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BARRIERS TO, AND INCENTIVES FOR, THE ADOPTION OF GREEN WATER INFRASTRUCTURE

7-8 November 2013

This paper is being circulated to WPBWE delegates as background information.

ACTION REQUIRED: Delegates are requested to provide comments by 30 November.

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NOTE FROM THE SECRETARIAT

This paper has been developed under Output area 2.3.2 Climate Change and Natural Resource Management of the WPBWE Work Programme for 2011-12. It contributes to Project 3.2 Water and Green Growth. It also contributes to Project 3.1. Water Policies for Future Cities of the WPBWE Work Programme for 2013-14.

Innovation is one of the major dimensions of green growth, and it plays a central part in the water agenda. The paper sheds some light on one particular set of water-related innovations: green infrastructures, which can contribute to urban water management at least cost for society.

The paper provides a definition of green infrastructures for urban water management. It sets the scene for water management in the transition to a green economy. It examines a number of case studies, where green infrastructures have been deployed to manage demand for water, treat wastewater, or limit rainfall runoffs and related risks of combined sewer overflow. Lessons derive from experience in this area, which can help decision makers stage the process of change towards green infrastructures for urban water management.

This paper was developed by Colin Green, Flood Hazard Research Centre, Middlesex University, in coordination with Xavier Leflaive (OECD). Colin Green has the copyright for all photos in the report.

The paper is circulated to WPBWE delegates as background information. Some of the main messages have been used in the report on Managing Water for Green growth [ENV/EPOC/WPBWE(2012)5/REV1] and will inform further work on Water Policies for Future Cities.

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EXECUTIVE SUMMARY

The report focuses on how to do more with less with regard to urban water management. It covers two sides of the question: the technological one and the organisational/governance one.

Green infrastructures are part of the answer, especially when urban water management is set in the wider context of competition of cities with other users (agriculture, thermal energy, in particular) to access the water they need, and when water management is considered in relation to land use and other policies.

Green infrastructures for urban water management include demand management, rainwater harvesting, source control of surface water (such as sustainable urban drainage systems), green roofs, and local processing of grey or black water.

Most of these technologies are mature, and some have been in use for centuries. For instance, Venice has been relying on rainwater harvesting since its infancy; in the XIX century, Paris adopted a three-pipe system supplying non-potable water to uses that did not require potable water. The question then is: why are some cities early adopters, while others lag behind? This is all about change, the barriers that have to be faced, and how they can be overcome.

Selected issues with regards to urban water management

Urban water management is about aligning water availability, which is variable, with water needs. Dealing with variability requires storage. High value uses tend to require even more reliable supply, and hence more costly investments.

However, most cities export more water than they import, sealed surfaces converting a high fraction of precipitation into runoff. This runoff potentially is a resource, whereas, when the quality and the quantity of running waters are not properly monitored, it can be a liability.

Urban water management is constrained by a series of issues. One is the multifaceted nature of water: whilst plants and animals require water, it has other properties as well, which have lead to a variety of other uses, from waste transport to cultural and symbolic uses.

Scale issues are complex. Urban water management generates physical economies of scale: it is generally cheaper to operate a large treatment plant than several smaller ones. However, system economies can off-set physical economies of scale: on-site treatment and reuse technologies or sustainable urban drainage can save capital costs of extending central infrastructures; they can however require more energy, as economies of scale apply here as well.

Distributed systems present other challenges. For instance, when facing water shortages, distributed storage forbids allocation of available resources where they are most needed.

Similarly, in cases of floods, the piecemeal implementation of sustainable urban drainage can have adverse effects, if peak rivers flows cannot be managed at catchment level in a coordinated way.

It follows that the usual drivers for change (e.g. pricing) may not be efficient for green infrastructures. Change management in this area faces specific challenges.

Managing change towards green infrastructure for urban water management

The case studies discussed in the report show that the incentives adopted to shift towards green infrastructures for urban water management must be i) appropriate to the barriers faced by those who will make the change and ii) large enough to overcome those barriers. Front runners have used a combination of positive and negative incentives. This has lead to dramatic changes in short times, with regards to demand reduction or sustainable drainage.

Large and rapid improvements in resource efficiency are possible because, considered only in resource terms, water usage is commonly inefficient. Hence, squeezing out some of those inefficiencies quickly results in major gains. Thus, the major barriers to change are the costs of change itself, the costs of attention, information and transactions, rather than the costs of the consequences of change; stakeholder engagement can reduce the costs of change.

More specific considerations follow.

The greatest problems exist in high density areas (central business districts), where they are most difficult to address because space is scarce to weave in water management. The existing stock of buildings adds to the complexity, as green infrastructures will require retrofitting.

Decisions makers face trade-offs, for instance when a flood plain is the only land available for urban expansion or economic development; or when water efficiency gains in appliances require additional energy.

Rules and institutions may be misaligned with the decisions needed to develop green infrastructures: it is not always clear who is in charge, or who is accountable for one particular issue, especially when the issue cuts across such domains as urban planning, environment and economic development.

Several factors make green infrastructures particularly unappealing for policy makers:

- data on water are scarce; capacities to measure, compute and model river flows are limited making it difficult to assess the benefits of green infrastructures and to design them;
- Uncertainty, in particular regarding O&M costs and safety, generate reluctance to adopt innovative approaches;
- Large physical interventions resonate with the urge to take immediate and visible action when facing a crisis, thus distracting attention and resources from green infrastructures; they give a signal that the problem will be solved permanently.

Lessons from experience with urban water management

Policy-relevant lessons derive from the analysis of cases where green infrastructures have been implemented for urban water management.

One general lesson is that green infrastructures (e.g. river restoration, or the reduction of permeable surfaces) can be indirectly induced by regulation on such issues as adaptation to climate change (this has been the case in London and New York City) or on water pollution from combined sewer overflows (in the US).

Incorporating water management into spatial planning and development control systems helps. In Germany, municipalities combine responsibilities for spatial planning and development control and for the provision of water services, including surface water drainage.

Local initiatives can combine several instruments: information campaigns on desired change; tax exemptions and financial incentives (when properly designed, targeted and time-bound subsidies can be less costly than expansion of traditional infrastructures); demonstration projects (symbols matter); and regulations. In Toronto, regulation was required to expedite downspout disconnections, an essential step to reduce run-off from rainfall and mitigate risks of sewerage overflow.

Working with firms in the UK, Envirowise demonstrates the benefits of weaving efficient water use in broader resource efficiency and waste minimisation programmes.

Technological innovation creates new options. Innovation covers engineering and treatment; Japan in particular was able to make extensive use of a variety of onsite recycling techniques, as large areas of the country were not connected to wastewater collection and treatment systems after World War II. Innovation covers complex mathematical modelling and hardware as well, used to better understand river flows and improve the design of green infrastructures, as in Denmark.

There is room for experience sharing. Lessons from the Danish approach to river restoration were disseminated through a series on international conferences as of 1991 and the establishment of the European Centre for River Restoration in 1995.

A balance has to be found between the benefits of being opportunistic (and start where and when there is an opportunity), and the benefits of a systemic approach: a watercourse being the residual of runoffs, it cannot be treated in isolation; urban and rural areas combine at the level of a catchment, the appropriate scale to think and plan green infrastructures for water management.

The adaptive management approach is not limited to small scale projects (typical of green infrastructures): it can be used for large infrastructures as well (see the Thames Estuary 2100).

A strategic approach to green infrastructure for urban water management

A strategic approach can help overcome the barriers that hinder the deployment of green infrastructures for urban water management.

Here are a set of generic principles that work well for green infrastructures and that can help to get started:

- Be opportunistic. Major urban developments (reconstruction, airports...) create opportunities to introduce green infrastructures: they have a high symbolic value, and it is cheaper to build green infrastructures upfront than to retrofit afterwards;
- Link sustainable water management to higher profile issues, such as adaptation to climate change, green growth, or improving productivity;
- Look for quick wins. Significant reductions in water demand and in rainfall runoffs have been achieved in relatively short periods of time through green infrastructures;
- Target leaders for change. Multi-site firms, for instance, can diffuse good practices in several locations, and along their value chain. Incentives must be tailored to the needs of specific target groups.

Pragmatic principles can help to keep going:

- Devolve responsibilities for drainage to municipalities. This facilitates the incorporation of green infrastructures, which often involve use of land surfaces or roofs. Dedicated wastewater utilities or water management agencies are unlikely to make this link;
- Create a community that cuts across constituencies and disciplines. Sharing knowledge and innovation across institutions, territories and problems will help;
- Develop a strategy, which combines compatible tools and options; planning is essential, to exploit synergies between several policies and minimise costs;
- Recycle revenues from charges. This turns the charge into an incentive for change and makes it work twice;
- Develop codes and standards for green appliances and processes (such as rainwater tanks, green roofs, or grey water reuse), which remove the risk to the purchaser that the product will fail.

Learning and adapting are required for green water infrastructures to serve urban water policies effectively in the long term. Failure plays a role here, as some innovations will fail: this will not stall change if safe areas for innovation are organised so that failure does not interrupt service and does not have widespread consequences. Failures should be used as opportunities to learn and gain experience.

Information, public education, awards and symbols contribute to learning and adaptation; they build on and result in social norms that can expedite change.

INTRODUCTION

We live on a fossil planet and have to live on this planet for the foreseeable future. All the molecules of the chemical elements that will ever be are here now; the only new inputs to the planet are solar and gravitational energy. Some of those chemical elements have been identified as being scarce (US Geological Survey 2012); notably, there is a debate as to whether 'Peak Phosphorus' has already been reached (Cordell et al., 2009; van Kauwenbergh 2010): phosphorus is an essential plant nutrient which is lost from the soil when plants are cropped. In order to survive on this planet, we have to do more with less, to learn to do a lot better than we have in the past and do so very quickly. Measures of the footprint both of development as a whole (Kitzes 2008) and the water footprints of cities and countries (Chapagain and Hoekstra 2004) show the scale of the problem. Seeking to do more with less immediately raises the questions of: more what? less what? how?

The 'more what' question is now being answered in terms of 'well-being' (CEC 2009; Stiglitz et al., 2009) whilst the 'less what' question requires us to live within the resources of the planet. Hence, this report focuses upon the 'how' question with regard to water management, and specifically urban water management. It assumes that the policy decision has already been made to start to make the transition to a green water infrastructure and thus the processes through which policy change occurs (Sabatier 2007) will not be discussed.

Green infrastructures, defined

The 'how' question has two interdependent sides: the technological; the organisational and governance aspects.

On the technological side, what we can do is ultimately limited by the laws of chemistry, physics and biology. Physicists would greet a claim that the law of the Conservation of Energy has been violated with extreme scepticism, coupled with great excitement if such a claim could be sustained. Similarly, the theoretical efficiency of a heat engine is defined by the Carnot cycle; we seek to approach ever closer to that limit but cannot exceed it.

Doing better requires that we seek to approach as close as we can to these theoretical limits. The history of technology is essentially one of closer approaching these theoretical limits through innovation. For example, over the last 100 years, the energy efficiency of the Haber-Bosch process of producing nitrogenous fertiliser has got ever closer to the theoretical minimum energy requirement (de Beer 2000). Again Weyerhaeuser has reduced the amount of water required to produce 1 US ton of paper from 25,900 US gallons to 11,100 US gallons between 1980 and 2004 (WBSCD 2004).

“Green water infrastructure” may therefore be defined either in terms of the outcome ('doing more with less') or of the process (adopting apparently more natural systems). In practice, because all systems are determined by the laws of physics, chemistry and biology, the difference in process is often more apparent than real. The processes in both a conventional wastewater treatment works and a wetland system are broadly similar: in particular, both involve bacteria to process and break down pollutants. The key difference between conventional processes and natural systems is that the latter are self-organising systems, a capacity which must be maintained, but in consequence they are dependent upon solar energy. In turn, whilst conventional systems are spatially intensive, relying upon an external supply of energy, natural processes are spatially extensive because of the relatively low incidence of solar energy. Hence, in this report, an outcome definition of green water infrastructure is used. It follows the classic mantra of waste minimisation: reduce, reuse and recycle. Hence commonest forms of green water infrastructure are:

- demand management;
- rainwater harvesting;
- source control of surface water: Sustainable Urban Drainage Systems (SuDS) and variants such as Water Sensitive Urban Design (WSUDs) and Low Impact development (LID);
- green roofs;
- local processing of grey water and/or blackwater.

Figure 1. Rainwater harvesting (O2 Arena, London)

Figure 2. SUDS - Retention basin, Belo Horizonte

This definition also avoids the trap of assuming that nature is inherently benevolent. Natural processes often have the advantage of providing a multiplicity of benefits. For example, green roofs reduce the heat island effect in cities, improve energy efficiency, and capture air pollution as well as reduce surface water runoff (Foster et al., 2011). But this is to argue that we need to look for approaches which have multiple benefits rather than seeking to solve individual problems in isolation. This is part of becoming cleverer in making use of resources.

Natural processes do not buck the natural laws: if cadmium for example is in a wastewater stream then cadmium in some form will remain after treatment whatever the form of treatment; what may differ between the treatment processes is the chemical compound in which cadmium remains and whether it is biologically available. Similarly, wetlands have many advantages for water management but are also often emitters of methane and nitrous oxide, both extremely aggressive green house gases (Mitsch and Gosselink 2000). Again, floodplain forests can be a very useful means of attenuating flood flows (Richards et al., 2003) but the means by which trees adapt to soil saturation result in the production of chemical compounds which are harmful to some other species (Parolin and Wittman, 2010).

How close we approach the currently prevailing technological frontier then is determined by prevailing organisational arrangements: that complex set of social relationships which is now termed governance (UNDP 1997). The evidence is that there is often a gap between the efficiency of resource usage that is currently technologically achievable and is cost-efficient and what is achieved in practice; that improving governance would yield substantial immediate benefits. For example, across the globe, crop yields are significantly below those that are theoretically possible in the local soil and climatic conditions (Thiam et al., 2001).

Many of the technologies which make up green water infrastructure are not simply mature but long established; for example, Venice depended for centuries upon rainwater harvesting for water, the whole city essentially being engineered to collect water. Soakways, a form of SuDS, have long been part of rural life and whilst green roofs in their modern form have a history of around 70 years, turf roofs are part of traditional building practices in several parts of the world. The 'three-pipe' approach, providing a non-potable water supply for those purposes that don't need potable water, was adopted in Paris in the nineteenth century.

The only new technology involved is grey water reuse and recycling but even here the medieval monasteries in Europe used water successively, a form of reuse but without intermediate treatment. Indeed, it might be argued that a green economy involves the return to the traditional path of development after the short interregnum in which we believed that we could always find some new resources somewhere else in the world, that resources were effectively infinite, so resources could therefore simply be thrown away after use.

One implication is that since green water infrastructural techniques are relatively mature, the explanation of why some cities have been early adopters of these technologies but others have yet to make the change must lie in either differences in conditions or differences in governance between the cities. So the question is why has change occurred in some cities but not in others. The simple model used in this report is that for a change to take place, the incentives to change must be greater than the barriers to change. Thus in order to make change it is necessary to understand the barriers facing the relevant parties and how effective each of the possible incentives can be to overcome those barriers.

Change as the enduring challenge

A central theme of this report is change. How to make change and inducing change are only two aspects: development itself is change. Doing better means becoming better at learning and innovating. At the same time, we have to cope with the changes we have created: most obviously climate change but also such other changes as an ageing population. We also live on a planet which is inherently variable; in the case of water, droughts and floods being simply the two extremes of the inherent variability of the climate.

Consequently, conceptually, the problem of delivering more well-being whilst simultaneously switching to the sustainable uses of resources is increasingly being framed in terms of dynamic terms and in terms of systems and resilience (Holling 1973). Thus, we have to make change in the face of change; making change obviously brings to the fore questions of learning (Goldstein 1981) (including social and organisational learning), adaptive management (Mysiak et al., 2010), and innovation and its diffusion (Rogers 1962). Mitigating and adapting to climate change simply mean that we have to make those changes which we would have to make in any case to make the transition to sustainable development (for a more systematic discussion of water and adaptation to climate change, see OECD, forthcoming 2013). Climate change is thus useful as a dramatic signal of the urgency of making the change. As a Minister of Industry in Germany observed, a green industrial strategy is a good industrial strategy.

Development itself is creating new challenges; the issue of the removal of PCPs (Personal Care Products) from wastewater, including the residuals and metabolic products from both prescription and non-prescription drugs, is being increasingly highlighted. In Europe, there are now some 148,000 chemical compounds registered for use, many of which may make their way into the water environment either directly or through wastewater discharges. At the same time, we are learning that it is more difficult to destroy bacteria than we thought and improved health surveillance is illuminating the health burden from helminths and protozoa. This is an example of the removal of one problem revealing the existence of another problem; for example, upgrading a wastewater treatment works has not always resulted in the anticipated improvement in the quality of the receiving water.

Urban water management in the context of competition to access the resource

This report is concerned with urban water management but this has to be understood in the wider context of the problems of water demand. These mean that cities will not only have to solve their own water problems but also seek to reduce their indirect demands.

Fundamentally, water management is dominated by agricultural use; plants depend upon water for cooling and other purposes in vast quantities. Whilst for domestic uses, 80 l/p/d of water per day is sufficient, the day's diet has consumed 3-7 tonnes of water (Rockstrom et al., 1999). Irrespective of whether crops are rainfed or irrigated, agriculture is the dominant water use across the world. Agriculture water use is also consumptive, plants requiring water in order to transpire it, whilst urban water uses are largely non-consumptive.

Governments have always had to focus on agricultural water use because as recently as 100 years ago, the average household was spending at least 50% of its income on food (Burnett 1979). At the same time, historically, crop prices were highly volatile (Clark 2003), the post-war period being one of unusual stability but crop prices now appear to be returning to their typical volatility. In addition, Malthus was right: in the hundred years after he predicted that population would increase faster than crop yields, this occurred; significant increases in yields did not take place until after the Second World War. In the nineteenth century, the increasing gap between population and crop yields was bridged by bringing new land into production, notably in the two Americans and Australasia (Offer 1989), and the adoption in Europe of potatoes as the basic foodstuff of the poor (Zuckerman 1998). There is now very limited good quality arable land left to exploit (FAO 1995) and projections of future food needs will require substantial improvements in yields. For example, the Rothamsted 20-20 programme aims to increase wheat yields in the UK to 20 tonnes/ha over the next 20 years, more than doubling current yields. Whilst crop water requirements are not a linear function of yield (Molder 2007), this will require significant additional water. Hence, gains in crop yields will have to be accompanied by gains in water productivity. For example, the Drysdale wheat variant developed in Australia (CSIRO nd) and the shift to aerobic rice in place of paddy rice (http://www.irri.org/Aerobic_Rice).

But even under optimistic assumptions, the Comprehensive Review of Water in Agriculture predicts that agricultural water usage will increase by 13% (Molder 2007). Projections vary (for a discussion of projections of irrigation water, see Treyer, Colombier, forthcoming 2013) but the point remains: if they want to eat, the populations of the cities will have to solve their own water problems rather than seeking to divert water from agricultural uses. In addition, phosphorus is an essential crop nutrient and, as Liebig's Law states, yield is dependent upon the least available of the crop nutrients. In turn, cropping removes the nutrients gained in the crop. Although predictions of when 'Peak Phosphorus' will occur differ, sooner or later it will become essential to recycle the phosphorus contained in urine and faeces to crop production.

A second major form of water usage is in thermal energy electricity production. In South Africa, forms of dry cooling (WBCSD 2006) have been introduced to improve the productivity of water usage: the Matimba power station by using direct dry cooling consumes about 0.1 litres of water per kWh of electricity put into supply compared to an average of 1.9 litres/kWh for conventional wet cooled thermal power stations. An incidental but highly desirable gain from the shift to renewable energy production is then to release water for other uses. But as long as the predominant source of electricity is thermal power stations, the requirements of water in electricity production is a factor to be considered in water planning, along with the kinetic energy requirements to move water, and the energy requirements of water use, notably for heating and cooling.

WATER AND THE TRANSITION TO A GREEN ECONOMY

Water management is essentially about coping with meteorology, particularly the inherent variability of a climate. Rivers are the residual of precipitation; the concentration of runoff, although there may be some base flow contribution from groundwater. What matters is the quantity of precipitation and the proportion of precipitation that, after infiltration into the soil, becomes runoff. The runoff coefficient is a variable and not a constant for permeable areas: the runoff coefficient is higher the longer and/or more intense the rainfall.

Issues with urban water management

For water supply, the problem is to bring the variability of water availability into alignment with the variability of demand; variability is more important than the average. Local climates vary enormously in terms of both intra-year, seasonal, variation in rainfall, many areas having a pronounced wet season. Intra-year variability then results in a requirement for a large storage capacity, commonly in the form of reservoirs. High inter-year variability is associated with multi-year droughts and even greater requirements for storage. Hence, Sydney has the equivalent of three years of demand for water in storage.

However, most cities export more water than they import: the impermeable areas of the city converting a high fraction of rainfall into runoff. Manchester in England has been estimated to export three times as much water as it imports (Green 2003) and even in the low density cities of Australia the ratio of exported water to imported water is often estimated as 2:1. This runoff is currently an expensive problem both in terms of dealing with the volume and also the polluting load; potentially it is a resource.

Water has several – at times conflicting – dimensions.

Water itself has some unusual physical and chemical properties (Ball 2000) which make it useful for a range of functions beyond the essential biological requirements of plants and animals. For those biological requirements, water has no substitute. For other urban purposes, water usage is largely non-consumptive. What is consumed in most urban water uses is thus essentially energy. In these other uses, some degree of substitution can be possible (e.g. the replacement of water dyes by oil based dyes; the use of ECOSAN techniques in place of water based urinals and water closets) but reducing the amount of water taken from supply is generally the main route to improved efficiency.

Because of these chemical, physical and biological properties, water is highly connected to other policy areas including energy, transport, health, agriculture and rural development. It may be said that consequently we have always managed water in order to try to make the best use of land. In turn, we cannot seek to manage water except in terms of this wider context.

In addition water has also taken on cultural and religious symbolism (Bouguerra nd); almost universally water has come to symbolise purity, ritual washing with water being part of most religions. Perhaps in consequence, there has developed the assumption that the disposal of any form of waste to water will purify that waste. This assumption is partly true but the use of watercourses and later sewers to dispose of all forms of unwanted waste products is one of the major problems in water management. A corollary is that successful water management depends upon the existence of an effective strategy for collecting and disposing of solid and liquid wastes. For example, FOGS (Fats, Oils and Greases) produced from cooking are a significant problem, particularly in restaurant areas, creating blockages in sewers. The potential value of FOGS as the basis for a biofuel is reducing the problem in some cities; one example of the gains from taking an integrated approach.

Part of that symbolic function of water is the articulation of social relations. A form of social relationships that is of central importance in making the change to green infrastructure is justice. Justice is generally considered to have two aspects (Lloyd 1991; Pettit 1980): distributional or substantive justice: the outcome of the decision; procedural justice: the process by which the decision was made.

From the economic perspective, water management involves a number of other problems (Green 2008).

The value of water in most human uses is dependent upon the reliability with which the water is available.

Higher value water uses are typically correlated with requirements for higher reliability and the requirement for high reliability of availability is driven in part by the requirement for investment. Large investments whose success depends upon a reliable supply of water will not be made unless such a reliable supply of water is first secured. The obvious example is agriculture; crops with a high return to water usage are almost invariably vegetables and fruit where the former require an investment in horticulture and the latter take several years before the trees or bushes produce a good return in terms of crop. Similarly, an investment in a thermal energy plant will not be undertaken until a secure supply of cooling water is first obtained.

In turn, since the value of land depends upon the return which can generated from the use of that land, where the return depends upon the availability of water, a large proportion of the value of the land is the value of the supply of water.

Water management is usually very capital intensive.

For example, the Replacement Values of the current water and wastewater assets in England are estimated to be equivalent to about 30% of national income, with the majority of that replacement cost being represented by sewers. This creates substantial inertia. Because water management is capital intensive, the pattern of capital expenditure is very lumpy and the time taken to bring a new investment on stream can be considerable. In turn, decisions on investments have to be made on the basis of anticipations as to future demand and supply. The capital intensity of water management means that the costs of water services are strongly influenced by the costs of capital and price regulation is ultimately determined by considerations of the fair return to capital.

Operation and maintenance costs, short run marginal costs, are frequently either constant or increase with falls in demand.

For example, if a sewer is to be self-cleansing then some minimum flow is required. In consequence, falls in demand may be accompanied by increases in operational and maintenance costs. Frequently, a fall in demand is not therefore accompanied by an equal fall in O&M costs, a problem experienced in Germany (Hummel and Lux 2007).

Water is commonly a Ramsey Good (Ramsey 1927).

From that perspective, the primary problem is to recover the fixed costs. Ramsey's own solution, that costs should be loaded on to those consumers whose demand is price inelastic is often unacceptable where those consumers are the low income consumers. In addition, since marginal cost pricing only generates sufficient revenues to cover costs when the marginal cost is above average cost, there is limited scope for adopting marginal cost pricing.

There are commonly pronounced physical economies of scale.

As a corollary of the capital intensity of water management, it is generally cheaper to construct one plant with a given capacity rather than several with the same total capacity. Fortunately, physical economies of scale can be offset by system economies. For instance in Japan, rather than incurring the costs of extending the sewer network it has proved less costly to subsidise the adoption of on-site wastewater treatment and reuse (Gaulke 2006; for a more detailed discussion of the deployment of such technologies, see OECD, 2009). Similarly, the driver to the adoption of SuDS approaches in many cities has been to avoid the capital costs of extending the system for collecting and treating surface water runoff (e.g. Toronto, Philadelphia, New York, Portland). Again, if potable water supply would require a new expansion such as a reservoir or bulk transfer, adopting a green infrastructure approach is often cheaper. The same economies of scale are also found in energy usage: a large pump requires less energy per unit output than several smaller pumps of the same total capacity. One consequence is that switching to a green economy is likely to come at a cost and energy penalty which has to be factored into the design of the system.

Reducing water consumption can often save water four or five times.

Opportunities for savings include: the reduced cost of potable water provision; the reduced cost of wastewater collection and treatment; a reduction in the costs of surface water management; lower costs in the costs of heating or cooling water in its application; and a reduction in materials lost to the wastewater. Thus, for example, a water efficient shower will also reduce the energy costs of heating the water for use in that shower.

Barriers and incentives to shift to green infrastructures

In order to induce change, the incentive to make the change has to be greater than the barrier to making the change. Hence, the necessary starting point is to identify what are the barriers that currently prevent the desired change from occurring. That barrier may require a one-off incentive (analogous to levering a rock out of the ground at the top of a slope) or continuing action (equivalent to rolling a rock uphill). The incentive adopted has to be appropriate to the barrier identified. The barriers to change that can exist are various and can be categorised as:

- Intrinsic limitations to green infrastructures for urban water management;
- The inherent problem;
- The challenge of change for the policy maker;
- The barriers to the adopter of making the change;
- Issues in making the change.

Before we analyse these barriers as they apply to green infrastructures for urban water management, some considerations about change can be useful.

Change

Water management has always been about coping with change: the inherent variability of meteorological systems and hence in water availability.

In examining change, we may be interested in:

- the trajectory of change over time: both how long it takes – we obviously require adaptation to climate change to be possible in a shorter time than climate change takes. But also whether the trajectory is linear or discontinuous at the other extreme, with marked 'tipping points';
- how change diffuses across some population (e.g. households, firms, cities);
- what are the determinants of that change or conversely what are the barriers inhibiting change.

Two forms of change which are of particular concern are:

- self-chosen change: adaptation and learning, especially the concept of learning organisations (Argyris and Schon 1966) and co-learning across organisations (Craps 2003; Ison et al., 2004);
- inducing change: inducing consumers, firms etc. to adopt sustainable consumption and production.

In making change, one area of organisational learning and adaptation where there has been a great deal of interest is the role of individuals: individuals as leaders, champions (Brown and Clarke 2007; Keath and Brown 2008), and policy entrepreneurs (Huitema and Meijerink 2010; Partzsch and Ziegler 2011). But if the individual and group is seen as a duality this is to exclude the other and especially the relationships between the two. The other side of the role of individuals in the framework of change is then:

- Not all innovations are desirable; examples of innovations in water management which in retrospect we might have done better to avoid include the triumph of the water closet over the competing earth closet (Eveleigh 2002); garbage disposal units; jacuzzis; top-loading washing machines; and power showers. The problem is not just to promote all innovation but also to select only good innovations.

- Organisational theory typically emphasises that successful teams are made up by people in different roles, with different skills (Katzenbach and Smith 1994). Emphasising one role implies that the other roles and skills are unnecessary which is not correct. What is important are the skills and techniques used by successful leaders, champions and entrepreneurs: these need to be understood so that they can be taught.

- It is the organisation that has to have the capacity to learn, the structure and ethos of the organisation must be such as to promote organisational learning (Argyris and Schon 1966).

- Finally, the emphasis on the role of individuals might be an example of cultural bias, the product of cultures which emphasise competitive individualism and hence of limited relevance to those cultures which emphasise either social solidarity or social harmony (Lustig and Koester 1993). Again, if Tannen (1991) is right that women expect decisions to be taken after discussion and by consensus then an emphasis on individuals would be a gender bias.

Intrinsic limitations to green infrastructures for urban water management

Green infrastructure are not a panacea for urban water management. They face two intrinsic limitations, which can only be addressed on an empirical, case-by-case basis. Both relate to the capacities to deal with shocks (a drought or a flood) in an economically optimal way.

Whether a city heavily reliant upon rainwater harvesting can cope with a drought at the lowest cost needs to be assessed. Distributed storage means the loss of the capacity to switch available supplies to the most critical uses and to ration water to the less critical uses. Again, in any catchment, the problem from a flood risk management perspective is to minimise the risk that the flood peaks from the different tributaries will coincide at some critical downstream point. This can mean delaying the discharge on some tributaries but it may in turn be desirable to promote early discharge on other tributaries. In extreme events all forms of SuDS will cease to have any significant effect on runoff, the intensity or quantity of accumulated rainfall exceeding their capacity. So, the piecemeal implementation of SuDS across a catchment could have adverse effects: the pattern of redevelopment may not coincide where it would be most helpful to introduce SuDS. A catchment is a system and efficiency is achieved by managing it as a system.

A more general problem with sustainable development is that it involves squeezing out existing inefficiencies in resource usage. However those existing inefficiencies provide the first level of resilience in the face of shocks. In droughts, voluntary restrictions commonly reduce consumption by around 20% (USACE 1995); amongst the richer households in South Africa, it has reached 40% (Millar 2012). Recovery from floods tends also to include squeezing out existing resource inefficiencies. So, it is important to distinguish between short run resource efficiency and long run resource efficiency, the latter taking account of variability in conditions. Thus, aircrafts typically have three independent control systems, each of which on its own is sufficient for the pilot to control the plane. In normal conditions, resources are being used inefficiently. But in an emergency, the three independent systems mean it is more likely that one of the control systems remains functioning.

The inherent problem

- **Urban densities:** water management requires both space and place and weaving water management structures into urban fabrics in particular is more difficult the higher the population density. Thus, it should be expected to be easier in the low density areas that characterise suburbs and North American and Australasian cities than the high densities of central business districts and Asian, African and South American cities. Yet it is those high density areas that experience the greatest problems. In many high density areas, roads and pavements are already underlain by a multiplicity of existing services making introducing ground based SuDS difficult.

Figure 3. Below ground utility congestion, Crossrail site, Oxford Street, London

- **Inertia created by existing stock**: in many countries, the rates at which existing building stock, especially dwellings, are replaced is very low. Hence, adopting a green infrastructure approach requires retrofitting the existing stock rather than relying upon new development and redevelopment carrying the load.

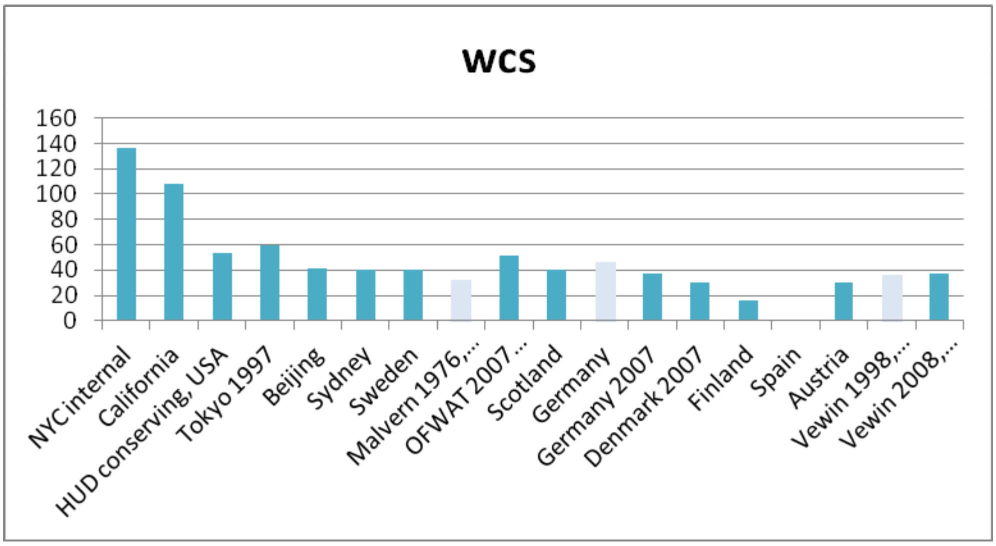
- **There are always trade-offs that have to be made**: for example, there is rarely a single environmental best option, the choice, for example, lying between a freshwater lagoon and a brackish water lagoon. In hilly areas, the flood plain can be the only developable land. At high efficiency levels, water efficiency in washing machines can only be increased at the cost of a loss of energy efficiency (MTP 2006).

- **Rules set boundaries to the power to act**: rules create spatial, functional and temporal boundaries to the capacity to act. Thus, action may be outside of the capacity of the responsible body or there may be gaps between the boundaries where no organisation has the power to act, or the rules may be ambiguous as to whether any organisation has the power to act (Green 2010a). One consequence is that water management is always a transboundary problem, it is only the nature of the boundaries that vary.

The challenge of change for the policy maker

- **Data**: traditionally water management has been undertaken with the minimum possible amount of data, partly because collecting data is expensive and water is a bulk, low unit value product. In addition, collecting data has tended to reveal problems which once revealed, need to be addressed. Ignorance in water management has often been bliss. But it is not possible to seek a shift to the sustainable use of water without knowing how much is used by whom for what purposes. For example, Figure 4 shows the amount of water used daily to flush toilets in dwellings in different countries, a usage which typically accounts for 30-35% of water consumption in the home. It is difficult to account for these differences, and in three cases there is data to show changes over time. What is not known is the uses to which WCs are put, the frequency of each of those uses, and the propensity to flush after each such use. For example, there is limited data on the frequency of urination and data that is available (Latini et al., 2003) implies that ageing populations will be associated with increasing water usage as a number of age related medical conditions such as prostate enlargement and Type 2 diabetes are associated with increased frequency of urination. But it is upon assumptions about the usages and propensity to flush that expectations as to the improvement in water efficiency from the adoption of dual flush cisterns depends.

Figure 4. Amount of water used daily to flush toilets



Source: compiled y the author from a number of sources.

- **Modelling capacity**: in the 1960s and 1970s rivers were often straightened and put in a concrete channel as a means of resolving a local flood problem. But the only aids to mathematical calculation then available to engineers were slide tools, log tables and mechanical calculators. Consequently, the mathematical models that could be analysed were both simple and coarse. Many green infrastructure approaches have only become possible once fast, high capacity electronic computers have become available with which to analyse their performance. Similarly, charging for surface water runoff on the basis of calculated impermeable area has only become financially viable with the existence of GIS data bases of land uses.

- **Uncertainty**: some uncertainty about the consequences is inherent to innovation, as some innovations must fail: absence of failure is a sign of the absence of innovation. Uncertainty creates a reluctance to adopt; early adopters of an innovation being the ones to discover the problems and the means to overcome those problems. Two areas of uncertainty commonly cited are: O&M costs and safety. Potential safety concerns include the risk of cross-connections to potable supplies in the case of rainwater harvesting and grey water reuse systems, and the risk to children of open bodies of water as in some forms of SuDS and in river rehabilitation.

- **The need to be seen to do something to deal with a crisis**: crises create a need for the responsible bodies to be seen to take effective action in the short term. The change to a green water infrastructure takes time but the short term measures (e.g. the installation of desalination plants) remove resources that could be spent upon green infrastructure.

- **Making the problem appear to go away**: undertaking a large physical intervention appears to deal with the problem permanently, removing the need to pay any further attention to it. In addition, once the decision to undertake the works is made, construction can be devolved to another organisation. Conversely, adopting a green infrastructure approach takes time and hence remains on the policy agenda requiring more organisational attention. To some extent this concern is justified: some dams and sewers remain in use after over one thousand years, concrete and masonry being robust in the face of both natural forces and human neglect.

- **The policy cycle**: policy changes occur at cyclical intervals. These intervals may be formally determined (e.g. there may be a requirement that a plan be reviewed every five years) or simply pragmatic: making decisions is expensive and there is a sensible reluctance once having made a decision to immediately revisit that decision.

The barriers to the adopter of making the change

- **Attention**: one absolute scarcity is attention. People have limited amounts of time and energy and have to allocate this across competing requirements; many forms of consumption require both time and a time slot. Decisions are consequently expensive to make. Hence, people have to prioritise their time and energy between these competing demands and in practice prioritisation implicitly or explicitly involves deciding what will be neglected. Habits are then a useful means of avoiding the costs of making decisions. Hence Rees (1969) concluded that the reason why companies use water inefficiently is because the costs of water are too low a proportion of operating costs. Two options are therefore either to reduce the attention costs of making one decision or reducing the attention costs of making some other decision or decisions. Regulation is one strategy here but conversely using a pricing mechanism may increase attention costs.

- **Information costs** are a recognised restriction on the efficiency that can be obtained from a competitive market (Stiglitz 2008): the costs to a potential purchaser of finding out what is available from whom at what price and to the supplier finding potential consumers. A corollary of attention costs is that large amounts of information will be ignored; a successful information campaign is then one which is sufficiently different to all others so as to capture attention.

- **Access to capital** – changing technologies requires capital investment and there are marked differences in the ease of access to cheap capital and the nature and levels of saving between different income groups (H M Treasury 1999; Taylor 2010). SMEs often also complain about access to, and the cost of, borrowing.

- **Behaviour or technology**. Water usage is a combination of behaviour and technology, and, in the case of domestic uses, demographics: the number of members of a household and the age composition of the household having a significant effect upon water usage. It is necessary to understand the relative importance of the different factors, and their interplay, if change is to be induced. For example, in Singapore, the recommendation is to turn off the shower whilst soaping or shampooing. But this depends both upon having a shower in which temperature and flow can be controlled separately, and a bathroom temperature in which it is possible to stand naked and wet without acute discomfort. Hence, behavioural change may be dependent upon technological change. A significant proportion of the differences in household water usage between the USA and Europe results from the differences in the technologies of household equipment and fittings.

- **Rental accommodation**: those who rent accommodation have less incentives and less capacity to make technological changes to their buildings than those who own and operate their buildings. At the same time, there are limited incentives for the owners of the building to adopt green infrastructure techniques. In some countries, large proportions of dwellings are in the rental sector. Equally, in the commercial sector, there has been a tendency for companies to adopt a lease back approach.

Issues in making the change

- **Reduce perverse incentives**. "First in time, first in right" water allocation systems are often associated with a "use it or lose it rule": if the water is not put to use then the abstraction entitlement is lost. This promotes use now simply to avoid loss of the potential to use the water in the future. In England, the price regime for the water and wastewater companies promotes capital investment and with it the implicit assumption of increasing demand; the challenge now is to devise a price regime which instead rewards the companies for promoting the adoption of sustainable water management. They need to be able to make profits not only through the promotion of these techniques but more especially to be confident that they will make profits when water use has dropped significantly. Again, if consultancies are paid on the basis of the capital cost of the works undertaken, a bias towards capital works is created. One side-effect is that whilst the cost estimation of capital works is usually highly detailed, estimates of O&M costs are at best vague.

- **Frictional and transaction costs**. An exchange is potentially beneficial to both parties if the value of the resource is lower to the party currently holding the resource than its value to the other party. But these gains will not be achieved if the costs of making the transfer exceed the net difference in value between the two parties. Those transaction costs include both the physical costs of making the transfer and interpersonal costs (including attention and information costs but also those of formalising the exchange). Since water is a low unit value bulk good, transaction costs are often high relative to the potential net benefit of the exchange. For example, the frictional costs of moving water have resulted in transferring water to southern California consuming 19% of the total energy consumption of California as well as a large quantity of diesel fuel (Klein et al., 2005). The proportions of total electricity consumption taken up in moving water are similarly high in Israel and Jordan. The interpersonal exchange costs can similarly be a large fraction of net benefit from the exchange: for example, the costs of domestic wastewater treatment and collection are almost universally collected simply as some multiplier of water supply cost, whatever means is used to collect that revenue. It is impractical to meter household wastewater discharges. Since Coase (1991) demonstrated that it is relative transaction costs that can determine what is the efficient solution, so there are significant implications for water management.

- **Technology-biased regulations.** Existing regulations make assumptions about the technology that will employed. For example, a barrier to the adoption of SuDS in England was argued to be that the wastewater companies had a duty to adopt and hence to maintain a Public Sewer but since a Public Sewer was defined in the relevant legislation (the Public Health Act 1936) essentially as a pipe, the wastewater companies were precluded from adopting a SuDS system. OECD (2009) makes the case for regulations that do not pre-empt technological choices for water supply and sanitation, including in OECD countries.

- **Public acceptance**. Public health specialists would probably never drink any water except from a potable water system with a well-established testing regime or swim in any water except a public swimming pool. Conversely, the cultural belief that water is purifying, and hence that natural water bodies purify, may be seen as a barrier to the adoption of the use of rainwater harvesting and grey water reuse, and especially to black water recycling when this does not first involve passing the water through the environment.

- **The disciplines**. Scientific progress has been achieved through a divide and conquer approach. But the result has been the fragmentation of knowledge between the different disciplines. At the same time, the different disciplines have become, in the anthropological sense, different cultures (Geertz 1993) making communication between the disciplines difficult, because of the differences in the languages and concepts used within each discipline. If we are lucky, each of the disciplines is working on a different part of the same jigsaw so that eventually they will join together but it is possible that they are working on different jigsaws. In turn, too often interdisciplinary studies are simply separate disciplinary chapters in a common cover. Finally, each discipline has simultaneously a social role and recruits because of what students consequently understand will be their career. So, on the one hand, decision makers would be surprised if they asked a lawyer for advice on water demand and were given the design for a reservoir. On the other, traditionally engineers became engineers in order to build things so one engineer in England complained that he did not become an engineer in order to distribute low flow shower heads. But engineers are always involved in transdisciplinary work and consequently probably closer to interdisciplinary groups than any other discipline. So the practical question is how to do interdisciplinary and transdisciplinary research, an area which is insufficiently researched.

LESSONS FROM EXPERIENCE

Different cities and countries differ in how far they have progressed in making the transition to a green water infrastructure both in terms of how far they have gone and how widespread is the adoption of the different techniques. In any process of change it is inevitable that some will have started the change before others and others will be the last to make the change. What are the transferable lessons that the latter can take from the former? Therefore, interest lies in the reciprocal questions: Why have some changed? And, why have some not yet changed? In turn: What is stopping the latter making the change? And, how the former overcome those barriers? How are they making the change? What determines the rate of change that is occurring?

Traditionally, organisations have been established in order to make large scale physical changes directly; for example, the Tennessee Valley Authority, the Metropolitan Board of Works in London, and the Ruhrverband in Germany. To be effective, those organisations had to have the capabilities to undertake, notably the capacity to raise the necessary capital to fund, those interventions. Some of the case studies described involve organisations making direct physical changes in the environment; for example, to carry out river rehabilitation. But much green infrastructure involves first changing other people so that they change the way in which they interact with the environment. For example, so they use less water, adopt green roofs or SuDS. Thus, success depends upon the degree to which individuals, households and firms can be induced to change their behaviour. Success depends upon finding the most effective means of influencing the behaviour of others.

There is inherent bias in the selection of the case studies: the availability of material in English. This bias works two ways; some very interesting experiences are not discussed in detail for lack of material in English describing the process which restricts the scope of learning from the experience. For example, in Copenhagen, household water consumption has been reduced to 125 l/p/d but this has not involved water pricing because the ratio of water meters to apartments is 1:30. Over much of the rest of Europe, household water consumption has been falling consistently over the last decade or decades (e.g. the Netherlands) for reasons that are not clear. But as with Copenhagen, this is not the consequence of pricing since in general whilst buildings are typically metered, individual apartments are not. Data on the proportion of dwellings which are individually metered is generally difficult to obtain. It may be that building metering has an effect on water consumption but economic theory does not provide an explanation of why this might occur.

Again, there are many significant changes occurring in Japan but the literature in English is limited. Perhaps the most interesting country from a water management perspective is China practically all forms of intervention and policy instrument are being tested somewhere but the documentation is difficult to obtain.

A second bias created is the appearance that English speaking countries are particularly advanced in the transition to green infrastructure. This is misleading; it is more accurate to say that the English speaking countries are generally coming from behind so that it is relatively easy to make significant improvements in water usage through the adoption of sustainable water practices. The advantage of the author coming from the UK, a country which only starting to make the transition to a green water infrastructure, is then both that it is possible to critically review the achievements in other countries and to see the barriers to making the transition.

Germany, a front runner

Germany is perhaps 20 years ahead of any other country in making the transition to sustainable urban water management (Green and Anton, 2010) as shown by both the long history of adoption of the techniques, the wide variety of approaches adopted and the proportion of the country which has adopted them. In Germany, domestic water consumption has stayed constant at around 130 l/p/d for the last twenty years and has now fallen to 121 l/p/d (Federal Statistical Office 2010) on average and only 93 l/p/d in parts of the former eastern Germany (Schleich and Hillenbrand 2007). Importantly for the wider transition to integrated urban water management, in parts of Germany, the problems of managing a conventional system of water and sewerage when demand falls, as is required to deliver sustainable water management, are being exposed (Hummel and Lux 2007; Schiller and Siedentop 2006).

Some 30% of municipalities in Germany have now introduced separate charges for foul and surface water (Federal Statistical Office, 2009). Charge rates vary but Cologne charges €1.1 m2/year; Berlin charges €1.4/m2/year; Dortmund €0.80/m2/year, and Munster €0.44/m2/year (Ngan 2004). Depending upon whether a fixed charge is also applied, the charges for surface water runoff vary between an average of €0.54/m2 impermeable area and €0.72/m2, and constitute 20-35% of the average charge for wastewater management (Federal Statistical Office 2009). Stormwater charges are reduced to varying degrees where different forms of SuDS are adopted; generally by around 50% (Ngan 2004) but Munster, for example, allows a rebate of 80-90% on a basic charge of €0.44/m2/year (Lawlor et al., 2006). In Berlin, any area not connected to a drain is excluded from the calculations of stormwater charges (Lawlor et al., 2006).

Figure 5. Green roofs; SuDS and rainwater harvesting, Berlin

North Rhine-Westphalia has been a particular leader in promoting green roofs, rainwater harvesting and other forms of SUDS. The Ecological and Sustainable Water Management Initiative provided €20 million for stormwater management initiatives (Lawlor et al., 2006). A subsidy of €15/m2 has been provided for both the retrofitting of existing areas and for installations in new developments. Between 1996 and 2004, some 6 million m2 of surface area was disconnected from the sewer system, including 825,000 m2 of green roofs (Lawlor et al., 2006). In the Emscher region, 17 municipalities covenanted in 2005 to reduce the proportion of impermeable area by 15% in 15 years (Seiker et al., 2006). Since 2005, 150 projects have been successfully implemented and as of 2010, 1.3 sq km - out of 40 sq km - of impervious area has been successfully disconnected. More widely, Weiss and Brombach (2007) reports that there are over 15,000 retention basins plus more than 2,500 settling tanks in Germany.

Green roofs first appeared in Germany about 100 years ago but only in the 1970s did the use of green roofs really expand. The expansion of the use of green roofs is driven partly by the use of surface water charges but also by land use planning requirements (Ngan 2004). Some 13.5 million m^2 of green roofs (about 14% of the total area of roof in the country) were constructed in 2001 alone (Lawlor et al., 2006). Stuttgart has been requiring green roofs since 1985, with green roofs now required on any roof with a slope of less than 20 degrees (Holzmuller 2009). In consequence an estimated 22-25% roofs in Stuttgart are green (Velazquez 2003). Since 1986, the municipality has provided 105,000 m2 of green roofs on public buildings, and the financial incentive programme has produced 55,000 m2 of green roofs on private buildings (Lawlor et al., 2006). Similarly, in Dusseldorf, 1.6% of all roof areas and 3% of the extended inner city zone are greenroofs and some 350 underground garages are also green roofed, giving a total 730,000 m2 (Holzmuller 2009). Berlin subsidised the creation of green roofs between 1983 and 1996 through a 'Courtyard Greening Program': this provided a subsidy equal to half the installation costs, resulting in nearly 66,000 m2 of green roofs being constructed (Ngan 2004). Green roofs have been variously promoted by different measures in each municipality, including through planning requirements (a given proportion of a site must be green), subsidies for green roof construction, and charging for surface water drainage and providing discounts for green roof adoption (Lawlor et al., 2006). But the primary driver for the adoption of green roofs in Germany has not been water management but compensation for land taken up by development (Ngan 2004). Green roofs typically attract rebates on surface water charges; most commonly at a rate of 50% (Ngan 2004). In addition, many cities also provide subsidies for the construction of green roofs where such roofs are a condition of development consent. North-Rhine Westphalia Land provided subsidies totalling €320 million (Ngan 2004), funded through the charges on the discharges of wastewater (Lawlor et al., 2006). Subsidies were available for green roofs, SUDS, and rainwater harvesting (Ngan 2004). Overall, as discussed below, the effect has been to significantly reduce the amount of impermeable area.

An estimated 35 % of new buildings in Germany are now fitted with rainwater harvesting, with some 500,000 buildings so fitted and a further 50,000 systems are built each year (http://www.rainwater-toolkit.net/index.php?id=21). The German rainwater harvesting market is estimated at about €340 million per annum (CIWEM nd).

Car washing is a problem for two reasons: the amount of water used by household washing by a hose and the pollution load created which, in separate sewer systems, then enters the stormwater drainage system. A number of municipalities in Germany now restrict vehicle washing to designated areas where the waste water does not enter the stormwater drainage system.

Several lessons can be learned from the breadth of German experience.

An apparent lesson is that making municipalities responsible for ensuring the provision of water services, including surface water drainage, whilst simultaneously those municipalities are responsible for spatial planning and development control, internalises the costs of water service provision to the planning process. But the limitation of this lesson is that it raises the question of what is the ideal size of a municipality. Why has the change occurred in Germany but not in France, for example? Is it simply that many of the communes in France are too small to be effective?

A more general lesson is that much of the change has been generated through the spatial planning and development control system; the adoption of green roofs is generally ascribed to the Federal Nature Conservation Act (BNatSchG). A generally transferable lesson is to use multiple instruments:

- information campaigns to define what are the desired behaviours and why they are desirable;
- a system of charges which indicate what is desired behaviour;
- subsidies or soft loans to promote the adoption of desired behaviours;
- regulations to require minimum behaviours;
- the organisation promoting the change starting by demonstrating that it has adopted the changes;
- the use of high profile developments, such as the Potsdamer Platz, to show the techniques.

Finally, and contentiously, from a British perspective it may be asked whether there is also a cultural explanation: whether not wasting resources is part of being a responsible citizen, along with avoiding debt. A cross-cultural comparative study on the motivations and take-up rates for sustainable consumption could address this question.

Reducing run-offs from rainfall - Toronto

Toronto is used to illustrate a common problem: urban areas both increase the amount of runoff from rainfall and speed up the rate at which it is concentrated. Two results are that the sewers, and especially combined sewers, overflow to watercourses creating a transient pollution episode, and that the volume of runoff generated results either in local flooding or the requirement for an expensive system of sewers. The emerging approach is then to reduce the amount of runoff generated and to delay its discharge either to a sewer or to a watercourse, whilst incorporating local treatment to remove part of the pollutant loads. Other examples, in addition to Germany and Japan, are Portland, New York City, Philadelphia, and Los Angeles.

In 2003 the City Council of Toronto adopted the Water Efficiency Plan (WEP) to avoid the capital costs of meeting a growth in population and employment which was projected to increase by 10 and 12 percent respectively, by 2011. As a result household consumption has fallen from 263 l/p/d in 2003 to about 225 l/p/d in 2010 (General Manager, Toronto Water 2011).

The primary measures adopted were:

- Single-Family Residential Multi-Unit Residential Toilet Replacement
- Clothes Washer Replacement
- Outdoor Water Audits
- Industrial/Commercial/Institutional/Municipal Toilet Replacement
- Water Distribution System Leak Detection
- Computer Controlled Irrigation
- Watering Restrictions
- Indoor Water Audits
- Educational and outreach programmes

Since the inception of the WEP, over 413,524 incentives have taken place, at a cost of $37.3 million, to achieve a reduction in water consumption estimated at 81.4 ML/d. The equivalent value of infrastructure expansion saved is estimated at C$180 million in 2010 construction costs. The educational and outreach programmes have been successful in achieving a change in consumer behaviour. Research in 2009 found that 89% of recent toilets purchased were a low-flow toilet and 85% of recent washers purchased were a water efficient model. Almost 100% of shoppers cited "water efficiency/low flow" as being a very important feature when purchasing a toilet or clothes washer (General Manager, Toronto Water 2011).

This was followed by action on stormwater (City of Toronto 2009; Toronto Water 2007b), a motivation again being the desire to avoid the capital works otherwise necessary and to reduce the risk of flooding from sewers. In one area it was estimated that disconnecting approximately one quarter of the downspouts in the study area would divert enough runoff to result in a 50% reduction of combined sewer overflows; disconnecting 2/3s would produce nearly a 100% reduction. For a cost of US$9 it was estimated that a community can save US$25 per disconnected household by diverting rooftop storm water from wastewater treatment plants.

Initially subsidies for voluntary downspout disconnections were provided but at the rate of take-up it would have taken over 20 years for the desired change. Hence in 2011 a mandatory downspout disconnection programme was adopted (City Clerk 2006; Toronto Water 2007a). This has three phases spread over 5 years:

- Phase 1, completed at the end of November 2011, covered properties in the central area of the city where there is a combined sewer system.

- Phase 2 covers those areas where there is a problem with the basement flooding from surcharging sewers. Completion deadline is December 3, 2013.
- Phase 3 covers the remaining area of the city and disconnection is required by December 3, 2016.

There are provisions for exemptions in some conditions and financial assistance is provided for those with a disability and the elderly on a low income.

In May 2009, Toronto became the first City in North America to have a bylaw to require and govern the construction of green roofs on new development: the bylaw includes a construction standard. The adoption of green roofs was calculated to save between C$313 million and C$37 million annually (Banting et al., 2005) and reduce local ambient temperature from 0.5 to 2°C. The requirement was phased in: new building permit applications for residential (over 6 storeys), commercial and institutional development made after January 31, 2010 and new industrial development (with a Gross Floor area of 2,000 m2 or greater) as of April 30, 2012. The requirement for the proportion of green roof coverage is graduated: 20% for buildings with a Gross Floor area of 2000 to 5000m2 up 60% for buildings with a Gross Floor area over 20000m2. A smaller amount of green roof than is required under the Bylaw is allowed, provided that a cash-in-lieu payment of $200/m2 is made for the reduced green roof area.

Lessons from Toronto's experience include:

- Each of the different strategies was adopted following extensive independent studies.
- The opportunity was taken of the need otherwise for an expensive capital investment.
- A multiplicity of incentives was used.
- Extensive stakeholder engagement, as in the other case studies, was a central feature.

Working with industry – Envirowise, in the UK

The Envirowise programme is an example of a long running programme seeking to reduce waste and hence to improve productivity in the industrial and commercial sectors. Similar programmes exist in parts of the USA and probably elsewhere: China has a commitment to improve water productivity in industry.

The Envirowise programme, now renamed WRAP, was set up by UK government's ministry of the environment to promote waste minimisation in UK industry and commerce, and therefore to enhance productivity, always seen as a problem in UK industry, and hence international competitiveness and profitability. Water efficiency was thus included as simply one component of resource efficiency. Although firms are generally metered for water usage and larger firms also pay for wastewater on the basis of the Mogden formula, the general finding of Envirowise is that firms could cut water usage by around 30% with a two year payback period (Envirowise 2005). This conclusion may be somewhat biased since participation by firms in the Envirowise programme is voluntary and a range of selection factors may influence the decision to participate.

In particular, in market economies, the number of SMEs is substantial and these are likely to be difficult to reach.

The programme directly or indirectly resulted in several further developments:

- the Market Transformation Programme, again sponsored by the UK's ministry of the environment. This programme is explicitly concerned to identify the market opportunities created by the transition to a green economy. Those opportunities include household fittings and water using equipment (MTP 2006).

- The Enhanced Capital Allowances programme established by the ministry of finance which allows increased tax allowances to companies to offset investment in specified equipment which promotes water efficiency.

Under the latter, companies can write off 100% of the first year capital allowance against tax on approved equipment in a series of categories. The categories of equipment so far included in this Water Technology List are: efficient washing machines; flow controllers; leakage detection equipment; meters and monitoring equipment; rainwater harvesting equipment; small-scale slurry and sludge dewatering equipment; vehicle wash water reclaim units; water efficient industrial cleaning equipment; water management equipment for mechanical seals; water reuse.

Again, the Strategic Forum for Construction (Waylen 2011) reports that 15-25% of water on construction sites can be saved; 85% where there are leaks.

Data on water productivity in industry is generally sparse, being available for few countries (e.g. the UK, Germany, Australia). It is also coarse, generally being aggregated into only a few sectors where different specialisations within that sector can have quite different water uses (for example, in the textile industry). Hence, it is difficult to compare water efficiency between countries and gains in water productivity may simply reflect changes in industrial composition.

Several lessons derive from Envirowise.

The programme was initially framed as a waste minimisation programme: reducing waste resulting in increases in productivity and profitability. Thus, companies which did not practice water efficiency and other waste minimisation approaches were framed as not maximising profitability rather than as being environmentally insensitive. This made it difficult for firms to argue that they had more important things to worry about. It demonstrated that substantial improvements in water efficiency were readily achievable with payback periods of less than two years.

The programme used various means to cut the costs of attention and focused upon low-lying fruits. It used innovation circles, developed simple tools for firms to check their water usage, provided subsidised water audits by specialised firms, published case studies, and provided yardstick data on water consumption in industrial sectors. The programme built partnerships with trade associations, local chambers of commerce and other bodies. For example, the commitment of members of the food and drinks manufacturers trade federation to improve water efficiency.

River rehabilitation – Denmark

The ecological health of a watercourse depends on the flow regime, the geomorphological form of the channel and the connection of the channel to the surroundings, and the loads discharged to the water-course. In the countries of Asia and Europe, the landscape and hence the ecosystems are now the product of millennia of human intervention. In some cases, the resulting ecosystems have themselves become of value but in most cases the physical changes have resulted in watercourses that can support only impoverished ecosystems. Denmark was a pioneer of river rehabilitation, of seeking to return watercourses to a more natural state, an approach now widely adopted elsewhere, notably Korea (Green 2010b), the UK (Environment Agency 2006) and in the USA where it is termed 'daylighting'. Originally, the approach was termed 'river restoration' but it is impossible to return watercourses to the state in which they would be if there was no human activity. In particular, watercourses are naturally dynamic, changing the form and position of their channel in response to changes in flows and loads, and occasionally in consequence of earthquakes. So, a characteristic of river rehabilitation is the shift to using natural materials to control the river.

Figure 6. River Rehabilitation, Seoul

As Denmark is a flat country, agricultural development required artificial drainage in order to limit soil saturation within the root zone. The result was a landscape of 30,000 kms of natural watercourse and an equivalent length of artificial watercourses, all being heavily engineered in the form of the only approach possible until the late twentieth century: straighten, narrow and reduce frictional resistance by removing all obstructions such as plants. Denmark now has 25 years experience in rehabilitating watercourses (the early term 'restoration' having been replaced by 'rehabilitation'), with more than 2000 projects having been undertaken. Denmark's experience has resulted in river rehabilitation being adopted in many other countries, including England

(Environment Agency 2006) and on a grand scale in Korea (Green 2010b). A fraction of those projects involve re-meandering and the majority are aimed at re-establishing connectivity between the watercourse and its natural floodplain. The individual projects are largely the result of local initiatives and consequently each is small in scale rather than a river being rehabilitated in total (Pedersen and Friberg nd).

The three classes of watercourses in Denmark and associated responsible authority are: county – county; municipality – municipality; and private – municipality.

Under the Watercourse Act, the responsible authority has to ensure compliance with the provisions of the Act; originally these provisions were limited to watercourse maintenance. In addition, under the original Environmental Protection Act of 1974, the County was required to set a water quality objective for each watercourse. The County also has supervisory responsibility for the state of pollution in all watercourses. Thus, a distinguishing feature of Denmark was the incorporation of water quality objectives into spatial planning; in turn, this reflects the Scandinavian emphasis on counties as primary governmental units.

Within this overall framework, river rehabilitation co-evolved with legislative changes. The new Watercourse Act of 1982 shifted the focus away purely from maintaining drainage capacity and made river rehabilitation legally possible. The New Action Plan on the Aquatic Environment (1987) was aimed at reducing the nutrient loading to watercourses and the national "Strategy on Marginal Lands" of the same year, which aimed to restore 20,000 ha of former wetlands both gave impetus to river rehabilitation. The scope of the measures which the County Council could adopt were expanded in 1995.

In 1994, a project was begun by the Danish Environmental Protection Agency, the National Environmental Research Institute and the 14 Danish Counties to learn the lessons of the rehabilitation works so far undertaken (Hansen 1996). This followed the first international conference on river restoration in 1991. In turn, the European Centre for River Restoration (ECRR) was established at NERI in Silkeborg in 1995.

Lessons from the Danish experience include:

- Create a community of interest: the creation of a European Centre for River Restoration and the holding of specialist conferences.
- Include water management into spatial planning.
- Technological innovation creates new options: the co-development of complex mathematical modelling techniques with the computer hardware with the capacity to run these models demonstrated that complex, multi-form channels could perform the drainage functions which formerly had depended upon concrete channels.
- Line single-functional budgets have been adopted to ensure accountability for the spending of public money but mean that multi-functional approaches have to be funded from several different budgets from different agencies with different functional responsibilities. This requires either the building of cooperative links between agencies

or the invention of funding streams that allow a multi-functional approach whilst maintaining accountability.

- It is necessary to start with an opportunistic approach but, over the long term, it would be desirable to start at the top of a catchment and work downwards.

- Similarly, since a watercourse is simply the residual of precipitation, the local concentration of runoff, a watercourse cannot be rehabilitated in isolation: rehabilitation ideally includes reconnecting the watercourse with the wider catchment.

- Symbolic actions are important: symbols convey messages.

Adaptive water management and stakeholder consultation – Thames Estuary 2100

The traditional approach to water management was to: predict future demand; determine the optimum means of satisfying that demand; and build that means. Implicit in this approach is that it is a technical problem which can be addressed by experts. The shift to a stakeholder based approach itself requires changes, notably instead of there being an optimum solution, the stakeholders have to discover what is the best available option, where that option increasingly involves changing behaviour instead of building a large piece of infrastructure. In periods of rapid change, the future is inherently uncertain.

So, the developing approach to water management involves:

- the use of scenarios, maximally different alternative futures (van der Heijden 1996);

- the search for an option that is robust to uncertainty, one that does not fail dramatically under some alternative future (Penning-Rowsell et al., 2005);

- the adoption of a path of development which can be adjusted in the light of circumstances (see OECD, forthcoming 2013, for a discussion of several tools in the context of adaptation to climate change); choosing the future has thus to be seen as analogous to a voyage of discovery rather than following a map to a known destination (Green 2003).

An advantage of green infrastructure approaches is that their small, local scale make them inherently suitable to an adaptable path approach. For example, New York City (New York City 2011) uses this argument in its adoption of green infrastructure.

Thames Estuary 2100 (TE2100) is an example of using this approach when large scale physical infrastructure may be necessary in some future circumstances. Adjusting to sea-level rise is also a problem which all coastal metropolitan areas will have to undertake (Linham et al., 2010) and TE2100 is an early example of how those problems can be approached.

Figure 7. Thames Barrier

A large proportion of economic activity and human occupation in the Thames estuary lies in the coastal regions and hence they face the problems of adapting to sea level. Like London, most of these settlements developed along and around estuaries as ports. The Thames Estuary region continues to be simultaneously an area of intense economic activity and high population density and an area of major change. The Thames Gateway down the estuary is the development corridor, new port development is taking place although the shift out of fossil fuels may reduce shipping activity, and the idea of building a new London airport in the estuary is being revisited. It is also a soft and low coastline and any deep depression that takes a southerly route after passing north around Scotland creates a tidal surge which is funnelled down the North Sea, creating the risk of flooding in one of the countries with a North Sea coastline. In 1953, the tidal surge reached the narrowest part of the North Sea resulting in large scale flooding in the Netherlands and along the coast of the Thames Estuary. In turn, a tidal surge which progresses up the estuary has the potential to flood the centre of London.

Adding climate change to this produces a rich mix. Whilst the Thames Barrier protects central London from a tidal surge, it does so by holding the surge in the estuary and consequently the areas to the seaward side also have to be protected. The Thames Barrier itself is a brilliant piece of engineering, in that it had a significant degree of adaptability built into it (Gilbert and Horner 1984); the majority of closures now are for fluvial flooding: closure at low tide creates a large upstream storage reservoir to hold fluvial flood volumes. However, the barrier and the downstream structures will need replacing or renovating and in doing so, it is necessary to take account of climate change including the resultant rise in sea levels.

Since flood defence is characterised by economies of scale and consequently by capital intensity and therefore by long lead times, it is necessary to respond to predicted change rather than being able to respond to change as it happens. The twin risks are therefore creating stranded assets, large capital investment whose justification was a change that did not occur, versus the loss of economies of scale or short run demand that runs ahead of supply. In the twentieth century, the predominant vision of the future was that it would be like to-day only bigger so the pattern was one of chasing predictions of increased future demand. We now have to make decisions about a future that will be different to the present and where we require it to be different to the present.

England is perhaps the most centralised country in the world and flood risk management is the responsibility of a national agency, the Environment Agency. However, land and water planning and management are entirely separated whilst adaptation to sea level rise will require progressive adaptation of spatial planning and build form. So, the Agency initiated a study of the options in association with the key stakeholders, notably the local authorities who have responsibility for spatial planning and development control.

Lessons from TE2100 include:

- Planning is a process and not a product;
- The adaptive management approach can be applied successfully to large capital investments as well as the smaller scale, local adaptations that characterise green infrastructure;
- Climate change adaptation requires the adaptation of land use and thus the spatial planning agencies are key stakeholders in water management.

Other good practices

In addition to these specific case studies, a large number of other cities provide transferable lessons but they are either earlier on the path of change; the material in English is less accessible; or the transferable lessons replicate those from the detailed case studies.

Australia

From the COAG meeting in 1994 (COAG 1994), Australia has embarked upon a progressive series of reforms in water management (Turral et al., 2010), a change accelerated by another multi-year drought. However, it started from a very low base and whilst in some areas great progress has been made (ICLEI Oceania 2009), in others, it is very much at the beginning of the transition. For example, Melbourne has set a target of 10,000 water gardens to be installed, and by late autumn 2012, there were nearly 6,000 such gardens; this may be compared to the achievement in Germany and the ambitions of Toronto. In practical terms however whilst the plans in Australia replicate experience in other countries, there is a much greater availability of documentation on these plans in English. At the same time, the process of change is itself being extensively analysed. In addition, as a Federal state, Australia also provides insight into the problems of transboundary water management.

Between 2004 and 2010, the proportion of households with rainwater harvesting increased from 17% to 26%, with 49% of households in South Australia having such a system (Australian Bureau of Statistics 2010). Similarly, grey water reuse reached 43% in Victoria in 2010. The use of subsidies for adopting water efficient equipment and appliances has been widely adopted. In the year to March 2010, more than 600,000 Australian households received a government rebate or incentive in the last 12 months for at least one water saving product: 41% of those received a rebate or incentive for a washing machine or dishwasher. In 2008, the Australian national government introduced the Water for the Future programme of investment: A$12.9 billion over ten years. A$250 million of this plan is to be delivered to the National Rainwater and Greywater

Initiative, which will provide rebates for citizens who install grey water systems (A$500 for a greywater reuse system).

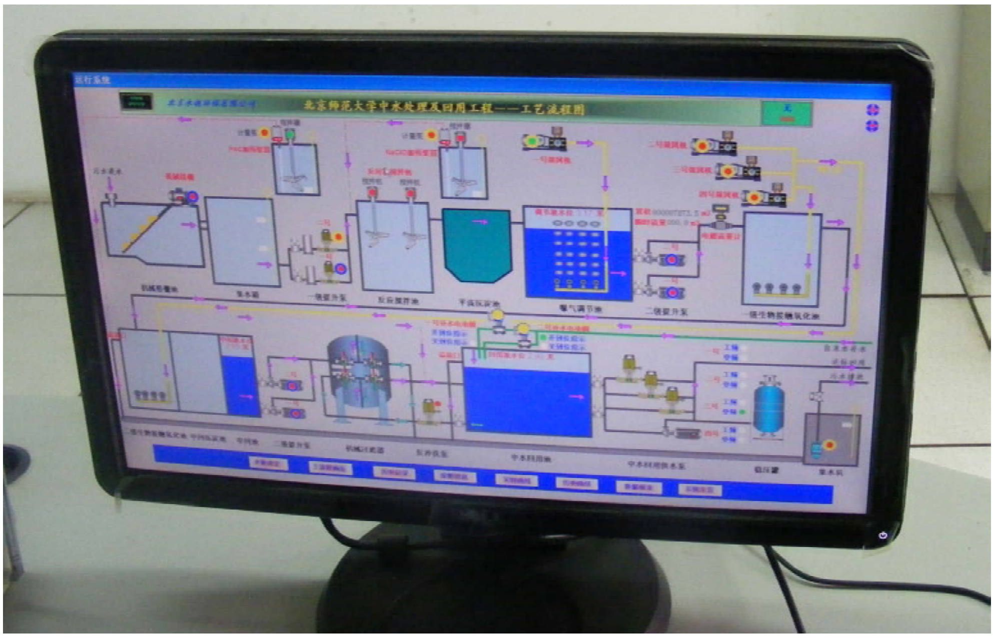
Belgium

Household water consumption in Belgium is low (107 l/p/d) and the requirement to adopt rainwater harvesting in dwellings was introduced early on so that in 2001 over 1.2 million dwellings had a domestic rainwater tank, equivalent to nearly 16% of total domestic water demand (Cornut et al., 2004). The different regions use differing combinations of subsidies or reductions in charges, regulations and information campaigns.

China

China is very receptive to innovation and once an innovation is accepted, it is adopted on a massive scale very quickly. Hence, most concepts of green infrastructure, including different forms of economic instruments, are being at least trialled in some part of China and some are being implemented on a very large scale. Both the current and previous Five Year Plans require significant improvements in industrial water efficiency (Jiang 2010). Similarly, one million people have been relocated off the flood plain around the Dong Ting lake on the Yangtze and 100 km of flood plain forest are being planted around Wuhan on the Yangtze; Beijing city government announced the intention of building 100,000 m2 of green roof each year (Zhang et al., 2010) with all 300ha of car parking within the 5th ring road being green by 2015. Grey water reuse for toilet flushing and landscape irrigation is quite common in large developments, such as universities.

Figure 8. Onsite Greywater Recycling, Normal University, Beijing



India

The CSE has been highly successful in promoting the adoption of rainwater harvesting mainly in rural areas, of learning from traditional techniques (Agarwal and Narain1997), but the approach is being increasingly extended to urban uses.

Japan

Japan started with the advantage after WWII that large areas of the country were not connected to a wastewater collection and treatment system. Hence, one motivation for adopting green infrastructure has been to avoid the costs of building a traditional sewerage system. In Tokyo, in buildings with an area of over 30,000m2 or a water usage of greater than 100m3/yr, onsite water recycling facilities are compulsory. In addition, any building with an area of over 10,000 m2 or a building footprint of more than 3000m2 is required to incorporate a rainwater harvesting system (Asano et al., 1996). In Fukuoka City, the limit is lower: any building over 5000 m2 being required to have onsite water recycling.

Thus onsite wastewater treatment of various kinds is commonplace throughout Japan, central and local government providing subsidies (Y21billion/yr in 2000) for their installation on the grounds that the subsidies are less than the cost of expanding the sewerage system. By 1997, there were 1475 building or block based local wastewater treatment systems in place, with an additional 130 systems being installed annually. In Tokyo, 61% of non-potable water usage is provided from local wastewater treatment works so whilst water consumption is high (Nakagawa et al., 2010), the impact upon the waterine environment is substantially reduced. Some 60 municipalities also subsidise the conversion of the former septic tanks to rainwater storage. The use of SuDS techniques at ground level is also widely practiced (http://www.mlit.go.jp), including the limited adoption of permeable pavements in urban areas (Sera 2006).

Victoria Business Improvement District, London

Business Improvement Districts are a government initiative which promotes the establishment of a stakeholder group centred on the local business community to make improvements which will promote local business development. The Victoria district includes one of the main London railway terminals, which connects to Gatwick London airport, and in addition to a major shopping centre includes hotels, restaurants and theatres and it also suffers from pluvial flooding. The district itself borders on Buckingham Place and is also close to the tourist centres of Westminster Abbey and the Houses of Parliament (Victoria Business Improvement District 2011). It includes the headquarters of Transport for London, whose responsibilities include the subway and bus transport networks in London. Since the Mayor of London has responsibility for Transport for London, this gives leverage to both the Business District and the Mayor. The District has an area of approximately 100 ha and was established in 2010.

Retrofitting the area with green infrastructure has been one primary objectives of the District with the focus being on green roofs, in addition to the three already in the area. The objective is to create an additional 25ha of green roof and to reduce carbon emissions by 20-30%. This focuses exclusively on the flat roofs, calculated to be some 36% of the land area in the district. Of this, about 3/4s is calculated to have some potential for having green roofs retrofitted (Land Use Consultants and Green Roof Consultancy 2010). Two of these roofs are now in the process of being retrofitted. Two rain gardens, one in Buckingham Palace, are also being implemented (Victoria Business Improvement District 2012) but the adoption of ground green infrastructure is restricted by the very high pedestrian and vehicle usage intensities.

New York City

For many years, NYC has been promoting demand management (USEPA 2002) albeit from a very high base level of consumption. In March 2012, the city and state agreed to promote green infrastructure in the city in conjunction with further investment in conventional wastewater infrastructure: the green infrastructure will reduce the necessary investment in conventional systems by US$1.4 billion. By 2030, it is intended to use green infrastructure to manage 10% of the runoff from impermeable surfaces.

Another driver for the adoption of the strategy was the conclusions of the Climate Change Adaptation Task Force convened by Mayor Bloomberg in 2008. This recommended the adoption of a flexible adaptation approach similar to that adopted in TE2100. A relevant comparison is between New York City and London where each Mayor has promoted climate change adaptation (GLA 2010) and a shift to sustainable water management (Mayor of London 2007, 2009) but the latter, in a highly centralised country, has limited capacity to actually do anything.

Paris

From a water management perspective, the use of green walls may be questioned, given the requirements to supply irrigation water to them. However, green walls have other advantages when used internally or externally, and Paris was an early adopter.

Figure 9. Green Wall, Paris

Philadelphia

Philadelphia has been using policies and demonstration projects throughout the city since 2006 to help promote green infrastructure in planning and development. As with New York, a driver has been to reduce the costs of complying with national standards to reduce water pollution from Combined Sewer Overflows (CSOs). The aim is to retrofit of nearly 10,000 acres (about one-third of the impervious area served by a combined sewer system) to manage runoff on-site. A variety of incentives are being used (Philadelphia Water Department 2011) including the introduction of a stormwater charge based upon impermeable area; regulations specifying SuDs for new developments; free design assistance and low-interest loans to owners of large impervious properties; a green roof tax credit (eligible green roofs must cover 50 percent of the total rooftop or 75 percent of the rooftop space that is structurally able to support a green roof. The one-time credit is for 25 percent of the total cost of installation, with a maximum credit of $100,000. Maintenance obligations are written into the property's deed, but the city retains the right to inspect the green roof); giving away rainwater butts; and expedited permit reviews (any project with 95 percent or more of its impervious area disconnected from the sewer system will have the stormwater management section of the project reviewed within five days of submittal).

Philadelphia also has installed dozens of green infrastructure demonstration projects, has published a technical design manual, and is developing a maintenance manual.

Portland, Oregon

Portland was an early adopter of SuDS, being one of the first cities in the USA to do so (USEPA 2010). It has calculated than US$8 million investment has saved US$250 million in conventional wastewater infrastructure costs. Portland's Green Street projects retain and infiltrate about 43 million gallons of water per year and have the potential to manage nearly 8 billion gallons, or 40% of Portland's runoff annually. Portland estimated that downspout disconnection alone would lead to a reduction in local peak CSO volume of 20%. So far through this program, 17,000 homes had their downspouts disconnected in a period of six and a half years; the most recent estimate is that 26,000 dwellings have been disconnected (Digman 2012), reducing the load from stormwater by some 1.2 billion US gallons annually.

Rotterdam, the Netherlands

Whilst the use of public open spaces, such as tennis or basketball courts or football pitches is routine in most systems of SuDS (e.g. Tokyo), Rotterdam has developed a specific design approach ('water squares') as part of a wider plan (Rotterdam Water City 2035) to adapt the city for climate change (de Graaf et al., 2007; van der Brugge and de Graaf nd).

Singapore

Singapore is an early adopter of black water recycling in the form of the NEWATER project, the processed water being returned to the potable water system (Dti 2006; Kim et al., 2012). As a tropical climate, water consumption levels are high (Lee 2005); a primary determinant of the adoption of the NEWATER system was to reduce reliance upon water supplies from Malaysia. The earliest adopter of wastewater recycling for potable use was Windhoek in Namibia (van der Merwe 1999).

CONCLUSIONS

The problem can be encapsulated as: where to start and how to keep going.

How to start

- **Take advantage of opportunities**. There are many kinds of opportunities and they should be exploited. Symbolic events such as the reconstruction of the Potsdamer Platz in Berlin after reunification and the London Olympics provided opportunities to showcase green infrastructure: rainwater harvesting and SuDS in the case of Potsdamer Platz and black water reuse in the London Olympics (ODA 2012). Airports as entries to countries also symbolic; both Schipol and Beijing airports include green roofs and the latest terminal at London Heathrow includes rainwater harvesting.

Figure 10. Green Roofs, Schipol and Beijing Airports

  The step nature of capital investment in water management means that at each step there is the opportunity to adopt alternatives. Thus, both Toronto and Philadelphia faced with very high capital investment costs to resolve pollution problems adopted a green infrastructure approach instead. New development is always a primary opportunity; it is cheaper to incorporate green infrastructure in a new development rather than to retrofit existing development

- **Never waste a crisis**. A drought, a flood or a heat wave provokes calls for a review of existing approaches and hence creates an opportunity to adopt a new approach.

- **Link sustainable water management to a higher profile issue** e.g. to climate change (e.g. London); waste minimisation and hence improving productivity (Envirowise); the transition to a green economy as a driver for economic growth (e.g. Philadelphia, Korea); or landscape preservation (Denmark, Germany).

- **Co-opt a marketing director from a large successful consumer company**. Marketing requires being good in practice at what economics aims to do in theory as the only way of inventing new products which will meet a user need.

Where to start

- **Some changes can be made very quickly:** significant reductions in demand have been achieved in very short periods of time (e.g. Barcelona, Toronto, Zaragoza) and reductions in surface water run-off have been achieve in relatively short periods of time (e.g. the Emscher region in Germany, Portland, Philadelphia, New York City, Toronto).

- **Squeeze out inefficiency**; the easiest place to start is to seek to squeeze out existing inefficiencies. The Envirowise programme shows that there are substantial gains to be made in this way.

- **Focus on the multi-site firms especially multi-nationals**; making sustainable use of resources does not increase market share but is important to avoiding reputational damage. Once the Board of a large company is convinced then they take the responsibility for ensuring the policy is put into practice. In turn, managers of individual branches of a multi-site firm may not be able to make changes except as part of company policy. Hassell (2008), in a local authority sponsored study to improve water efficiency in the retail and leisure sectors in Croydon, found that whilst individual branch managers could see the benefits of change, they could not make the changes. The benefit of targeting large multi-site firms is not limited to the changes in the actions of the firms themselves as large companies enforce good practice upon the firms making up their supply chain as well (e.g. the ‘Better Cotton Initiative’ of Business for Social Responsibility).

Strategic principles

- **Make municipalities responsible for ensuring the effective drainage of the land within their area**: since SuDS involves either use of land surfaces or roofs, the logic is to make the body responsible for land and the built form responsible for ensuring effective land drainage. Giving this responsibility to a separate wastewater organisation both implies that the solution lies in pipes and that surface water is waste water. Similarly, giving the responsibility to a water management organisation implies the answer lies in watercourses.

- **Bridging:** rules necessarily create boundaries to power and the boundaries to power rarely match the boundaries of the problem (Green 2010a). However, unless all problems had the same boundaries, they can never be a set of organisational boundaries which match all of the problems. Hence, the requirement is for a series of bridging mechanisms: to transfer information, knowledge and innovation across the boundaries and to enable cooperative action to take place.

- **Create a community as mechanism to the adoption of transcience;** one insightful definition of a community is “people in conversation”. Holding conferences of policy makers, do-ers, researchers and other stakeholders is.a bridging mechanism for knowledge and innovation. This is part of the strategy in Denmark and the annual Land Drainage conference established by the Ministry of Agriculture, Fisheries and Food may be argued to one of the reasons for the diffusion of innovation in flood risk management in the UK. The opportunities of existing communities such as ICLEI and Eurocities, the WEF, BSR, and WBCSD exist to be exploited.

- **Innovate and expect failures**; it is an inherent feature of innovation that some will fail. We need to make failure safe. This requires safe areas for innovation, areas where failure will not have widespread consequences. Secondly, the framework in which innovation takes place must ensure that failure does not result in an interruption of service. Thirdly, since public bodies are differentially judged on failure rather than success, they are biased towards conservative approaches. If we want them to innovate, the criterion of failure has to be whether or not they sought to innovate. In short, we need more successful failures; failures from which we learn how to be successful in the next trial. Conversely, if we do not learn from history, we risk repeating an innovation that has already been found to fail. An example of a case where failure has been recognised as a cost of progress is the BedZED housing scheme in London (BioRegional 2009). The initial use of a 'Living Machine', the use of a reed bed system, to treat wastewater was abandoned because the costs exceeded those of conventional sewerage treatment. The development was then used as test bed for the membrane technology for black water reuse which was implemented at the London Olympics Park (ODA 2012).

Figure 11. The Original Living Machine and its replacement - BedZed

- **Think about what can go wrong**: how it may fail, how you can then recover. For example, greywater reuse systems in countries such as Australia and Israel use different coloured pipes than those for potable water as well as incompatible couplings. An example of a failure to consider how a system may fail is the adoption of separate sewer systems. Three common problems here are misconnections, exfiltration and infiltration between sewers, and the use of drainage supposedly reserved for surface water to dispose of pollutants. Because these problems are diffuse, they are proving very difficult to resolve: an argument for the adoption of SuDS being that it will create separation between probably polluted surface water drainage and the water environment.

- **Have a coherent and consistent strategy**: don't rely upon a single tool, use a combination of mutually reinforcing strategies which do not work against each other. The German experience involved regulations, charges, subsidies, symbolic actions and publicity. Similar approaches are seen in Toronto and Philadelphia.

- **Don't underestimate the importance of symbols**: all actions, including the use of prices, have a symbolic meaning. For example, the same amount as a charge, a tax, a price and a bribe can have different symbolic meanings (Green 2003).

- **Social norms**: marketing research (Kotler et al., 1999) shows that social norms have an influence even upon mundane purchasing decisions, most obviously advertising commonly exploiting expectations as to what characterises a 'good' mother. Social norms have the advantage that they are enforced by the population as a whole. Hence a grand simplification is to say that the change to a green economy involves creating the appropriate social norm. Equally, that it involves using existing social norms. Public information programmes and education programmes in schools are then means to these ends.

- **Provide recognition**; for example, by setting up an award programme. Awards and prizes can work in three ways: by showing that the issue is important and demonstrating what is the social norm expectation; giving kudos to those who are identified as exemplars; and illustrating what can be done. The World Bank's New Initiatives in Pollution Regulation (Wheeler et al., 2000) showed that the converse approach of 'naming and shaming' is also useful. Simple signage can also be used, e.g. signs saying that garden irrigation is being provided by grey water reuse.

- **Identify the different market segments**. Different groups have different requirements and different barriers; incentives should be tailored accordingly.

- **Charges are generally important as a signal rather than as an incentive**: politically feasible prices are too low to provide an incentive; on their own, they are relatively ineffective in inducing a change in behaviour. But they provide a signal as to what is desired; examples here are the adoption of charges for impermeable areas in many cities in Germany.

- **Recycle revenues from charges**: use the revenue from charges for related purposes e.g. charge for surface water runoff and use the revenue to provide soft loans and grants to implement green infrastructure. This shows that charge is not a tax, a revenue raising measure, but part of the incentives to change. Secondly, the charge works twice both providing a penalty and reducing the cost of adopting the desired behaviour. In addition, given the change in behaviour is often dependent on capital investment, it makes access to capital easier.

- **Be realistic**: for example, building and development controls are part of the array of tools for implementing green infrastructure but if existing controls are widely ignored, adding new controls will not be an effective strategy.

- **In a modern market, codes and standards are required**. The caveat emptor principle disappeared in the nineteenth century; whilst early adopters will buy a product even when it is uncertain whether it will perform satisfactorily, widespread adoption requires confidence that the product works. Hence, for widespread adoption of rainwater harvesting, green roofs, greywater reuse, a national code or standard removes the risk to the purchaser that the product will fail.

- **Cut attention costs**: either of action or in total; this is one advantage of regulation; banning top-loading washing machines reduces the complexity of the purchasing decision for consumers.

- **Build in adaptive capacity**: don't think in terms of an end state, instead focus upon creating a capacity for learning.

REFERENCES

2030 Water Resources Group 2009 Charting Our Water Future, Davos: World Economic Froum

Agarwal A and Narain S (eds.) 1997 Dying Wisdom, New Delhi: Centre for Science and the Environment

Argyris C and Schon D A 1966 Organizational Learning II, Reading MA: Addison-Wesley

Arthur W B 2009 The Nature of Technology, London: Penguin

Asano T, Maeda M and Takaki M 1996 "Wastewater reclamation and reuse in Japan: Overview and implementation examples", Water, Science and Technology 34(11), 219-226

Australian Bureau of Statistics 2010 Environmental issues: water use and conservation, www.abs.gov.a u

Ball P 2000 H2O: A biography of water, London: Phoenix

Banting D, Doshi H, Li J, Missios P, Au A, Currier B A and Verrati M 2005 Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto, Toronto: Dept of Architectural Science, Ryerson University

BioRegional 2009 BedZED seven years on, Wallington: BioRegional Development Group

Bouguerra M L nd Water: symbolism and culture, Les Rapports de l'Institut Veolia Environnement, Paris: Institut Veolia Environnement

Brown R R and Clarke J M 2007, "Transition to water sensitive urban design: The story of Melbourne, Australia," Report No. 07/1, Facility for Advancing Water Biofiltration, Monash University,

Burnett J 1979 Plenty & Want: A social history of diet in England from 1815 to the present day, London: Scolar

CEC (Commission of the European Communities) 2009 GDP and beyond: Measuring progress in a changing world, COM(2009) 433 final, Brussels: Commission of the European Communities

Chapagain A K and Hoekstra A Y 2004 Water Footprints of Nations, Delft: UNESCO-IHE

City Clerk 2006 Options for Implementing a Mandatory Downspout Disconnection Program (City-wide), City of Toronto

City of Toronto 2009 Wet Weather Flow Master Plan: The Plan in Action, Toronto: City of Toronto

CIWEM nd “Rainwater harvesting” (http://www.ciwem.org/resources/water/rainwater/index.asp)

Clark G 2003 The Price History of English Agriculture, 1209-1914, University of California, Davis

COAG 1994 Water Resources Policy. Report of the Working Group on Water Resources Policy, Council of Australian Governments, Canberra, Australia (www.coag.gov.au)

Coase R H 1991 “The Institutional Structure of Production”, Nobel Prize Lecture, Stockholm (www.nobel.se/economics/laureates/)

Cordell D, Drangert J-O and White S 2009 “The story of phosphorus: Global food security and food for thought”, Global Environmental Change 19, 292-305

Cornish G, Bosworth B, Perry C and Burke J 2004 Water charging in irrigated agriculture: An analysis of international experience, Rome: FAO

Cornut P, Aubin D, van Criekingen M, Dubois O, Prevedelllo C, Dessouroux C and Decroly J-M 2004 “Private 'Club' and individual management of natural resources: the case of domestic rainwater tanks in Belgium”, paper given at the conference “Environmental Economic Geography: state of the art and prospects”, Köln, Germany, May 25th – 28th 2004

Craps, M., (ed.) 2003 Social Learning in River Basin Management, HarmoniCOP WP2 Reference Document (www.harmonicop.info)

CSIRO nd Drysdale – a world’s first, Clayton, South Victoria: CSIRO

Dalhuisen J M, Florax R J G M, de Groot H L F M and Nijkamp P 2001 Price and Income Elasticities of Residential Water Demand, TI 2001-057/3, Amsterdam: Tinbergen Institute

de Beer J 2000 Potential for Industrial Energy Efficiency Improvement in the Long Term, Berlin: Springer

de Graaf R, van der Brugge, van der Vliet W and Valkenburg L 2007 “Local water resources and urban renewal. A Rotterdam case study”, paper given at Novatech 2007, Lyon

Digman C 2012 An insight into the USA approach: Sustainable drainage systems in Portland and Seattle, MWH

Dti 2006 Water recycling and reuse in Singapore and Australia, London: Department of Trade and Industry

Environment Agency 2006 A strategy for restoring rivers in North London www.environment-agency.gov.uk

Envirowise 2005 Cost-effective water saving devices and practices – for commercial sites, Didcot: Envirowise

Eveleigh D J 2002 Bogs, Baths and Basins: the story of domestic sanitation, Stroud: Sutton

FAO 1995 Dimensions of Need: An Atlas of Food and Agriculture, Rome: FAO

Federal Statistical Office, 2010, https://www.destatis.de/DE/Publikationen/Thematisch/UmweltstatistischeErhebungen/Wasserwirtschaft/WasserOeffentlich2190211109004.pdf?__blob=publicationFile

Foster J, Lowe A and Winkelman S 2011 The value of green infrastructure for urban climate adaptation, Washington DC: The Center for Clean Air Policy, www.ccap.org.

Gaulke L S 2006 "On-site wastewater treatment and reuses in Japan", Proceedings of the Institution of Civil Engineers, Water Management 159, 103-109

Geertz C 1993 The Interpretations of Cultures, London: Fontana

General Manager, Toronto Water 2011 Water Efficiency Plan Update, report to the Budget Committee, City of Toronto

Gilbert S and Horner R 1984 The Thames Barrier, London: Thomas Telford

GLA (Greater London Authority) 2010 Mayor of London's Draft Climate Change Adaptation Strategy, London: GLA

Goldstein, H. (1981) Social Learning and Change, London: Tavistock

Green C and Anton B 2010 " Why is Germany 30 years ahead of England", International Journal of Water 6(3), 195-212

Green C H 2003 Handbook of Water Economics, Chichester: John Wiley

Green C H 2008 "The current crisis in water economics" in Strosser P, Le Roux J, Rouillard J and Badger R (eds.) Considering the role of costs and benefits in supporting regulatory actions, Edinburgh: Scottish Environment Protection Agency

Green C H 2010a "The practice of Power: Governance and Flood Risk Management" in Pender G, Thorne C, Cluckie I and Faulkner H (eds.) Flood Risk Science and Management, Oxford: Blackwell

Green C H 2010b The restoration of the river Cheonggyecheon, Seoul, SWITCH http://www.switchurbanwater.eu/

H M Treasury 1999 Access to financial services, Report of PAT 13, London: H M Treasury

Hansen H E (ed.) 1996 River Restoration – Danish experience and examples, Copenhagen, National Environmental Research Institute

Hassell C 2008 Saving Water in Crawley's Hospitality Sector, London: ech2o

Holling C S 1973 "Resilience and stability of ecological systems", Annual Review of Ecology and Systematics 4, 1-23

Holzmuller K 2009 "Climate protection, naturally – green roofs in Dusseldorf, financial support and quantitative analysis of aerial photographs" http://www.greenroofs.com/content/guest_features006.htm

Huitema D and Meijerink S 2010 "Realizing water transitions: the role of policy entrepreneurs in water policy change", Ecology and Society 15(2), http://www.ecologyandsociety.org/vol15/iss2/art26/

Hummel D and Lux A 2007 "Population decline and infrastructure: The case of the German water supply system", Vienna Yearbook of Population Research 2007, 167-191

ICLEI Oceania 2009 Water Campaign Actions Profile (www.iclei.org/oceania/water)

Ison, R. L., Steyaert, P., Roggero, P. P., Hubert, N., Jiggins, J. 2004 Social Learning for the Integrated Management and Sustainable Use of Water at Catchment Scale, SLIM Final Report, Milton Keynes: Open University

Jiang YL, Chen YS, Younos T, Huang HQ and He JP 2010 "Urban Water Resources Quota Management: The Core Strategy for Water Demand Management in China", Ambio 39, 467-475

Katzenbach J R and Smith D K 1994 The Wisdom of Teams, New York: HarperCollins

Keath N A and Brown R F 2008 "Are Extreme Events a Crisis or Catalyst for Sustainable Urban Water Management? The Case of two Australian Cities", paper given at the 11th International Conference on Urban Drainage, Edinburgh

Kim R, Mun J and Park J 2012 Water Resource Management: Low Carbon Green Growth Roadmap for Asia and the Pacific, Background Policy Paper, ESCAP

Kitzes J, Galli A, Rizk S, Reed A and Wackernagel M 2008 Guidebook to the National Footprint Accounts, Oakland CA: Global Footprint Network

Klein G, Krebs M, Hall V, O'Brien T and Blevins B B 2005 California's Water-Energy Relationship, CEC-700-2005-011-SF, Sacramento CA: California Energy Commission

Kotler P, Armstrong G, Saunders J and Wong V 1999 Principles of Marketing, London: Prentice-Hall

Land Use Consultants and Green Roof Consultancy 2010 A Green Infrastructure Audit of the Victoria Business Improvement District www.victoriabid.co.uk

Latini J, Mueller E, Lux M, Fitzgerald M P and Kreder K 2003 "Voiding frequency in American men: what is normal?", paper given at ICS 2003 (www.urotoday.com)

Lawlor G, Currie B A, Doshi H and Wieditz I 2006 Green Roofs: A Resource Manual for Municipal Policy Makers, Ottawa: Canada Mortgage and Housing Corporation

Lee P O 2005 "Water Management Issues in Singapore", paper presented at the Water in Mainland Southeast Asia, Siem Reap, Cambodia

Linham M M, Green C H and Nicholls R J 2010 Costs of adaptation to the effects of climate change in the world's large port cities, AVOID DECC: GAO215/GASRF 123 2009-2012, Southampton: University of Southampton/ Middlesex University

Lloyd D 1991 The Idea of Law, Harmondsworth: Penguin

Lustig M W and Koester J 1993 Intercultural Competence: Interpersonal Communication Across Cultures, New York: HarperCollins

Mayor of London 2007 Water matters: The Mayor's Draft Water Strategy, London: Greater London Authority

Mayor of London 2009 The Mayor's draft water strategy, London: Greater London Authority

Millar J 2012 Sustainable water resource development and desalination-integrated water management challenges in South Africa , unpublished MPhil, Kingston University

Mitsch W J and Gosselink J G 2000 Wetlands, Chichester: John Wiley

Molder D (ed) 2007 Water for food, Water for life, London: Earthscan

Molle F and Berkoff J (eds.) 2007 Irrigation Water Pricing: The Gap Between Theory and Practice, Wallingford: CAB

MTP (Market Transformation Programme) 2006 Product Overview: Water, Harwell: MTP (www.mtprog.com)

Mysiak J, Henrikson H J, Sulllivan C, Bromley J and Pahl-Wostl (eds.) 2010 The Adaptive Water Resource Management Handbook, London: Earthscan

Nakagawa N, Kawamura A and Amaguchi H 2010 "Analysis of Decreasing Tendency of Domestic Water Use per Capita in Tokyo", paper given at BALWOIS 2010, Ohid, Republic of Macedonia - 25-29 May 2010

New York City 2011 NYC Green Infrastructure Plan: 2011 Update, New York City

Ngan G 2004 Green roof policies: Tools for Encouraging Sustainable Design, Landscape Architecture Canada Fund (www.gnla.cn)

ODA (Olympic Delivery Authority) 2012 The Old Ford Water Recycling Plant and non-potable water distribution network, London: ODA

OECD (2009), Alternative ways of Providing Water. Emerging Options and their Policy Implications, OECD

OECD (forthcoming, 2013), Water and Climate Change Adaptation. Policies to Navigate Uncharted Waters, OECD Publishing, Paris.

Offer A 1989 The First World War: An Agrarian Interpretation, Oxford: Clarendon

Parolin P and Wittman F 2010 "Struggle in the flood: tree response to flooding stress in four tropical floodplain systems", AoB Plants.2010 plq003, http://aobplants.oxfordjournals.org/

Partzsch L and Ziegler R 2011 "Social entrepreneurs as change agents: a case study of power and authority in the water sector", International Environmental Agreements 11, 63-83

Pedersen M L and Friberg N nd "River Restoration in Denmark: 30 years of experience and what have we achieved?"

Penning-Rowsell E C, Johnson C, Tunstall S, Tapsell S, Morris J, Chatterton J, Green C, Wilson T, Koussela K and Fernandez-Bilbao A 2005 The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques, London: Middlesex University Press

Pettit P 1980 Judging Justice: An Introduction to Contemporary Political Philosophy, London: Routledge

Philadelphia Water Department 2011 Amended Green City Clean Waters, Philadelphia: Water Department

Ramsey F P 1927 "A Contribution to the Theory of Taxation", Economic Journal 37, 47-61

Rees J 1969 Industrial demand for water: a study of south-east England, London: Weidenfeld and Nicolson

Richards K, Gire J, Moss T, Muller E, Nilsson C, and Rood S.2003. The Flooded Forest: Guidance for Policy Makers and River Managers in Europe on the Restoration of Floodplain Forests. FLOBAR2.Cambridge: Department of Geography.

Rockstrom J, Gordon L, Folke C, Falkenmark M and Engwall M 1999 "Linkages Among Water Vapor Flows, Food Production, and Terrestrial Ecosystem", Conservation Ecology 2

Rogers E M 1962 Diffusion of Innovation, Glencoe: Free Press

Sabatier P A (ed.) 2007 Theories of the Policy Process, Boulder CO: Westview

Schleich J and Hillenbrand T 2007 Determinants of Residential Water Demand in Germany, Working Paper Sustainability and Innovation S3/2007, Karlsruhe: Fraunhofer Institute for Systems

Schiller G and Siedentop S 2006 “Preserving cost-efficient infrastructure supply in shrinking cities”, paper given at 2nd International Conference on Smart and Sustainable Built Environment, Shanghai

Seiker H, Bandermann S, Becker M and Raasch U 2006 „Urban Stormwater Management Demonstration Projects in the Emscher Region“, paper given at the First SWITCH Scientific Meeting, Birmingham http://www.switchurbanwater.eu/.

Sera T 2006 “Japan’s Policy Instruments on Urban Heat Island Measures by MLIT”, paper given at the International Workshop on Countermeasures to Urban Heat Islands, Tokyo

Stiglitz J E 2008 “Information”, The Concise Encyclopaedia of Economics (www.econlib.org)Lewis R D 2006 When Cultures Collide, Boston: Nicholas Brealey International

Stiglitz J E, Sen A and Fitoussi J-P 2009 Report by the Commission on the Measurement of Economic Performance and Social Progress, Paris: Commission on the Measurement of Economic Performance and Social Progress www.stiglitz-sen-fitoussi.fr

Tannen D 1991 You Just Don’t Understand: Women and Men in Conversation, London: Virago

Taylor M 2010 Financial capability and saving Evidence from the BHPS, CFEB Consumer Research Report CR02, London: Consumer Financial Education Body (CFEB), Occasional Paper Series 34, London : Financial Services Authority

Thiam A, Bravo-Ureta B E and Rivas T E 2001 “Technical efficiency in developing country agriculture: a meta-analysis”, Agricultural Economics 25, 235-243

Toronto Water 2007a Implementing a Mandatory Downspout Disconnection Program: report to the Public Works and Infrastructure Committee, City of Toronto

Toronto Water 2007b Wet Weather Flow Master Plan: Implementation Report 2006, City of Toronto

Treyer S., M. Colombier (forthcoming 2013), Global Irrigation Water Demand Projections to 2050. An Analysis of Convergences and Divergences, OECD Environment Working Paper

Turral H, Connell D and McKay J 2010 “Much Ado about the Murray: the Drama of Restraining Water Use” in Molle F and Wester (eds) River Basin Trajectories: Societies, Environments and Development Wallingford: CAB International

UNDP (United Nations Development Programme) 1997 Governance for sustainable human development, New York: UNDP

US Geological Survey 2012 Mineral Commodity Survey 2012, Washington DC: US Geological Survey

USACE (US Army Corps of Engineers) 1995 National Study of Water Management During Drought: The Report to the US Congress, IWR Report 94-NDS-12, Fort Belvoir VA: Institute for Water Resources

USEPA 2002 Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs, Washington DC: Office of Water, US Environment Protection Agency

van der Brugge R and de Graaf R nd "Transforming water infrastructure by linking water management and urban renewal in Rotterdam",

van der Heijden K 1996 Scenarios, Chichester: John Wiley

van der Merwe B 1999 "Reuse of water in Windhoek, Namibia", paper given at the 9th Stockholm Water Symposium, Stockholm

van Kauwenbergh S 2010 World Phosphate Rock Reserves and Resources, International Fertiliser Development Centre

Velaquez L S 2003 "Sky gardens" http://www.greenroofs.com/archives/sg_oct03.htm

Victoria Business Improvement District 2011 2010-11 Annual Report www.victoriabid.co.uk

Victoria Business Improvement District 2012 2011-12 Annual Report www.victoriabid.co.uk

Waylen C 2011 WATER: The 2009 progress report on reducing water usage on construction sites, Report 012, Strategic Forum for Construction www.strategicforum.org.uk

WBCSD (World Business Council for Sustainable Development) 2004 Case study Weyerhaeuser Pulp – It's part of our nature (http://www.wbcsd.org)

WBCSD (World Business Council for Sustainable Development) 2006 Case study Eskom: Reducing water consumption, (http://www.wbcsd.org)

Weiss G and Brombach H 2007 "Today's practice in stormwater management in Germany - Statistics", paper given at Novatech 2007, Lyons

Wheeler D et al 2000 Greening Industry: New Roles for Communities, Markets, and Governments, Oxford: Oxford University Press

Zhang Y, Xu P, Wang H, Feng C and Yang H 2010 "Application of Green Roof Techniques in Beijing, China", paper given at the IEEE Management and Service Science International Conference

Zuckerman L 1998 the Potato, London: Macmillan