Environment Agency

Evidence

A Low Carbon Water Industry in 2050

Report: SC070010/R3

Resource efficiency programme

Evidence Directorate

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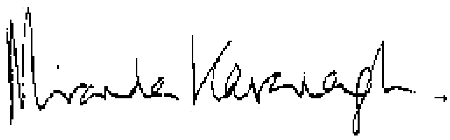

Miranda Kavanagh

Director of Evidence

Executive summary

Six academic authors were invited to independently describe their visions for a low carbon water industry in 2050. The essays have different styles and emphases, but the authors agree on many of the present and future challenges, opportunities and constraints that will shape the water industry of 2050.

All of the authors identify a holistic approach as the key to reducing the industry's carbon footprint. They emphasise that the challenging targets for reducing CO_2e (carbon dioxide equivalent) emissions can only be met if the industry enters far-sighted partnerships with its suppliers and consumers and is supported by a framework of effective policy.

This report is an important part of an Environment Agency science project that is examining the potential for, and barriers to, reducing greenhouse gas emissions from the water industry. Failure to appreciate the breadth of opportunities for reducing carbon footprint and how they are inter-related may result in failure to maximise the benefit of particular opportunities. Failure to appreciate the challenges and constraints that surround opportunities may lead to poor planning and policy-making.

The context for this report, and the Environment Agency's wider project, is the Climate Change Act, which imposes a legally binding target of reducing, by 2050, UK greenhouse gas emissions by 80% from their 1990 levels.

The authors were asked to consider especially:

- what paradigm shifts are needed to deliver a low carbon industry, for example in water infrastructure, scale of operations and technology options?
- what associated behaviour change from consumers and companies will be needed and how could barriers to achieving this be overcome?
- are the mechanisms, to deliver a low carbon industry, already in place through use of the Shadow Price of Carbon and Carbon Reduction Commitment from 2010?

The authors identify a holistic approach as the key to reducing the water industry's carbon footprint to meet the UK's national target.

They specifically refer to the need to:

- decarbonise the electricity industry,
- exploit renewable energy sources available within the water industry,
- encourage cultural change amongst consumers (water efficiency, appreciation of water's 'value'),
- develop risk-based decision-making that balances water quality against carbon mitigation,
- reduce levels of pollutants at source,
- decentralise the water supply,
- use sustainable drainage systems (SUDS),
- encourage research, development and deployment of new technologies,

- make appropriate and effective policy changes and,
- develop carefully targeted financial incentives.

The water industry will be at the forefront in dealing with the effects of climate change. Several of the authors highlight the effects of climate change on the UK and describe both the likely extent of the impacts and the uncertainties associated with predicting impacts. The complexities are illustrated by visions of sea level rise and increased drought driving population migration within Europe and the UK, while the water industry simultaneously addresses the effects of extreme weather events eg more frequent and severe flooding and increased incidence of water-borne disease. 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.

The authors recognise that stakeholder engagement is crucial in affecting consumer behaviour and managing societal expectations through a period when radical changes in the industry will have to take place. The authors acknowledge this is a task that should not be underestimated.

All of the authors identify energy use as the water industry's main source of CO_2e emissions. Several suggest that water companies may merge with energy producers to create more effective partnerships for tackling emissions. There are suggestions that water industry 'wastes' could be used as renewable energy sources. One author describes a pilot project that is currently generating 4% of a company's power requirement from a third of their treated sewage.

New technologies for treatment and processing of 'waste' streams are suggested, which would recover heat and valuable raw materials for agriculture and manufacturing, further reducing carbon use.

Among the visions described in the essays are many innovative and radical approaches to reducing CO_2e. Together they highlight what is captured by a quote from one of the authors "the only certainty for 2050 is that the situation will be more different than the one we can imagine now."

It is in this context that the authors emphasise the need for effective, joined-up and far-sighted policy-making, which encourages and supports desired changes in the behaviour and performance of the water industry, its suppliers and end-users.

Contents

1 Introduction

This introduction summarises the views expressed by Professors Dieter Helm (University of Oxford), Charles Ainger (MWH and Cambridge University), David Butler (Exeter University), Issy Caffoor (University of Sheffield), Douglas Crawford-Brown (Pell Frischmann and University of North Carolina) and Tom Stephenson (Cranfield University).

As part of an Environment Agency Science Project examining the potential for, and barriers to, greenhouse gas reduction by the water industry, six academics were commissioned to provide their visions for a low carbon water industry in 2050. Along with other parts of UK society, the water industry must move towards a low carbon approach in order to contribute to delivery of the Climate Change Act's legally binding target for 2050 of reducing UK greenhouse gas emissions by 80 per cent from 1990 levels.

The authors were invited to contribute a short 'think-piece' considering the following questions:

- What paradigm shifts are needed to deliver a low carbon industry, for example in water infrastructure, scale of operations and technology options?
- What associated behaviour change from consumers and companies will be needed and how could barriers to achieving this be overcome?
- Are the mechanisms, to deliver a low carbon industry, already in place through use of the Shadow Price of Carbon and Carbon Reduction Commitment from 2010?

The think-pieces are presented in this report and summarised below. They are a combination of ideas and suggestions for the water industry and its regulators as they consider how to reduce carbon emissions in line with national targets.

Overall the authors highlight the need for a holistic approach, decarbonisation of the electricity industry, use of internal renewable sources, cultural change (water efficiency), risk-based balancing of water quality with carbon mitigation, reduction of pollutants at source, decentralisation of supply, use of sustainable drainage systems (SUDS), enhanced technologies, increased piloting of technologies, policy changes and financial incentives.

Key Features

In order to move towards a low carbon water industry the authors agree that a holistic approach will be one of the key requirements to meet the ensuing challenges. Partnerships and joint working between water companies, customers and suppliers - including energy companies and technology suppliers - will need to be commonplace.

The largest proportion of the water industry's carbon dioxide equivalent (CO_2e) emissions is attributed to energy use. Therefore, decarbonisation of the energy industry is essential to enable the water industry to meet its target for reduction of emissions. The authors envisage an increasing trend for water and energy companies to merge in order to effectively and collectively reduce CO_2e emissions. This will be achieved by use of renewable energy sources, management of electricity demand (by the water industry) to take account of the intermittency of renewable energy sources and increased emphasis on harnessing renewable energy from water industry activities. There will also need to be strong links between the water industry, the agriculture sector and waste companies in order to ensure interlinked cradle to cradle planning for all sectors.

The task of engaging stakeholders and facilitating cultural change should not be underestimated. Significant end-user education will be required to communicate to users the value of water and assign greater consumer responsibility for the protection of this valuable resource. However, as Caffoor states, “the climatic stresses of the future will contribute to the removal of these barriers and to a culture change in the stakeholder base.”

In realising the CO_2e reduction targets the industry and its regulators will need to take a risk-based approach, with greater emphasis on balancing the need to reduce carbon emissions with the need to protect human health. One effect of climate change could be an increase in water-borne diseases; emerging risks like this will also have to be managed carefully and effectively. This will require regulatory reform as the Environment Agency, Defra and Ofwat were not set up to deal with the risk-based nature of these issues. Crawford-Brown notes that “someone needs to perform this balancing, but at present it is not clear that any one authority has the power or incentive” to do so.

It is the view of the authors that to reduce energy consumption in water industry operations the emphasis will have to move towards prevention of contamination at source. “The carbon footprint of cleaning water after it has been contaminated is almost always significantly higher than preventing the contaminant from entering the water in the first place.” (Crawford-Brown). Such prevention measures will require large changes in agricultural practices. The impacts of climate change will inevitably force changes in land management. However, ensuring alignment of land management to reduce contamination with management for agricultural productivity will be a significant challenge. Fully integrated catchment management, including catchment based consents, will be required to ensure optimum environmental, social and economic solutions.

Policy Implications

To implement all the changes that will be required to move to a low carbon water industry, significant policy and regulatory reform will be needed to further incentivise the low carbon approach. Policy will need to encourage the use of lower quality, previously unused water sources. Regulatory changes will be necessary to reward carbon innovation through tax breaks. To encourage cross boundary co-operation between water industry stakeholders, institutional reform will be required. It is noted that Government must address the Shadow Price of Carbon, as its current price is too low to incentivise major change. Also, changes to the Renewable Obligations Certificates are required to allow water companies to claim for internal low-head hydro schemes. Ofwat’s previous remit, to ensure an inexpensive water supply, will need to be reformed, to align the whole industry with the challenge of reducing carbon emissions. Regulatory reform for abstraction licensing will be needed, both in terms of increased emphasis on water efficiency in those organisations requiring abstraction licenses and license durations. Short duration licensing will become more common.

Infrastructure Implications

Regarding the infrastructure changes that will be required in the future. The authors note the effects of increased rainfall, due to climate change, on the water industry. The increasing frequency and severity of floods is likely to require additional infrastructure. This will include additional storage requirements, increased pumping capacity and increased volumes requiring treatment. Flooding constraints are also likely to mean that the industry will be forced to remove surface water from foul sewers. Ainger notes that, by 2050, flood events will have led to a change in urban design, with widespread sustainable urban drainage systems.

Cafoor notes that the overall length of the water infrastructure will be significantly reduced, as will pumping. In combination with this, improved location and condition assessment technology for underground infrastructure will provide significant carbon savings on mains rehabilitation programmes. The energy demand for water distribution will be reduced through pump optimisation, low friction linings, online energy/resource optimisation systems and pressure reduction systems, and smart and self healing pipes. Design standards for pumping stations will be revised to reduce pumping inefficiencies induced by cavitation in pipes. Energy recovery will also be possible through small-scale hydro in pumped networks, given changes to Renewable Obligation Certificate incentives.

Energy Implications

Increased flooding is likely to increase energy demand, in the water industry, because of the increased water volumes requiring treatment and pumping. Use of renewable energy sources to supply the additional energy required will help towards the low carbon approach. Energy recovery, through on site small-scale low head hydro schemes, may provide a carbon efficient means of meeting demand and maintaining a low carbon approach. The intermittency of renewable energy sources is an issue that will need to be addressed in the future and the water industry should be able to capitalise on this by implementing ‘electricity demand side management’ (EDSM). EDSM would require the water industry to shift parts of their electricity load from periods of high electricity demand to periods of low demand. This helps to balance demand across the grid and hence lessens some of the inefficiencies and technical difficulties that would result from electricity storage. This would contribute to the low carbon approach and potentially reduce energy costs if peak and off peak tariffs were applicable. (Butler).

Business Models

By 2050 the industry and regulators will be well used to focusing on long term strategies that encourage carbon critical design to achieve wider sustainability. Such long term strategies will require new business models to meet the required carbon reductions and this will inevitably raise concerns about the financial sustainability and operational efficiencies of the companies. Therefore, it is essential that the relevant financial incentives are embedded into future policy and business plans. Ainger suggests that water companies should produce 2050 asset plans, based on a low carbon objective, to allow comparison of their current and near future plans with their 2050 plan and assessment of whether they are progressing in the right direction.

Technology Requirements

To bring about the large scale changes needed to reduce the carbon impacts of the water industry, significant technological and scientific advances will be required. Co-operative research will be necessary to facilitate development of the required technologies and, it is hoped, the Cave Review will start to encourage this co-operation. Crawford-Brown notes that "technological innovation must be set within a framework of reform in which all who affect water quality as sources of contaminants, all who consume water, all who regulate water and all who provide it become an integrated system in which responsibilities fall equitably and effectively." This research and development will therefore require large financial investment.

In the future, advances in water and waste-water effluent treatment will reduce carbon emissions from the water industry, these may include maximisation of biomass production to reduce CO_2 emissions, use of bubble-less gas mass transfer bioreactors, reduced use of aeration as a result of greater understanding of microbial processes and process controls (Stephenson), novel adsorbents and catalysts, low pressure self-cleaning free membrane systems and energy monitoring at a sub-process level. As Stephenson notes, attention to process management in a carbon context will be essential for ensuring that CO_2 emissions are reduced, at Waste Water Treatment Plants for instance.

Decentralisation and Water Quality

It is likely that the water industry will need to decentralise water supply and take a more localised focus, where resources allow. It is noted that to make a large reduction in carbon use associated with water it will be necessary to lower the quality of water used for non-potable applications. This is likely to mean that local water sources will be used for low quality applications, as will rainwater, grey-water, surface water and water contained in SUDS. End of tap treatment of drinking water could be implemented. This would mean that water treatment works could treat to a lower 'general use' quality and consequently lower their energy use and CO_2e emissions. Dual water supply systems will be common at a community level, in new developments and in urban regeneration projects. Local processing will be powered by electricity from micro-generation projects.

The Environment Agency will move to set discharge standards to levels, based on sustainability assessment, that balance both local and global environmental need and provide for carbon trading. This will provide more specific, local regulation that will enable companies to reduce energy intensive treatment where river needs allow (Caffoor).

Societal Impacts

The major changes envisaged for the water industry as a result of climate change and low carbon strategies are likely to cause societal changes. The authors suggest that, under extreme water resource constraints, population distributions could change as a result of water pricing and availability, e.g. movement to the north and west, away from water stressed areas in the south east. In the future, the UK may need a more sustainable food production system to address climate change induced reductions in the reliability of food availability from overseas. A major education programme is required to instil in users the value of not only water, but all resources and with this some of the responsibilities for water efficiency need to be assigned to the consumer.

Financial Implications

The drawbacks of moving to a low-carbon water industry are the costs that will be incurred in changing from current practices, driven by economics, to practices that are influenced by the need to reduce carbon footprint. It is likely that the asset base will increase due to low carbon approaches and the technologies required. Financing such changes will be a challenge for the industry and will require policy, regulatory and consumer backing. Water tariffs will have to be increased to support the sustainability of the resource, in the light of potential climate change, and the industry's low carbon approach to the supply of the resource. Such price increases will help to instil in consumers the value of these resources. Helm suggests that harnessing the industry to the climate change agenda now "…needs a price of carbon, a rebuilding of the R&D capability and a regulatory regime which ensures that the costs are recovered. Attractive though it may be to politicians and regulators to keep prices down now, it is a poor deal for the future generations who will have to live with the consequences."

Conclusion

The common view of the authors is that, by 2050, the effect of climate change will have removed the barriers that currently inhibit a low carbon approach in the water industry. These barriers include; the low value stakeholders place on resources, regulations, high water quality standards, lack of financial incentives and low carbon pricing.

In short, in 2050, "water will be the new oil and carbon will be its currency" (Caffoor).

2 A Low Carbon Water Industry in 2050

Professor Dieter Helm

University of Oxford

6th March 2009

Introduction

Climate change is a daunting global challenge. The trends are adverse, emissions are growing, the CO_2 concentrations are approaching 400ppm (from a pre-industrial 275ppm), and the share of coal in world energy is expanding. All this is happening in the context of a projected population rise from 6 to 9 billion by 2050 – representing more additional people than the entire world population in 1950. The extra three billion will be predominantly in China, India and Africa.

Global action is vital, but local action counts too. In the UK, although carbon production has fallen by around 15% since 1990, carbon consumption has gone up by around 19%. The difference is explained by adding back in the carbon content of imports from the energy intensive industries that are now offshore in countries like China and India, and taking aviation and shipping emissions into account. So there is a very steep challenge if the UK is to make an appropriate contribution to global decarbonisation. The water industry has a considerable contribution to make and it is an industry that is going to be significantly affected by the warming which is now inevitable.

Decarbonising the water industry

The water industry is responsible for a number of different carbon emissions. It uses a significant amount of energy, the wastes give off a variety of emissions and its management of water systems affects land, rivers and reservoirs. It also has a lot of land – and sites for electricity generation.

The energy use is primarily for pumping, although there are transport and other needs. In principle this energy could be significantly decarbonised. The industry could, by a careful balancing of generation from waste (methane in particular), generation from renewables and the management of its demand patterns, become completely carbon neutral. It is not a question of technical capability, but rather economic and regulatory incentives and constraints.

Moving into active low carbon generation is likely to raise costs significantly above those of conventional sources of supply. Wind generation in particular is expensive. Water companies do not control their prices – these are in the hands of the regulators. Therefore, whether companies push ahead rapidly with decarbonisation depends on their being allowed to pass these additional costs through. Currently there is much regulatory resistance.

Generating from waste is also an area where there are heavy regulatory and policy influences. Biogas can be burnt or, more efficiently, it can be cleaned up and put directly into the gas distribution system. The latter is more efficient than the former, but there are few incentives on the gas distributors to push this forward. The economics of burning the methane depend upon the costs of the alternatives – and alternative disposal routes for the waste.

Indirect carbon emissions are affected by the ways in which land is managed. Some innovative companies have already become more proactive in land management to deal with the diffuse pollution problems created by agri-chemical farming methods. It is sometimes more economic to pay farmers not to pollute the water systems with fertilisers and chemicals than it is to clean up the pollution in water treatment works. In flood management, keeping water meadows free from ploughing can help limit flooding and the amount of silt in water systems. It also limits the pollutants reaching water courses.

Soil is a significant reservoir for carbon and its use affects both the carbon sequestration of plants and the release of captured carbon. Policy and regulation for land use has primarily focussed on the farming angle and, more recently, on biodiversity. For the water industry to play its full part it will need to move on to integrate climate change in approaches between water companies and farmers in a much more holistic way.

Adapting to climate change

Whether or not the water industry decarbonises, the rest of the world is not likely to keep pace and temperatures will rise and climate will change. Two degrees warming is very likely and on present trends it may go much higher. Higher global temperatures mean changing weather patterns and there is very great uncertainty as to what this means for both the amount, and the distribution, of rainfall. Current estimates of what will happen in specific water company areas 20 or 30 years hence are very much stabs in the dark.

As a consequence, it is far from clear whether water resources will have to be increased. Greater rainfall in winter replenishes supplies and reduces the need to provide for summer droughts. Higher rainfall in summer reduces demand and increases supplies. Whilst it is possible that the densely populated south east will be hotter and drier, it could be hotter and wetter.

Given the uncertainties, actions which retain flexibility are very important. The most obvious is the ability to manage demand; this means metering and eventually more complex volume-related pricing. This is probably a good idea, whether or not climate change occurs, as it increases the efficiency with which existing resources are used.

In the event that resources come under pressure, there are important choices about new water resources. They could come from desalination. Here the objection is that this is energy intensive. However it is only detrimental to climate change if the energy itself is carbon intensive. For the reasons explained above, it need not be. New reservoirs have pluses and minuses. For example, if intensive arable land is displaced by a reservoir, this may reduce carbon emissions and improve carbon sequestration relative to what was there before. Leakage reduction provides another new resource – perhaps increasing water supplies by 10-20%.

A price of carbon

Reducing the carbon footprint will not happen spontaneously. The water industry is one of the most heavily regulated in the UK. To provide an overarching incentive, the price of carbon needs to be internalised in every aspect of the water industry's activities. In principle this may come through including the industry into the EU Emissions Trading Scheme. However this is a highly volatile and, at best, limited route to establish incentives and it will need to be supplemented in investment planning and operations by a more stable measure. The obvious way to do this is to require the industry to incorporate a social cost of carbon – a price – in all its business planning activities and to incentivise the companies to outperform, in carbon terms, against this benchmark.

An objection to this is that such a mechanism is crude and there will be much argument about the precise number. This is beside the point: what matters is that the industry is on a near-zero emissions path by 2050 and if it gets there a bit quicker this should be a subsidiary concern.

Technology, technology, technology

A carbon price helps, but over the next few decades what really matters is technology and technical progress. In 40 years time we can only guess at the possibilities – just as 40 years ago the internet, the mobile phone and even the fax machine were unknown. It is gradually dawning on many in the industry that waste is a big resource and that it potentially has significant positive value. At the other end, smart meters might in 40 years time be able to manage our water use with an efficiency we would find it difficult to comprehend today. From our present crude world in which we use treated drinking water to clean the car and water the garden, technology offers enormous scope for improvement.

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.

Great potential

Bringing these dimensions together, it is clear that there is very considerable scope for the water industry to contribute towards the low carbon economy. Some of the measures necessary are obvious, such as the shift towards low carbon generation and supplies. The use of waste and the better management of land are also important. Adaptation too can be low carbon. Technology has lots to add to the supply and demand sides.

But none of this will happen without a clear policy and regulatory framework. For the water companies, low carbon strategies have to pay. This needs imagination on the part of the government to set out a clear framework and associated targets for the water industry. It also needs to be joined up with the regulation. Customers will have to pay, but then they are the ultimate polluters. Carbon is produced in the process of delivering their water supplies and dealing with their sewerage.

Customers also have a responsibility to ensure that these supplies are provided in a way that meets the sustainability requirement – to ensure future customers are at least as well off as they are. Since we are all currently polluting so much that the very climate is being changed, it is our responsibility to make sure that we not only clear up our emissions, but also pay for the R&D that will help those in the future to cope with the potentially much worse climate we will bequeath them.

Harnessing the industry now to the climate change agenda is not rocket science. It needs a price for carbon, a rebuilding of the R&D capability and a regulatory regime that ensures that costs are recovered. Attractive though it may be to politicians and regulators to keep prices down now, it is a poor deal for the future generations who will have to live with the consequences.

3 Municipal Sewage Treatment in 2050

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This think-piece considers what the sewage treatment works of 2050 might look like. Factors that will influence the choice of flowsheet, such as sewerage infrastructure, carbon accounting and water use, are considered. Management of the sewage treatment flowsheet itself is predicted to be a major innovation, together with the use of novel unit operations.

Introduction

Pick up a textbook from the start of the 20th Century and those familiar with today's sewage works will not have difficulty recognising the flowsheet of the 1900's (1). The sewage treatment flowsheet has remained largely unaltered for almost a century.

At its core, sewage treatment relies upon sedimentation and aerobic biological processes. The great innovation of the late 19th Century was the trickling filter, harnessing biology to allow polluting organic matter to be removed. In 1913, a long time ago, the development of the activated sludge process introduced greater control and in modified forms allows nutrient removal i.e. nitrogen and phosphorus (2).

So why might a new flowsheet be needed and what will a sewage works look like in 2050? It is worth quoting Kershaw (1) from almost a century ago, "There is no 'best method of sewage disposal' which can be universally adopted regardless of local conditions". This will remain true; but the nature of the sewage to be treated in 2050 will have changed.

Sewerage

In 2050 there will still be an extensive sewerage network. Dry composting and urine separating toilets will be more readily available, but their acceptability to society will remain limited and particularly so in urban areas. Life cycle analysis, public acceptability and public health studies will have shown that continuing to use water-borne sanitation remains the accepted and most universally applied system.

Currently, the total waste sector is reckoned to be responsible for 3% of total global greenhouse gas (GHG) emissions (3). Between now and 2050 the big reductions in GHG emissions are likely to come from other sectors, such as primary energy production and transport. This means that in 2050 the carbon footprint of sewerage networks and treatment plants will be a higher proportion of the overall carbon footprint and so be subject to greater scrutiny. Alterations will be avoided whenever possible to reduce increases in embedded carbon (4).

Planning permission, with greater stakeholder engagement embedded through EU legislation, means that relocation of existing wastewater and waste disposal sites will remain very difficult and often uneconomic. Therefore, best use must be made of existing sites and their infrastructure.

Sewage Flows and Loads

In 2050, influent flows and loads to municipal sewage treatment works will have changed – but not dramatically. There will be some attenuation of stormflows through the application of techniques such as Sustainable Urban Drainage Systems (SUDS). However, the cost of retrofitting sewer networks – in money and carbon footprint terms as noted above – means that extensive separation of foul and storm waters will not have taken place.

There will be a much reduced contribution from trade effluents as industry moves to more efficient water use and better in-process water recycling. Changed formulation of detergents, cleaning and personal care products will mean that non-biodegradable – 'hard' - chemical oxygen demand (COD) and nutrient concentrations will have been reduced. Therefore, sewage constituents will be more biodegradable.

Domestic water consumption will have fallen, reaching today's upper target of 120l per head per day (5), but not beyond because of people's lifestyles. Therefore, typical sewage strength will have increased. There will be more widespread use of collected rainwater for toilet flushing, presenting the regulators and water utilities with an interesting problem of how to charge for sewerage decoupled from potable consumption.

So the sewage of 2050 will remain variable in terms of flow and quality, but will be stronger and more biodegradable.

Flowsheet Management

At all medium and large treatment works, smarter use of flow balancing and internal recycles will be the norm. Rather than designing all parts of the works to treat 3 dry weather flows, whatever the flowrate, this will allow crucial unit operations to be operated at near-steady hydraulic loads close to their optimal design.

On-line sensors will also allow the strength of sewage, in terms of key components such as suspended solids and biochemical oxygen demand (BOD), to be monitored and adjusted by blending different streams to maintain constant loading. These sensors will not be 'fit and forget'. However, many will not only be self-cleaning, but self-calibrating. Managers of treatment plants will recognise that care and maintenance of sensor systems will be crucial to better treatment.

Overall, control of sewage treatment works will look more like that of chemical process plants than sewage works of today. Techniques that have been commonplace in the manufacturing sector, such as the use of statistical process control, implementation of continuous improvement ('Kaizen') and application of 'six sigma' will be widespread. Good quality data from the sensor systems mentioned above will be critical in applying the techniques that will allow plants to be operated in optimal modes, thereby reducing overall life cycle costs of operation and minimizing the carbon footprint.

The practice of composting green wastes will have been restricted; it will have been realised that this fast-tracks carbon dioxide back to the atmosphere. At suitable sites, modified anaerobic digesters will receive a mixture of organic municipal waste with primary sludge to generate methane.

The New Flowsheets

As noted above, in 2050 there will be a range of flowsheets applied to sewage treatment depending upon the local circumstances, as there always has been.

However, there will have been a revolution in the core unit operations used in municipal sewage treatment works. A major development will have been the application of anaerobic processes to mainstream flows. Ambient temperature anaerobic treatment of sewage will be possible by fortification of the influent waste stream, either from sludges generated on-site or other imported organic wastes. These processes produce biogas to recover energy, but the major benefit will be reduced aeration costs (Cartmell, pers. comm.).

Where aerobic processes are used, they will be operated to maximise biomass production. This leads to a reduction in carbon dioxide emissions – at a maximum, 5 times less oxygen is required to treat organic carbon when compared to a zero biomass yield aerobic process (6). Aeration costs will be reduced further by using bubbleless gas mass transfer bioreactors; this technology removes the need to dissolve oxygen in water, the rate limiting step for oxygenation (7). Aeration needs will be further reduced through greater understanding of the underlying microbial processes and better process control. For example, nitrification will be stopped at nitrite prior to denitrification and anammox-type processes, oxidation of ammonia by nitrite will be more widely used.

More works will be covered to prevent odour dispersion to local communities. This will offer the opportunity of removing pollutants via the off-gases. For example, low energy total nitrogen removal could be achieved by inhibiting nitrification to form nitrous oxide gas, reducing aeration requirements compared to converting ammonia to nitrite or nitrate, which can be removed while off-gas odours are treated.

At some works, primary sedimentation will have been replaced by continuously moving fabric belt filters. These ensure that suspended solids removal is more efficient, leaving an almost solids free effluent – which might be called ‘filtered sewage’ rather than ‘settled sewage’ – for onwards treatment. Mechanical removal of the solids – ‘primary filtered sludge’ – from the filters ensures that the solids dry weight composition is high, eliminating the need for one or more solids thickening and dewatering stages prior to further sludge treatment.

The overarching principle of waste minimisation – to deal with waste at the source rather than mix and dilute – will be applied to sludge treatment and handling. Sludges will be treated as a fuel rather than a waste (8). The drive will be to remove water in order to recover energy from sludges. Sludge dewatering technology will have benefitted from concerted research investment so that economic physico-chemical unit operations are available.

Almost complete removal of solids, either as described above or using membrane bioreactors, will allow adsorption processes to be applied to remove residual nutrients. For example, ammonia and phosphate selective ion exchange processes will recover these materials for industrial uses, including fertilizer. Alongside biogas and biomass production, some sewage works will be considered as chemical production plants.

Final Effluent Uses

By 2050, consenting will have changed. An environmental risk-based approach will see sewage works operators changing discharge quality depending on the receiving waters capacity for self-cleaning without adverse environmental impact.

Where local conditions permit, final effluents will be reused in agriculture rather than undertaking expensive nutrient removal. Secondary effluents will be delivered to farm storage reservoirs or direct to fields and glasshouses for crop production. Better quality effluents will be reused locally for non-potable applications such as toilet flushing and irrigation of sports fields.

Thus in 2050, smarter use will be made of final effluents, as cleaner water will remain the most valuable product resulting from sewage treatment.

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4 In 2050 Water is the New Oil and Carbon is the Currency

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Abstract

Water is the new oil and carbon is the currency that will drive the Water Industry to make significant changes to reduce its carbon budgets. The industry will also be a significant player in the Carbon Reduction Commitment in 2010 and contribute to the UK's carbon reduction targets. This paper outlines a vision for a low carbon water industry in 2050. It recognises that a multifaceted approach will be required that: builds on research, technology and skills development; requires policy and institutional reform that allows new approaches; requires cross boundary cooperation and systems; builds stakeholder capacity to understand risk and mitigation and provides financial support to incentivise a low carbon approach.

This paper describes the potential business and infrastructure models that may result and outlines how demand reduction, water sensitive urban design - including community based solutions and significant changes to water industry operations will contribute to the low carbon vision. The paper identifies the many barriers that inhibit a low carbon approach and suggests that future climatic stresses will contribute to the removal of these barriers and to a culture change in the stakeholder base.

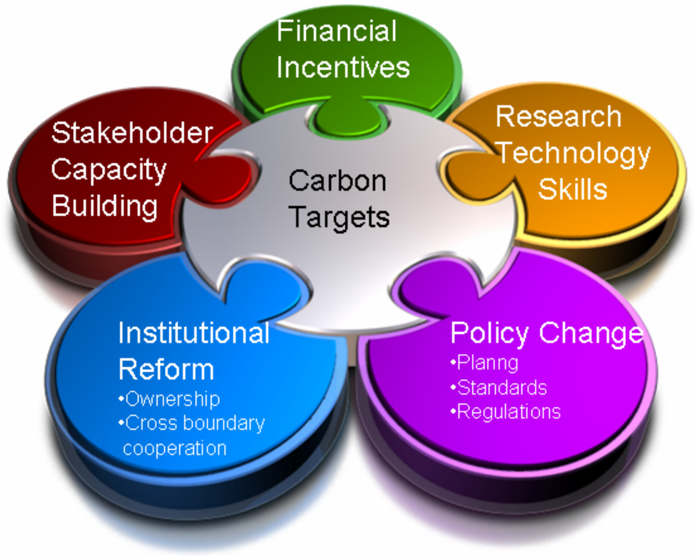
Introduction

In the years leading up to 2050 the UK Water Industry will see major changes in response to the UK's carbon targets. Water will be the new oil and carbon will be its currency. The following paragraphs paint a vision of what the industry might look like in 2050 in response to this paradigm.

There will be a growing recognition that the achievement of the government's carbon targets require a multifaceted approach (See Figure 1) involving: research, technology and skills development; policy changes that provide new planning guidelines, standards and regulations; institutional reforms providing clarity on ownership and encouraging cross boundary cooperation; capacity building in all the stakeholder base to build knowledge, awareness of risk and mitigation and financial incentives/disincentives to mobilise end-user commitment, commercial manufacture and uptake of solutions.

In 2010 the water industry will find itself contributing significantly to emissions traded in the Carbon Reduction Commitment (CRC) and may face financial penalties.

Figure 1 – The muti-faceted approach required to achieve carbon targets.



Impacts of Climate Change

In 2050 there will be areas of severe water stress in most areas of the country as a result of low river flows in the summer months. Many rivers will be prone to drying up altogether for significant periods of time. Groundwater sources may be subject to serious contamination from agricultural chemicals, micro-pollutants and saline intrusion. Consequently, more energy will be being used for additional pumping from stored water and for additional treatment to maintain water quality. The Environment Agency (EA) will be forced to rethink policy on abstraction licensing and short duration, time limited licenses may become common, as will the abstraction of previously unused poorer quality resources. Climatic effects will increase flooding, with potentially a 25% increase in precipitation and increased river flows in the winter months. This will require more infrastructure and increased energy use for additional storage, increased pumping and treatment of increased volumes.

Socio-economic changes

Water Resources and flooding

The value of the water industry asset base will increase significantly to facilitate low carbon approaches (£200Bn to circa £400Bn). Tariffs will reflect the cost of long-term infrastructure, climate change adaptation and resilience strategies and a rising block tariff pricing system is likely to be imposed. In some parts of the country this will probably result in water prices tripling, in real terms, reflecting the true local value of water, but with appropriate protection for the poor and vulnerable. The higher value placed on water in water-stressed parts of the country, combined with insurance premiums in flood risk areas, will result in a slow redistribution of population away from water/flood stressed areas. This managed retreat is inevitable as demand grows, due not only to a growing population (by 2015 London could potentially have an additional 800,000 citizens), but also because of changes in the way people live.

Retreat from coastal areas will free up more land for intensive farming, combined with a move away from meat to crop production and towards extending seasons by using greenhouses, this will further increase pressure on water resources. However, the need to establish a sustainable food supply for the UK is likely to reverse the move to bio-fuel crops, as climate induced changes in water quantity and quality affect food availability, stability, access and utilization.

Maintaining the demand/supply balance will prove challenging in the next few decades. Leading up to 2020 water demand could increase significantly, up to an average of 165 l/p/d from 150 l/p/d in 2009. In 2050, the average per capita consumption may need to be closer to <100 l/p/d (70 l/p/d in some regions) to be sustainable. The demand /supply balance may stabilise following severe droughts in the coming decades and as a result of initiatives to reduce consumption, decrease leakage and facilitate cross company resource planning and regional water transfers. This will likely include an accelerated move to universal metering in the period 2020 - 2030, from the planned 50% in 2020 to an accelerated plan resulting in circa 90% of houses metered in 2050.

The Code for Sustainable Homes, introduced in 2008, will become mandatory for all new housing stock and be superseded by a Code for Sustainable Communities, specifying community infrastructure standards. The government will develop a "Sustainability Strategy" and define the metrics against which solutions can be measured.

A major public education programme to value water will be introduced into the national curriculum, with particular focus on primary school children. The Department of Environment, Food and Rural Affairs (DEFRA) will introduce an accreditation scheme for water efficient devices that will reduce demand and waste. A universal metering target will be imposed.

Urban design

The carbon-neutral eco-projects in the Thames Gateway, for the 2012 Olympics, will be followed by a programme of building public-funded flagship housing settlements. This will roll out from the eco-towns programme and in response to the depression in 2010. These settlements will have Water Sensitive Urban Design (WSUD) and be "Smart Homes" with "water neutrality" as a centrepiece. They will incorporate:

- sustainable technologies such as smart multi-utility meters for demand control, leakage detection, tariff flexibility and providing consumer information;
- water and energy efficient white goods;
- solar panels, to heat water;
- water efficient fittings such as low flush toilets, restrictors on sinks and showers;
- community/property level rainwater harvesting and grey water recycling;
- surface water management strategies including, separate sewers for foul and surface water;
- source control of storm water;

- SUDS (Sustainable Urban Drainage) and other natural flood mitigation infrastructure such as Rain Gardens (sunken gardens planted with native perennials) and Green Roofs;
- community level and 'at tap' water and wastewater treatment facilities and,
- dual water systems.

Heating of water constitutes 25% of the total energy consumption in the home and accounts for 89% of CO_2 emissions associated with water (35 million tonnes Green House Gases). Reductions in shower duration and water consumption by dishwashers and washing machines will be seen as crucial to reducing the carbon footprint associated with water. Community level micro-generation and ground-source heat-pumps will become more prevalent as the technologies mature. Micro-generation will increase as the water companies work in partnership with energy producers, once OFWAT (Office of Water Services) removes the barriers that prevent the use of regulated capital. There will be an expansion of transmission capacities that link the areas of best solar and wind energy supply to population centres and industry. The Water industry will be ideally placed with its land bank and assets. The above will provide the stimulus to undertake non-regulatory activity, such as micro-generation, the growing of bio-fuels and partnering with councils on waste to energy projects. The Department of Energy and Climate Change (DECC) will realise that the water sector has a significant role to play in the energy markets, both as a large-scale user and as a potential generator. DECC will work with water companies to review the use of ROCs (Renewable Obligation Certificates). This will incentivise further development on new approaches such as "blue energy" (utilising the osmotic potential between freshwater and seawater in estuaries) and energy from algae.

Policy and Planning

Public sector housing projects will provide valuable demonstration programmes for innovation, supported by the government Technology Strategy Board's (TSB) Water Technology Innovation Platform and any future funding from carbon mitigation programmes.

Private sector housing schemes will be incentivised to introduce measures through carrot and stick mechanisms, administered through fiscal incentives and planning laws. The introduction of sustainability metrics and changes in regulation to reward carbon innovation, through tax breaks, will incentivise end-users, the supply chain and private sector housing to introduce, and invest aggressively in, energy and water efficiency. Economic regulators will take a much longer term view of investment, building on the Water Companies Strategic Direction Statements, and ensure appropriate incentives are in place to encourage sustainable practices.

Planning authorities and their statutory consultees, who will include the EA and the Water Companies, will place flood mitigation and low carbon water supply at the heart of urban design, through WSUD and integrated urban water management (IUWM). The government will recognise that it is impossible for a single sector to reduce the risk of flooding, manage the water supply, protect the aquatic environment and predict and adapt to the impacts of climate change, without the cooperation of other sectors. Coping with climate change and meeting its carbon target requires a joined-up partnership approach to risk assessment and strategic planning. To achieve this the government will introduce institutional reform, to encourage cross-boundary cooperation, cross boundary systems, a programme of stakeholder capacity building (to induce cultural change) and policy changes to bring in changes to regulations and standards, support for up-skilling the operational workforce of the sector, financial incentives for carbon efficient technologies and increased financial support for research and technology development/demonstration.

Technology development will focus on carbon neutral adaption and mitigation technologies. Technology development will be accelerated following the Cave Review (2008) recommendation, which encouraged greater innovation in the water sector through more co-operative R&D support.

A multi-criteria decision analysis framework will be developed for formulating and evaluating alternative water supply plans/policies to balance security of supply and sustainability. This will lead to new approaches to water industry policy and operations.

Water Company Operations

The government will achieve its key policy of decarbonising grid electricity by 90% by 2050. For a typical water company, where emissions comprise around 70% grid electricity, this will reduce carbon emissions based on 1990 levels by around 63%. However there will be significant increases to the baseline (circa +100%) as a result of the implementation of various EU directives. Only changes to water industry operations will enable the industry to absorb this increase and move to a low carbon future. The major change to water industry operations in the period 2009-2050 will be the move to decentralisation of operations. The onset of pseudo-competition from 2010 onwards, following the Cave Review in 2008, will see a variety of new business models emerging. Concerns regarding the impact of reductions in scale on: financial sustainability; access to capital; operational efficiencies; compliance; and purchasing power, may or may not be unfounded, but the benefits in terms of carbon reduction will be significant.

The contribution to Greenhouse Gas Emissions from water industry operations are in the following proportions: wastewater 56%; clean-water 39%; administration and transport 5%. The approach taken to reduce wastewater and clean-water carbon is covered in the sections below.

For administration and transport, organisations based on smaller catchments will reduce the need for travel by operational staff. Similar benefits will result from the move towards significant home working, based on developments in video conferencing and communication technologies. The EA will move away from statutory sampling and laboratory analysis for regulatory monitoring, to MCERTS (EA Monitoring Certification Scheme) accredited sensors, which will save on transportation carbon, provide for more efficient and responsive operations and improve data access for stakeholders through Web-based access. A range of low-carbon transportation options will be available including, ecologically sustainable fuels, plug-in hybrid and fully electric vehicles, and mass-transit options, all of which will reduce the environmental (and economic) impact of transportation.

Decentralisation will also lead to a decentralisation of processes, largely at a community level. Sweating assets was a feature of the AMP3 (Asset Management Plan) and AMP4 programmes, but as many assets come to the end of their useful lives in AMP5/6/7 there will be a recognition that resuscitating these assets, particular old underground infrastructure, is not sustainable in terms of carbon use. In conjunction with this, flooding constraints will force the industry to remove surface water from foul sewers and will result in a rethink on infrastructure design. Combined with the emergence of carbon neutral ‘at tap’ and ‘at source’ treatment technologies this will result in the emergence of new designs for operational infrastructure in new developments. These will be progressively retrofitted into most scenarios, except for some densely populated urban areas where conventional solutions and infrastructure may need to be maintained. The industry will start to cherry pick the high carbon options and install unconventional solutions as infrastructure comes up for renewal. This will start a migration towards a low carbon industry. This will be made easier when UKWIR (United Kingdom Water Industry Research Ltd) publishes its new carbon accounting methodology in 2010 which should include the contribution from embedded carbon, and will be used for scheme appraisal once endorsed by OFWAT. DEFRA will move to address industry's concern that the shadow price for carbon (SPC) is too low to alter infrastructure decisions.

Water Treatment and supply

A typical community level water supply process flow-sheet will probably consist of low quality (non-potable water) supplied, either via mains or sourced locally, to the household/community and treated by end of tap or community level packaged treatment. In a few scenarios bulk supply of potable water may be identified as the most sustainable option. This will be dependent on DEFRA reviewing water quality standards. Local sources of water will be used for low quality applications, as will rainwater, grey-water, surface water and water contained in SUDS. Local processing will be powered by micro-generation of electricity.

The overall length of the water infrastructure will be significantly reduced, as will pumping. This, in combination with improved location and condition assessment technology for underground infrastructure, will provide significant carbon benefits on mains rehabilitation programmes and indirect carbon benefits through improved traffic management. Redundant pipes will be used for routing of communications services. Improved leakage detection and repair, including platelet technology and structural linings, will reduce reported leakage to below 2000Ml/d. The energy demand of water distribution will be reduced through pump optimisation, low friction linings, online energy/resource optimisation systems and pressure reduction systems, and smart and self healing pipes. Design standards for pumping stations will be revised to reduce pumping inefficiencies induced by cavitation in pipes.

Energy recovery will be possible through small-scale hydro in pumped networks, given changes to ROC incentives. Dual water supply systems will be common at a community level, in new developments and in urban regeneration projects.

The carbon cost of conventional water treatment processes will be significantly reduced as a result of:

- novel adsorbents and catalysts that can be regenerated using sunlight;
- new dissolved air entrainment systems for DAF (Dissolved Air Flotation) processes; low pressure self cleaning chemical free membrane systems;
- energy monitoring at the sub-process level, providing systems that automatically optimise process decisions based on energy/chemical usage and carbon production.

This will be helped by the rapid development of wireless sensor technologies and decision support systems over the next decade. The building of some enhanced treatment processes will be obviated by improved catchment management, particularly on upland catchments that have seen climate induced deterioration in water quality.

Wastewater

In AMP5/6, the implementation of catchment-based strategies, to reduce end of pipe solutions, will be an important factor in cutting industry emissions overall, as will development and investment in cleaner technologies. The EA will move to set discharge standards to levels, based on sustainability assessment, that balance both local and global environmental need and provide for carbon trading. This will provide more specific, local regulation that enables companies to reduce energy intensive treatment where river needs allow.

The opportunity to achieve carbon benefits by the use of large sewers for preliminary bio-treatment will be realised.

We will see a reduced load in sewers as a result of incentives to recycle carbon sources such as food waste and the banning of macerators. Water companies will place more emphasis on waste minimisation and work with industry to remove non-biodegradable materials from sewers. These materials will be treated at site or in specialist treatment centres. The EA will allow discontinuous processing matched against incoming load, providing process flexibility and enabling modular plug-and-play type approaches.

Novel fine bubble or bubble-less aeration systems will provide for significant improvements to aeration energy budgets and make in-pipe treatment possible. New biology, able to operate at lower partial pressures of oxygen, will offer significant energy and other benefits, such as biological recovery of resources such as phosphates and metals. The major change to wastewater processing will be the move to low temperature anaerobic treatment and the use of anaerobic membrane bioreactors, enabled by TSB funding of full-scale demonstration and OFWAT allowing funding to retrofit and adapt existing ASP (Activated Sludge Plant).

Control and automation, benchmarking, best practice and the production of a carbon efficiency process catalogue, will all add to the reduction in carbon production. There will also be some focus on low energy passive systems for community based applications and sunlight based photo-catalytic processes for micro-pollutants.

Separate sewer systems for foul and surface water will be commonplace. In many community based systems foul sewers will consist of shallow small bore vacuum systems

Sludge

Much greater emphasis will be placed on the non-CO_2 component of emissions eg nitrous oxide and methane. AMP 5/6 will see a change to sludge strategies that focus on advanced Anaerobic Digestion with CHP (Combined Heat and Power) as existing assets, such as incinerators, come to the end of their useful lives. Research, conducted in AMP4, into the use of digestate as a soil conditioner and as a renewable fuel for energy generation, will play a significant role. Reuse will be helped by the EA removing the regulatory barriers to co-digestion and co-combustion and by DECC changing the banding for ROCs. The water industry will lead the way on digestion technology and, with partners, develop and build power stations that use putrescible “waste” from industry (food, forestry, green waste, pharmaceuticals etc) to maximise resource recovery. Bio-gas will source the national grid with the potential for meeting a significant part of the countries energy needs, although local use will often be found to be the more sustainable option. Destructive (oxidative) processes, such as gasification and pyrolosis, may become more common as they provide higher energy yields. Other valuable resources, such as antibiotics, metals and phosphorous, will be recovered from the sludge for recycling. Waste process heat will be diverted to communities to reduce the carbon commitment for water heating or used on site for sludge thickening or drying processes.

Chemicals

A change to the carbon accounting methodology will mean that the carbon cost of chemical production is accounted by end-users. This, combined with the implications of the REACH Directive (Registration, Evaluation, Authorisation of Chemicals), will require the water industry to introduce measures to reduce the usage of chemicals in its treatment processes. These include:

- benchmarking process level usage;
- identifying best practice;
- improved mixing and flocculation systems;
- process modelling and automation;
- control of dosing;
- development of new catalysts, resins , coagulants, enzymes;
- advanced oxidation;
- free radical producing materials or reductive surfaces;
- chemical recovery and re-use;
- use of passive chemical free treatment systems and,
- source control and catchment management.

Construction

To reduce the cost of embedded carbon the industry will specify a 30% minimum of post-consumer waste to be used in all their building and mains laying contracts with a specification to source local materials. This will enable the industry to reduce decommissioning carbon by disposing of their waste products in this way (eg reinforced cement structures using incinerator ash concrete). They will also specify a requirement to create low maintenance woodlands/green areas or improved environment, as an offset to carbon in all construction projects, including decommissioned sites. Construction techniques will be specified to minimise carbon costs. To reduce the carbon cost of decommissioning, every opportunity to reuse or convert structures will be taken.

Conclusion

The achievement of a low carbon water industry in 2050 will result from fundamental changes requiring a multifaceted approach that involves all stakeholders, an abandonment of unsustainable infrastructure, use of new management approaches, business models and technologies and the embedding of culture change in the stakeholder base. (See Figure 2)

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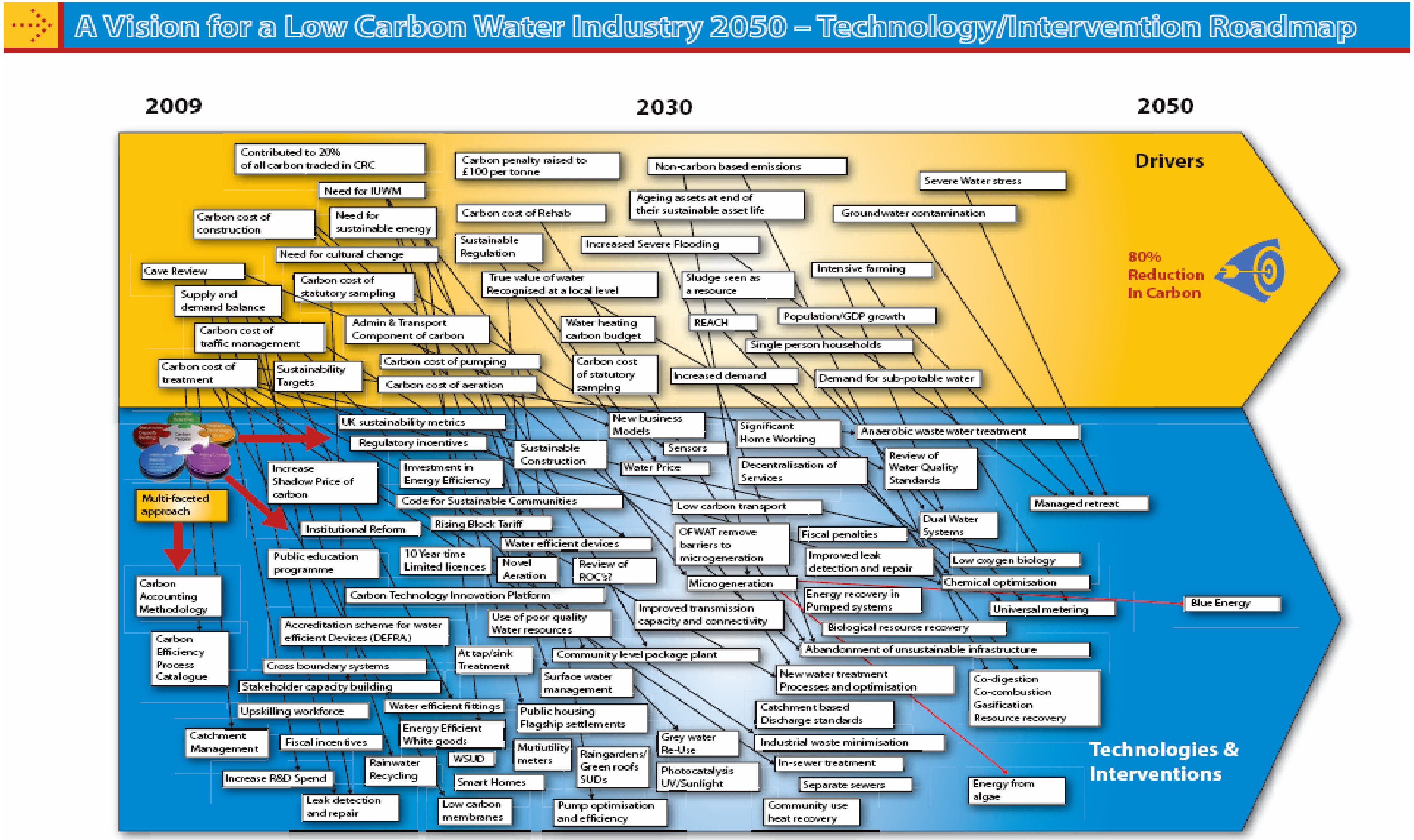
Figure 2 – Technology/Interventions roadmap for a low carbon water industry – 2050.



5 Rapid Decarbonisation of the Water Industry for a Sustainable U.K.

Dr. Douglas Crawford-Brown
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Framing the Issue

The national target of an 80% reduction in greenhouse gas emissions by 2050 says little about how that cut is to be shared across society. In public planning, the water industry would be a second or even third tier option because it represents only a percent (4.9 million tCO_2e/year) of the national emissions inventory[1], well below transport, power generation, buildings and manufacturing as targets for reduction.

The national 80% reduction is unlikely to be guided by such an approach. The argument is that we all got ourselves into an escalating threat of climate change and so we can all contribute to the solution. Therefore, each sector is to reduce emissions by 80% regardless of where it stands in the league table of emitters. A theme of this short paper is that it took the collective actions of utilities, consumers, developers, Ofwat, Defra and EA to get us to the current state of greenhouse gas emissions and it will take all of them working collectively to get us back out.

The unique challenge for the water industry lies in risk-risk balancing. Prior to climate change, provision of safe, plentiful and affordable water was THE environmental issue for the world. Reductions in greenhouse gas emissions at the expense of rising levels of microbes in drinking water would be a public health disaster. Couple this dilemma to the need for active programmes in climate adaptation within the water industry. A recent study[2] shows that more than half of infectious disease outbreaks occur after extreme weather events that swamp water and sewage systems - precisely the events predicted to increase in the U.K. under climate change. Mitigation efforts, therefore, must be balanced with resources for adaptation.

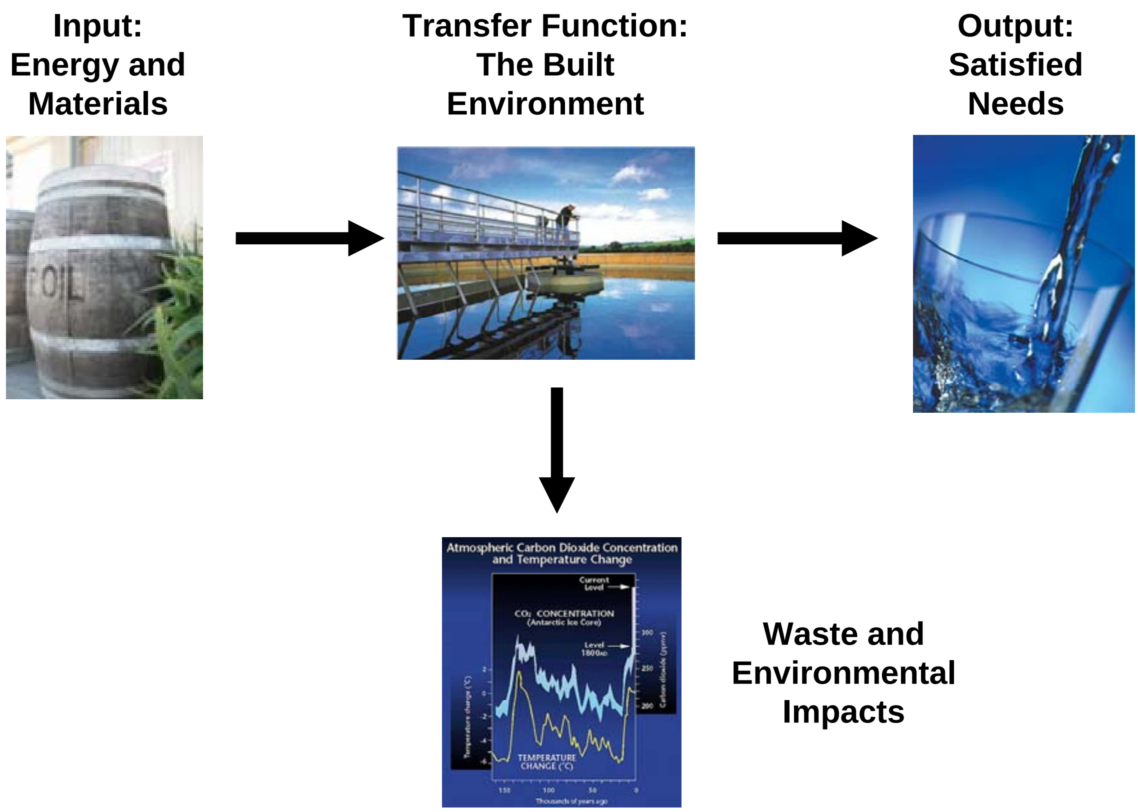
This paper explores how to get an 80% reduction in greenhouse gas emissions from the water industry, while protecting against water-borne disease and providing adequate water for essential services. The claim is that we won't get there by relying on what I might call the "internal" actions of the industry. Just as a Code for Sustainable Homes level 6 building won't be achieved without considering the connection of that building to others in the community and to the energy infrastructure, emission reductions by the water industry will require consideration of the social, technological and regulatory setting within which they operate.

Closing the cycles

Carbon footprint methods differentiate between cradle-to-gate, cradle-to-site and cradle-to-grave approaches. None of these is sufficient here. What is needed is a cradle-to-cradle way of thinking[3], in which waste from one process becomes the nutrient of another, much as in the nutrient cycling of closed ecosystems. Water provision and sewage treatment are prime candidates for such an approach. Sewage that is well treated is both a nutrient source and an energy source for other societal operations.

I use here the example of South West Water, with whom I have been working on this issue. They currently send about a third of their treated sewage to anaerobic digesters. The biogas generated produces 10.6 GWh/year of power, or 4% of their total power consumption. Complete diversion of the sewage stream, closing the cycle of waste, would generate around 30 GWh/year, or 12% of total consumption. This is an 11% decrease in the carbon footprint of the operation – 12% if one counts the decreased need for lime treatment, which itself has a carbon footprint. Adding a cell lysis system to the front end of each digester improves the reduction to more than 13%, even after accounting for the embodied energy and carbon in the additional equipment. It is clear that this is only a partial path to the 80% reduction target, but as Pacala, Socolow and colleagues have argued, society needs to think in terms of wedges rather than magic bullets[4]. The final solution will be a combination of 8-9 wedges, each contributing a 10% reduction. Closing the cycle on waste is one such wedge.

Figure 1: The key to effective reduction strategies is a view of the water industry as a system of material and energy use, with a goal of transferring as much of the input energy and materials into useful output (water) as possible, with minimal waste emissions.



Meeting human needs

Industries have focused discussions of efficiency on components: better pumps, more efficient lights, lower u-values for the energy envelopes of buildings. These are important considerations, but climate change policy has suffered from this focus on getting more energy efficient things. The problem has been that we are all satisfied to have each thing we purchase be more energy efficient. But then we buy more of these energy efficient things and energy use goes up.

There is a better metric of success: the carbon footprint per litre of legitimate water need met. At first this may seem an odd construction. The current sustainability metric, embodied in the Water UK sustainability reports[1], is carbon footprint per litre of water produced. The problem with this latter definition is that it suffers from the same problem as talking about the energy efficiency of each thing we purchase. The carbon footprint per litre of water produced can go down as overall emissions go up because we all consume more water. The way out of this dilemma is to bring a similar pressure on reduction in water use, making sure water consumed truly meets a “legitimate” human need. This calls for a partnership between the utilities and consumers, with the utilities agreeing to supply water with the lowest feasible carbon footprint per litre and the consumers agreeing to use this water in ways that focus on meeting legitimate human needs with the fewest litres of water. Introduction of Code for Sustainable Homes levels 5 and 6 will provide pressure in this direction, but there is no substitute for consumers agreeing to their role of increasing the efficiency with which they use water. A feasible target, a wedge, is 100 litres of water per person day as a national average for domestic use, which is about a 33% decrease on current use[1]. With a similar reduction in non-domestic water uses, through improvements in industrial efficiency, there would be a 33% decrease in the carbon footprint for treatment and distribution. This will not affect the emissions associated with offices, transport, etc, but could result in a 10% to 15% reduction in overall carbon footprint.

Catchment scale responsibility

The utilities have traditionally served as backstops for practices that load pollutants into receiving waters. Do we have a problem with soil being eroded into the rivers? Let the utilities remove it from the water. Do we have a problem with microbes being carried into aquifers under animal farms? Let the utilities treat the water to kill the microbes.

This is both immensely wasteful and inequitable. The carbon footprint of cleaning water after it has been contaminated is almost always significantly higher than preventing the contaminant from entering the water in the first place. The embodied energy and carbon of maintaining a riparian buffer is well below that of reducing turbidity at the treatment facility and provides a number of other benefits (preservation of habitat, the social amenity of an un-eroded riverbank). Catchment-scale policies that distribute the burdens and responsibilities across the residents of a catchment are not simple, but they have been accomplished in the States and there will be increasing pressure in the U.K. as the Water Framework Directive is seen as an adjunct to climate change policy. Given that the carbon footprint of treatment is approximately 40% of the overall footprint of the water industry[1] and with an expected load reduction of 20% to 30% using best management practices, this approach is a wedge that will bring a 10% reduction.

Regulatory reform

This is likely to be a controversial topic. One of the great successes of the engineering and environmental communities has been the improvement of water quality and the accompanying benefits to human health. And yet, with the increasing sophistication of monitoring instruments and epidemiological studies, the regulatory limits on water-borne contaminants have become more stringent. We have moved from the realm of avoiding threats to human health rooted in historical experience to increasingly speculative improvements rooted in the mathematics of risk assessment.

Climate change policy calls this process into question. The efficiency of contaminant removal goes down as the level of contaminant goes down. The carbon footprint of removing the last 20% of a contaminant is significantly higher than that of removing the first 20%. At some point a balance must be met between the threat of climate change and the threat from the contaminants being regulated. Such a balancing act was difficult enough when society considered risks from microbes and disinfection by-products, both of which were under the control of the utilities and their regulators. The new balancing act will require regulatory reform, because institutions such as the Environment Agency, Defra and Ofwat were established with particular remits that did not include a balancing of climate change and water-borne risks. The newly created Department of Energy and Climate Change does not have a remit to consider the risk to human health if reductions in carbon emissions by the water industry reduce controls on contaminants. Someone needs to perform this balancing, but at present it is not clear that any one authority has the power or incentive to supply this balance.

Decarbonized grid

Just as a rising tide lifts all ships, a decarbonized grid reduces the carbon footprints of all consumers. It is the key to the water industry meeting the 80% reduction target. In fact, it is hard to imagine the target being met without decarbonisation of the grid, given that renewables generation by the utilities is unlikely to rise above 25% in the time needed for the 80% reduction.

At first, this seems an area in which the water utilities have little influence. However, they do have two strategies here. They can produce renewable energy themselves and feed that energy back into the grid when they don't need it for their own operations. Renewable Obligations Certificates provide a financial incentive for them to do so, even at the currently low price of £26 per MWh.

They can also support efforts to bring about decarbonisation by lobbying as consumers for national renewable energy portfolios or by supporting an increasingly stringent cap-and-trade system that will push carbon prices above £100 per tonne. This is the level at which technology change is likely to happen; the currently much lower prices are being absorbed as operating costs in the energy system. With calls for increased carbon costs, the water utilities must be ready to join the energy utilities to ensure costs are borne equitably. It is likely that the costs of water and sewage will rise, so Ofwat must be brought into the discussion to re-think a strategy that has focused on providing inexpensive water, rather than providing water that reflects the environmental costs of its greenhouse gas emissions.

Closing comments

Technological innovation will reduce greenhouse gas emissions by the water industry. More efficient pumps, better control of pipe sizes to reduce pressure losses and improved treatment methods, all go towards reducing the carbon footprint per litre of water. However, solutions must include significant social reform. Cheap energy rooted in fossil fuels got us to where we are today and our institutions and practices reflect these past realities. Technological innovation must be set within a framework of reform in which all who affect water quality (as sources of contaminants), all who consume water, all who regulate water and all who provide it become an integrated system in which responsibilities fall equitably and effectively. Changes in the system of water protection and provision will provide half of the needed wedges for a solution, with a larger societal effort to decarbonise the grid providing the other half.

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6 A Low Carbon Water Industry by 2050?

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Introduction

The UK is the first nation in the world to commit itself to reducing carbon emissions by at least 80%, compared with 1990 levels, by 2050, with the aim of creating a 'low carbon society'. This will begin with a 20% reduction by 2020 (Committee on Climate Change, 2008). The water industry is a very large user of energy, it consumes 8100 GWh per annum resulting in over 4 million tonnes of greenhouse gas (GHG) emissions; about 1% of all UK emissions. It is the fourth most energy *intensive* sector in the UK (POST, 2007) with the costs for bought in power accounting for over 13% of total production costs (Marshall, 1998).

The national target poses a huge challenge for Water Service Providers (WSPs). No single measure, or group of measures, will achieve the target and only radical thinking coupled with root and branch reform throughout the sector will be good enough. This will consist of an extensive portfolio of mitigation *and* adaptation strategies, ranging from behaviour change through to technology upgrade and replacement, and from improved energy efficiency to renewable energy production. Of course, in all this the core activities of the sector must be maintained, including safe production and delivery of drinking water and safe return to the environment of used water.

This short article will identify three different aspects of the business and discusses the problems and the potential for contributing towards the low carbon goal: customers, company and suppliers.

Customers

The water efficiency agenda is now well established within the UK water industry thanks to work by partners in Defra's Water Saving Group[1], waterwise[2] and the WATERSAVE[3] network. WSP's commitment to water efficiency is moving beyond the legal 'duty to promote' and is currently being strengthened by Ofwat's voluntary (and then probably mandatory) water efficiency targets. So far, the motivation behind water efficiency has been to reduce per capita water consumption (to the government's target of 130 litres per person per day by 2030), but with particular emphasis on water stressed areas. Targets set in the Code for Sustainable Homes are even more onerous and are set at 80 litres per person per day at level 6 (CLG, 2008).

It is clear that a water efficiency agenda can, in principle, also serve an energy saving agenda. Each megalitre of water that is not used will reduce the energy delivery and disposal needs and their associated carbon emissions by 0.969 tCO_2e (Water UK, 2008). However, a recent insight is the importance of hot water. Approximately, 30% of

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[1] www.defra.gov.uk/environment/water/conserve/wsg/
[2] www.waterwise.org.uk
[3] www.watersave.uk.net

water used in the home is hot and domestic water heating is responsible for 5% of UK GHG emissions (Defra, 2008), far outweighing water industry delivery and disposal emissions.

In a low carbon future, much more emphasis must be placed on the *use* of water and that in turn means WSPs will need greater involvement with their customers and the way they live. Significant gains must be made in reducing use of both cold and hot water. How will this be achieved? As an example of an innovative cold water saving device, we can quote the example of the Propelair toilet[4]. This device uses locally pressurised air to 'flush' the toilet and requires just 1.5 litres of water to cleanse the bowl. Drain clearance and user satisfaction have both been shown to be good (Littlewood *et al*., 2007; Millan *et al*., 2007). Some energy is required per flush (500 J), but this is much less than that used by the displaced water supply, indicating that the device is able to deliver substantial water *and* energy savings. Yet, despite many years of development and trials, this appliance is still not commercially available, indicating the significant difficulty in bringing innovations onto the market.

Care is necessary when joining the water and energy efficiency agendas. For example, our work is showing that Code for Sustainable Home water use requirements, at any particular level, can be achieved by many combinations of appliances, but many (most?) actually increase GHG emissions - primarily because they use hot water less efficiently. Joined up regulation is a must and will become more acute in the future to ensure that no double counting takes place or conflicting advice is given. It would not be a step too far beyond today to envisage a duty placed on WSPs to promote (water) energy efficiency and that might ultimately be expressed as energy efficiency targets. These must be carefully dovetailed with existing water efficiency requirements.

Whatever technological or legislative changes are made, ultimately sustained carbon reductions can only be achieved by behavioural change. This cannot be achieved solely by customer 'education' or promotion of best practice, but will need significant, prolonged and costly partnering with customers and their other service providers and equipment suppliers. Joint benefits will have to be identified and ultimately realised. For example, we need to move beyond the hotel admonishment to reuse bathroom towels for the 'environment's sake'. While the environment may indeed benefit, so too will the hotel's bottom line through reduced laundry costs, but this is never passed on to the customer in lower room rates.

Companies

All WSPs will be looking into a variety of approaches to minimise carbon emissions, typically by using less energy or by generating renewable energy. However, a danger is that, firstly, they are effectively considered in isolation and, secondly, that their performance implications or knock-on effects are not identified. Indeed, if these could be identified and represented there is scope for additional emission reductions. An example is the urban wastewater system consisting of the engineered sewer system and wastewater treatment plant and natural receiving watercourses (Butler, and Schütze, 2005). The existing wastewater infrastructure is generally designed and operated separately, with little holistic water quantity and quality analysis carried out and no joint consideration of the energy consumption required for wastewater conveyance and treatment. Even research is limited in this field at present (Fu et al., 2008).

[4] www.propelair.com

However, energy efficiencies are being proposed throughout this system, with little thought as to their combined effects or their *system* performance including:

- In-house or in-development water efficiency measures and recycling options,
- Sustainable drainage systems (SUDS),
- Reduced energy wastewater treatment processes,
- Renewable energy generation techniques,
- Integrated system control and management.

Firstly, the chosen options must not compromise system performance, integrity or robustness and to ensure this requires a good understanding of the operation of the whole system. Secondly, understanding system operation allows the possibility of identifying synergies and win-win situations. For example, energy conservation might be achieved in the treatment plant through better control of storage tanks and pumps in the sewer system, while hydraulic efficiency is preserved and the same water quality is maintained in receiving waters. Finally, we know, from a theoretical standpoint, that integrated control systems can improve water quality compared with uncontrolled systems (Butler, and Schütze, 2005). We also know something of the relationship between system energy use and river water quality. For example, Fu et al. (2008) have shown that receiving river dissolved oxygen concentration is inversely proportional to whole wastewater system energy consumption. It would be of great interest, and potential, to establish whether energy reduction dividends can be obtained in practice using a more active and integrated control environment, while maintaining system performance.

A related point arises from work we carried out on infrastructure needs for Sustainable Communities (Butler & Makropoulos, 2006). Modelling work indicated that trade-offs can be made between water use, energy use and land take such that there can be significant gains in all three aspects, up to a point: the technological state-of-art. Beyond that point, improvements in one aspect can only be made at the expense of others. For example, further improvements in water savings require increases in either energy consumption (for high-tech solutions) or land use (for low-tech solutions) and vice versa for energy savings. In the future, as the industry comes to terms with its carbon commitments, models will be required that can not only account for carbon (i.e. simple spreadsheets) but also:

- Simulate energy use and GHG emissions in the context of system performance,
- Capture system independencies and synergies,
- Allow trade offs to be explored between the dependent variables.

Suppliers

New relationships will be needed between WSPs and their suppliers. In particular, companies will need to liaise much more closely with their energy providers who, after all, are directly responsible for most of the GHG emissions associated with the water industry.

The electricity generation and supply sector has its own constraints and challenges. Helping to solve these challenges can be of benefit to the water industry and its carbon emissions. One of these challenges is the need to constantly balance generation and demand in the electricity supply grid. Failure to balance supply and demand can lead to power outages and damage to electricity distribution infrastructure. Interestingly, a particular challenge is formed by intermittent renewable energy sources, notably wind energy. The following methods can be used for grid balancing:

- Reserving electricity generation at power plants. This includes spinning reserve (running generators below their optimum state of performance, allowing to step up performance within seconds whenever necessary) and standing reserve (firing up additional generators at peak times).
- Storing electricity, using methods such as pumped storage, batteries, pressured air, fly-wheels or electrolysis of water.
- Electricity Demand Side Management (EDSM), which involves users shifting at least part of their electricity load from periods with high electricity demand to periods of low demand on the grid.

The provision of reserves at power plants adds significantly to the fuel demand and carbon emissions per supplied electricity unit. The main reason is the lower efficiency of the generators used for reserve provision, compared to base-load electricity generators. Recent estimates suggest that the provision of spinning or standing reserve in the UK adds between £10,000 and £40,000 per MW per year to electricity generation costs and creates emissions of between 300 and 750 tonnes of CO_2 per year per MW (DTI, 2006). Electricity storage increases fuel demand and carbon emissions per supplied electricity unit as only a fraction of the stored energy can be reconverted into electricity. Other disadvantages are the high capital costs of the installations and limited suitability (pumped storage, for instance, can only be implemented in mountainous areas).

On the other hand, EDSM engages electricity users with the grid balancing process. It can be implemented using existing equipment, in which case the only additional capital cost will be that of the implementation of advanced hardware and software necessary for communication, metering and decision-making. By shifting electricity load into times of low strain on the grid, the fuel consumption and carbon emissions related to electricity generation or storage are reduced. This is particularly true if the load can be shifted into periods of abundant supply of renewable energy.

EDSM can be performed in different ways. Offering different peak and off-peak tariffs is already widely practised, but a massive switch-on of loads at the rigid tariff boundary can add additional strain to the grid. Alternatively, load shedding on demand involves users switching their equipment off following an instruction by the grid operator. The National Grid offers such contracts for users able to shed a load of at least 3 MW. However, such load shedding contracts require that the load concerned would normally be operational unless switched off on instruction from the grid operator. The abilities of WSPs, to participate in such schemes are limited, because pumping capacity must respond to the changing needs of the water transport and supply system and demand patterns are similarly timed in both systems.

A promising approach is *real-time billing*. Under a real-time billing scheme the user pays an electricity price related to the real-time electricity generation and distribution costs. The electricity price then becomes one among several factors determining whether a certain piece of equipment should be operated, or not, at a given time. The real-time price will at times be above and at times below the conventional electricity tariff. The user receives a net benefit only if the annual cost of electricity is lower than a conventional contract. Overall, there is the potential to improve electricity grid operation, reduce GHG emissions substantially (by reducing the need for grid balancing) and generate cost savings to the water sector.

Conclusion

As can be seen from this short article, significant challenges face the water industry in its quest to become low carbon. New partnerships with customers and suppliers are needed, new management and operational approaches must be adopted and new technologies developed and deployed, all within the context of a highly regulated business that is subject to mandatory and ever increasing water service obligations. Despite these challenges, or perhaps because of them, the transition to a low carbon industry also represents an unsurpassed opportunity to develop much broader business opportunities, while at the same time securing wide-reaching environmental gains, to the ultimate benefit of each participating company, the UK as a whole and indeed the planet we share.

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7 A Vision for a Low Carbon Water Industry in 2050

Charles Ainger, MWH: 19/3/09

*[This is not a **prediction**; it aims to identify the innovative **possibilities** we can see now that can contribute to achieving the 80% CO_2e reduction goal. The intent is that they all should be examined, tried out and experimented with by the existing 'players'. Therefore, it does not speculate on major changes in structure, regulation and ownership. The only certainty for 2050 is that the situation will be more different than the one we can imagine now.]*

What the world is like in 2050

The 2050 water sector has had to deal with these 'warmed climate' impacts[5][6][7].

Average global temperature is heading for +3, maybe +4 degrees C by 2100.

In the UK, this has driven more extremes of floods and droughts, and large changes in agriculture with more competition for water. Sea level rise is heading for +1.0–1.5m, causing selective abandonment of low-lying, vulnerable coasts and a movement of assets and people away from them. Rising temperatures and densities in the South East are driving the population north and west.

Internationally, warming is causing increased stress and conflict over water and food resources, with major famines and millions of deaths, in Africa and tropical areas. Southern Europe and Mediterranean areas are less habitable. There has been large-scale immigration into the UK, with +10 Million in population.

'Peak oil' is well past and there is a strongly stressed, largely renewable, energy supply; industry norms are 'zero waste', reducing water demand. Urban design has changed in response to worse flooding and 'design for exceedance'; with widespread SUDS, combined sewers left to deal with rain water and separation of foul sewage.

More climate 'tipping points' are becoming likely - including Greenland ice loss, tundra CH_4 release and Amazon forests turning into CO_2 emitters rather than absorbers – so there is much concern about a worse future, in spite of the major changes experienced already.

So the water company 2050 context is:

- Many customers and their water demand have moved geographically combined with a large growth in customer numbers;
- Overall demand for 'centralised' water supply is lower than today;
- Urban infrastructure re-planning enables re-thinking of the scale and approach to sewerage and WwTWs;
- There is a wish for more locally-resourced and controllable solutions.

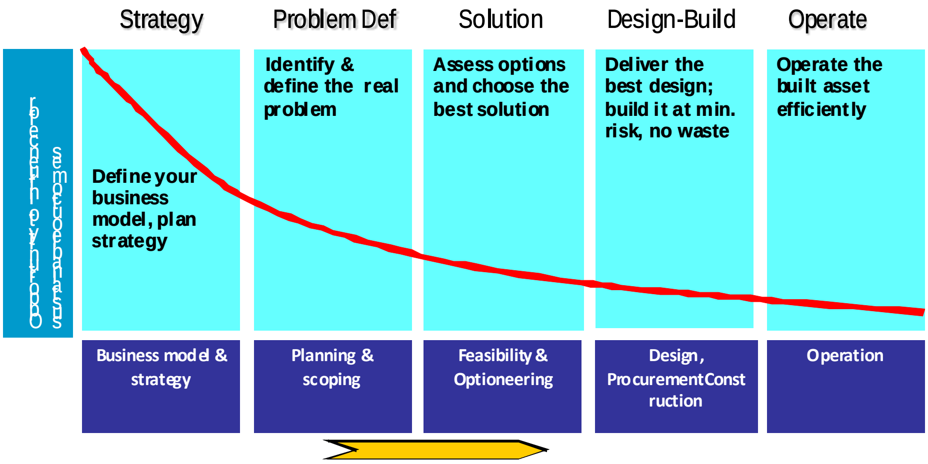
Thus, climate change adaptation itself has demanded a large change in assets. This could facilitate transforming their CO_2e emissions.

[5] See: http://climatecongress.ku.dk/newsroom/congress_key_messages/
[6] See: http://www.guardian.co.uk/science/2009/mar/18/perfect-storm-john-beddington-energy-food-climate
[7] See: http://www.guardian.co.uk/world/2009/mar/22/environment-population-conference-britain

The 2050 low-carbon vision

The water industry has met its 80% reduction targets, but only by radical changes at all stages of the asset investment process – see Figure 1.

Figure 1: Innovation to reduce CO2e, at all investment stages



• CO2e and energy can be reduced at every stage; *but*

• The best opportunities for more sustainable, lower CO2e, lower energy outcomes are at the *early stages* of asset investment

Utility types, business models, principles and scale of operations:

The business model has enlarged, to include water 'in-use', including heating, and to provide the 'service' – 'as little water as you need' - rather than the product. Combined water/ energy utilities are common; working locally with agriculture and municipal solid waste for community scale energy generation.

Low water use and domestic solar thermal heating are widespread, enabled by WatCo financial and management strengths, in combination with customer community groups, and enabled early on by Government community-scale feed in tariff incentives. There is a more decentralised, simpler, low-energy and CO_2e approach in small communities for water and wastewater treatment; the smallest have reverted to local water supply and septic tanks for sewage, unless there is a real health or pollution risk.

Water pollution and quality management

All WQSs are defined in terms of ecological 'outcomes' (as in WFD); pollution control at source is first preference in any sector (industry air pollution, transport, agriculture, customer lifestyle, etc, as well as water), rather than 'end-of-pipe' removal. This applies to N, P, heavy metals and newer 'lifestyle' esoteric contaminants.

'Catchment consenting' is widespread and the second preference for control, using a 'systems' approach to pollution reduction. All diffuse agricultural run-off, N, P, and raw water quality is preferentially controlled by changes to farm land-use and management. This is enabled by large changes in agricultural practice in response to higher temperatures and water and food scarcity.

For larger WTWs and WwTWs, controls include continuous quality monitoring and modelling of raw source or receiving water, and process control in real time. This allows process adjustment to match the environmental quality and capacity of the source or receiving waters, while minimising CO_2e.

Water resources and supply-demand balance

All water supply is metered. Rainwater harvesting is near-universal in water stressed areas, which will have enlarged.

Centralised mains supply is of 'general use' quality only – with a low risk if drunk, but not at 2010's increasingly marginal EU quality. 'Top potable quality' water only comes from designated 'drinking water' taps fitted with 'in-line' final purification units, which are the responsibility of the consumer. These changes give customers more local control, less at risk to centralised supply failures.

All water pumping systems incorporate upstream balancing, to use the 'hole in the ground' at minimum velocity and thus minimum friction head; this may also allow optimum use of intermittent local renewable energy sources to power pumps.

Water treatment and distribution

Water networks are serving smaller per capita flows, but sometimes more customers.

Leakage has further reduced wherever it is cost, water saving and CO_2e-effective, after full 'externalities' pricing, in comparison with other measures

WTW's now generally treat to the lower 'general use' quality only, lowering energy and CO_2e. Treatment has been transformed by application of 'Green Chemistry'[8] principles, replacing most WT chemicals with benign, biodegradable, low embodied CO_2e chemicals.

Sewerage; and flood risk management

Foul sewage separation, in conjunction with surface flood routing[9], SUDS and rainwater harvesting, has allowed re-design of urban systems to use smaller scale WwTW units, with local water and energy re-use. This also applies to most separately-sewered suburban areas.

This has helped minimise sewage water pumping distances. Where pumping remains essential most systems incorporate upstream balancing, to use the 'hole in the ground' at minimum velocity and thus minimum friction head. This means that 'preliminary treatment' for wastewater is more often done upstream of pumping stations.

Wastewater and sludge treatment

Smaller WwTWs use simple land or lagoon treatments, partly wind assisted. These are monitored by testing receiving water quality outcomes, not 'effluent' at a 'discharge' point, and this allows treatment integration into the local environment.

Medium to large WwTWs' performance goals have been extended to be 'resource recovery plants' – water, nutrients, energy, and CO_2 sequestering, with CHP and possibly hydrogen production - as well as controlling effluent quality. They use very

[8] See: Professor Paul Anastas, Yale University, USA, 2008: *Green Chemistry: The Molecular Basis of Sustainable Infrastructure;* 'Blueprints' Conference, Auckland NZ, December 2008; and: http://www.york.ac.uk/res/gcg/site/index.htm

[9] See, eg: C Digman, D. Balmforth, R Kellagher, D Butler, 2006: *Designing for Exceedance in Urban Drainage – good practice* (C635), CIRIA.

efficient high tech processes to optimise these operations and are expected to be CO_2e negative or at least CO_2e neutral.

In more rural areas, medium-scale WwTWs integrate sludge with local agriculture and municipal solid waste treatment - for community-scale energy generation, including CHP.

Some process technical changes include:

- As sewage temperatures rise in more concentrated sewage the use of anaerobic, low CO_2e, main WwTW treatment processes has increased, particularly as front-end processes. These can also utilise the greater influent septicity connected with lower velocity pumping systems.
- Medium and large-scale WwTW extract heat from final effluent via a water source heat pump[10] and use it for all process and building heat, including raising anaerobic digestion to thermophilic temperatures. Spare heat is made available for other local uses. All gas is freed for use in renewable power generation.

At large centralised plants, high tech treatments for sludge product recovery have been added, including forms of pyrolysis or algae production, which deliver bio-fuels and soil-enhancers such as bio-char, to reduce and sequester CO_2.

Barriers to innovation, and changes needed

All the stakeholders have barriers - of mindsets, rigid interfaces, too-narrow views of responsibility and the constraints of current practice. Removing these involves learning new and more collaborative behaviour, with both sides of interfaces incentivised by technical opportunity and commercial benefits. Examples include:

WatCos and Customers – have worked across their interface in a 'water service' model: minimising water use, optimising rainwater use, sharing more responsibility for water quality risk, reducing water-heating associated CO_2e by low-use equipment[11,12]; and assistance with installing solar thermal or other low CO_2e systems. This will be incentivised by target tariffs and financing assistance from WatCos.

Engineers – have learnt to optimise (rather than maximise) the scale of solutions, with optimum community input and energy benefit; this is challenging design codes and practice that drive over- conservative design.

Water Companies and EA, DWI – have taken responsibility for planning '25 year plus' strategies – in real outline asset master-planning terms, not just aspirational goals, working collaboratively with their stakeholders in doing so, helping EA monitor, better model and manage the WFD 'good ecological status' outcomes, on a 'catchment consenting' basis. This will be a self-assured partnership, more like the IPPC regime than the current 'poacher and gamekeeper' one. Work with DWI to re-define water safety plans and risk, to switch to customers' 'end of tap' responsibility.

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[10] See: Tommi Fred, Helsinki Water; 2008: *Large-scale heat transfer from wastewater to city heating and cooling systems;* IWA WWC 2008 Vienna, Water and Energy Workshop, 09.09.2008

[11] See: http://www.melbourne.vic.gov.au/info.cfm?top=120&pa=1001&pg=3670,

[12] See: http://www.sydneywater.com.au/SavingWater/WaterWiseProducts.cfm

Water Companies and their Supply Chains – have defined scopes, solutions, specifications and detail design to measure CO_2e and incentivised them on a whole life cost and target price basis, to deliver in detail what the strategy demands.

EA, Defra and EU – took the 'systems' approach to WFD and other new directives; made 'reduce at source' the clear preference for water quality improvement, not demanding more 'end-of pipe' treatments; challenged directives with ever-diminishing returns that go against the low CO_2e goal.

OFWAT, with EA, DWI, Water Councils, Water Companies - incorporated CO_2e into efficiency measures and targets, measured 'per customer' not 'per ML; adjusted the balance of capital and operating cost effectiveness measures, to drive the 'higher capital investment, for lower energy, CO_2e and operating cost' regime that is needed to transform the asset base; extended regulatory boundaries to require WatCos to operate the 'water service' business model.

How did we get there?

The journey to a low carbon water sector in 2050 was an interaction between general government climate change policy and water sector specific innovation. From government, the EU ETS and carbon price development initially proved to be *'too little, too late'*. However, RoCs and their successors, particularly the rapid simplification of the CRC after early experience, were more effective in reinforcing water sector asset policy. Once legally enforceable company CO_2e limits, carbon taxes and personal carbon rationing came in, after 2012, these meshed with the sector's own innovation to drive change.

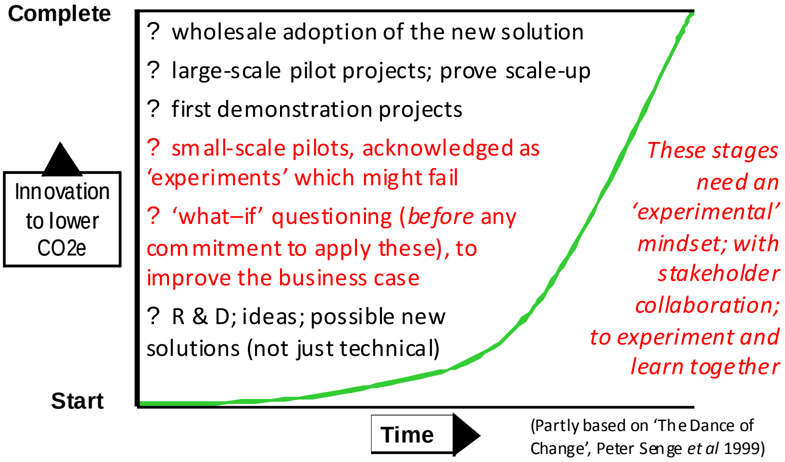
The potential for sector change started with a range of actions and new ideas emerging during 2005-10:

- the introduction of CO_2e measurement and OFWAT's 'SD duty' and 'CO_2e in CBA' requirements;
- the WFD focus on outcomes – good ecological quality - rather than consents, allowing the application of 'systems' approaches, as in several EA studies on CO_2e efficiency[13];
- Defra's introduction of the 'water service' idea and,
- the improvement in technologies for water quality monitoring, deterministic modelling and real-time control.

A series of R&D 'what-if' studies and pilots of smart metering and water demand management demonstrated how innovative practice can be tested, demonstrated and become widely accepted.

[13] See: http://publications.environment-agency.gov.uk/pdf/GEHO0508BOBS-E-E.pdf

Figure 2: The 'tipping point' curve of sector innovation



The 'tipping point' for a step-change in attitudes, behaviour and practice occurred during 2009/10. The sector became embarrassed at the continuing CO_2e rise in AMP5 agreed business plans and the fact that many AMP5 investments were perpetuating high CO_2e solutions – compared with the aspirational statements on reduction in the 2007 SDSs. This started to be challenged as many water companies implemented strong 'whole life cost and carbon' commercial contract incentives throughout their supply chains, leading to increasing challenges to the business plan assumptions. Leaders of each of the players realised that a more radical innovation framework – and a long-term innovation strategy - was needed.

In 2010, all water companies agreed that they would do a 'clean sheet' (i.e. as if they had no pre-existing assets) outline asset master plan for 2035. These were critical in making real, in asset planning terms, the different types and distributions of assets that were likely to be needed to deal with changed future conditions, 80% CO_2e reduction and new capabilities. They defined the end point of an asset-based innovation strategy, against which to test all investment decisions; subsequently all investment, whatever its other drivers, also contributed to CO_2e reduction and the envisaged 2035 asset distribution, scale and technology.

During AMP5, many of the innovative approaches described in the vision, from business models to new technologies, were taken from 'ideas' stage through 'proof of concept' to demonstration project stage, by a series of 'what if' and pilot scale collaborations between all the players – see Figure 2. As a result, many of the innovations were credible enough to be added into revised AMP5 plans or included in AMP6. From 2015 onwards, all investment was heading towards the 2035 master plan concepts (reviewed at 5 year intervals) and an 80% CO_2e reduction.

Further innovations, including the fruits of collaborative R&D on applying 'Green Chemistry' to the water, agriculture and plastics sectors, allowed the key principle of 'all controls at source, not end of pipe' to be fully implemented. Further, the increased confidence in 'in-line' technology for final purification[14], coupled with more crisis examples of unavoidable loss of centralised supply capacity during major weather events, enabled the switch away from 'all supply to potable standards'.

[14] See the beginnings of this miniaturised technology at: http://www.lifesaversystems.com

As a result of their success, the UK water sector has been seen as a leader in successful climate change response, to be copied in other sectors and countries.

List of abbreviations

AMP	Asset Management Plan
CRC	Carbon Reduction Commitment
CHP	Combined Heat and Power
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DWI	Drinking Water Inspectorate
EA	Environment Agency
EDSM	Electricity Demand Side Management
EU ETS	European Union Emissions Trading Scheme
GHG	Greenhouse Gas
IUWM	Integrated Urban Water Management
MCERTS	Environment Agency's Monitoring Certification Scheme
OFWAT	Office of Water Services
ROC	Renewable Obligation Certificates
SPC	Shadow Price of Carbon
SUDS	Sustainable Drainage System
TSB	Technology Strategy Board
tCO_2e	tonnes of carbon dioxide equivalent
UKWIR	United Kingdom Water Industry Research
WFD	Water Framework Directive
WQS	Water Quality Standards
WSP	Water Service Providers
WSUD	Water Sensitive Urban Design
WTW	Water Treatment Works
WwTW	Wastewater Treatment Works

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