in process operation, leading edge technology, embodied carbon reduction within new infrastructure schemes (or maintenance programmes), and in opportunities to offset energy used operationally through the generation of renewable energy.

There are also crucial savings to be made in areas relating to resource efficiency and waste minimisation. These principles are likely to become watchwords for society as this century progresses. Thus, broad principles such as putting less water into supply, encouraging (and enabling) consumers to be more efficient in their water use and only treating water and effluent to a standard appropriate for its use or receiving water, must be central to thinking throughout the industry, including regulators. A key element of this should be the roll-out of widespread water metering and an enhanced effort to bring forward smart metering for water.

These opportunities can deliver significant emissions reductions, if given the appropriate regulatory support and incentives, and if the value of water is fully recognised (as will be necessary given the pressures which will increasingly be placed on it as a resource by population growth, demographic change and climate change over the 21st Century). Yet they are in themselves unlikely to deliver the 80% emissions reduction by 2050 sought by the Climate Change Act, and may go little beyond mitigating future rises in emissions that may result from additional future treatment and resource requirements.

This observation must be couched by the fact that 40 years is a long time in the world of technological innovation. However, there remain some immutable facts concerning water company activities and water itself that mean the industry is likely to always remain an energy intensive industry: water is a heavy medium to move around, social acceptance of any loss of drinking water quality will remain low and the way we use water and our ambitions for a healthy local environment will continue to mean that water will require large amounts of treatment before it is discharged back into the environment.

It is incredibly difficult to predict the carbon emissions reductions that could be achieved across the industry by a given date. Variance in opportunity for renewable energy generation, geography, local environmental factors which dictate pumping and treatment requirements, and a host of other factors mean that low certainty would be attached to any such prediction over a 40-year time horizon. Nevertheless, with the right incentives, the water industry is well placed to innovate. **We consider that in light of the discussions in section 2, the industry as a whole should be actively encouraged to decarbonise by 80% by 2050 through a combination of the opportunities described**.

The water industry will, to a certain extent, always be reliant on the provenance of grid electricity which is purchased to make up the shortfall between resource and energy efficiency measures, renewable energy generation and an 80% reduction target (this is particularly the case for water supply-only companies who do not have the opportunity to generate biogas from wastewater biosolids). **CIWEM considers this context should be recognised and that the water industry should be required to send a clear signal to the energy market for its own decarbonisation by 2050, through the purchase of increasing proportions of zero carbon grid electricity where this is required.**

CIWEM considers that the water industry should be set targets for carbon emissions reduction, by Defra and its economic regulator, mirroring the longer-term target set under the Climate Change Act. This would not be out of step with some of the aspirations set out in water company Strategic Direction Statements (quite the reverse, as a number state aspirations of becoming carbon neutral within the timeframe discussed). Companies should be afforded the flexibility to meet emissions reduction targets in the most cost effective way possible including through the purchase of renewable grid electricity, but preferably through a renewed focus on R&D and innovation. We do not consider it realistic to include a 34% by 2020 emissions reduction target, to precisely mirror the Climate Change Act, given that PR14 will dictate investment up until 2019 and it is too late in the planning process to introduce such a target. **We suggest that formal emissions reduction targets are included from PR19 onwards.**

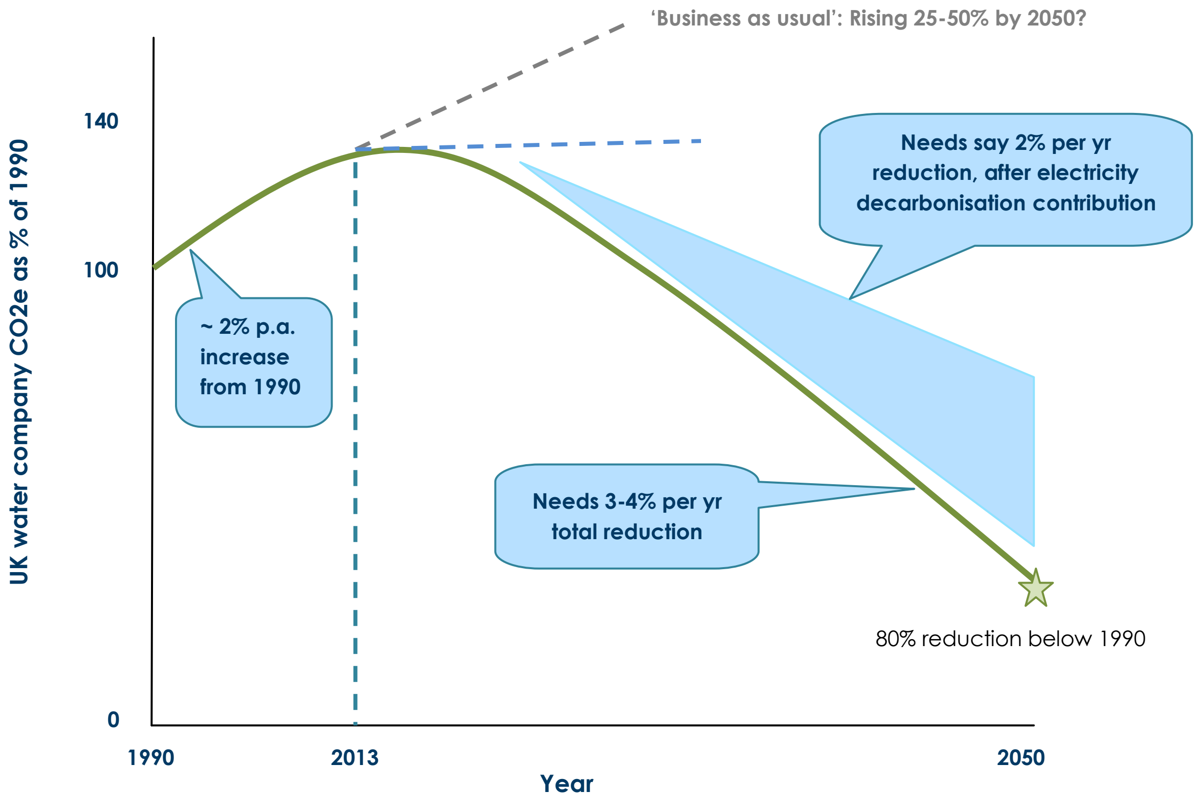

Figure 4: CO2e reduction trajectory for 80% reduction by 2050. From Ainger 2012[78]

Figure 4 illustrates the scale of the challenge. It equates to an emissions reduction across the industry of between 3 and 4% per year, on average; 2% beyond the reduction associated with grid electricity decarbonisation. Some companies are progressing at this kind of pace at present, however, there remain plenty of 'quick wins' that may be achieved quite readily and affordably. Once these efficiency savings are achieved, there is likely to be an increased reliance on technological advancements and schemes requiring significantly longer payback periods than those which are currently commonly accepted by the regulator.

Parsons et al[79] state: *"Of equal importance to innovative technologies and techniques however is the knowledge and professional culture required to drive innovation and delivery of low carbon and energy solutions... this, perhaps above all other factors, is the area in need of catalysis if our communities are to realize a lower carbon future."* We consider that the water industry in the UK is well placed to assist in driving forward these solutions.

[78] Ainger, C. Setting the Scene – for Innovation in Water. CIWEM conference on Water and Innovation – Learning from innovators. December 2012.
[79] Parsons et al. Policy brief on carbon sensitive urban water futures. Trust, January 2013

Research and development needs

Literature on the subjects of carbon reduction and innovation in the water sector in recent years suggests that there is a real role for R&D in addressing these challenges, and that investment in R&D is likely to need to increase markedly in order to provide appropriate solutions to the challenges the industry faces.

According to Helm, "R&D has been a big casualty of privatisation. It has all but collapsed in the water industry. The returns are long term, but the companies are more focussed on short term returns. Regulators are judged by their ability to keep prices down, rather than the passing through of R&D costs for the benefit of customers perhaps far into the future."[80]

The Council for Science and Technology[81] state: "...if the water sector is to contribute to meeting the UK's carbon reduction targets it is unlikely to do so based on existing technologies, and R&D investment in low carbon technologies will be necessary." It highlights that in an industry with approximately £3 billion in capital expenditure per annum, the annual expenditure on R&D of approximately £18 million annually is notably low. For this, it places responsibility at the door of Ofwat, stating "the regulatory regime militates against research and development and provides insufficient rewards for innovative solutions."

R&D is a term that can be defined quite broadly. It may be used to describe research that looks for genuinely new and innovative ideas in terms of technologies, processes and ways of working. Then there is the development of technology to the commercially beneficial stage. Finally R&D can refer to analysis of performance and opportunity for the purpose of providing information to regulators and other stakeholders including customers.

The R&D landscape is likely to vary from water company to water company, mainly dependent on the nature of challenges faced, and the availability of cost effective solutions to address these. Larger companies may have centralised R&D functions, whereas smaller companies may be working with a very small R&D department, but with other employees undertaking research in other departments.

Presently, much of the R&D which is of a common interest to the industry is undertaken by UK Water Industry Research (UKWIR). Over the past 15 years, UKWIR's members (broadly, the water companies in the UK) have contributed £50 million to research, with a further £30 million coming from research collaborators.[82] UKWIR's research centres on the issues of drinking water quality and health; toxicology; water resources; climate change; wastewater treatment and sewerage; sewage sludge; water mains and services; sewerage; leakage and metering; as well as customer and regulatory issues.

Areas of work of more specific interest to individual companies is still undertaken in-house, with technological development undertaken by specialised industrial companies. In general, it is understood that research into genuinely innovative approaches and technologies has declined dramatically since privatisation. Cost drivers have reduced the effort and finance afforded to research both internally and externally. It is not uncommon for water companies to place contracts for their capital delivery with contractors who will bear the risk alongside performance guarantees. This is driven by a regulatory emphasis on high levels of service and has the effect of encouraging conservatism, often because the rewards for innovation (a share of gains achieved) are outweighed by the scale of penalty clauses for under-performance.

[80] Environment Agency. A low carbon water industry in 2050. December 2009

[81] Council for Science and Technology. Improving innovation in the water industry: 21st Century challenges and opportunities. 2009

[82] http://www.ukwir.org/site/web/contents/about-ukwir/about-ukwir

According to UK Trade & Investment[83], the UK water industry, with some of the world's leading academic institutions behind it and a significant clean technology investment sector, is ideally placed to lead research. If this is indeed the case, the industry is well positioned to lead innovation in water, in order to deliver large-scale carbon emissions reduction, should Ofwat permit or require increased levels of investment in R&D.

The particular R&D need exists in relation to longer-term solutions. At present, it is doubtful whether the UKWIR R&D vehicle delivers adequately on this need and may need to modify its focus so it is able to address longer-term challenges such as carbon emissions mitigation. Of course, UKWIR does reflect the industry R&D demand and therefore if financed and briefed to consider more strategic, long-term issues it could be an appropriate vehicle.

Ainger[84] emphasises the **need for collaboration and improved knowledge sharing to rapidly drive forward the commercial applicability of innovative solutions within the industry to the broad dissemination stage**. He considers that this approach allows a diversity of approaches to challenges, allowing a number of different attempts to take solutions forward with a quicker route to adoption of solutions as standard across the industry. **This, he contends, is required if the decarbonisation challenge is to be answered with any effectiveness** and it will need to be incentivised by Defra and Ofwat.

Data and monitoring requirements

The importance of high quality data and a good level of understanding of exactly where the greatest gains may be achieved throughout the sector cannot be emphasised enough. Therefore, the **widespread use of metering (preferably smart metering) and other up to date means of telemetry must become the norm and put in place at least as quickly as water company infrastructure is upgraded.** The examples in Section 2 illustrate that there is significant carbon emissions reduction potential associated with process and system performance optimisation but this detailed level of control will not be possible without effective monitoring, measurement and reporting throughout the industry.

Regulating for innovation and outcome certainty

Risk aversion within the water industry is understandably widespread. The industry is one which is required to ensure the supply of safe, potable water and sewerage services to its customers and maintain high levels of service in this regard, with penalties for failure. It is common practice for water companies to require performance guarantees from their contractors on capital investment schemes with significant penalties for failure, effectively transferring risk over to them. This approach does nothing to incentivise innovation, however, and there is a difficult balance for Ofwat to make between actively incentivising water companies to be more innovative in their choice of schemes whilst still requiring the same high levels of service for customers and the environment.

This has led to the question of whether it will be feasible to encourage water companies to take on more risk in order to deliver innovation. It is quite inconceivable that the regulators would ever afford the industry greater flexibility in terms of failure, particularly if there is a real or perceived public health or safety implication involved. However, a move towards more risk-based and dynamic permitting may at least go some way to reduce the temptation to over-treat water.

[83] UK Trade & Investment. Water and Wastewater: An innovative UK industry. 2012
[84] Ainger, C. Setting the Scene – for Innovation in Water. CIWEM conference on Water and Innovation – Learning from innovators. December 2012.

Evidence that another UK utility has been successful with a lower carbon design or a loading rate that permits a smaller (lower carbon) unit to be built is more likely to result in change than a scientific paper (no matter how well written and researched) based on lab and pilot studies or overseas work.

It is important that water companies and Ofwat do not fall into a 'locked in' approach to risk and innovation. **It is clear that if the challenges of climate, population and demographic change are to be met during the next few decades, regulators must encourage innovation and extend the testing period available for new technologies and solutions, so that water companies are not over-incentivised to deliver cost-effectiveness in the short-term (around 5 years)**.

At the same time, if company boards' primary motivation is to ensure that their capital maintenance and/or asset replacement schemes are cost-effective within 5 years, they will not dare to implement more innovative solutions, whose costs and risks are uncertain and which require long-term implementation scales. Taking the example of SUDS, where the approach in other countries is that of 'learning-by-doing', this would mean that 'failure' (to a reasonable scale) is incorporated as part of the innovation process and assumed as a learning experience. For this to happen, regulators must be more flexible (with both time scales and satisfactory outcomes). Ofwat's 'outcomes-based' approach to regulation is intended to afford companies more freedom to take on such experience and build it into a more innovative and long-term approach to business planning. The effectiveness of this change in approach will only become apparent over the next few AMP rounds.

Financial and investment implications of decarbonisation: Does low carbon = high cost?

There is growing evidence from within the industry that low carbon solutions are available, giving the lie to conventional wisdom which says that these are typically more costly. The importance of rigorously considering embedded and operational carbon at early design stage of schemes cannot be overstated and companies are increasingly finding that schemes with lower embodied carbon are cheaper to construct as well as still being able to achieve improved operational efficiency. It might even be argued (and companies such as Anglian Water have experienced this[85]) that a key mechanism for achieving cost reduction has been the incorporation of challenging carbon reduction targets from project inception. Clearly this will not always be the case, and it is likely that society will face significant costs associated with meeting climate change targets.

It is necessary to set this issue in its proper context, however. A clear outcome of the Stern Report[86] was the statement that the longer action on climate change is delayed, the greater the associated costs will be. The best part of four decades is arguably adequate time for the water industry to very seriously address its carbon emissions. However, realistically, regulatory incentivisation for this process cannot be put in place until PR19, which reduces the timescale down to three decades.

CIWEM considers that the UK should continue to be an international leader on climate change, that its water industry and customers should be closely involved with this, and that there will be opportunities for companies to benefit from taking experience and expertise gained from building a low carbon water industry into international markets.

[85] Riley, D. Carbon Management in the water industry. Climate Change in the water sector. CIWEM, November 2011
[86] HM Treasury and Cabinet Office: Stern Review on the Economics of Climate Change. 2006

Regulatory support is required, but what and when?

The current Ofwat KPI target for emissions reductions is for water companies to effectively manage their carbon emissions so that they can deliver their core services in a low-carbon way and to play their part in reducing national carbon emissions, *where it is economic to do so and in customers' interest*[87]. Whilst this is welcome, it does include two major caveats which, whilst acceptable in their appropriate contexts, do introduce opportunities for targets to be reduced or loosened if it appears that they may be challenging to meet. There is also no stated time component or context, to establish whether measures should be solely economic under present conditions or those projected for the future, or whether they should be only in the interests of today's customers, or tomorrow's.

Other statements from the regulator, concerning its expectations of companies' carbon emissions, illustrate clearly that both it and Government policymakers currently place responsibility for action squarely at the doors of the water companies and there is little appetite to force the issue from a policy and regulatory standpoint:

> ***"We expect companies to understand and take responsibility for their own GHG emissions."***[88]
>
> ***"We expect water companies to consider low-carbon investment options."***[89]
>
> ***"We want frameworks that encourage more low-emitting, sustainable approaches to water and sewerage service delivery."***[90]
>
> ***"We think that the water and sewerage sectors have the potential to reduce their emissions alongside the rest of the economy...But this will only happen if the companies challenge themselves to find new and innovative ways of working."***[91]
>
> ***"Neither the water and sewerage sectors nor we as the regulator can make sweeping decisions about how, and how much, the companies and their customers should contribute to emissions reductions...It is for Government to ensure that all sectors of the economy are incentivised to adequately reduce their emissions."***[92]

The position that Ofwat appears to be taking in the context of carbon emission reductions is that it is either the responsibility of the water companies themselves to deliver these, or for the Government to adequately incentivise them. Under the Coalition Government, Ofwat has been moved away from making policy directions and this responsibility falls to Defra alone. **We consider that whilst the Defra Statement of Obligations[93] does put out the right messages on carbon, these could be made more overtly and afforded greater weight. In particular, we propose that companies should be actively encouraged to reduce their carbon emissions by 10% per AMP round, against an appropriate baseline.** This encouragement could take the form of financial incentives under the Ofwat Future Price Limits framework.

We consider that the water industry should be strongly encouraged to take into account the provenance of the grid electricity it purchases, even though this is associated with indirect emissions. These remain arguably the greatest source of emissions for the industry and will make a significant contribution to its own decarbonisation. However, ultimately, **efficiency**

[87] OFWAT. Key performance indicators – guidance. 2012
[88] OFWAT. Preparing for the future – Ofwat's climate change policy statement. 2008
[89] Ibid
[90] OFWAT. Playing our part: How can we cut greenhouse gas emissions in the water and sewerage sectors?. 2010
[91] Ibid
[92] Ibid
[93] Defra. Statement of Obligations: Information for Water and Sewerage Undertakers and Regulators on Statutory Environmental and Drinking Water Provisions Applicable to the Water Sector in England, October 2012

and avoidance-associated emissions reductions are more preferable and should also be actively encouraged by industry regulators.

Summary of recommendations

In light of the evidence presented in this report, CIWEM proposes that:

- **Water companies in the UK should be incentivised to make progressive carbon emissions reductions between now and 2050, aiming for 10% emissions reduction per AMP round, against an appropriate baseline. This would drive a trajectory broadly in line with achieving an 80% emissions reduction by 2050.**

  It should be at the companies' discretion how they would meet such a target. Earlier savings may be more cost effective to achieve through direct efficiency, avoidance savings and offsetting from renewable energy generation, taking advantage of 'low hanging fruit'. As these opportunities diminish and the price of renewable grid electricity becomes less, this balance may change.

- **Water companies must be allowed to take on greater innovation risk – this could be achieved through a financial incentive and may take the form of not forcing water companies to demonstrate cost effectiveness within 5 years. There is a need for a longer-term perspective to investment decisions. We understand that Ofwat are willing to accept this approach and we welcome this.**

- **Ofwat should encourage greater investment in R&D on low carbon solutions, including those which have a longer-term time horizon. UKWIR may be the ideal vehicle for such R&D, but there is a need for greater focus on these more strategic carbon-reduction issues and how findings may be shared in the widest possible common interest.**

- **Ofwat and the Government should encourage and if possible, facilitate greater collaboration between water companies in the development of innovative technology to the commercial stage. UKWIR, in a modified guise, could be an appropriate vehicle for this.**

- **Ofwat, the Environment Agency and Defra must ensure that a balanced and proportionate approach is taken to the dichotomy between high carbon treatment solutions and local environmental regulations. There is a conflict between this kind of environmental quality legislation and the climate change mitigation implications of treating water to an ever-higher standard. A more risk-based approach including more dynamic consenting is a way to mitigate against this driver and should be promoted where outcomes would be likely to be positive.**

- **Building regulations must be aggressive in encouraging low water use in new developments and in the development of infrastructure which enables greater discretion between where highly treated water is required and where it is not.**

- **Water companies should be given a target of reducing water demand of 1 l/p/d/year for domestic supplies. For non-households this should be 3% a year.**

- **Greater attention should be paid to removing the regulatory barriers to widespread employment of co-digestion.**

- **Water companies should be actively encouraged to use their landholdings for the optimum generation of renewables.**

- **Water companies should become water service providers, providing advice and assistance to their customers on both water and energy efficiency associated with water use.**

- **The Government, Ofwat and water companies should re-examine the appropriate timescale for smart metering for water. Given that much of the cost associated with meter installation falls in relation to the deployment of installation teams, it seems entirely counterproductive to have a widespread metering programme currently in place by many water companies, installing 'dumb' meters, when in 10 years' time many of these may need to be replaced with smart meters as the water industry catches up with the energy sector.**

- **Externalities in the SELL analysis should be reconsidered to ensure that these better reflect the full value of water and leakage should be reduced, if necessary by setting tighter leakage targets.**

- **Both domestic and non-domestic customers should be encouraged and helped to reduce their water consumption through a change in conscious behaviour, rooted in a deeper understanding of the value of water. Whilst water efficient appliances and metering have a role to play, education and awareness, leading to understanding and behavioural change, will be essential in reducing the amount of water required to be put into supply.**

CIWEM considers that there is a wide range of existing and developing technologies which have the potential to achieve appreciable emissions reductions within the water industry, despite the existence of drivers in the form of increasingly stringent water quality standards, which will continue to require more intensive treatment for some time to come. The actual contribution that these might make is unclear and is likely to depend on a number of factors including regulatory incentivisation and future carbon prices, which are likely to impact directly on the level of importance and focus attached to emissions reduction.

The UK is well placed to lead low-carbon innovation within the industry, given its strong academic and engineering bases. The importance of knowledge sharing in this process is key, in order to shorten the timescale over which innovative ideas become commercial realities. Over a timescale approaching 40 years, it is conceivable that the operational methods and technologies the industry employs could change dramatically.

At the same time, there are certain realities that mean the industry is unlikely to deliver an 80% reduction in its carbon emissions without reliance on savings on 'indirect' emissions associated with low carbon electricity. It is a highly energy intensive industry and water is always likely to require a large amount of energy to treat to a high standard and to pump around networks, even if significant efficiencies can be found and generation of renewable energy by water companies can be maximised. It is essential, if the UK is to meet the targets under the Climate Change Act, that a committed approach is taken to all these considerations.

CIWEM is committed to playing its role in this process. Through this study we have identified further areas of research including the industry-wide quantification of carbon (and economic) savings, and the need for a scenario study to examine future issues associated with population, consumption and efficiency savings, environmental regulation, and cost. CIWEM will promote this research. We will also be seeking to bring relevant parties together to discuss water, energy and carbon – and the specific barriers identified here, in a series of seminars. This will be supported by our Climate Change and Energy Networks.

The Chartered Institution of Water and
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