Water and Climate Change Adaptation
© OECD 2013

Chapter 4

Improving flexibility: Adaptive governance, policy options and financing approaches

An uncertain future for freshwater, the potentially rapid pace of change and the existence of possible irreversible tipping points increases the value of flexibility and calls for a dynamic, future-oriented approach to water governance and policy. This chapter highlights how "adaptive" water governance is gaining attention as a means to increase flexibility and deal with uncertainty related to long-term trends. It highlights how well-designed economic instruments can improve the efficiency and timeliness of adaptation responses by reducing baseline stress on water resources and providing flexibility to deal with increased variability, risks, and uncertainty. Based on a number of case studies it draws out lessons for adaptation on the use of insurance schemes, water trading, water pricing, and ecosystem-based approaches. Finally, the chapter examines some of the potential pitfalls in financing adaptation for water and looks at how a real options approach can be used to value flexibility in long-term investments.

Key messages

- **Adaptive water governance** and **sound water policy** will go a long way to enhancing resilience to climate change. At the same time, some existing water policies may also need to be adjusted to deal with increasing risk and uncertainty. Regulatory, information-based and economic instruments all have a significant role to play.
- Well-designed **economic instruments** can improve the efficiency and timeliness of adaptation responses by reducing baseline stress on water resources and hence, vulnerability. They can also provide flexibility to deal with increased variability, risks, and uncertainty and lower the cost of adjusting to changing conditions.
- **Flood insurance schemes** can provide incentives to reduce exposure and vulnerability to floods, efficiently spread residual risk, and offset the economic impact of floods. Greater uncertainty about the likelihood and severity of floods makes appropriately pricing flood insurance increasingly difficult.
- **Water trading** can allow efficient reallocation of water resources in response to changing conditions, including increasing variability and more frequent episodes of shortage. While temporary transfers can be effective for managing drought-induced supply variability, they are insufficient on their own to adjust to long-term changes in total water availability.
- Climate change strengthens the economic case for **efficient water pricing** that can reduce inefficient water use, encourage the diversification of sources of supply and raise financing for potentially higher investment needs. Prices could also be used to signal scarcity and hence the optimal timing for expanding supply. However, in practice, water has long been inefficiently priced in most cases and scarcity pricing has met with resistance.
- Incentives for **ecosystem-based adaptation** and **green infrastructure** can provide a cost-effective means to address uncertainty by avoiding or delaying lock-in to capital-intensive infrastructure, hence providing an additional "option" value. Although these approaches are gaining attention, especially in urban settings, experience to date remains preliminary.
- Adapting to climate change will likely add to the already substantial **financing gap** for water systems in OECD countries. It also raises several specific challenges due to long time frames and pervasive uncertainty. Attribution can also be an issue in the case of dedicated adaptation funding mechanisms. Financing adaptation should build on sound approaches to financing water systems generally, and avoid skewing financing to "speciality" projects that might be easily labelled as adaptation, but do not necessarily maximise net benefits.

It is well recognised that sound water policy will go a long way to enhancing resilience to climate change. Failure to adequately consider the policy context can constrain or undermine specific adaptation programmes or projects for water systems or result in maladaptation. Regulatory, information-based and economic instruments all have a role to play in effective and timely climate change adaptation. These instruments can be used in combination to "know", "target" and "manage" water risks to achieve an acceptable level of risk in a way that maximises social welfare over the long term. At the same time, some existing water and water-related policy settings may undermine effective and efficient adaptation, by distorting market signals or providing perverse incentives (e.g. subsidising water supply to certain users, encouraging development in areas at high risk of flood). These policies should be reviewed and adjusted in light of climate change and its impact on water security.

An appropriate policy mix employing a combination of regulatory, economic and information-based instruments is required to adequately address water risks. Table 4.1 provides examples from this policy toolkit. This chapter takes a closer look at how several economic instruments can facilitate more efficient and timely adaptation for water systems and provides some illustrations from recent experience. The specific focus on economic instruments was selected because these instruments tend to be under represented in both water policy and climate change adaptation policy discussions. As a result, they are often poorly understood or poorly applied in practice. Some literature on climate change adaptation for water points to the potential for using economic instruments, but there remains a gap in terms of analysis and examples of how these instruments could be used to respond to specific adaptation challenges. This chapter aims to help fill that gap. It also highlights some of the financing issues confronting adaptation for water systems and discusses some emerging approaches to address them.

Table 4.1. **Examples of water policy instruments to address water risks**

	Regulatory	Economic	Information-based
Risk of **water shortage** (including drought)	• Restriction on water use (e.g. hosepipe ban). • Administrative allocation of water. • Abstraction limits.	• Water pricing. • Water trading (e.g. water markets, water banks, dry year options). • Payments for ecosystem services (PES). • Microfinance schemes (e.g. to invest in rainwater tanks).	• Information and awareness campaigns to promote water saving. • Drought warning and information.
Risk of **inadequate quality**	• Water quality standards. • Pollution discharge permits.	• Pollution taxes, charges. • Tradable pollution permits. • PES.	• Information and awareness campaigns. • Technical assistance for improved farming techniques (to minimise negative impacts on water).
Risk of **excess** (including flood)	• Land use planning, zoning restrictions. • Building codes, standards.	• Flood insurance. • Public private partnerships (e.g. for flood defence structures). • PES.	• Flood risk maps. • Early warning systems.
Risk to the resilience of **freshwater systems**	• Minimum environmental flows.	• "Buy backs" of water entitlements from the water to ensure adequate environmental flows.	• Promoting awareness of the value of freshwater ecosystem services.

Adaptive water governance

Institutional frameworks and governance arrangements have an important influence on which policy instruments are the most appropriate in a given context and how they work in practice. Institutional fragmentation and poorly managed multi-level governance present obstacles to improved water management, especially in a context where regional, basin, and local authorities are usually in charge of water resources management and service delivery (OECD, 2011a). Effective public governance is a prerequisite for the effective implementation of policy instruments (e.g. abstraction limits, water pricing, and trading). It is also crucial to ensure sustainable financing and provide incentives for the efficient use of funds (OECD, 2011a).

While efforts to address climate change adaptation could provide an opportunity to revisit, and perhaps improve, existing governance arrangements, they will also likely strain existing multi-level governance challenges, both horizontal (across policy domains) and vertical (across levels of government). For example, while nationally led mandates may provide a strategic framework for adaptation in many OECD countries, climate change impacts on freshwater will be felt locally. Implementation of many adaptation responses will inevitably be local in nature, albeit conditioned by policy and institutional settings at all levels of government (supra-national, national, regional and local). Local development pathways shape exposure and vulnerability to water risks (e.g. land use planning affects flood risk). The broader policy environment may constrain or enable the efficient management of water risks at local level (e.g. cost-sharing arrangements across levels of government to provision flood protection or water storage). The way in which existing institutional arrangements affect the distribution of the costs and benefits of adaptation across levels of government and between the public and private sector will have a significant influence on what kind of adaptation occurs, where and when.

Co-ordination between climate and water policy communities is also important for effective adaptation. Addressing water resources as a priority theme or sector in the development of national or sub-national adaptation strategies and plans requires input and expertise from the water policy community. At the same time, mainstreaming climate change adaptation into water strategies, plans and policies requires integrating expertise and knowledge from the climate science community and may also benefit from guidance or tools developed for climate change adaptation more generally.

In addition to multi-level governance issues, climate change poses additional challenges to existing water governance arrangements. A non-stationary climate, the potentially rapid pace of change and the existence of possible irreversible tipping points increases the value of flexibility and calls for a dynamic, future-oriented approach that explicitly deals with uncertainty. Making the best use of constantly evolving scientific evidence characterised by significant uncertainty is a particular issue. As discussed in Chapter 1, there are significant gaps in the existing evidence base that pose challenges for informing practical site-specific adaptation decisions for water and may require new approaches and practices (see examples in Chapter 2). The science-policy interface is particularly important and there remains significant scope for improving the relevance and ease of use of climate science for practical adaptation decision making for water systems.

The long time frames involved in adaptation planning, along with the fact that measures incur upfront costs and have deferred benefits (in terms of avoided climate impacts, often difficult to quantify), also pose challenges for institutions' typical planning and policy cycles. There is also significant learning potential related to climate change adaptation, as the scientific evidence base improves, new approaches to adaptation are developed and practical experience is gained. Adequate mechanisms are needed to transmit new knowledge and feedback from experimentation at the local level to inform national level policy development.

Box 4.1. **Adaptive delta management in the Netherlands**

In the Netherlands, future socio-economic developments and changes in sea level, soil subsidence, river discharges and precipitation patterns are very uncertain. In response, the Delta Programme is using "adaptive delta management" to actively look for flexible strategies and highlight the added value of that flexibility. Adaptive delta management is not about deferring decisions or measures because of uncertainty, but rather about taking the right steps at the right time. It encourages an integral approach to tasking and reduces the risk of over- or underinvestment in future flood risk management and freshwater supplies.

Thinking long-term does not mean setting down measures today for the next 50-100 years. Solutions should be allowed to develop along with new insights and circumstances. However, it is advisable to guarantee that the solutions can be implemented in a cost-effective way when they are needed, and in the short term, to take the first steps that are worthwhile in every scenario, "no regret" measures.

Key points of adaptive delta management:

- Linking short-term decisions with long-term tasking.
- Incorporating flexibility in possible solution strategies (where effective).
- Working with multiple strategies that can be alternated between (e.g. adaptation pathways).
- Linking different investment agendas.

There are three key steps to implement this approach. First, it is important to clarify which short-term developments influence long-term tasking related to flood risk management and freshwater supply. Second, insight must be gained into the flexibility of the potential solutions for the tasking – e.g. is it easy to carry them out step by step and adjust them to accommodate actual developments? Finally, it is important to identify the decisions that are necessary in the short-term to enable the adaptive approach.

In developing the various "adaptation pathways", the circumstances under which it would be logical to move from one approach to another are studied along with how options can be kept open to actually enable that transition. The examination of adaptation pathways identifies both "no-regret" and "avoid-regret" (a measure has to be implemented in order to avoid a situation in which shifting to a different measure will no longer be possible or only at exorbitant cost) decisions for the short-term. Development paths are a powerful way to gain insight into which measure need to be taken when and how long-term tasking impacts short-term decisions.

The approach has already been applied in several of Delta sub-programmes. For example, the Rhine Estuary-Drechtsteden sub-programme developed adaptation pathways and explicitly identified when interventions would be required ("tipping points"), in the light of both flood risk management (e.g. dykes that no longer meet the standard) and freshwater supply (e.g. salinisation of intake points).

In order to take into account the added value of flexibility in the evaluation of Delta strategies in a systematic manner, the Netherlands Bureau for Economic and Policy Analysis is exploring options for a simple and broadly applicable method to structurally embed the added value of flexibility in economic analysis.

Source: Delta Programme, (2012), "Delta Programme 2013: Working on the Delta – the Road Towards the Delta Decisions", The Netherlands Ministry of Infrastructure and the Environment and Ministry of Economic Affairs, Agriculture and Innovation, *www.deltacommissaris.nl/english/Images/Delta_Programme_2013_ENG_tcm310-334162.pdf* (accessed 22 March 2013).

In response to the challenges posed by climate change and other drivers of water risk, "adaptive" water governance is gaining attention as a means to increase flexibility and deal with uncertainty related to long-term trends. The Delta Programme in the Netherlands has adopted an approach called "adaptive delta management" that consists of "phased decision-making that explicitly takes uncertain long-term developments into account in a transparent manner" (The Delta Programme, 2012) (Box 4.1). Experience with "adaptive" water governance is still preliminary, but is an important area that would be valuable to explore in greater depth in the future.

Existing political economy challenges to reforming water policies should not be underestimated as potential barriers to effective adaptation. Manifestations of past policies present significant obstacles to reform (e.g. historical land and water entitlements, existing infrastructures, stakeholder expectations). Crises may create political capital or windows of opportunity that can be used to enact water reforms, but they are not necessarily a precondition of reform (Winpenny, 2011). Aside from water crises, *per se*, water reformers can also take advantage of other types of crises (e.g. economic) and radical reforms (e.g. political transitions) to improve water policies. In the case of climate change adaptation for water, exceptional weather events that impose substantial costs on human lives and property may prove to be more catalytic than mounting scientific and economic evidence in terms of spurring action.

Improving incentives to manage risk and increasing flexibility in water policy

There are two key principles underlying the economic management of water – efficiency and equity (Grafton, forthcoming). Efficiency aims to maximise the welfare that is obtained from a resource by allocating it to its most valuable economic use. Equity concerns the distribution of resources across a given population. In the context of risk and uncertainty, adaptive efficiency is also important. Adaptive efficiency addresses the least cost path to maximise social welfare over the long term in the context of complex resources, unpredictability, feedback effects and path dependencies (Marshall, 2005).

Economic instruments can contribute to achieving the dual objectives of efficiency and equity. These are policy tools that influence behaviour through their impact on market signals rather than explicit regulation (Grafton, forthcoming). For example, water charges, pricing and trading can reduce baseline stress on water systems, building resilience to future climate change impacts by promoting efficiency in water use, allocating water to where it creates the most value and identifying low-cost options.

Economic instruments can also be used to achieve adaptive efficiency required for dynamic, decentralised and flexible responses to changing circumstances and deal with increased variability, risk and uncertainty. Water pricing and trading provide flexibility and help to minimise timing errors of adaptation actions by signalling scarcity and hence, the optimal timing for investments in supply augmentation. Adequate water pricing can encourage the development of alternative water supplies, providing supply diversification, thus improving reliability. Flood insurance schemes, properly designed, can provide incentives to reduce exposure and vulnerability to flood risks, spread residual risk and offset the economic impact of disasters. Incentives for ecosystem-based approaches and green infrastructures can provide cost-effective adaptation and provide flexibility in dealing with uncertainty by avoiding or delaying lock-in to more capital-intensive built infrastructures or costly retrofitting of existing infrastructures.

Many of these economic instruments are commonly used in water policy and are not specifically designed for adaptation. Previous work at the OECD and elsewhere has looked at the role these instruments play in promoting good water resources management, generally. This section examines how these instruments could be more systematically applied to facilitate climate change adaptation by not only reducing baseline stress on water systems, but also providing a flexible and cost-effective means to deal with increased variability, risk and uncertainty.

Flood insurance schemes

Insurance has long been used to deal with climate variability and weather risks. Population growth, the concentration of assets in exposed areas and climate change all contribute to the increasing costs of flood damage and create challenges for insurability (Swiss Re, 2012). Well-designed flood insurance schemes can provide incentives (through a price signal) to reduce exposure and vulnerability to risk, especially if premium discounts are awarded for risk reduction. Compensation in the event of a flood can offset the economic impact of the disaster and provide finance to restore damaged capital and speed up recovery. At the same time, flood insurance schemes need to avoid inadvertently promoting mal-adaptation, for example, by encourage development in high-risk areas and undermining incentives to adapt to long-term climate change. Designing insurance schemes that are priced to reflect actual risk while remaining affordable and offering comprehensive coverage will be increasingly challenging, and in some cases unviable, under climate change. Uncertainty about future flood risk will make efficiently pricing insurance increasingly difficult. A non-stationary future means that historical references will be an increasingly unreliable basis for the design of flood insurance.

Flood insurance schemes exist in various forms, including traditional indemnity-based insurance and index-based insurance. The type of insurance scheme and its design determines whether and to what extent it provides incentives for risk reduction and addresses problems such as moral hazard, asymmetric information, and adverse selection.[1] Traditional indemnity-based insurance covers the policyholder against the loss of an asset (a home or business). Although the design results in the payout being close to the actual loss incurred, there is a perverse incentive for the insured party not to undertake risk reduction if they know that the damage will be covered, hence creating moral hazard. Indemnity-based insurance also involves asymmetric information and may be prone to adverse selection. In addition, the process of settling claims can be time consuming and costly, thus entailing significant transaction costs (Agrawala and Fankhauser, 2008).

Index-based, or "parametric", insurance can address some of the problems related to indemnity-based insurance. This type of insurance makes a payment when a specific trigger event occurs, as opposed to indemnifying a specific loss. These insurance schemes may be more suitable for dealing with water risks related to climate change, as a number of weather conditions can be quantified and specified as a trigger event ahead of time. Parametric insurance can reduce moral hazard by decoupling the actual payout from the actual loss incurred, thus, preserving the incentive to reduce risk. However, this feature may also be a disadvantage, as actual payouts may not sufficiently compensate for losses. As there is no need for an assessment or verification of actual damage, the transaction costs are lowered and the speed of payout is improved. These features are particularly advantageous for dealing with catastrophic events (Agrawala and Fankhauser, 2008).

Flood insurance schemes can promote risk reduction in various ways. Insurers have effectively used differential premium pricing to discourage construction in high-risk areas (IPCC, 2012). Besides providing incentives for risk reduction via premiums, specific risk reduction measures can be required by insurance contracts. Insurance schemes also require a detailed analysis of risk, thus they can both raise awareness and provide valuable information (e.g. flood risk maps) to inform responses (ClimateWise, 2010). Insurers also typically monitor policyholders to ensure that loss-reducing measures required by contracts are actually implemented and adhered to (Botzen and van den Bergh, 2008). Insurers can also partner with governments and communities to establish appropriate regulatory frameworks and promote land use planning, building codes, emergency response and other policy responses to reduce flood risk (Botzen and van den Bergh, 2008; ClimateWise, 2010).

While well-designed flood insurance may facilitate adaptation, increasing flood risks due to climate change and other drivers present important challenges for flood insurance schemes. First, major weather events are occurring more frequently than in the past, which will mean higher expected losses and higher payouts, resulting in reduced time for insurers to recoup costs (Agrawala and Fankhauser, 2008; Thomas and Leichenko, 2011; IPCC, 2012). This trend makes it increasingly difficult to maintain affordability while pricing insurance efficiently (to reflect actual risk). This will limit the penetration of insurance coverage in cases where it is not compulsory. Subsidised premiums may increase the low uptake of insurance in certain areas, but also causes a shortfall between premium revenue and the payout of claims (Botzen and van den Bergh, 2008).

Uncertainty about future conditions also poses major obstacles for flood insurance schemes. It is becoming increasing difficult to price future flood risks, as historical references are a less reliable indicator of future trends. Despite some improvements in forecasting, a major challenge for the insurance sector is to improve the accuracy and resolution of hazard data and the likely impacts of climate change. As long as climate impacts are uncertain, insurance companies, which are risk-adverse themselves, will overcharge for climate risk and may refuse coverage of risks that might otherwise be insurable (Agrawala and Fankhauser, 2008). In addition, in most countries, the insurance industry is highly regulated, especially with regard to pricing of premiums, which limits the ability of insurers to adjust premium prices based on new evidence of climate change risks (Thomas and Leichenko, 2011). Overall, these challenges may restrict the availability of insurance and constrain its use as an instrument to facilitate adaptation.

Public policy measures may be needed to overcome some of these issues and facilitate sharing of flood risks between insurers and governments. For example, policy responses may take the form of publicly funded measures to bring risks (and hence premiums) down to an acceptable (and hence insurable) level (Agrawala and Fankhauser, 2008). This approach is reflected in the agreement by the UK Government and the insurance industry, called the "Statement of Principles", whereby insurers commit to continue to offer flood insurance to existing customers where they are at significant risk and the UK Environment Agency announced plans to reduce that risk within five years. A layered public-private system, where private insurers provide coverage up to a certain limit of damages followed by government provided insurance, has been proposed as an option for insuring against increased risks (Kunreuther, 2006; Litan, 2006; Botzen et al., 2009, *in* Thomas and Leinchenko, 2011). Broader use of premium subsidies, however, may reduce incentives to move away from activities that become progressively less viable under the changing climate (Skees et al., 2008, *in* Agrawala and Fankhauser, 2008).

Across the OECD, several different approaches to address flood damage exist, reflecting different risk sharing arrangements between the public and private sectors. Table 4.2 illustrates characteristics of these arrangements in the Netherlands, the United Kingdom, France and Germany. This section provides several examples of arrangements to address flood risk in the UK, the US, France and the Caribbean states and how they are being reviewed or reformed to address increasing risks from climate change and socio-economic drivers.

Table 4.2. **Arrangements against flood damage in the Netherlands, the UK, France and Germany**

Kind of arrangement	The Netherlands	The United Kingdom	France	Germany
Private coverage available	No	Yes	Yes	Yes
Premium differentiation	n.a.[1]	Yes	No	Yes
Public reinsurance	n.a.[1]	No	Yes	No
Public compensation scheme[2]	Yes	No	No[3]	Yes

1. Not applicable because private coverage is not generally available.
2. Does not involve a right to compensation.
3. Evidently, the public reinsurance scheme is (partly) financed through taxes.

Source: W.J.W. Botzen and J.C.J.M. van den Bergh (2008), "Insurance Against Climate Change and Flooding in the Netherlands: Present, Future, and Comparison with Other Countries", *Risk Analysis*, Vol. 28/2, Wiley-Blackwell, *http://dx.doi.org/10.1111/j.1539-6924.2008.01035.x.*

Case Study: Co-operation between public and private sectors to manage flood risk in the UK

The UK is one of very few countries that have a private market for flood risk insurance. Unlike many other countries, the UK government does not provide compensation in case of flood damage (Botzen and van den Bergh, 2008; ClimateWise, 2010). Over 5 million people in England and Wales live or work in properties that are at risk of flooding. In response to concerns about rising flood damages, the Association of British Insurers (ABI) and the UK government signed a voluntary agreement, called the "Statement of Principles" (SoP) in 2002, to ensure that flood risk is managed effectively and that competitively priced flood insurance remains widely available for households and small businesses. The agreement was most recently revised in 2008. Under the agreement, ABI members agreed to continue to make flood insurance available for households and small businesses as a feature of standard policies if the flood risk is not significant (e.g. no greater than 1 in 75 annual probability of flooding). Insurers also committed to continue to offer flood cover to existing customers at significant flood risk, provided that the Environment Agency announced plans to reduce the risk for those customers below significant levels within five years (HM Government, 2008).

Analysis by ClimateWise (2010) has identified several lessons from the UK experience. One of the key successes of the SoP has been in promoting a long-term strategy for flood risk management, taking into account the impact of climate change. It was also seen as a useful driver for an improved legislative framework for flood risk management in England and Wales, via the enactment of the Floods and Water Management Bill. The co-operation between insurers and the government has also shown to be effective in triggering collaboration at various levels. The various work-streams attached to the SoP on flood risk mapping, planning policy, investment strategy, property level resilience and access to insurance have led to collaboration among industry practitioners, civil servants and experts to improve flood risk management.

However, collaboration between the industry and government can lead to market distortions, which can have a negative effect on flood risk reduction efforts. For example, maintaining insurability despite significant risk exposure can undermine incentives for property owners to improve flood resistance of their properties. Also, the agreement that maintains current arrangements for properties at significant risk could hold back the development of specialist flood insurance more suitable for these properties. Finally, while risk-based pricing has been encouraged by both parties, its application in practice has proved difficult (ClimateWise, 2010). The SoP will come to an end on 30 June 2013 and the government and the ABI are continuing negotiations about risk sharing arrangements going forward. Clearly, a number of difficult issues will need to be addressed in terms of the balance between government's role in reducing flood risk and the role of insurance in transferring residual risk.

Case Study: Reforming the National Flood Insurance Programme in the US

The National Flood Insurance Program (NFIP) in the United States was created in 1968 to offer federally subsidised flood insurance for property owners and to promote land-use controls in floodplains (US Federal Emergency Management Agency, 2012). Participation in the programme is compulsory for properties with a federally-backed mortgage that are located in areas at risk of flooding at least once every 100 years. The programme's significant financial and operation challenges have been recognised for many years. Increasing risks due to climate change exacerbates these challenges. Concerns regarding the program's long-term financial solvency were heightened after unprecedented losses due to Hurricane Katrina in 2005.[2]

While the NFIP is intended to be fully-funded by premiums from policyholders, its design is not actuarially sound (US Government Accountability Office, 2010). A report from the Government Accountability Office (GAO) of the US Government (2010) pinpointed several design features that impeded the programme from more efficiently managing risk and constrained its ability to remain fiscally-sound, some of which were addressed in recent reforms. These features included statutory limits on rate increases and the inability to reject high-risk applicants. In addition, NFIP premiums did not reflect actual flood risk (nearly one in four property owners were paying subsidised rates) and the NFIP allowed "grandfathered" rates that permitted some property owners to continue paying rates that did not reflect reassessments of their property's flood risk. Further, the programme could not deny insurance on the basis of frequent losses, even though repetitive loss properties accounted for 25 to 30 per cent of claims, but only 1 per cent of policies (US GAO, 2010).

To address some of these challenges, the US Congress passed the Biggert-Waters Flood Insurance Reform Act in July 2012. The Act includes several reforms that could facilitate adaptation to flood impacts related to climate change. Key provisions of the recent reforms address the fiscal soundness of the programme, promote more efficient risk management and explicitly account for future changes to flood risk based on the best available scientific evidence. Analysis by Grannis (2012) highlights the Act's key provisions. These include the increase in premium rates of 20% annually (twice the previous limit) and the requirement that premiums be calculated based on "average historical loss year", including catastrophic loss years. Subsidies are phased out for a number of properties, in particular severe repetitive loss properties. To promote fiscal soundness, a Reserve Fund was created. The reforms also allow the Federal Emergency Management Agency (FEMA) to update flood insurance rate maps to include "future changes in sea levels, precipitation, and intensity of hurricanes", among other relevant information and data. The reform also extends flood insurance coverage at lower rates to communities that "have made adequate progress" in constructing or building flood control structures that protect from a 100-year flood (Grannis, 2012).

While these reforms are an important step forward in improving the efficiency and fiscal soundness of the programme, they are already being tested. The New York Times recently reported that early estimates suggest that Hurricane Sandy will rank as the nation's second-worst storm for claims paid out by the programme (Lipton et al., 2012). It is estimated that costs could reach USD 7 billion at a time when the programme is only allowed by law to add an additional USD 3 billion to its existing debt (Lipton et al., 2012).

Case Study: Assessing options to reform the "CatNat" scheme in France

In France, flood risk is addressed via a public-private partnership. Property insurance is not obligatory in France, although there is near universal coverage, with 99% of housing insured. Insurance for vehicles is obligatory. Under the "CatNat" scheme, coverage against flood risk and other natural hazards[3] is compulsory when the property is insured and included via a surcharge on property insurance provided by private insurers. The government sets a uniform rate for CatNat coverage (12% for a package policy for dwellings, 6% for an insurance contract for vehicles). This represents about EUR 1.3 billion per annum (Bommelaer et al., 2011). A portion of CatNat premiums is channelled into a state-managed fund for natural risk prevention, known as the Barnier Fund. Created in 1995, this fund was considerably reinforced recently, its resources growing from 2% to 12% of the CatNat premiums between 2007 and 2009. The estimated income of this fund in 2010 was EUR 154 million, of which more than EUR 140 million was allocated to flood prevention. Over the 1982-2006 period, 60% of the compensation paid for natural disasters (EUR 7.3 billion) concerned damage from floods (Bommelaer et al., 2011). The State also provides low-priced reinsurance with unlimited coverage via the Central Reinsurance Fund, guaranteed by State (Botzen and van den Bergh, 2008).

The CatNat scheme is based on the principle of solidarity in three main ways: *i)* the legal obligation for property insurance to provide cover for natural disasters; *ii)* all policy holders pay a uniform rate for the CatNat premium; and *iii)* the State guarantee to the Central Reinsurance Fund (Grislain-Letrémy and Peinturier, 2010; Bommelaer et al., 2011). Because coverage is mandatory, problems with adverse selection are reduced and nearly universal coverage is ensured. While insurance arrangements include deductibles to stimulate loss-reducing measures, the absence of differentiated premiums means that incentives to reduce risk are less than optimal (Botzen and van den Bergh, 2008).

Climate change is adding to the questions regarding the sustainability of the CatNat system and the effectiveness of measures to encourage risk reduction (Letremy and Grislain, 2009). Reforms of the CatNat scheme are currently undergoing study regarding the possible adjustment of insurance rates to support increased responsibility of individuals and businesses regarding their actual risk exposure. A law proposal to enable the adjustment of rates is currently under review in the Senate.

Case Study: Pooling catastrophe risk of excessive rainfall events in the Caribbean

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is the first and only multi-country parametric risk pool in the world. It is a regional catastrophe fund that provides coverage to Caribbean governments designed to limit the financial impact of disasters by quickly providing financial liquidity when a policy is triggered. It operates as a public-private partnership. The CCRIF was conceived in response to the severe damage caused by

Hurricane Ivan in 2004. This disaster caused billions of dollars of losses across the Caribbean, with losses close to 200% of GDP in both Grenada and the Cayman Islands. At the request of the Head of Governments of the Caribbean Community and with the assistance of the World Bank, the CCRIF was established to implement a cost-effective risk transfer programme for member governments (CCRIF, 2012a).

The CCRIF offers parametric insurance, which disburses funds based on the occurrence of a pre-defined level of hazard and impact, minimising delay and transaction costs imposed by an on-site assessment of losses. In May 2012, the CCRIF introduced a product for excessive rainfall. It is currently working with Swiss Re to generate a rainfall index, in order to inform the design of the policy. Data on exposure and vulnerability to excessive rainfall events generated by Swiss Re are used to produce rainfall risk profiles by the CCRIF. Premiums will be risk-based, so they will be determined as a function of the rainfall risk profile of each particular country and the coverage characteristics selected. Once rainfall risk profiles have been developed, the CCRIF will discuss coverage options with each country individually and policies can be issued once coverage levels have been agreed (CCRIF, 2012b).

Several features of the CCRIF products contribute to maintaining governments' incentives to invest in risk reduction. Premiums are based on estimates of countries' risk profiles, reflecting an analysis of actual risk. As a parametric scheme, potential compensation does not cover all potential damages, thus retaining incentives to undertake loss-reducing measures. Risk pooling offers the advantage of diversifying risk, hence greatly reducing the cost of reinsurance compared to the price each government would have paid individually (IPCC, 2012). By providing compensation quickly in response to a disaster, the human and economic costs of such disasters are reduced. This innovative approach to pooling catastrophe risk related to excessive rainfall events is promising and lessons from early experience should be useful to inform future adaptation decisions.

Water trading

Water trading is only one approach to allocating water resources and managing risk of scarcity (see Box 4.2 for an example of using operational guidelines to mitigate the consequences of extreme drought and address water availability in the Colorado Basin, US). However, water trading can promote efficiency in allocation and a flexible approach to

Box 4.2. **A co-ordinated approach to preserve flexibility to deal with water scarcity in the Colorado Basin, US**

Nearly 40 million people in the United States rely on the Colorado River for drinking water and populations that depend on the River are projected to increase to between 49 and 77 million by 2060 (USBOR, 2012). About 5.5 million acres of farmland are in production in the Basin. Climate models project that within this century, runoff in the Basin may be reduced by up to 20 per cent, due to reduced precipitation and temperature rise. By 2060, it is expected that commitments governing the allocation of Colorado River water (including the Colorado River Compact and the US Treaty with Mexico) will be met no more than 60 per cent of the time (USBOR, 2012). Water quality in the Colorado River may be affected by low soil-moisture conditions, predicted to be lower in the Southwest by 2050 than conditions experienced during any of the most severe droughts of the 21st century, including the 1930s Dust Bowl (Belnap and Campbell, 2011).

Box 4.2. **A co-ordinated approach to preserve flexibility to deal with water scarcity in the Colorado Basin, US** *(cont.)*

In 2007, the Colorado River Basin entered its eighth year of drought and the worst eight-year period in over 100 years of continuous recordkeeping. Storage in Colorado River reservoirs fell from approximately 94% of capacity in 1999 to a low of 52% capacity in 2004. A drought of this magnitude was the first of its kind in modern history for the Colorado River Basin and climate scientists suggest that droughts of this severity are likely to occur in the future. In May of 2005, the Department of the Interior began a public process to develop operational guidelines to mitigate consequences of extreme drought and address water availability in the lower basin during low-reservoir conditions.

After a two and a half year process of facilitating, analysing, and considering input from stakeholders including Governors' representatives of the seven Colorado River Basin States, a Record of Decision (ROD) was signed by the Secretary of the Interior in December 2007 to balance water supply, environmental protection, hydropower production, and recreation on the River. This ROD specifies interim guidelines that remain in effect through 2025. The guidelines are intended to provide contract users of Colorado River water certainty on the availability of water supplies during drought conditions. They include:

- Codification of Lead Mead elevations that define "normal", "surplus", and "shortage" conditions for deliveries to the Lower Basin States. The ROD defines how extra water during surplus conditions will be shared as well as how reduced deliveries during shortage conditions will be shared. These definitions are intended to "provide water users and managers in the Lower Basin with greater certainty to know when, and by how much, water deliveries will be reduced in drought and other low reservoir conditions".
- Establishment of four operational tiers based on water elevation in Lake Powell that trigger release amounts in the operational tiers from Lake Powell to Lake Mead in order to minimise shortages in the Lower Basin States and protect key reservoir elevations in Lake Powell. This addresses potential risk-risk tradeoffs with a "co-ordinated operation that would minimise shortages in the Lower Basin and avoid the risk of curtailments in the Upper Basin".
- Codification of rules for the creation, accounting, and delivery of Intentionally Created Surplus (ICS) to provide a "mechanism to encourage and account for augmentation and conservation of water supplies, referred to as ICS, that would minimise the likelihood and severity of potential future shortages".

This agreement represents an important evolution in the governance of the Colorado River, suggesting that the many interests in the basin can work together to address shared risks, concerns, and needs. The public process to develop ideas to address drought conditions in the Basin resulted in consensus among stakeholders to "encourage conservation, plan for shortages, implement closer co-ordination of operations of Lake Powell and Lake Mead, preserve flexibility to deal with further challenges such as climate change and deepening drought, implement operational rules for a long – *but not permanent* – period in order to gain valuable operating experience, and continue to have the federal government facilitate – *but not dictate* – informed decision-making in the Basin" (USBOR, 2007).

Source: Case study provided by the Arizona Water Science Centre, US, based on J. Belnap and D.H. Campbell (2011), "Effects of Climate Change and Land-use on Water Resources in the Upper Colorado River Basin: U.S. Geological Survey Fact Sheet 2010-3123", *http://pubs.usgs.gov/fs/2010/3123* (accessed 2 October 2012); United States Bureau of Reclamation (USBOR) (2012), "The Colorado River Basin Water Supply and Demand Study", *www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html* (accessed 14 March 2013); United States Bureau of Reclamation (USBOR) (2011), "Lake Powell Operations, Equalization and the Interim Guidelines", *www.usbr.gov/uc/rm/crsp/gc/Eq-IntGuide/Eq-IntGuidelines-Fact.pdf* (accessed 2 October 2012); United States Bureau of Reclamation (USBOR) (2007), "Record of Decision, Colorado River Interim Guidelines for Lower Basin Shortages and the Co-ordinated Operations for Lake Powell and Lake Mead: Final Environmental Impact Statement", *www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf* (accessed 2 October 2012).

meeting future demand and dealing with uncertainty in the context of climate change. Variations of water trading arrangements include surface water markets, groundwater markets, water auctions, and water banks (Dinar et al., 1997). Water trading also allows access to water resources to be reallocated over time in response to changing conditions, including fluctuating commodity prices, changing environmental conditions, shifting demand for and availability of water. It promotes efficiency in allocation by allowing water transfers from areas of surplus to areas of scarcity and from low to higher value uses as well as creates incentives to use water efficiently.

The system of water rights which underlie water trading arrangements can also be used to more equitably share risks (Box 4.3). For example, this can be achieved by establishing rights in terms of proportional shares of an overall allocation as opposed to rights defined by a system of prior appropriation (e.g. first in time, first in line), which place

Box 4.3. **Water rights and risk sharing: Proportional rights vs. prior appropriation**

In the Murray-Darling Basin, Australia, risk of shortage is shared proportionally among water users. Australia's National Water Initiative set out two major principles regarding the sharing of risk arising from changes in the availability of water (Quiggin, 2011). The first principle established water allocations based on a share of available water, rather than a specific volume. Thus, in times of shortage, all users typically receive some water, but less than their full amount. However, during times of extreme shortage, there are circumstances where some entitlement holders might not receive any water. The second principle assigns risk arising from reductions in the overall availability of water for consumption depending on the reason for the change. Changes in water availability due to new knowledge about the hydrological capacity of the system will be borne by users. Reduction in water availability arising from changes in public policy, such as changes in environmental policy, will be borne by the public, which may imply compensation to users (Quiggin, 2011).

The system of water rights in many states in the Western US is based on prior appropriation that results in a continuum of senior right holders to junior rights holders. Appropriative rights are assigned in order of application of a quantity of water for a beneficial use. Those applications submitted earlier will be more senior to those submitted later ("first in time, first in line"). Water is then allocated according to seniority. In an extreme drought, even "senior" rights holders may not receive their allocation. In a mild drought, all but the most junior rights holders may receive full allocations. This system means that more junior users bear a greater risk of water shortage, while more senior users are relatively more insulated from risk. Compared to the system of prior appropriation, a system of water rights based on proportional shares, such as Australia's, allows for more flexibility in water use, provides incentives for all water users to take steps to conserve water and more equitable risk sharing.

Analysis of water resources in California under climate change by Hanemann et al. (2012) indicates that if the projections for sharp reductions in stream flows, increases in variability, and increased demand materialise, the current system of prior appropriation with seniority based on a historical hydrology may face growing political opposition. This may provide an opportunity to move to a new framework for water rights (with a grace period and perhaps some compensation), although any such changes in California would require extensive consideration and investigation. In the meantime, shoring up California's existing water rights systems will put California in a better position to adapt to

Box 4.3. **Water rights and risk sharing: Proportional rights vs. prior appropriation** *(cont.)*

climate change, by at least creating a baseline of use and supply, and by providing information about the pace of change in the water sector (Hanemann et al., 2012).

Source: Hanemann, M., D. Lambe and D. Farber (2012), "Climate Vulnerability and Adaptation Study for California: Legal Analysis of Barriers to Adaptation for California's Water Sector", *Public Interest Energy Research (PIER) Program White Paper*; Quiggin, J. (2011), "Managing Risk in the Murray-Darling Basin", *in* D. Connell and Q. Grafton (eds.), *Basin Futures: Water Reform in the Murray-Darling Basin*, Australia National University E-Press, pp. 313-326.

disproportionate risk of shortage on more junior rights holders. Markets for emerging derivative products for water, such as leases and forward contracts, may also provide more flexible arrangements to hedge risk, but experience to date is limited.

There are numerous requisites for the effective and efficient operation of water trading arrangements. Markets for water entitlements cannot alone resolve environmental, economic and social issues involved in the allocation of water across different uses (OECD, 2009). Well-defined and transferable property rights must exist, usually requiring the unbundling of land and water rights. The total number of rights must not be over allocated, taking into account environmental needs. The establishment and oversight of a properly functioning market requires an important role for governments to establish and adjudicate water rights, quantify, monitor and regulate harmful "third party effects", and provide the appropriate legal and institutional support (Dinar et al., 1997). Depending on the specific hydrological context, the relatively high cost of executing water transfers and lack of transport infrastructure may limit the scope for trade.

Case Study: Water markets in the Murray-Darling Basin, Australia

Australia's Murray-Darling Basin (MDB) is a well-known example of a comprehensive water market that has generated significant economic gains. The large majority of trading has occurred between irrigators – from low-value uses to higher-value uses. Despite severe reductions in water availability during the recent drought, it has been estimated that between 2006 and 2010 intra-regional trade and increased on-farm flexibility from water trading have provided benefits to irrigators of AUD 3.4 billion, as compared to scenarios without trade. Inter-regional trade over the same period contributed to an additional AUD 845 million in agricultural productivity (NWC, 2012).

Under the National Water Initiative (NWI), water trade allows the transfer of water access entitlements (permanent) and seasonal water allocations (temporary) between different entities. Water trading allows scarce water resources to be transferred to their most productive uses and allows access to water resources to be reallocated over time in response to changing conditions. The NWI also established means to equitably share risk of shortage among water users by establishing water allocations based on proportional shares of available water.[4] The Australian Government has introduced water market and charge rules and will introduce the trading rules in 2014 under the Water Act 2007 that will improve the water market by freeing up and setting rules for trade, and by ensuring appropriate price signals.

Extreme variability of inter-annual rainfall in areas of high population, agricultural and environmental significance is a key vulnerability for Australia in the context of climate change. Decreases in precipitation are expected across the country in the coming decades, with the largest decreases projected for central and southern Australia. Australia is also expected to experience more frequent droughts. A recent study by Jiang and Grafton (2012) looked at the role of water trading and the economic impacts of climate change and reduced surface water availability in the Murray-Darling Basin. It found that inter-regional water trade in periods of much reduced water availability reduces the negative on farm impacts of climate change. While the results show that losses to irrigated agriculture under a median climate change scenario are modest, under a "modified 2030 dry extreme scenario" there would be substantial reductions in water use, irrigated land use and profits. Nevertheless, the Basin-wide proportional economic impacts would be less than the percentage decline in water use. Thus, water trading, along with the development of drought-tolerant species and improved farming practices, could help irrigated agriculture adapt to climate change (Jiang and Grafton, 2012).

Case Study: Water banking and dry-year options in the Western US

In the Western US, experience has been gained in recent years with market-based instruments to manage risk associated with water scarcity and drought. Water banks and dry-year options are mechanisms that facilitate the voluntary, temporary water transfers during dry periods. Transfers may occur between different types of users – e.g. between agricultural users and cities or freshwater ecosystems – as well as the same type of users – e.g. from low-value to high-value crops. Such transfers have proved to be an essential means to transfer water to higher value uses and increase reliability for users that value it most highly (Colby and Pittenger, 2005). While the temporary nature of such transfers makes them effective for managing periodic scarcity, this makes them unsuitable on their own to provide reliable supplies over the long term and to adapt to long term changes in supply availability due to climate change impacts or increasing demand (Colby and Pittenger, 2005; Hanemann et al., 2012). In the case of California, while water marketing is playing an increasing role in coping with variability, long-term transactions (leases or permanent sales) are constrained by costs associated with environmental review and by the fact that many smaller users' water rights are essentially unquantified (Hanemann et al., 2012).

Colby and Pittenger (2005) define dry-year options as contracts that provide for temporary and voluntary water transfers in the event of drought. Buyers pay a fee to secure an option that will result in the transfer of water if the specified dry-year conditions are triggered. If the contract is triggered, buyers pay a set amount per acre-foot to exercise the option and receive the water transfer. While arid regions worldwide have experimented with dry-year option contracts, they have taken on an increasingly important role in the Western US in recent years. For example, in 2003, almost 100 000 acre-feet of water were transferred between the Metropolitan Water District of Southern California and Sacramento Valley irrigators via dry year options contracts. Because dry-year options are much more expensive than outright water purchases (often by a factor of four), the cost of using them to secure water supply need to be carefully weighed against the benefits provided in terms of reliability (Colby and Pittenger, 2005). While more expensive than permanent water transfers, the use of dry-year options are often employed to avoid third party impacts associated with permanent fallowing of agricultural land.

Water banks perform a range of functions to facilitate voluntary, temporary water transfers. Usually created to respond to drought conditions, a water bank is often used to facilitate the negotiation of temporary water transfers, in particular leases from irrigators. Water banks can also store water for future use, as is the case of the Arizona Water Banking

Authority, whose express purpose is to store water underground in aquifers in more abundant years for use in times of shortage (Megdal, 2007).

Dozens of regional water banks exist throughout the US. The Bureau of Reclamation created the Klamath Water Bank in 2003 to facilitate voluntary reductions in water diversions in order to ensure required flows for endangered fish populations (Colby and Pittenger, 2005). The Idaho Water Bank system traces its origins to the 1930s. The Bank facilitates the use of water rights to natural flow water or water stored in Idaho reservoirs. Water right holders can offer unused water rights to the Bank, which allows the water to be rented to other users (Idaho Water Resource Board, 2012).

The California Emergency Drought Water Bank (DWB) was established in 1991 as an adaptation mechanism to respond to one of the most severe droughts in the state's modern history. The DWB was created to buy water, mainly from agricultural users and water agencies in northern California, for resale to urban, municipal, and agricultural sectors in southern California. In the space of a few months, the DWR negotiated 351 contracts to purchase over 820 000 acre-feet of water. The offer price was set at USD 125 per acre-foot, and was resold for USD 175 per acre-foot to cover transaction costs of executing the transfer (Colby and Pittenger, 2005).

Analysis by Hanemann et al. (2012) points to several useful lessons from the experience of the DWB. While the transfers facilitated by the DWB were useful adaptations to deal with shortage, they were essentially temporary, and thus, exempt from meeting environmental requirements of the California Environmental Quality Act. There is no evidence that sellers would have been willing to transfer water for multiple years. Temporary responses may not be an adequate solution in the event that water shortages become more frequent under climate change. In addition, pumped groundwater was often used to substitute for surface water transferred to the Water Bank, reinforcing the tendency to overdraft groundwater that already exists. Transaction costs were high due to legal manoeuvring required to facilitate the transfers. Overall, reducing transactions costs and facilitating long-run transfers of water on a larger scale through the modification and better enforcement of surface water rights would be beneficial adaptive response to climate change (Hanemann et al., 2012).

Water pricing

Water pricing can promote water use efficiency and generate revenues to finance investments in water infrastructures and service provision. In general, putting the right price on water and water–related services encourages people to waste less, pollute less, and invest more in water services (OECD, 2012a). Increasing variability in rainfall, more frequent and severe droughts and greater uncertainty about future hydrological conditions due under climate change strengthen the economic case for efficient water pricing that can reduce inefficient water use, encourage the diversification of sources of supply and raise financing available for potentially higher investment needs.

Despite the good economic case for efficient water pricing that allows for sustainable cost recovery, most existing rate structures under price water. Water authorities often set prices without proper consideration of efficiency, which can lead to significant welfare losses (Grafton, *forthcoming*). In addition, most existing rate structures are inadequate as they are backward looking (relying on a historical cost basis) rather than forward looking (accounting for future replacement cost). As climate change, along with more stringent environmental and health standards, may increase the replacement cost of existing infrastructure, prices may need to increase to meet growing financing needs.

Increasing variability of water supply and uncertainty about future conditions in a changing climate also complicate the efficient timing of supply enhancements. While the costs of water supply augmentation are usually well-known, the inherent variability of water resources makes predicting the payback period for investment much more difficult (Hanemann, 2006; Grafton, forthcoming). Greater variability and uncertainty due to climate change will exacerbate this problem. For example, during a prolonged period of low rainfall, a large investment in water infrastructure may appear to be beneficial. However, a shift in available water supplies due to a break in drought conditions may make the supply augmentation unnecessary.

In theory, water pricing can also be used to effectively signal scarcity value of water and reduce demand during periods of scarcity. Scarcity pricing can signal the optimal time to invest in water infrastructure, so that supply is augmented efficiently (Grafton, *forthcoming*). Basically, scarcity prices work by triggering higher prices during periods of drought-induced excess demand. Higher prices make investments in water supply infrastructure more economically attractive, thus providing an incentive for the augmentation of water supply and evening out supply and demand for water. However, despite these theoretical arguments, scarcity pricing for water has not been put into practice to date. Another option to improve the efficiency and timing of investments in water supply infrastructures is the use of a real options approach to planning and investment, which is gaining interest in OECD countries.

In moving toward more efficient water pricing, ensuring the affordability of water services is also an important policy consideration. Water tariffs can be structured to account for the basic needs of all segments of the population (OECD, 2012a). Affordability for low-income households can be ensured, preferably through direct social transfer. Yet, challenges remain in order to gain social acceptability to raise water prices to efficient levels and to put scarcity pricing into practice.

While a full discussion of the complexities of water pricing is beyond the scope of this report, the following section provides some illustrations of how more efficient water pricing can facilitate climate change adaptation. For example, in some cases, it can promote efficient water use. Efficient pricing can also encourage the diversification of supply sources (e.g. recycled water or wastewater reuse), which builds the resilience of water systems to increased variability and prolonged periods of shortage. At the same time, systematically under-pricing water can encourage overuse and hold back investment in alternative sources of supply. However, diversification of supply sources is not only about pricing – regulatory barriers can also be significant, as well as issues of social acceptability. Examples from Israel, Australia and Spain provide insights for considering the role of water pricing in the context of climate change adaptation.

Case Study: Water pricing promotes efficient use and diversification of supply in Israel

Due to increasing water scarcity, water prices in the agricultural sector in Israel have risen by around 100% over the past decade. Price increases led to substantial changes in the use of agricultural water including: a move to drip irrigation, adoption of more appropriate crops, and an increase in the use of alternative water sources. As a result, agricultural water use has significantly decreased and saline and recycled sources of water now make up around 50% of irrigated water use. Despite the significant decline in agricultural water use, efficiency gains have meant that agricultural production has actually increased. Higher water prices and increased use of alternative sources of water have stimulated technological innovation and exports of water technology grew by around 20% year (OECD, 2010).

In the domestic sector, water tariffs were raised in 2010 by 40%, mainly to recover the cost of large-scale desalination plants.[5] Domestic users pay according to an increasing two-block tariff structure, which encourages water conservation. The addition of a third block with a much higher tariff that would apply to large water consumers in the event of exacerbated drought conditions was considered. The "drought tax" was initially applied in the summer of 2009 as a surcharge on water prices for consumption in excess of household allocations. This tax, however, was suspended in early 2010 in response to social protest and has not been reintroduced (OECD, 2011b).

Although scarcity prices have not yet been adopted in Israel, higher water prices, in combination with other measures (e.g. distinct level of security of volumes for alternative sources, versus less secure access to freshwater) have resulted in significant improvements in the efficiency of irrigated water use and the increased use of alternative sources of water. Higher water prices for the domestic sector encourage water conservation and allow for cost recovery of supply augmentation. The diversification of water supply and efficiency gains reduce Israel's vulnerability to increased variability of rainfall and more pronounced droughts. The experience of Israel also demonstrates the challenges of introducing scarcity pricing, even in countries where public awareness of water issues is high.

Case Study: Low water prices constrain the development of alternative sources, an example from Spain

In Spain, to meet the challenge of declining natural water availability and the limits to increasing the amount of abstracted "conventional" water resources, reused water and desalination have been playing an increasing role. Recycled water is used to supply public gardens, golf courses and selected irrigated agriculture as well as to recharge aquifers. The potential for further development of recycled water is relatively promising in Spain, in part due to the proximity of densely urbanised regions to intensive agriculture in dry regions. However, prices that adequately reflect costs are a condition for expanding the use of recycled water. The cost of producing recycled water often exceeds prices at current levels, slowing further development of this alternative source (Fuentes, 2011).

Spain is also relatively well-positioned to take advantage of desalination, especially along the dry Mediterranean coast, where pressures on water resources are particularly acute. Even so, production capacity in desalination is currently limited to a very small share of water supply. Despite the halving of production cost over the past ten years (according to government estimates), the cost of desalination still far exceeds the cost of conventional supplies and desalinated water is supplied at subsidised rates (Fuentes, 2011). Overall, the expansion of both conventional and unconventional water supply is constrained at current prices.

Case Study: Exploring options to improve the efficiency and timing of supply augmentation decisions, an example from Sydney, Australia

In 2007, Sydney, Australia commenced plans to build a desalination plant in response to concerns over water shortages. However, before the construction of the plant was completed, the drought ended, reducing pressure on water resources. To assess the welfare effects of investment in the desalination plant, Grafton and Ward (2010) evaluated the decision considering various combinations of volumetric price, water restrictions, and supply augmentation. The study found that the investment in desalination in Sydney was made prematurely, leading to welfare losses valued at hundreds of millions of dollars per year. These losses partly arose from the costs associated with using mandatory water restrictions and high volumetric water prices needed to cover the high capital costs associated with the premature construction of the desalination plant (Grafton and Ward, 2010). However, the study argues that losses could have been avoided if dynamically efficient volumetric pricing had been adopted in response to variability in water availability (Grafton and Ward, 2010).

Incentives for ecosystem-based approaches and green infrastructure

Ecosystem-based adaptation approaches involve making use of the services that biodiversity and ecosystems provide in order to adapt to the adverse effects of climate change (UNFCCC, 2011). Examples include restoring wetlands to reduce vulnerability to floods or improving catchment management to improve water quality or quantity. Green infrastructures use natural systems, such as vegetation and soil, to manage water. Ecosystem-based approaches and green infrastructure can be used in combination with or as an alternative to conventional "grey" infrastructures. As "no-regret" investments, often with multiple co-benefits (e.g. biodiversity), these approaches can be a cost-effective strategy to manage climate change impacts on water systems. They can also be effective strategies to address uncertainty, as these approaches are often less capital intensive and more easily reversible or adaptable than engineered alternatives, hence providing an additional "option" value. They can also provide a scalable complement to existing built infrastructure, allowing for incremental changes over time, as required.

Regulatory, economic and information-based policy instruments can be used to promote the use of ecosystem-based approaches and green infrastructure. Policy responses to encourage such approaches include tax incentives, land use planning, and payments for ecosystem services, among others. This section provides examples using several types of policy instruments.

In the context of climate change adaptation, ecosystem-based approaches and green infrastructure are gaining increasing attention.[6] While these approaches are not new, experience with using them in an adaptation context is just gaining ground. Challenges to implementing such schemes vary depending on the specific instruments used to put them in place. In general, putting these approaches in practice often requires a thorough understanding and assessment of the value of ecosystem services and adequate institutional capacity to establish, monitor, and enforce them.

Case Study: Recharging groundwater and managing stormwater with green spaces in Nagoya, Japan

Since the 1970s, the frequency of intense, localised rainfall events has increased in Nagoya, Japan's fourth largest city with 2.2 million inhabitants. Urbanisation has significantly encroached on green space in recent years, which has disrupted the natural water cycle. Surface sealing, for example, has decreased the volume of rainwater permeating into the ground. The amount of green space has been significantly reduced in the past decades, with green area making up only 25% of the city in 2005 (Yamada, 2010). The increased surface runoff of rainwater has increased pressure on existing sewer systems and rivers and increased urban flood damage. Evapotranspiration has been declining, which has exacerbated the heat island effect (Kamierczak and Carter, 2010; Yamada, 2010).

To address these challenges, the city of Nagoya has advanced efforts to promote the use of green infrastructures. Water and green corridors are used to promote flood control, cooling effects and ensure wildlife habitats (Yamada, 2010). The city's Water Cycle Revitalisation Plan (part of the Biodiversity Strategy) aims to increase the infiltration of water into the ground from the present level of 24% to 33% and to reduce runoff levels from 62% to 36% by 2050. This is to be achieved through protection and increased provision of green space, green roofs, permeable paving and structural measures (Kamierczak and Carter, 2010).

Nagoya is using a set of innovative incentives to promote the scheme: *i)* under the programme of preservation of existing green spaces, the City uses "loan for use" agreements with private green space landowners in order to secure favourable urban environments and provide the public with opportunities to experience local natural surroundings; *ii)* an incentive scheme for property developers, which allows them to increase the volume of their buildings if they reduce the total land footprint of the site and allow for the creation of continuous green areas (Kamierczak and Carter, 2010); and *iii)* in order to reduce the heat island effect and enhance water infiltration, the city recently established a requirement for tree planting on all plots of new development over 300 m^2, requiring greenery on 10-20% of the plot. The rule is now a prerequisite for planning permission (Commission for Architecture and the Built Environment, 2010).

Case Study: Reducing flood risks through the restoration of wetlands and green roofs in Denmark

Several cities in Denmark are using green infrastructure and ecosystem-based approaches to deal with heavy rainfall and increasing risk of flooding. Examples include using wetlands to reduce flood risks in Aarhus and an innovative approach to green roofs in Copenhagen (Danish Climate Change Adaptation portal, 2012).

In Denmark, more intense rainfall events and rising sea levels implied by climate change increase the urgency to provide flood protection for low-lying and densely populated areas. Using restored wetlands to hold water during and after extreme rainfall events and at high tide is viewed as an inexpensive solution to this challenge. A recently restored wetland, Egå Engsø, is being used to channel water from heavy rainfall, thus provisioning flood protection for the low-lying and densely populated area near Aarhus, Denmark's second largest city. The wetland also reduces nitrogen leaching from surrounding agriculture (Danish Climate Change Adaptation portal, 2012).

In 2007, following months of significant rainfall and a large amount of snowmelt, the limits of the flood protection systems were tested and required an emergency response to prevent a flood that could have had major economic consequences. This event highlighted the need for further preventive measures. A new wetland, Hede Enge, has been proposed to reduce risk from extreme rainfall events, which are projected to become more frequent and severe with climate change. The cost of the proposed project is estimated at approximately DKK 25 million, of which 80 per cent is for compensation for affected landowners for expropriation of land. Considered as a unique example of climate change adaptation, this project provides a good illustration of an ecosystem-based approach to adaptation for water systems (Danish Climate Change Adaptation portal, 2012).

In Copenhagen, an innovative green roof design has attracted international attention. The "8 House development", near the city centre, has two sloping green roofs that are exceptionally steep (30 degrees for one of the roofs, 32 degrees for the other) and wide (1 700 m^2) covered with drought-tolerant sedum plants. The building houses a day care centre, 476 flats, penthouses and townhouses, a café, businesses and shops, and has rapidly become a popular attraction for tourists as well as professionals interested to study the design on site. From a climate change adaptation perspective, the design provides effective stormwater management, mitigating the negative effects of heavy rainfall events. About 80% of the rain falling onto the surfaces evaporates, with the remaining water led directly into a flood retention basin. The roofs also combat the heat island effect (Danish Climate Change Adaptation portal, 2012).

Case Study: Managing stormwater with green roofs and "bluebelts" in New York City, US

In New York City, street, basement and sewer flooding is expected to become more frequent due to greater storm intensity and sea level rise due to climate change. Increasing stormwater and wastewater flows will be a challenge for the City's existing sewerage system. Built over hundreds of years, the current system is mostly gravity-based. The sunk-cost of the City's sewer systems is huge and there is almost no flexibility to modify existing piping, either in size or scope without extremely costly and disruptive retrofitting. Ecosystem-based and green infrastructure approaches have been identified as feasible and cost-effective alternatives (New York Department of Environmental Protection, 2008).

Several initiatives have been taken to promote the use of green infrastructure to manage stormwater, including expanding the use of natural landscape for drainage and run-off control, the modification of codes to increase the capture of stormwater and the provision of incentives for green infrastructure. Since 2007, USD 1.5 billion has been committed for green infrastructure to clean New York City waterways by making the city greener and more permeable. The initiative comes as part of Mayor Bloomberg's goal of making 90% of NYC's waterways suitable for recreation, which are currently being degraded by excess sewer and rain runoff. The City expects that this investment, combined with targeted cost-effective grey infrastructure, will reduce Combined Sewer Overflows (CSOs) by 40%. Compared with an "all-grey" approach, this plan is expected to save ratepayers more than USD 2 billion. In addition to improving the quality of the city's waterways, green infrastructure has a number of other benefits, including improvements in air quality, lower energy demand, reduce carbon emissions, increased species habitat and property values, and reduction in the city's vulnerability to the impacts of climate change (City of New York, 2011).

New York City is also using tax incentives to expand the use of green roofs by helping to offset their cost. Expansion of the "Bluebelt" programme, which provides runoff control using natural landscape, is promoting cost-effective stormwater management. The programme preserves natural drainage corridors, called "bluebelts", including streams, ponds and other wetlands areas, which allows them to perform their functions of conveying, storing and filtering stormwater, while providing community open spaces and diverse wildlife habitats. It is estimated that the Bluebelt programme saves tens of millions of dollars in infrastructure costs, when compared to providing conventional storm sewers for the same land area (New York City Department of Environmental Protection, 2008).

Financing issues: Avoiding potential pitfalls and accounting for option values

The cost of adapting to climate change will likely add to the already substantial financing gap for water systems in OECD countries. Investment needs in OECD countries are significant to confront the huge cost of modernising and upgrading their systems, so as to comply with increasingly stringent health and environmental regulations, maintain service quality over time, address pollution and growing populations, and in some cases, overcome years of neglect and under-financing. Estimates suggest that this could cost 0.35-1.2% of GDP a year over the next 20 years (OECD, 2012a).

Challenges for financing climate change adaptation for water

A range of factors will influence any additional cost imposed on water systems due to climate change adaptation. The nature and magnitude of specific climate impacts, the level of acceptable risk, and the timing of adaptation actions will have a significant influence on the cost of adaptation, and thus financing needs. In some cases, the additional cost imposed by adaptation needs may be marginal, relative to overall costs. This may be the case, for instance, for water quality, where other stressors may be the dominant cost drivers. In other cases, the additional cost for adaptation may be significant, such as in situations where natural water storage in the form of snowpack is destroyed due to rising temperatures and shifting precipitation regimes. Replacing this natural storage with infrastructure is likely to be very costly. In areas where precipitation is expected to increase, additional costs to manage floods may be significant (see Box 2.3 for a summary of evidence on costs of adaptation for water).

Societies' willingness to pay for adaptation will be influenced by its understanding of the risks faced and the level of risk considered acceptable. Cost-sharing arrangements between national governments and local communities will also influence the approach taken to manage water risks, and ultimately, the cost of doing so. For example, in cases where the cost of structural flood protection is partly or fully funded by national governments, while local communities bear the full opportunity cost of leaving flood plains undeveloped, incentives for local communities are skewed towards opting for structural approaches to manage flood risk, even if they may be more costly overall.

The timing of considering adaptation within the project cycle can also have an important bearing on costs, as well as the overall effectiveness of adaptation responses. Since water infrastructure projects have long lead times, if climate change adaptation is only considered towards the end of the process, (e.g. when financing is being sought) project developers may resist reconsidering the fundamental design and siting of the project in light of climate change considerations. This may result in a "bigger pipes" approach to adaptation, where safety margins are tacked onto projects that have already been conceived without consideration of climate change. A more effective and efficient approach to adaptation would take potential climate change impacts into account from the inception of the project and consider all possible risk management options, including possibly altering the design or siting of the project. If the projects account for adaptation at an early stage, it can be much cheaper than building add-ons or retro-fitting later on.

Beyond widening the financing gap, financing climate change adaptation raises several particular challenges for financing, due long time frames and pervasive uncertainty about future impacts. The expected cost of adaptation measures are usually known and incurred in the short term, while the expected benefits are more uncertain and accrue far into the future. This complicates the task of trying to determine an economically efficient level and timing of adaptation actions. Many water projects have very long asset lives (e.g. 80-100 years for dams), which means that taking climate change into account is essential to avoid mal-adaptation. However, project financing typically operates on a scale of 20 years or less, which may dull incentives for financiers (and also governments) to account for climate change impacts in the design of water projects.

Attribution issues may also pose a problem in the case of dedicated adaptation funding mechanisms. The problem of attribution arises from the fact that climate change adaptation typically occurs in the context of responding to a range of natural and socio-economic pressures on water systems. Adapting water systems to better deal with current climate variability also increases resilience to long-term climate change. Thus, identifying specific measures or actions that respond solely and exclusively to the impacts of long term climate change is both difficult and often impracticable. Indeed, mainstreaming climate change adaptation into water policies, programmes and projects is important to ensure that responses address a range of stressors and achieve overall water policy objectives at least cost.

However, mainstreaming can frustrate efforts to identify the "incremental" cost of adaptation. Attempts to identify this incremental cost are often driven by political imperatives motivating processes to account for how adaptation funding is spent. This is a particularly pressing issue for countries whose eligibility for climate finance is linked to demonstrating "additionality". While it is clearly important to promote accountability in the disbursement of dedicated adaptation funding and to ensure value for money, efforts to label financing for adaptation should avoid impeding mainstreaming and distorting the allocation of financing to "speciality" adaptation projects that may be easily labelled as "adaptation" but do not necessarily maximise net benefits.

Existing codes, standards and rules for economic valuation may also present a barrier to considering long time frames and dealing with uncertainty required for making decisions about adaptation investments for water. Discount rates appropriate for long frames (including declining rates) may be appropriate. The UK has addressed some of these issues with its supplementary guidance on "Accounting for the Effects of Climate Change" produced for the Treasury's "Green Book". The Green Book sets out the economic guidance used by the UK government to assess spending, investment and policy decisions. The supplementary guidance sets out the criteria that determine when it is particularly important to consider the risks and effects of climate change if a programme, policy or project. It provides tools for climate change risk assessment and offers real options analysis as an options appraisal framework, able to incorporate the uncertainty of climate change and the value of flexibility into decision making.

Mobilising financing for adapting water systems to climate change

Financing adaptation should build on sound approaches to financing water systems generally. For water supply and sanitation, this includes reducing costs (via efficiency gains or the choice of cheaper service options) and increasing the basic sources of finance – tariffs, taxes, and transfers (commonly known as the 3Ts) that can fill the financing gap. Repayable finance can be mobilised to bridge the financing gap, including from capital markets or from public sources. Improving the efficiency of operations can help to redress important losses of funds within the sector. Operational inefficiencies include poor revenue collection, distribution losses (leakage, or nonrevenue water), labour inefficiencies and corruption. The choice of service levels and the choice of hardware and technologies to implement them can make a significant difference to costs (OECD, 2012a).

Financing for water resources management can rely on four principles. The first is the polluter pays principle, which can provide incentives to pollute less and/or generate revenues to alleviate pollution and compensate for welfare loss. The second is the beneficiary pays principle, which allows for the financial burden to be shared by those who benefit from water resources management. The third principle is equity to address affordability or competitiveness issues. Finally, coherence between policies that affect water resources (e.g. agriculture, land use, or energy policies) is the fourth principle. This principle recognises that factoring in the impacts on water into the allocation of public money to water-related sectors can be a more cost effective approach than mobilising additional funding for the water sector (OECD, 2012b).

As discussed in Chapter 3, experience with financing climate change adaptation for water systems in OECD countries is rather limited to date. The lack of economic evidence on the cost and benefits of adaptation for water may contribute to the relatively slow progress on financing issues. To shore up financing for adaptation, countries can further leverage existing sources of finance for water systems. To the extent that climate change adaptation is mainstreamed into water policies, programmes and investment decisions, existing sources of financing for water systems will also fund adaptation. In principle, the additional costs imposed by adaptation could be recouped via sustainable cost recovery. Yet, in cases where incremental costs will be substantial, this could make achieving sustainable cost recovery even more difficult.

In countries where dedicated funds for general climate change adaptation have been established, a portion of these funds is being channelled to water systems, given the priority that they are usually accorded in the context of national adaptation planning. Yet, water will continue to compete with other sectors for limited funds. A few OECD countries will continue to rely on international funding to support water and climate change adaptation efforts, including EU Structural and Cohesion Funds. Several countries are also exploring potential new sources of financing and innovative mechanisms (Box 4.4). To address pervasive uncertainty for water investments, real options approaches are gaining increasing attention. However, practical experience with the application of this approach for water investments in the context of adaptation is still limited.

Box 4.4. **Exploring innovative financing mechanisms for climate change adaptation and water**

Several OECD countries and the European Union are exploring innovative financing mechanisms to address climate change adaptation and water. Examples include:

- In **Denmark**, the government is currently scrutinising water sector legislation in order to prepare a new law proposal related to the financing of climate change adaptation of the water sector. The purpose of this work is to increase the possibilities for Danish water and sewer companies to finance more intelligent and socio-economic optimal climate change adaptation measures. For example, the proposal could make it possible for sewer companies to co-finance new measures on roads and in waterways, which keeps rainwater out of the sewer system.

Box 4.4. **Exploring innovative financing mechanisms for climate change adaptation and water** *(cont.)*

- The **European Commission** is considering the use of revenues generated from auctioning allowances under the Community greenhouse gas emission allowance trading system (EU ETS) for climate change adaptation. The EU White Paper *Adapting to Climate Change: Towards an European Framework for Action* (2009) supports the possibility of using such revenue for adaptation purposes. The revised Directive governing the EU ETS provides that at least 50% of the revenue generated from auctioning allowances should be used, *inter alia*, for adaptation in Member States and developing countries. The EU is also exploring the potential implementation of payments for ecosystems services linked to natural water retention measures aiming at the prevention of floods and droughts.
- The **German** Federal Government is examining the possibility of including aspects of climate adaptation in Federal funding programmes and joint funding instruments financed by the Federal Government, the *Länder* and the EU. The recent incorporation of adaptation into the funding instruments of the National Climate Protection Initiative is an example. The Federal Government also has a scheme to fund innovative initiatives and demonstration schemes at local and regional level. This scheme provides financial incentives to adaptation frontrunners to foster innovation and to spread awareness about the necessity of adaptation. At the end of 2011, the Environment Ministry (BMU) introduced a funding scheme promoting adaption to climate change at the level of individual enterprises and local authorities. This funding is expected to cover networking and education projects at the local/ regional levels and support for drawing up adaptation concepts.
- **Mexico's** *2030 Water Agenda* proposes to establish an Adaptation Contingency Fund that would improve Mexico's capacity to effectively replace or significantly modify water supply systems and flood systems. CONAGUA is still analysing alternatives for implementing the Fund. The recently adopted General Law for Climate Change specifies the need to create a fund for projects, studies, actions. In addition, since 2006, Mexico has been selling catastrophe bonds ("cat bonds") each year as an innovative form of risk financing. If a disaster occurs during a bond's lifetime, the government uses the money borrowed to pay for repairs. If no disaster occurs, the government pays the money back with interest. The latest such bond was issued on 15 October 2012 and raised USD 315 million.
- In the **United States**, legislation has been proposed that would establish an infrastructure bank to fund adaptation for water systems. The *Water Infrastructure Resiliency and Sustainability Act* was submitted to the US Congress in October 2011. The bill would authorise the Administrator of the EPA to establish a program of awarding grants to owners or operators of water systems to increase the resiliency or adaptability of the systems to any ongoing or forecasted changes to the hydrological conditions of a region of the US.
- As part of its National Adaptation Plan, **France** is undertaking a review of existing financing mechanisms to determine how they may be used in their existing form or potentially modified to support adaptation. It is also studying potential sources of additional financing.

Source: See country profiles associated with this publication on iLibrary as well as at *www.oecd.org/env/resources/waterandclimatechange.htm*.

Real options approaches

The pervasive uncertainty introduced by climate change poses challenges for considering investments in water infrastructure, which are typically capital intensive and long-lived, often with high sensitivity to climate. Low confidence in projections of future impacts presents a significant challenge to plan and design projects with potentially huge upfront capital investments to avoid risks that are difficult to quantify. When confronted with a range of possibly futures based on climate projections, there can be a temptation to look for an "average" future within that range, even if all of the projections may be equally likely and futures outside of the range of projections are also possible. There may also be a tendency to treat projections as predictions and overestimate the extent to which they can be relied on in a deterministic way. However, trying to build for an "average" future or misusing projections with low confidence as predictions can result in serious errors, including significant mismatches between water infrastructures and future climate that may require costly retrofitting or result in stranded assets. Instead, using investment approaches that accommodate uncertainty and value flexibility may be required.[7]

Real options approaches have been gaining increasing attention by OECD governments in the context of climate change adaptation. For example, the UK's Green Book supplementary guidance on adaptation offers real options analysis as an options appraisal framework to incorporate the uncertainty of climate change and the value of flexibility into decision-making. A real options approach has been employed to assess water-related projects under climate change in The Netherlands. In its report on urban water, the Australian Productivity Commission proposed wider use of real options approaches for water supply augmentation decisions. The Commission's modelling indicated that applying a real options approach could reduce the cost of supply for two cities in Australia (Melbourne and Perth), by over AUD 1 billion over a 10 year period, compared with traditional approaches to planning and investment.[8] Given the advantages in dealing with risk and uncertainty, as compared to traditional planning and investment approaches, the National Water Commission and the Water Services Association of Australia have endorsed the real options approach to planning and investment (Government of Australia Productivity Commission, 2011).

Real options analysis explicitly incorporates the value of flexibility into decision-making. A "real option" is an alternative that can be put into place, adjusted or discarded as new information is gained. It is particularly useful in cases where sunk costs are high, projects are scalable and have long lead times and there is an expectation of learning over time. In the case of climate change, water investments could be readjusted to respond to higher or lower magnitude impacts, sooner or later than expected as knowledge about future conditions improves.

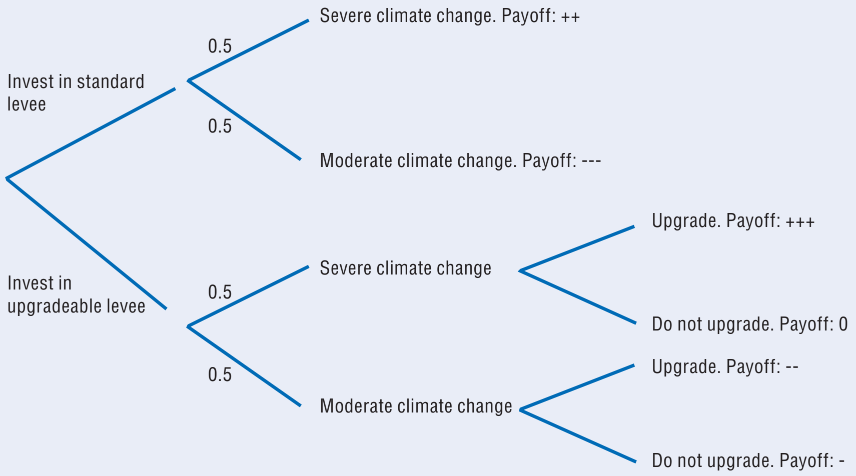
Similar to a standard costs benefits analysis, a quantitative real options appraisal compares discounted costs and benefits over time to generate a net present value, but incorporates an additional step in order to account for the value of flexibility. A decision tree can be used to map out the sequence of project actions, decision (or "trigger") points and key events. Information on costs, benefits and probabilities associated with different options can be used to calculate how payoffs change according to different future scenarios. (HM Treasury, 2009). An illustration is provided in Box 4.5.

Case Study: Real options approaches for the Thames Estuary 2100 Project, UK

The Environment Agency's Thames Estuary 2100 (TE2100) project is developing a strategy for tidal flood risk management to the year 2100. The Thames estuary floodplain contains 1.25 million people (one sixth of London's population), about GBP 200 billion of property, and key transport and infrastructure assets, including the London Underground, 16 hospitals and eight power stations. Given the value of assets at risk, the long lead times involved in developing solutions and the uncertainty of future climate effects and the

Box 4.5. **Illustration of using a real options approach for flood protection**

A simple decision tree can be used to set out two options for flood protection – an investment in a fixed levee today or the investment in a portion of an upgradable levee today, with an option to upgrade the levee in the future. Each option is evaluated under two possible climate change scenarios (severe or moderate climate change).



In this example, two future climate scenarios, severe or moderate, are equally likely scenarios (probability of 0.50). The high flood wall is built today and has positive net benefits only under the severe climate scenario. Under the moderate scenario, the levee has a negative payoff.

In the case of the upgradeable wall, the first portion is built today, with an option upgrade in the future. Under the severe climate change scenario, a higher payoff can be attained than in the case of the standard levee because the upgrade can be scaled as appropriate and a portion of the total cost of the wall deferred into the future. Thus, in terms of discounted net present value, the upgradable wall under the severe climate scenario has the superior payoff. In the case of moderate change, the most appropriate option is to not upgrade the wall, as additional flood protection is not needed, minimising potential losses associated with the initial investment.

Source: Adapted from HM Treasury (2009), "Supplementary Green Book Guidance: Accounting for the Effects of Climate Change". *http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf* (accessed 11 November 2012).

potential for learning, a flexible, adaptive approach to incorporating climate change has been taken. The project identified options to cope with different levels of sea level rise, and the thresholds at which they will be required. The options were designed to implement the small incremental changes common to all options first, leaving major irreversible decisions as far as possible into the future. The strategy can be reappraised in light of the new information and options can be brought forward (or put back) (HM Treasury, 2009).

One issue in using a real options approach is the possibility of some options being prematurely closed off or ruled out, for example through the actions of private property owners. For TE2100, one example of this is the potential development of areas which may be needed for future flood risk management activities (new defences, flood storage areas, etc.). As a result, the TE2100 strategy is likely to recommend the safeguarding of land in order to keep these options open. This entails the opportunity cost of foregoing development on the land, but provides an option value. If it is possible to minimise the opportunity cost of not developing relatively small parcels of land (for example by making other sites available through the land use planning system), then the value of maintaining options for protecting London from increasing flood risk is arguably large (HM Treasury, 2009).

Concluding remarks

Given the scale of the challenge, governments need to explore the full range of options improve the flexibility of water governance, policy and financing approaches. "Adaptive" water governance is gaining attention as a means to increase flexibility and deal with uncertainty related to long term trends. Drawing lessons from early experience with adaptive governance approaches will be important for steering adaptation responses in the future.

In terms of policy responses, regulatory, information-based and economic instruments all have a role to play to "know", "target" and "manage" water risks. Most water policy instruments were not specifically designed with climate change adaptation in mind and may need to be adjusted in light of new evidence to better address increasing risk and uncertainty. At the same time, climate change strengthens the case for addressing existing inefficiencies in current settings.

To date, economic instruments are comparatively under-explored in the context of water policy and climate change adaptation. Economic instruments are just one part of the policy toolkit, but a potentially powerful one, when properly designed and carefully implemented. In the context of increasing variability and declining predictability, they can provide flexibility and minimise the costs of adjusting to changing conditions. Climate change provides opportunities for more systematic use of these instruments, but also challenges.

Finally, the long time frames and pervasive uncertainty about future climate change impacts pose challenges for financing adaptation for water. Climate change is also likely to contribute to existing funding shortfalls. In cases where dedicated adaptation financing is available, an excessive emphasis on additionality can undermine effectiveness by skewing funding towards projects that may be more easily labelled as "adaptation", but do not necessarily maximise net benefits. Sound financing approaches are called for along with the use of flexible investment strategies where appropriate.

Notes

1. Moral hazard occurs when the person making decisions involving risk taking does not bear the full cost of potential negative consequences. Asymmetric information exists when one party in an exchange has better information than another. In the context of insurance schemes, insurers will not have perfect information about the risk taking behaviour of the insured, leading to under- or over-estimation of risk and hence, a certain amount of inefficiency. Adverse selection is the propensity of persons with higher risk to buy insurance more frequently and in greater amounts as compared to those with lower risk. This situation may come about where there is asymmetric information and insurers are unable to reflect this effect in the price of insurance.
2. As of August 2010, NFIP's debt to the US Treasury stood at USD 18.8 billion (Government Accountability Office, 2010).
3. With the exception of storms and hail.
4. While there is some variation among States, generally, water entitlements are divided into categories by the level of risk that an entitlement holder is willing to accept. Higher security

entitlements are met with available water before allocations are made to general or low security entitlements.

5. While the expansion of desalination reduces reliance of more variable conventional supplies, the high energy intensity of the production process means that it may be considered "mal-adaptive" in the context of climate change, due to their contribution to increasing greenhouse gas emissions. However, the energy source used (e.g. fossil fuel, renewable, etc.) and the degree of energy efficiency bear considerably on the actual level of greenhouse gas emissions. Desalination plants in Israel are among the most energy efficient and cost efficient in the world.
6. See the UNFCCC *Nairobi Work Programme's Database* on ecosystem-based approaches to adaptation, *http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/6227.php*; The Green and Blue Space Adaptation for Urban Areas and Eco Towns (GRaBS) project website, *www.grabs-eu.org*.
7. See Hallegate et al. (2012), for a recent review and an assessment of approaches for making investments under deep uncertainty.
8. See Government of Australia Productivity Commission (2011), "Australia's Urban Water Sector", *Productivity Commission Inquiry Report*, Vol. 2, No. 55, 31 August.

References

Agrawala, S. and S. Fankhauser (eds.) (2008), *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*, OECD Publishing, *http://dx.doi.org/10.1787/9789264046214-en*.

Belnap, J., and D.H. Campbell (2011), "Effects of Climate Change and Land-Use on Water Resources in the Upper Colorado River Basin: US Geological Survey Fact Sheet 2010-3123", *http://pubs.usgs.gov/ fs/2010/3123* (accessed 2 October 2012).

Bommelaer, O., J. Devaux, C. Noel (2011), "Financing Water Resources Management in France: A Case Study for an OECD Report", *Collection Études et documents*, Department for the Economics, Assessment and Integration of Sustainable Development, Department of the Commission-General for Sustainable Development.

Botzen, W.J.W. and J.C.J.M. van den Bergh (2008), "Insurance Against Climate Change and Flooding in the Netherlands: Present, Future, and Comparison with Other Countries", *Risk Analysis*, Vol. 28/2, Wiley-Blackwell, *http://dx.doi.org/10.1111/j.1539-6924.2008.01035.x*.

Caribbean Catastrophe Risk Insurance Facility (CCRIF) (2012a), "Understanding CCRIF's Hurricane and Earthquake Policies", *Technical Paper Series #1*, *www.ccrif.org/sites/default/files/publications/TechnicalPaper1-HurricaneEarthquakePoliciesAugust2012.pdf* (accessed 18 November 2012).

CCRIF (2012b), "Newsletter", Vol. 3/3.

City of New York (2011), "PlaNYC Update: A Greener, Greater, New York", *http://nytelecom.vo. llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_planyc_full_report.pdf* (accessed 15 November 2012).

ClimateWise (2010), "Adapting to the Extreme Weather Impacts of Climate Change: How can the Insurance Industry Help?", *www.rms.com/Publications/ClimateWise_Adaptation_Report_120910.pdf* (accessed 5 November 2012).

Colby, B.G. and K. Pittenger (2005), "Structuring Voluntary Dry Year Transfers", New Mexico Water Resources Research Institute, pp. 149-154.

Commission for Architecture and the Built Environment (2010), "Developing an Urban Heat Island Strategy", Greater London Authority, *http://webarchive.nationalarchives.gov.uk/20110118095356*, *www.cabe.org.uk/sustainable-places/advice/urban-heat-island-strategy* (accessed 15 November 2012).

Danish Portal for Climate Change Adaptation (2012), *www.klimatilpasning.dk/en-US/Sider/ClimateChangeAdaptation.aspx* (accessed 14 November, 2012).

Delta Programme, (2012), "Delta Programme 2013: Working on the Delta – the Road Towards the Delta Decisions", The Netherlands Ministry of Infrastructure and the Environment and Ministry of Economic Affairs, Agriculture and Innovation, *www.deltacommissaris.nl/english/Images/Delta_Programme_2013_ENG_tcm310-334162.pdf* (accessed 22 March 2013).

Dinar, A., M.W. Rosegrant and R. Meinzen-Dick (1997), "Water Allocation Mechanisms: Principles and Examples", *Policy Research Working Paper,* No. WPS 1779, The World Bank, Washington, DC, *http://documents.worldbank.org/curated/en/1997/06/694756/water-allocation-mechanisms-principles-examples* (accessed 10 October 2012).

Fuentes, A. (2011), "Policies Towards a Sustainable Use of Water in Spain", *OECD Economics Department Working Papers*, No. 840, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5kgj3l0ggczt-en*.

Government of Australia Productivity Commission (2011), "Australia's Urban Water Sector", Productivity Commission Inquiry Report, Vol. 2/55.

Grislain-Letrémy, C. and C. Peinturier, (2010), "Le Régime d'assurance des catastrophes naturelles en France métropolitaine entre 1995 et 2006", *Collection Études et documents*, Department for the Economics, Assessment and Integration of Sustainable Development, Department of the Commission-General for Sustainable Development.

Grafton, R.Q. (*forthcoming*), "Economic Instruments for Water Management", *OECD Environment Working Papers*, OECD Publishing, Paris.

Grafton, R.Q. and M.B. Ward (2010), "Dynamically Efficient Urban Water Policy", *Centre for Water Economics, Environment and Policy Research Paper*, pp. 10-13, Australia National University, Canberra.

Grannis, J. (2012), "Analysis of How the Flood Insurance Reform Act of 2012 (H.R. 4348) May Affect State and Local Adaptation Efforts", *Georgetown Climate Centre*, *www.georgetownclimate.org/analysis-of-the-flood-insurance-reauthorization-and-reform-law-2012* (accessed 15 December 2012).

Hanemann, M. (2006), "An Economic Conception of Water", *in* P.P. Rogers, M.R. Llamas and L. Martinez-Cortina (eds.), *Water Crisis: Myth or Reality?*, Taylor & Francis plc., London.

Hanemann, M., D. Lambe, and D. Farber (2012), "Climate Vulnerability and Adaptation Study for California: Legal Analysis of Barriers to Adaptation for California's Water Sector", *Public Interest Energy Research (PIER) Program White Paper.*

HM Government (2008), "Revised Statement of Principles on the Provision of Flood Insurance", DEFRA, *http://archive.defra.gov.uk/environment/flooding/documents/interim2/sop-insurance-agreement-080709.pdf* (accessed 5 November 2012).

HM Treasury (2009), "Supplementary Green Book Guidance: Accounting for the Effects of Climate Change", *http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf* (accessed 11 November 2012).

Idaho Water Resource Board (2012), "Water Supply Bank", *www.idwr.idaho.gov/WaterManagement/WaterRights/waterSupply/ws_default.htm* (accessed 14 December 2012).

Intergovernmental Panel for Climate Change (IPCC) (2012), "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation", *A Special Report of Working Groups I and II* of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY, USA.

Jiang, Q. and R.Q. Grafton (2012), "Economic Effects of Climate Change in the Murray-Darling Basin, Australia", *Agricultural Systems*, Vol. 110, Elsevier Science, pp. 10-16. *http://dx.doi.org/10.1016/j.agsy.2012.03.009*.

Kazmierczak, A. and J. Carter (2010), "Adaptation to Climate Change Using Green and Blue Infrastructure", *Database of case studies, Green and Blue Space Adaptation for Urban Areas and Eco Towns* (GRaBS) project website, *www.grabs-eu.org* (accessed 15 November 2012).

Kunreuther, H.C. (2006), "Has the Time Come for Comprehensive Natural Disaster Insurance?", *in* R.J. Daniels, D.F. Kettl and H. Kunreuther (eds.), *On Risk and Disaster: Lessons fromHurricane Katrina*, University of Pennsylvania Press, Philadelphia, PA.

Lipton, E., F. Barringer and M.W. Walsh (2012), "Flood Insurance, Already Fragile, Faces New Stress", *The New York Times*, *www.nytimes.com/2012/11/13/nyregion/federal-flood-insurance-program-faces-new-stress.html?pagewanted=all&_r=0* (accessed 7 December 2012).

Litan, R. (2006), *Sharing and Reducing the Financial Risks of Future "Mega-catastrophes",* The Brookings Institution, Washington, DC.

Marshall, G.R. (2005), *Economics for Collaborative Environmental Management: Regenerating the Commons*, Earthscan, London.

Megdal, S.B. (2007), "Arizona's Recharge and Recovery Programs", *in* B. Colby and K. Jacobs (eds.) *Arizona Water Policy: Management Innovations in an Urbanizing, Arid Region*, RFF Press.

National Water Commission (2012), "The Impacts of Water Trading in the Southern Murray-Darling Basin Between 2006-07 and 2010-11", National Water Commission, Canberra.

New York City Department of Environmental Protection (NYCDEP) (2008), "Climate Change Program Assessment and Action Plan", *Report 1*, *www.nyc.gov/html/dep/html/news/climate_change_report_05-08.shtml* (accessed 14 November 2012).

OECD (2013), "Water Security for Better Lives", *OECD Studies on Water*, OECD Publishing, *http://dx.doi.org/10.1787/9789264202405-en*.

OECD (2012a), *Meeting the Water Reform Challenge*, OECD Publishing, *http://dx.doi.org/10.1787/9789264170001-en*.

OECD (2012b), *A Framework for Financing Water Resources Management*, OECD Publishing, *http://dx.doi.org/10.1787/22245081*.

OECD (2011a), *Water Governance in OECD Countries: A Multi-level Approach*, OECD Publishing, *http://dx.doi.org/10.1787/9789264119284-en*.

OECD (2011b), *Environmental Performance Review: Israel 2011*, OECD Publishing, *http://dx.doi.org/ 10.1787/9789264117563-en*.

OECD (2010), *Taxation, Innovation and the Environment,* OECD Publishing, *http://dx.doi.org/10.1787/9789264087637-en*.

OECD (2009), *Managing Water for All: An OECD Perspective on Pricing and Financing*, OECD Publishing, *http://dx.doi.org/10.1787/9789264059498-en*.

Quiggin, J. (2011), "Managing Risk in the Murray-Darling Basin", *in* D. Connell, and Q. Grafton (eds.), *Basin Futures: Water Reform in the Murray-Darling Basin*, Australia National University E-Press, pp. 313-326.

Skees, J.R., B.J. Barnett and B. Collier (2008), "Agricultural Insurance – Background and Context for Climate Adaptation Discussions", *Consultant Report to the OECD*.

Swiss Re (2012), "Flood: An Underestimated Risk", *http://media.swissre.com/documents/Flood.pdf* (accessed 20 November 2012).

Thomas, A. and R. Leichenko (2011), "Adaptation through Insurance: Lessons from the National Flood Insurance Programme", *International Journal of Climate Change Strategies and Management,* Vol. 3/3, pp. 250-263.

United Nations Framework Convention on Climate Change (UNFCCC) (2011), "Ecosystem-Based Approaches to Adaptation: Compilation of Information", United Nations Office, Geneva.

United States Bureau of Reclamation (USBOR) (2012), "The Colorado River Basin Water Supply and Demand Study", *www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html* (accessed 14 March 2013).

United States Bureau of Reclamation (USBOR) (2011), "Lake Powell Operations, Equalization and the Interim Guidelines", *www.usbr.gov/uc/rm/crsp/gc/Eq-IntGuide/Eq-IntGuidelines-Fact.pdf* (accessed 2 October 2012).

United States Bureau of Reclamation (USBOR) (2007), "Record of Decision, Colorado River Interim Guidelines for Lower Basin Shortages and the Co-ordinated Operations for Lake Powell and Lake Mead: Final Environmental Impact Statement", *www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf* (accessed 2 October 2012).

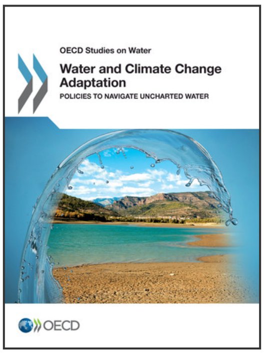
United States Federal Emergency Management Agency (FEMA) (2012), "The National Flood Insurance Program", *www.fema.gov/national-flood-insurance-program* (accessed 11 November 2012).

United States Government (2012), "Biggert-Waters Flood Insurance Reform Act of 2012", in *Moving Ahead for Progress in the 21st Century Act*, United States Government, Washington, DC.

United States Government Accountability Office (GAO) (2010), "National Flood Insurance Program Continued Actions Needed to Address Financial and Operational Issues, Testimony Before the Committee on Banking, Housing and Urban Affairs, US Senate, Statement of Orice Williams Brown, Director Financial Markets and Community Investments", GAO, *www.gao.gov/highrisk/risks/ insurance/national_flood_insurance.php* (accessed 3 August 2012).

Winpenny, J. (2011), "Report of the Rapporteur", *OECD Global Forum on Environment: Making Water Reform Happen*, *www.oecd.org/environment/biodiversitywaterandnaturalresourcemanagement/49769095.pdf* (accessed 4 October 2012).

Yamada, M. (2010), "Soil, Water, Green: Toward Biodiversity Nagoya", *www.kankyo-net.city.nagoya.jp/citysummit2010/images/kaigi/session2/04_nagoya.pdf* (accessed 14 November 2012).



From:

Water and Climate Change Adaptation

Policies to Navigate Uncharted Waters

Access the complete publication at:
https://doi.org/10.1787/9789264200449-en

Please cite this chapter as:

OECD (2013), “Improving flexibility: Adaptive governance, policy options and financing approaches”, in *Water and Climate Change Adaptation: Policies to Navigate Uncharted Waters*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264200449-8-en

This work is published under the responsibility of the Secretary-General of the OECD. The opinions expressed and arguments employed herein do not necessarily reflect the official views of OECD member countries.

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

You can copy, download or print OECD content for your own use, and you can include excerpts from OECD publications, databases and multimedia products in your own documents, presentations, blogs, websites and teaching materials, provided that suitable acknowledgment of OECD as source and copyright owner is given. All requests for public or commercial use and translation rights should be submitted to rights@oecd.org. Requests for permission to photocopy portions of this material for public or commercial use shall be addressed directly to the Copyright Clearance Center (CCC) at info@copyright.com or the Centre français d’exploitation du droit de copie (CFC) at contact@cfcopies.com.