Title: Future Water Resources Management: Reform of the Water Abstraction Regulation System **IA No:** DEFRA1365 **Lead department or agency:** Department for Environment, Food and Rural Affairs **Other departments or agencies:** Welsh Government, Environment Agency and Natural Resources Wales	**Impact Assessment (IA)** **Date:** 11/10/2013 **Stage:** Consultation **Source of intervention:** Domestic **Type of measure:** Primary legislation **Contact for enquiries:** Henry Leveson-Gower 02072385393

Summary: Intervention and Options

RPC Opinion: Amber

Cost of Preferred (or more likely) Option				
Total Net Present Value	**Business Net Present Value**	**Net cost to business per year** (EANCB on 2009 prices)	**In scope of One-In, Two-Out?**	**Measure qualifies as**
See Below	See below	See Below	Yes	Zero Net Cost

What is the problem under consideration? Why is government intervention necessary?

Water, in rivers and aquifers, is a common property resource and therefore needs a system of regulation to manage its use. This use, called abstraction, is currently regulated by a system of licences set up in the 1960s. This system is not flexible or responsive enough to deal with the challenges of climate change and predicted increases in water demand with pressures already on the environment. Reforming the abstraction regulation system effectively is key to successfully regulating access to water in the future to promote resilient economic growth and protect the environment in a manner which is fair and adaptable at a reasonable cost

What are the policy objectives and the intended effects?

The UK Government initially committed to reform of the abstraction regulation system in the Natural Environment White Paper published in June 2011 and then set out the proposed direction, principles and process for reform in the Water White Paper in December 2011. We are committed to introduce a reformed water abstraction regulation system in England able to promote resilient economic growth while protecting the environment in a manner which is fair and adaptable to future uncertainty at a reasonable cost. We intend to go out to consultation in December 2013 and legislate early next Parliament. A Water Strategy is currently being prepared for Wales which will cover water resources licensing and the need for change.

What policy options have been considered, including any alternatives to regulation? Please justify preferred option (further details in Evidence Base)

Option 0: current system with no reform; Option 1: Current System Plus takes some of the characteristics of the previous system, such as flow based restrictions on abstraction, but makes the system more flexible, responsive to water availability, fairer for abstractors and more supportive of trading; and Option 2: Water Shares, includes many of the elements of Current System Plus, but also introduces a new share-based system which explicitly establishes abstractors' interest in a jointly managed variable resource and facilitates more extensive and shorter-term trading. We have decided not to conclude on a preferred option in order to promote an open and broad consultation. We have not considered non-regulatory options as we are looking at reforming a regulatory system required for a common property resource. Other options considered included using administered water prices that flex with water availability to keep abstraction within environmental limits, but this was not taken forward as it was counter to UK Government tax policy.

Will the policy be reviewed? It will be reviewed. **If applicable, set review date:** 01/2020						
Does implementation go beyond minimum EU requirements?			Yes / No / N/A			
Are any of these organisations in scope? If Micros not exempted set out reason in Evidence Base.	**Micro** Yes	**< 20** Yes	**Small** Yes	**Medium** Yes	**Large** Yes	
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)			**Traded:** Minimal	**Non-traded:** Minimal		

I have read the Impact Assessment and I am satisfied that, given the available evidence, it represents a reasonable view of the likely costs, benefits and impact of the leading options.

Signed by the responsible Minister: Dan Rogerson Date: 29/11/13

Summary: Analysis & Evidence

Policy Option 1

Description: Current System plus

FULL ECONOMIC ASSESSMENT

Price Base Year 2013	PV Base Year 2013	Time Period Years 25	Net Benefit (Present Value (PV)) (£m)		
			Low: 117	**High:** 494	**Best Estimate:** 305

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	20.6	1	0.4	**26.6**
High	21.3		0.8	**34.5**
Best Estimate	21.0		0.6	**30.6**

Description and scale of key monetised costs by 'main affected groups'

There are transition costs to government as a result of moving the existing abstraction licences into a new system totalling £21m, when compared to the baseline. There are then some administration costs to government associated with the new system in Wales, averaging £0.6m a year as a mid point estimate.

Other key non-monetised costs by 'main affected groups'

None

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	0	0	9.2	**151.6**
High	0		31.7	**520.3**
Best Estimate	0		20.5	**336.0**

Description and scale of key monetised benefits by 'main affected groups'

Business benefits from admin savings, access to high river flows and from abstraction trading. Monetised as the change in profit earned by non-public water supply businesses, including from using water more efficiently, to produce more output or different, more profitable products (~£40m central PV). Due to more efficient allocation of water, businesses can change their investment profile (~£215m central PV). There are on-going administration cost savings to government in England from the new system (£80m central PV).

Other key non-monetised benefits by 'main affected groups'

No attempt has been made to monetise the benefits to the environment that result as all the options are designed to achieve the same environmental outcomes set in EU legislation. However modelling results suggest that this option could improve how quickly and effectively these outcomes are achieved. The improved abstraction market should facilitate competition in the water industry and increase the economic benefits of upstream competition in England (estimated at £1.7bn).

Key assumptions/sensitivities/risks — **Discount rate (%)** 3.5

Results are preliminary to inform consultation. A key sensitivity of the results is to the different climate conditions. Hence we have used a range of climate scenarios to represent the potential spread of future climate.

BUSINESS ASSESSMENT (Option 1)

Direct impact on business (Equivalent Annual) £m:			In scope of OITO?	Measure qualifies as
Costs: 0.2	**Benefits:** 12.4	**Net:** -12.2	Yes	Zero net cost

Summary: Analysis & Evidence

Policy Option 2

Description: Water Shares

FULL ECONOMIC ASSESSMENT

Price Base Year 2013	PV Base Year 2013	Time Period Years 25	Net Benefit (Present Value (PV)) (£m)		
			Low: 95	**High:** 498	**Best Estimate:** 297

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	23.2	1	0.5	**32.2**
High	23.9		1.7	**52.0**
Best Estimate	23.6		1.1	**42.1**

Description and scale of key monetised costs by 'main affected groups'

There are transition costs to government as a result of moving the existing abstraction licences into a new system totalling £24m when compared to the baseline. Water Shares is slightly more expensive to implement as it requires more extensive development of rules for pre-approval of trades, a system to predict water availability over allocation periods and more work in changing existing volumetric licences into shares. There are then ongoing admin costs (£1.1m) to government with the new system in Wales.

Other key non-monetised costs by 'main affected groups'

None

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low		0	8.8	**147.4**
High			32.4	**530.6**
Best Estimate	0		20.6	**339.0**

Description and scale of key monetised benefits by 'main affected groups'

Other key non-monetised benefits by 'main affected groups'

No attempt has been made to monetise the benefits to the environment that result as all the options are designed to achieve the same environmental outcomes set in EU legislation. However modelling results suggest that this option could improve how quickly and effectively these outcomes are achieved. The improved abstraction market should facilitate competition in the water industry and increase the economic benefits of upstream competition in England.

Key assumptions/sensitivities/risks — **Discount rate (%)** 3.5

Results are preliminary to inform consultation. A key sensitivity of the results is to the different climate conditions. Hence we have used a range of climate scenarios to represent the potential spread of future climate.

BUSINESS ASSESSMENT (Option 2)

Direct impact on business (Equivalent Annual) £m:			In scope of OIOO?	Measure qualifies as
Costs: 0.5	**Benefits:** 13	**Net:** -12.46	Yes	Zero net cost

Evidence Base (for summary sheets)

Contents Page

Executive Summary

The problem

Water in rivers, referred to as surface water, and water in aquifers, referred to as groundwater, is a common property resource and therefore needs a system of regulation to manage its use. This use, called abstraction, is currently regulated by a system of licences set up in the 1960s. The current abstraction regulation system, which regulates how water is taken from rivers and aquifers, is not flexible enough to cope with the challenges of climate change and increased demand from a growing population. This is a regulatory failure in managing a public resource and essentially arises because licenses have been rigidly defined in volume terms, with little link to actual availability, and are slow and expensive to change. We are already beginning to see water scarcity in some catchments, and this is likely to increase in future. Reforming the abstraction regulation system is essential to avoiding impacts on the economy and risks to the environment due to water scarcity.

Policy objective

The UK's Government's 2011 Water White Paper, Water for Life, set out a vision, direction and process to reform the abstraction regulation system to make it more responsive to future uncertainty and enable us to manage England's water resources more effectively. The UK Government is committed to introducing a reformed water abstraction regulation system able to promote resilient economic growth while protecting the environment in a manner which is fair and adaptable to future uncertainty at a reasonable cost. By resilient economic growth we mean growth that is not significantly affected by water scarcity in the short and/or long-term.

A Water Strategy is currently being prepared for Wales which will cover water resources licensing and the need for change. Consultation on these proposals will inform the Welsh Government's decision on these proposed changes.

Options

To meet this policy objective we have developed two reform options which improve the efficiency of the regulatory system and better harness market forces. The first option, Current System Plus, takes some of the characteristics of the previous system, such as restrictions on abstraction when flows are low, but makes the system more flexible, responsive to water availability, fairer for abstractors and more supportive of trading. The latter allows some price signals to emerge and facilitates better allocation of water to high-value uses. The second option, Water Shares, includes many of the elements of Current System Plus, but introduces a new share-based system which explicitly establishes abstractors' interest in a jointly managed variable resource and facilitates more extensive and shorter-term trading. Options are designed to achieve consistent levels of environmental protection in line with statutory requirements such as in the Water Framework and Habitats Directives. A third, a variable administered pricing option, was ruled out during policy development for reasons of feasibility and inconsistency with UK Government tax policy.

Methodology

Quantifying the costs and benefits of abstraction reform options is challenging as it requires:

- Understanding long-term future scenarios to take into account risks of future water scarcity;
- Representation of complex trading rules and environmental standards linked to continuously varying water resources; and
- Representation of short and long-term decision making on water management in the context of uncertainty.

To meet this substantial challenge we have developed combined "agent-based" behavioural and hydrological models of 4 catchments running in daily steps between 2025 and 2050 with abstractor "agents" making short and long term decisions on water management, trading and investment driven by economic and other factors, drawing on behavioural economics. The results from these carefully-selected case studies have then been used to produce tentative aggregated results at an England and Wales level. The assessment examines impacts between 2025 and 2050 to take into account climate change impacts. A range of climate change and socio-economic scenarios have been used based on previous Environment Agency work which are shown on the "x" axis in **Figures A and B** (see below)[1]. Further explanation of these scenarios can be found in detailed methodology section. The methodology has been quality assured by a panel of expert external peer reviewers and has drawn on extensive interactions with stakeholders. Nevertheless, it is important to understand that at this stage, the modelling is most useful in understanding the mechanisms by which policy options may play out, and to present illustrative estimates of likely economic impacts. This interim analysis is presented to inform consultation; views on the options and the analysis are invited. After consultation, analysis will continue to be firmed up as policy development of the options continues.

Summary of costs and benefits

Monetised

Initial results indicate that the reform options provide economic benefits compared with the current system in all scenario combinations ranging, in England, from about £100m up to about £500m net present value (NPV) over 25 years (see Figure A).

[1] Explanation of x-axis notation in figures A and B: **Letter before hyphen is climate change scenario**: A involves less significant change in climate (and hence flows); C, G or J involve greater changes in flows at different locations. **Letters after hyphen are socio-economic scenarios**: Innovation (I); Uncontrolled demand (UD); Sustainable Behaviour (SB); Local Resilience (LR) (**See page 25 for more on the scenarios**)

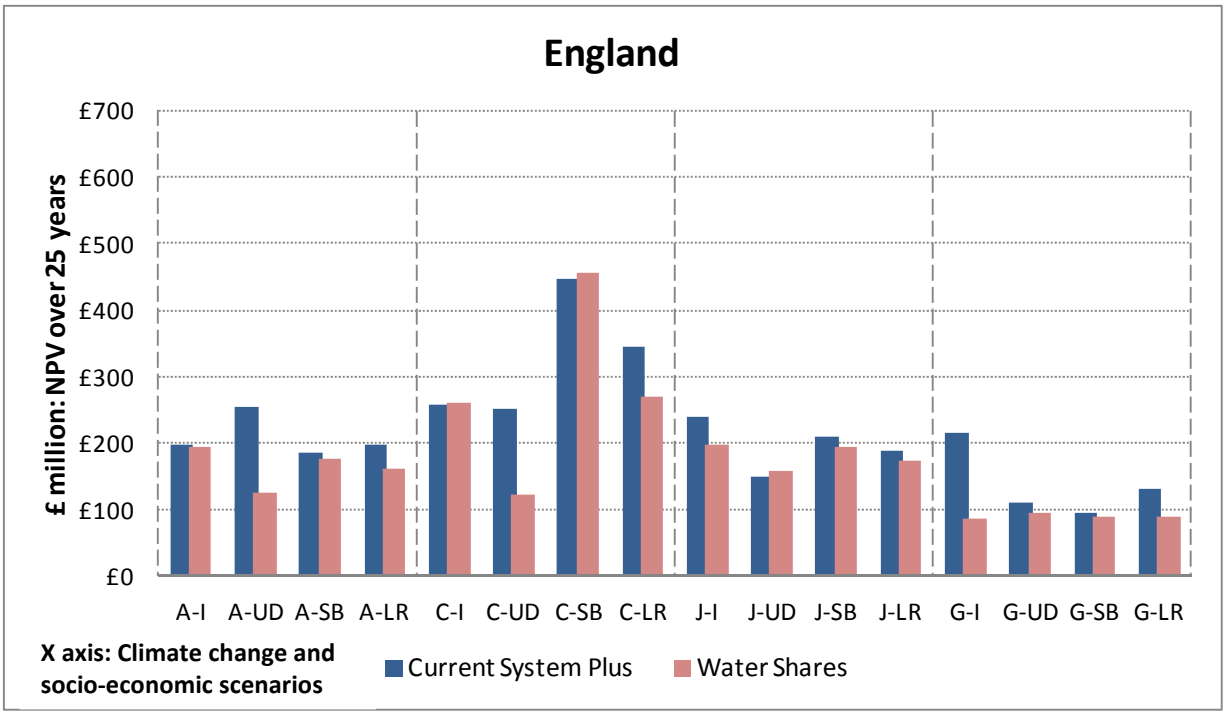


Figure A: Reform Benefits for England

For the two reform options (Current System Plus and Water Shares), components to better link abstraction to flows and facilitate trading will only be introduced in catchments where there are clear environmental and economic benefits due to water scarcity and the potential for trading. Catchments where this is the case are called **enhanced catchments**. This means that much of the benefit of reform will only be seen in the *enhanced catchments*. It also means that some elements of administration systems such as smart meters and rules for pre-approval of trading will only be required in enhanced catchments. "Enhanced (Trading)" catchments undergo enhanced reforms. As well as the administrative costs and benefits they are also able to achieve the full benefits from trading reforms possible under Current System Plus or Water Shares. "Enhanced (Env)" catchments are assumed to require more administrative reform than Basic catchments due to their high environmental sensitivity, but the full trading reforms are not implemented because the benefits of potential trading are not estimated to outweigh the costs of facilitating trading such as establishing pre-approval rules for trades in that catchment. See figure 2 for further information.

Catchments that do not show clear environmental or economic benefits for enhanced reform will undergo basic reform only. These are called ***basic catchments***. However, as the climate changes, the number of basic catchments is likely to decrease. More detail on the differences between basic and enhanced reform is provided in the detailed description of the reform options in Appendix B.

In England the administrative cost of operating the "basic" reformed water abstraction licensing system is lower than it is under the current system. Both main reform options (Current System Plus and Water Shares) have set up costs ranging from about £10-16m with Water Shares being more expensive due to its increased complexity. Once operating, reform options should deliver administrative savings mainly due to the reduction in the need for investigations of risks to the environment. The costs of implementing Enhanced reforms to allow trading are higher than Basic reforms and will only be introduced where the benefits of trading are expected to outweigh the costs. The numbers of catchments falling into the Basic or Enhanced category varies with time and depends on both the reform option and the scenario combination under consideration. On average, around 50% of catchments fall into the Enhanced category by 2050.

In general, when the financial benefits of enhanced reform are high for a particular sector of the economy in the catchment models, these become the dominant contributors to the overall NPV figures estimated by the Aggregation Model. When the financial benefits are marginal, it is the administrative cost savings that become more significant.

In Wales, the case is more variable, with net benefits of up to £30 million NPV in some scenarios and net costs of up to £10 million NPV in others (see Figure B).

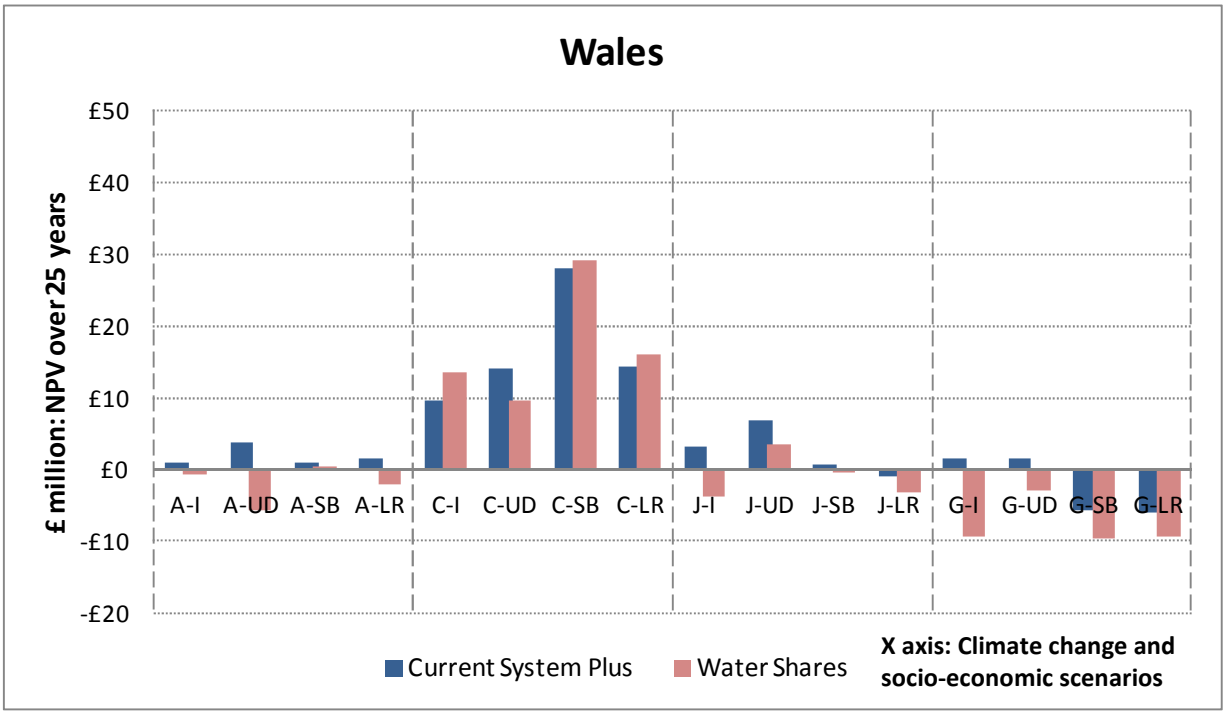


Figure B: Reform Benefits for Wales

In Wales a much higher percentage of catchments are classified as Basic than in England, reflecting higher water availability and therefore less need for trading[2]. In addition, administrative cost savings relative to England are lower because there are relatively few investigations required in Wales under the current system. Overall, administrative costs increase in Wales. So the case for reform in Wales depends on whether the benefits in a particular scenario outweigh the increase in administrative costs.

The modelling demonstrates that reform can provide benefits in a number of ways, and (depending on the catchment and scenario combination) different factors become more or less important. Benefits of enhanced reform accrue from better access to high river flows and improved facilitation of abstraction trading providing increased profits and more efficient investment profiles in water management infrastructure while delivering the same levels of water security.

The modelling to date suggests there is no significant difference in benefits between the two reform options. However, simplifications in the model could be leading to a systematic under-reporting of the level of trading that might be expected under Water Shares. A small increase in the benefits of trading under Water Shares would make it the preferred option in a number of scenario combinations. It is not possible to determine at this stage how significant this effect is and therefore we have not concluded on a preferred option. After consultation we will continue to develop the analysis, but in the meantime views on the modelling, and any evidence relating to anticipated levels of trading in a reformed market are invited.

Many of the benefits are driven by improved facilitation of trading and we are aware that some stakeholders are concerned about unintended consequences of markets. We therefore intend to do further work exploring options to regulate markets while still reaping their benefits. We have already examined international case studies from other sectors and initiated a dialogue on options.

These results represent an important snap shot from a modelling exercise that we intend to further refine, including using more case studies and further stakeholder input. We believe though these results are sufficiently robust to support consultation. We are reasonably confident in the overall positive results for reform options given the consistency of aggregated results across all scenario combinations. However we believe further work is necessary to better represent the reform options and related decision making in order to distinguish between their impacts. We will also use this work to further refine the reform options.

[2] Under most scenario combinations, none of the Welsh catchments have a cost benefit case for becoming Enhanced (Trading) catchments from 2025. Trading benefits are expected to start around 2037 - note that 2037 has been used for consistency with the 12 year interval approach applied for modelling purposes.

Non-monetised

No attempt has been made to monetise the benefits to the environment that result as all the options are designed to achieve the same environmental outcomes set in legislation. However results suggest the reform options seem to more quickly and effectively achieve these outcomes and option 2 seems to generally outperform option 1. The reform options have an approach to reviewing abstraction regulation that should be fairer, more effective and efficient at delivering environmental objectives than the current system.

There are also wider potential benefits that should be greater under option 2 due to the more extensive abstraction market it facilitates. This should facilitate competition in the water industry and increase the economic benefits of upstream competition in England (estimated at £1.7bn)[3]. Businesses may also be able to diversify their income by developing a business in water management. There are also likely to be benefits to non-abstractors and the rural economy from more efficient use of water.

Summary conclusion

The evidence supports the need for reform. However at this stage we are not advancing a preferred option as the evidence needs further development to distinguish clearly between options. We also want to promote an open and broad consultation and take into account further qualitative and quantitative evidence before deciding on a preferred option.

Next steps

Following the consultation, we intend to further refine and improve the evidence base to support a policy decision. Once a policy decision has been made, we are aiming to legislate early in the next Parliament. We will continue working closely with stakeholders in developing the policy and legislation.

[3] http://www.parliament.uk/documents/impact-assessments/IA13-19N.pdf

Problem under consideration

Individual and industrial abstraction

While most individuals and businesses use water from the public water supply, many others rely on access to untreated water abstracted directly from the environment. This water can come from surface water, such as rivers, or from groundwater, in aquifers. Abstracted water is significantly cheaper than treated public water supplies and can provide large volumes of water where it is needed. This would be substantially more expensive if supplied by a public water supplier.

Examples of abstractors include farmers who use water for irrigating crops, manufacturers and industry who use water for processing products and power generating companies who use water for cooling. Reliable access to water supports economic growth and investment in these areas.

Abstraction varies between sectors both in volumes used and number of licences. Power generation including thermal generation and hydropower is the largest sector both for licensed volumes (the amount they are able to take) and estimated volumes (the amount the Environment Agency – the licensing authority - has estimated that they take). The next largest abstractor group by volume comprises public water supply companies. The largest number of licences is found in spray irrigation, which is mostly agricultural, however these are some of the smallest volumes (see table 1).

Different uses also return (discharge) different proportions or the water originally abstracted back to the river. The proportion of water lost is known as consumption, and has an impact on how much water there is available after that abstraction for the environment and other users:

- Some sectors such as the power sector, tidal abstraction and fish farming are almost totally non-consumptive returning nearly all water back very close to the point of abstraction;
- Industry returns substantial amounts close to the point of abstraction although some is lost to evaporation in cooling or incorporated into products;
- The Public Water Supply returns much of what is abstracted but generally substantial distances from the point of abstraction via their supply systems and the sewage system; and
- Irrigators consume all of their water without discharging any directly back to rivers.

Table 1 shows the number of licensed purposes (some licences may have more than one purpose) and volumes licensed and used by the different sectors from freshwater and tidal sources. It sets out gross abstraction and does not take into account how much these sectors consume. Overall, there are around 19,500 licences and 21,280 licensed purposes. It also should be noted that the vast majority of thermal electricity consumption is from tidal sources, with only 184 million cubic meters (2.6%) abstracted from freshwater in 2011.

Table 1: Abstraction by sector with licence numbers, estimated and licensed abstraction volumes in England and Wales 2011 from freshwater and tidal water

	Licensed purposes for each category		Abstraction (Millions of cubic meters)			
	No.	% of total	Licensed Volumes	% of total	Actual Volumes	% of total
Electricity (thermal) (97% tidal)	192	0.9	18,276	35.6	6,999	36.3
Hydropower	327	1.5	15,683	30.5	3,717	19.3
Public water supply	1,617	7.6	9,712	18.9	5,830	30.2
Other industry	3,896	18.3	5,254	10.2	1,737	9.0
Fish farming, cress growing, amenity ponds	685	3.2	1,840	3.6	847	4.4
Spray irrigation	10,330	48.5	338	0.7	118	0.6
Other	210	1.0	162	0.3	23	0.1
Agriculture (excl. spray irrigation)	2,992	14.1	95	0.2	26	0.1
Private water supply	1,031	4.8	37	0.1	9	0.0
Total	**21,280**	**100%**	**51,397**	**100%**	**19,306**	**100%**

The number of licences will soon increase. The New Authorisations project aims to bring a variety of areas which are currently exempt into the abstraction management system. This includes activities like dewatering of quarries and some types of irrigation. Around 4,500 abstractors in England and 500 abstractors in Wales will be brought into the licensing system and it is intended that this will happen before transition to the new abstraction regulation system.

Environmental protection

Water abstraction can significantly affect water flow and levels. In rivers, this can have an impact on the quality and type of habitat; the amount and type of sediment that is carried in the water and where it is deposited; and on water quality (temperature, dissolved oxygen, dilution of pollutants, and residence time of chemicals). In aquifers, abstraction can affect the availability of water for wetlands and rivers, damaging the environment or allowing saline intrusion. Saline intrusion, where saltwater is able to flow into freshwater aquifers due to a loss of pressure, can damage the environment and contaminate drinking water supplies. Depending on sector, much of the water abstracted is returned to surface water. However, there can be substantial changes in flow patterns, as abstraction and discharge can be substantial distances apart, leaving depleted river reaches and lowered groundwater levels.

What challenges are we facing?

Regulating efficiently and effectively is likely to become more difficult in the future as the UK faces substantial challenges from changing climate and the possibility of increasing water demand. We already face challenges in water availability. Many catchments have no spare water that can be allocated for abstraction due to a need to protect the environment and in some locations abstraction is harming nature conservation sites or the ecological health of catchments.

Currently the Environment Agency and Natural Resources Wales are investigating about 220 locations (about 210 in England and 12 in Wales) where there are significant risks that abstraction is damaging important conservation sites including Natura 2000 sites and Sites of Special Scientific Interest. Following previous investigations, a total of 121 abstraction licences (77 in England and 44 in Wales) have already been changed to protect Natura 2000 sites. Abstraction pressures are instrumental in the failure of water bodies to meet EU Water Framework Directive obligations on good ecological status (GES) - see Box 1: Water Framework Directive. About 13 per cent of river water bodies in England[4] and 2% of water bodies in Wales[5] are failing to support GES due to abstraction.

Box 1: Water Framework Directive.

The Water Framework Directive (WFD) requires Member States to prevent deterioration in the status of water bodies and aim to achieve good ecological and chemical surface water status and good chemical and quantitative groundwater status by 2015. Good ecological status indicators for surface waters include Environmental Flow Indicators which are used to assess whether the quantity and variation of the flow of water in a river are sufficient to support healthy biodiversity and habitats. Groundwater abstraction needs to be balanced with recharge to maintain its chemical quality and surface waters and habitats. No deterioration is the key standard for ongoing management of water, where the ecological status of a water body shouldn't be allowed to go below the status it had reached.

This pressure on the environment combined with the level of water already allocated to abstractors means that there is limited reliable water available for new abstractors. This impacts on the ability of new businesses to start up that need access to water impacting on economic growth. The Environment Agency's Case for Change[6] states that at present, a quarter of water bodies in England and seven per cent of water bodies in Wales can no longer provide a reliable source of water for new consumptive abstraction. This is because these water bodies can only provide water for new abstractions 30 per cent or less of the time.

Inadequate supplies of water can have significant impacts on economic growth. Shortages in public water supplies affect households, the provision of increased housing and a wide range of businesses. The power sector depends significantly on abstracted water and shortages could affect the availability and affordability of electricity. A wide range of other industries rely on abstracted water, particularly the chemical, metals, paper and food & drinks industries, with the main use being process cooling. Water shortages can result in reduced yields or even losses of crops such as potatoes for farmers, which can be very costly, particularly for small businesses.

[4] Abstraction and Flow Problem: Significant Water Management Issues , Environment Agency (2013) http://www.geostore.com/environmentagency/Abstraction_and_Flow_Technical_Summary_v1_external.pdf

[5] Living Waters for Wales – Supporting Information for Wales Challenges & Choices Consultation http://naturalresourceswales.gov.uk/our-work/consultations/list-of-current-consultations/challenges-and-choices-consultation/?lang=en

[6] The Case for Change – current and future water availability. Environment Agency (2011): Report No: GEHO1111BVEP-E-E

The Environment Agency's Case for Change has provided the main source of evidence for the future challenges we face- see Box 2.

Box 2: Case for Change

The Environment Agency developed its *Case for Change: current and future water availability* report in 2011 in support of the UK Government's Water White Paper. It set out current evidence on the availability of water now and in the future. It includes a range of projected futures, based on different climate change, environmental and socio economic scenarios. In understanding the potential range of futures we can begin to understand the risks for future water availability.

The analysis uses four socio-economic scenarios, of possible future water demand and describes what this means for future water availability under four climate change scenarios. The socio-economic scenarios look at futures where water demand is set in the context of sustainable behaviour, local resilience, innovation or uncontrolled demand. The four climate change scenarios were selected to cover a reasonable range of scenarios from a larger set in a national assessment of changes in river flows and groundwater levels up to the 2050s. The analysis also takes into consideration different levels of environmental protection involving different assumptions on the water flow requirements for future environmental protection.

The Case for Change analysis of 2050 water availability has been updated in 2013 to include the recently developed projections for water demand relating to the electricity generation sector. It also includes refreshed demand forecasts relating to the agriculture sector, industry and commerce sectors, and household. The analysis now includes an additional environmental protection scenarios relating to Water Framework Directive principle of 'no deterioration'.

The refreshed 2013 case for change concludes that:

- Changing lifestyles and an increase in population could have a substantial impact on demand for water. By the 2030s, the total population of England and Wales is expected to grow by an extra 9.6 million people, rising to 15 million by the 2050s, so despite forecasts of reductions in per capita consumption as a result of recent demand management initiatives by water companies, overall use is likely to grow although the range is from 28 per cent lower to 49 per cent higher than today in 2050
- The climate change scenarios predominantly show decreases in summer flows through the UK, but range from +20 per cent to -80 per cent.
- The combined impacts of climate change and increases in population show there are significant risks of less water available for people, businesses, agriculture and the environment than today.
- The challenge of future water resource availability is not likely to be limited to the south and east of England. Catchments across Wales, south west and northern England are predicted to experience significant unmet demand under many of the scenario combinations.
- As the severity of pressures on water resources may vary across England and Wales, the approach for managing them will need to be adaptive and flexible.

Rationale for intervention

The licensing system created in 1963 evolved with the introduction of the Water Resources Act 1991 and the Water Act 2003. The 2003 Act introduced time limits for all new licences and deregulated around 20,000 licences of less than 20m^3/day. It also provided mechanisms to make trading easier, and a greater focus on efficient and sustainable water use. However, these changes only affected licences granted after their introduction, leaving older licences unchanged.

Even with these changes, as our understanding of the water environment has developed, it has become clear that this system has weaknesses and government intervention is needed again to address remaining regulatory failures from the initial set up. In economic terms, there can be ***negative externalities*** inherent in abstraction from the common water resource. This means the private costs of

abstraction to an individual abstractor can be less than the social costs, in terms of damage to the environment or lack of availability to other users. The licensing system is an attempt to "internalise" these externalities through regulation, but this is not being done effectively.

The weaknesses of the current system (set out below) may constrain economic growth due to reduced resilience and getting less economic value from water while increasing risks to the environment. They create a system that treats abstractors unfairly, is unable to adapt to a changing and uncertain climate, and is very costly to administer.

The current system does not systematically link access to water to the levels of water flows in rivers, to control the negative externalities of abstraction when availability is low. Only some licences, generally newer ones, have flow-based limits on abstraction, called Hands Off Flows (see Box 3). The system also does not generally allow higher flows, where there may be additional water, to be abstracted. This is particularly true for those with winter licences who cannot use periods of higher flows in the summer to fill reservoirs, a particular issue in the recent drought. Discharges are often not accurately accounted for so cannot always be relied upon and exploited by those downstream.

Box 3: What is a 'hands off flow'?

A hands off flow or HOF is a regulatory condition applied to abstraction licences which requires abstractors to stop abstracting when the flow in a river reaches a certain point. They are mostly crude, 'on-off', controls which mean that abstraction must be ceased entirely once flows have dropped below a certain level. Hands off levels can be used in the same way but related to levels rather than flows.

The current process to change most licences that allow damage to the environment is expensive and time consuming. Most licences have no expiry date. To change the conditions of licences which are not time-limited the regulator (Environment Agency or Natural Resources Wales) has to follow a slow and expensive regulatory process. In the Case for Change, it was noted that enforcing a licence change "from investigation to issue of a licence change, can take at least two years and cost between £50,000 and £100,000 per scheme in staff time and legal costs"[7]. This means that reducing current unsustainable abstraction is time consuming and expensive, and will become more so. As the climate changes and flows potentially reduce, more licences are likely to require changes, making this problem much worse. The cost of compensating abstractors for changing their licences is currently funded by other abstractors, meaning the costs for other abstractors could also increase in the future.

[7] Environment Agency Case For Change-Reforming Water Abstraction Management in England, pg 20

The system does not facilitate trading of access to water and so does not provide price signals to promote efficient water management, nor facilitate efficient allocation of water rights. At present there is little trading or sharing of licences to abstract (see Box 4). This is due to the cost and time taken to trade which in turn means there are no price signals to inform decisions about trading or investing in water efficiency, as an alternative to abstraction, and infrastructure such as reservoirs to build resilience and supply others. The charges for abstracting water are generally administrative, and not linked to actual use. As such, they do not internalise negative externalities of abstraction and so do not incentivise efficient water management. Neither does the current charging regime allow efficient allocation of licensed volume .In some catchments, much of the water that is licensed is not actually used. But because abstractors are licensed to use that water, the Environment Agency and Natural Resources Wales cannot make it available to someone else. Environment Agency research found that in 2008, only 40 per cent of licensed volume in England was actually abstracted[8].

Box 4: Trading

It is currently possible for holders of abstraction licences to trade their rights to water. To do so, they must enter into a commercial private transaction, between licences in hydrologically linked water bodies, generally in the same catchment and subject to approval from the regulator. The trade actually happens through the seller applying for a variation in their licence and the buyer applying for a similar level of variation or a new equivalent licence in a different location. The regulator will investigate the potential environmental impacts of any such trade before agreeing it. Between 2003 and November 2010 there have been 53 trades, with the main traders being agricultural irrigators in East Anglia. The Environment Agency and Ofwat commissioned work in 2009 to assess if there were any unnecessary barriers to trading in abstraction licences. One identified barrier was confusing rules, which prompted the Environment Agency to publish new guidance. The EA continues to work on simplifying and encouraging trading in the short-term. However, some of the complexity is due to the nature of the current system and reform of this system presents the greatest opportunity to simplify trading.

The system fails to incentivise abstractors to manage risks from climate change at least cost. Under the current system abstractors pay into a fund used to compensate licence holders if they suffer a loss when changes are made to their licences to tackle over abstraction. This approach may be able to deal slowly with the legacy of unsustainable abstraction, but it does not encourage abstractors to invest and proactively manage their own risks from climate change.

These weaknesses significantly affect England and Wales's ability to address the future challenges of water scarcity. There is a clear rationale for intervention to correct the failings of the current system and future proof abstraction regulation. Without this, England and Wales face the following risks:

Impacts on economic growth particularly due to a lack of resilience to water scarcity

- Access to water at high flows may be unnecessarily limited, reducing water availability that could be stored to build resilience to water scarcity;
- A lack of ability and incentives to make more efficient use of water and trade water may reduce the economic value from the water resources, prevent new market entrants from accessing water and reduce investment in infrastructure to improve resilience to underpin economic growth.
- Cumbersome and slow processes to change most licences on the one hand and on the other hand uncertain time-limited licences may undermine the ability of businesses to plan and invest.

Risks to the environment

- Delays in resolving unsustainable abstraction and a lack of controls on abstraction when flows are low will increase risks to the environment particularly as the climate changes.

Lack of adaptive capacity

- This inflexible system will not be able to respond effectively to longer-term uncertain changes in weather and population while not providing incentives for abstractors to invest to adapt and manage their risks from climate change.

With unfair impacts

- The system will become increasingly unfair, with newer abstractors generally facing the greatest impact from variable flows and water scarcity as they will be the ones with time-limited and

[8] Environment Agency Case For Change-Reforming Water Abstraction Management in England, pg 22

restricted licences, unable to access more reliable licences which will be increasingly unavailable.

High administration costs

- The system will become increasingly expensive to administer, particularly due to the increased need for investigations into potential environmental damage due to abstraction as the climate changes.

Policy objectives

The UK Government initially committed to reform of the abstraction regulation system in the Natural Environment White Paper published in June 2011 and then set out the proposed direction, principles and process for reform in the Water White Paper[9] in December 2011.

We are committed to introduce a reformed water abstraction regulation system able to promote resilient economic growth while protecting the environment in a manner which is fair and adaptable to future uncertainty at a reasonable cost. By resilient economic growth we mean growth that is not significantly affected by water scarcity.

The same abstraction regulation system is in place in Wales. Although many of the water resources in some parts of Wales are not stressed in the same way as some of those in England, the potential pressures are the same. The Welsh Government has therefore agreed to consider the need for reform in Wales. A Water Strategy is currently in preparation for Wales. This will be consulted upon separately. The Welsh Government will consider the different options for reform in developing its Water Strategy and will await the outcome of the consultation before committing to reform.

Box 5: The Water White Paper vision

A reformed abstraction regulation system should:

- Give clear signals and regulatory certainty on the availability of water, to drive efficient investment to adapt to climate change and meet water needs;
- Better reflect the value of water to customers, its relative scarcity, and the value of ecosystems services to ensure our rivers, lakes and aquifers are protected;
- Reflect the benefit of discharges to river systems;
- Drive efficiency in water use, using market forces and smart regulation to lower costs and reduce burdens;
- Be fair to all abstractors, taking into account current licences;
- Be flexible and responsive to changes in supply and demand, including providing greater access to water when more is available; and
- Meet our water needs for people and the environment at least cost to water bill payers, and the consumers of other products and services which depend on water.

Detailed objectives

Over the policy development period, we have developed detailed objectives building on the Water White Paper vision (Box 5), and informed by our policy development and evidence gathering.

Promoting resilient economic growth

- Water availability is linked to water flows, taking into account discharges, to maximise water available particularly for storage to create resilience.
- Charges are made for actual water use to promote efficient use of water.
- Trade is facilitated to maximise the economic value from available water, allow new entrants access to water and incentivise investment in infrastructure to deliver resilience to underpin economic growth in the face of future uncertainty.
- The system for setting water availability over the short and long-term is transparent and provides reasonable certainty for abstractor business planning.

[9] *Water for Life*, Defra 2011

While protecting the environment

- Water ecosystems are protected in line with legal requirements through linking water availability to water flows and reviewing water availability regulation over the longer term, taking into account discharges.
- Initial abstraction permissions on reform do not create risks of environmental deterioration.

In a manner that is fair

- No groups are unfairly discriminated against including potential future abstractors.
- Current licences and actual abstraction are taken into account in providing initial abstraction permissions on reform.

And adaptable to future uncertainty

- Abstraction management is able to respond as water scarcity changes over the longer-term.
- Abstractors face incentives to manage risks from and adapt to climate change efficiently.

With reasonable administrative costs

- Costs of regulatory transactions are minimized.
- Regulation is risk based.

Transition principles

In the Water White Paper, the UK Government committed to principles for transition to the new system. To maintain these commitments, it is important to ensure that any options chosen are compatible, as follows:

- First, the volume, price and reliability of water allocated to abstractors in a new regime will take account of current licences and the actual volumes used. However, we envisage that any new licences will be designed to vary the volume available for abstraction according to overall water availability.
- Secondly, we do not intend to fund compensation for any losses individual abstractors incur in the change to a new system. This would be administratively impractical and not legally justified as the change will be designed to better protect the environment in the future.
- Thirdly, we will not use the transition to change licensed volumes to address current unsustainable abstraction. We will strengthen our approach to using mechanisms in the current regime to tackle this historic legacy in advance of, and alongside, reform. We do though intend a new system to provide stronger protection for the environment when water is scarce.
- Lastly, we want to ensure that the move to a new regime does not create barriers to investment. The Environment Agency will assist abstractors considering water dependent investments on the risks that climate change may pose for projects that are likely to involve substantial water use at low flows.

The Welsh Government is currently developing its Water Strategy and whilst it has not yet taken a decision on the need to reform abstraction licensing, believes these transition principles are appropriate.

Description of options considered (including do nothing)

This section summarises the process of developing the options, and the options themselves. Further details of both can be found in Annexes A and B.

Options development

The process for gathering evidence to develop options for this policy has been extensive. It started following the publication of the Water White Paper in December 2011[10] and was managed by Defra and the Environment Agency.

Project oversight and governance has been provided by the following bodies:

- A project board comprising personnel from Defra, Welsh Government, Environment Agency, Natural Resources Wales, Natural England and Ofwat; and
- The Abstraction Reform Advisory Group (ARAG) comprising representatives of abstractors from a wide range of sectors across England and Wales. The list of members can be found in Annex C. During the options development phase, a wide range of research was commissioned in order to design the options for assessment. This included exploration of international best practice and market development and regulation. Following the options development work we arrived at 3 final options: the current system, the current system plus enhancements ("current system plus") and the "water shares" approach.

Further details of the options development process can be found in Annex A: Evidence gathering and methodology.

The options

These options have been developed and specified for the purposes of the impact assessment. Each of the elements will be further refined and developed following consultation. Although options have different mechanisms for protecting the environment, it is assumed that all will be operated with the aim of meeting legally required environmental objectives such as in the EU Water Framework and Habitats Directives. Many of the changes are focused on abstraction from surface water given its variability and are not relevant to groundwater which changes in quantity at a much slower rate. The full details of the options can be found in Annex B.

Option 0 - Do nothing/Current system

The current system uses daily and annual abstraction limits and in some cases hands off flows to control abstraction, maintain environmental protection and protect the rights of downstream abstractors. Licences often have seasonal restrictions. Water trading is possible but uncommon and not dynamic enough to meet short term changes in demand. Most licences have no end date and can be varied if losses are compensated for in many cases. Charges are set to recover management costs and are not designed to react to water availability.

Option 1 - Current System Plus

The current system plus option aims to refine the current system to make it more flexible and capable of supporting abstractors as they adapt to the risks of increasing water scarcity. This option uses the current annual and daily volumetric abstraction controls, and hands off flow conditions from the current system. However, it aims to refine these tools to improve the link between water availability and abstraction including the removing of seasonal restrictions. Groundwater regulation largely remains unchanged from the current system. Licences would no longer be time limited instead all would be subject to transparent and risk based catchment reviews to protect the environment. It also makes it easier for abstractors to trade water with pre-approval of low risk trades.

[10] Water for life, Defra, (2011)

Option 2 - Water shares

The water shares option explicitly embeds the principle that abstractors have a share in the available water resource rather than an absolute allowance whatever the water resources available. For a particular period, assumed to be a fortnight for surface water abstractors in the modelling, abstractors receive a water allocation based on water availability and depending on the reliability[11] and size of their share in a particular resource. This creates the potential to implement a more systematic approach to accounting and managing water in rivers to reflect the variability in their flows, and facilitate shorter-term and higher risk trading (e.g. trading up stream). Because groundwater levels are slower to respond to changes in availability annual allocations are issued to groundwater abstractors that only change slowly in response to long term changes in groundwater recharge. This option includes many of the changes proposed in "current system plus", for example:

- Linking abstraction to water availability by moving from seasonal to availability-based conditions; and
- Introducing transparent and risk based reviews of catchment regulation to protect the environment while providing reasonable certainty to allow business to plan and invest.

For both option 1 and 2, components to better link abstraction to flows and facilitate trading will only be introduced in catchments where there are clear environmental and economic benefits due to water scarcity and the potential for trading. Catchments where this is the case are called **enhanced catchments**. This means that much of the benefits of reform will only be seen in these enhanced catchments. It also means that some elements of administration systems such as smart meters and rules for pre-approval of trading will only be required in enhanced catchments. However as the climate changes, the number of enhanced catchments is likely to increase. (Other catchments are termed "basic" catchments).

Options summary

	Option 0	Option 1	Option 2
Linking abstraction to water availability	Abstractors generally have fixed volumetric limits. Around a quarter of abstractors have hands off flows or levels.	Abstractors may have enhanced hands off flows, access to additional water at high flows and will all have a requirement to stop abstracting at low flows.	Abstractors have a share of available water. Surface water abstractors receive fortnightly allocations based on water availability and depending on the size and reliability of their share. Groundwater allocations are annual.
Trading water	Trades are possible but they require individual approval and take up to three months.	Some low risk trades are pre-approved and therefore quicker.	Shorter-term trading is possible and a wider range of trades can be pre-approved.
Making licence changes	Some licences are time limited and some are not. Changes are currently slow and expensive.	Time limits are removed and a clear and consistent approach to changing licences is introduced based on risk based reviews.	
Application to different catchments	One system applied in all catchments with approaches tailored to local needs.	A basic or an enhanced version of the system can be used depending on local water availability.	

[11] Some shares will be in highly reliable resources ie available at most flow levels of rivers, while other shares may only be in high flow resources with low reliability. Abstractors with reservoirs are likely to have low reliability shares so they can fill their reservoirs when flows are high.

Transition and system assumptions

The modelling of options includes assumptions on initial abstraction constraints and whether catchment management is “enhanced” or not (i.e. in an enhanced catchment), which impacts on costs and benefits. A key element of transition is to reduce unused licensed volumes to prevent risks of environmental deterioration due to reform. Both reform options facilitate trade which can lead to unused licensed volumes coming available for use and so significantly increasing abstraction levels with risks to the environment. This was a key lesson learnt from international case studies of trading schemes particularly Australia. For the purpose of the impact assessment, for enhanced catchments the total volume of water that may be abstracted under an individual licence is assumed to be the smaller of the current licence limit, and the recent average use (generally assessed over the last 6 years) plus 20 per cent. This will be considered further in the light of consultation. Initial catchment regulation systems are based on current environmental risks and estimated trading benefits. Future water scarcity scenarios then drive any changes in status.

We have also made assumptions on the practical and technical requirements of each of the options. Key assumptions are the need for water accounts for all catchments, while enhanced catchments require smart meters, enhanced telemetry and trading “bulletin boards”. We have also assumed that private sector brokers will facilitate trading in enhanced catchments charging fees. These costs are included in the administrative costs of reform to government and to business.

Further details of each of these areas can be found in Annex B. Views are invited on all assumptions used in modelling, to enable us to develop analysis in further policy development.

Non regulatory options considered

We have not considered options which do not involve any regulation, but we have sought to harness market forces better in reforming the existing regulatory system. This Impact Assessment looks specifically at reforming a regulatory system required for a common property resource to make it more efficient and effective in particular through improving market aspects. We are also required under the WFD to have a permitting system in place, which will require regulation. Although demand-reduction measures would also help to achieve some of our objectives, these are being taken forward elsewhere.

Other options considered

Variable administered pricing

We also considered a third option, which we called **Pay as You Go**. Under the Pay as You Go option the Environment Agency or Natural Resources Wales would regularly set a price for abstracting water according to local water availability. This price, which would increase as water availability decreases and decrease as water availability increases, would aim to constrain demand and ensure environmental protection.

This approach presented significant technical issues in terms of setting prices in the context of complex systems that ensure sufficient water remains to protect the environment at the same time as ensuring water is available for other abstractors at the right time and place. Estimating the necessary prices to meet environmental requirements on a frequent basis would be very complex, risky and costly. Hence for these reasons, the pricing approach was not assessed or pursued any further.

Hybrid options

In this impact assessment we only assess two reform options. However, these reform options do have variants or hybrids depending on whether catchments are classed as “enhanced” or not. There is further potential to develop variants or hybrids of these options. So for instance, the shares option could be implemented with shorter or longer allocation periods. Very flashy catchments, those where river levels peak and recede quickly following rainfall, could benefit from very short allocation periods. This will be explored further post consultation.

Methodology

Analysis has presented substantial methodological challenge for quantifying costs and benefits as it has required:

- Understanding long-term future scenarios to take into account risks of future water scarcity;
- Representation of complex trading rules and environmental standards linked to continuously varying water resources; and
- Representation of short and long-term decision making on water management in the context of uncertainty.

To meet this challenge we have used detailed modelling in a range of case study catchments to explore the costs, benefits and risks of the different reform options when compared with the baseline. For each catchment a fully integrated hydrological and agent based model was developed. The model estimates the overall costs and benefits of each reform option against the baseline in day steps over a 25 year period to be consistent with the available data on climate change and socio economic scenarios. For example, several key benefits come from moving large scale infrastructure projects forwards/backwards in time – these have a lifetime significantly in excess of 10 years, and are large in value (so small changes in timing have large NPV effects). Also, weather pattern variations which have a significant effect on the hydrology and abstractor responses have longer time frames (than 10 years). Flow Duration Curves are based on 18 year averages for this reason to reduce the impact of short term drought / surplus over a few years skewing the results.

The results for the catchments (which were carefully selected to represent a range of types) have then been aggregated and scaled up to provide an initial indication of costs and benefits for England and Wales.

Leading external technical experts in modelling, economics, and hydro-geology and water policy were brought in to provide quality assurance of the methodology and establish priority areas for the modelling project. The experts were:

- Professor Jon Stern (City University), specialising in policy decision making and economics.
- Rob Soley (AMEC) specialising in hydrological modelling.
- Dr Kieran Conlan (Cascade Consulting) specialising in water management.
- Professor Scott Moss (Scott Moss Associates) specialising in agent-based modelling.
- Robin Smale (Vivid Economics) specialising in Economics.

Further details on the approach to evidence gathering and quality assurance on the methodology are included in Annex A.

In addition, this work was also presented to Defra's Economics Advisory Panel in April 2013, whose role is to provide an independent challenge and support capacity to Defra's Economists.

Why adopt this approach?

The abstraction reforms are very complex and the level of benefits will be critically dependent on local characteristics of the catchments including the local hydrology (which determines for example who *can* trade with whom) and the characteristics of the abstractors (which determines who *will* trade with whom). Further, the determination of the level of benefit must take account of complex interactions and feedbacks between the hydrology, weather, the licensing regime and abstractor behaviour, and between agents. Agents also range significantly in their type from water companies with substantial water management capacity and subject to economic regulation, through large industry needing very reliable water, to small farmers irrigating potatoes when the weather is dry.

Traditional "top down" economic modelling (e.g. at regional or national scale) struggles to deliver meaningful conclusions in these situations because it is difficult to represent the complex interactions. It is also difficult to model differences between options that arise, for example, due to differences in the detail of implementation. Nevertheless, we have used a "top down" model as part of our wider analysis to complement, and provide some degree of comparison with, the "bottom up" (catchment) models,

especially when results of the latter are aggregated. The top down modelling approach we used and its key findings and limitations are detailed in **Annex E**. As part of further work it would be useful to explore the differences between these approaches further, and comments are invited as part of consultation. The top-down modelling work has reinforced, however, the importance of the hydrological aspects of the main "bottom up" (catchment-based) modelling approach.

The catchment-based models rely on insights from **behavioural economics**. The literature on this branch of economics was summarised in a paper by Defra[12] in July 2013 that looked at how key theories and empirical studies could be applied to policy. The conclusion was that there is a role for behavioural economics both in 'fine tuning' existing policies and in thinking about how best to design new policies.

Agent-based modelling has emerged as a key methodology for developing understanding of the interactions between people and their environment in situations such as these. Drawing on techniques from social sciences (in particular behavioural economics) and ecological modelling, agent-based modelling allows the investigation of several key issues including: the effects of policy on decision-making, inertia, the impact of heterogeneity for example of agents, and feedbacks between agents such as learning, imitation and communication; and feedbacks between environmental change and agent actions. Further, agent-based modelling is a bottom-up approach that allows more specific local arrangements, rules and complexities to be incorporated (such as local hydrology, real licence conditions and production process specific requirements). As such, agent-based modelling has been used in our main catchment-based modelling approach.

Case study modelling

For this consultation impact assessment, modelling results from the following case studies are being used:

- Cam and Ely Ouse
- Hampshire Avon
- Stour
- Usk

In parallel with consultation, we expect new results from models of the Trent and Derwent, and Dee catchments to become available, which will be added to the evidence base, notably to ensure adequate coverage of the power sector. In the meantime the model results for the above four catchments allow initial analysis of reform options to inform consultation.

The integrated hydrological – agent based model

Figure 1 shows the interaction between the hydrological model and the agent based model (the Abstractor Behaviour Model or ABM) applied at catchment scale. For each case study catchment the hydrological model calculates the river flow and groundwater for a point in time for each 1km² cell. The agent based model estimates both Public Water Supply (PWS) and non-PWS abstractors' demand requirements, and determines their behaviour taking into account the information received from the hydrological model. It determines abstraction and return flows, and passes this information back to the hydrological model, which in turn enables it to calculate the hydrological position for the next day.

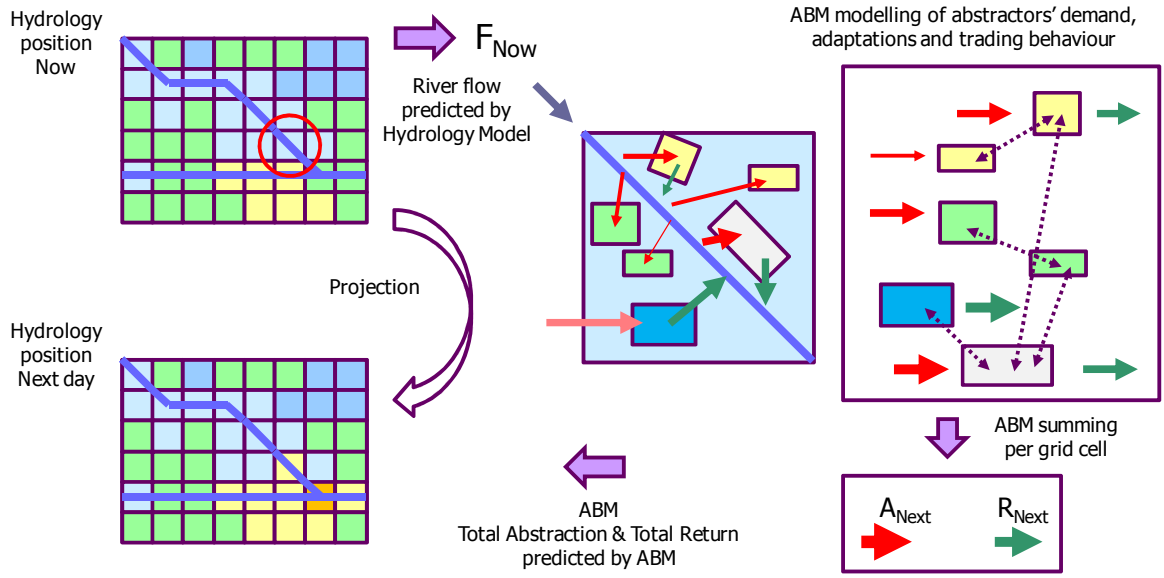
In addition to day to day operational decision making (for example, whether to irrigate crops, or from which source to abstract water to serve PWS customers) the model also determines abstractors' longer term decision making. This may include for example a decision to stop producing a particular product, to invest in infrastructure, to leave, or enter a catchment. At each step the model establishes the costs to abstractors associated with water abstraction and investment decisions.

The model then calculates the water abstractions and returns in the next time period for each hydrological model cell based on abstractors' water requirements, adaptation behaviour and responses to reform options. Agents located in one cell may make abstractions and returns to other cells

[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223835/pb13986-behavioural-economics-defra.pdf

depending on their particular circumstances. In particular it considers how abstractors might react to price signals to make adaptations, and how they might interact with each other as individual abstractors make choices about cooperation, investment and market opportunities.

Figure 1: Interaction between the hydrological model and ABM



Key: F_{Now} River Flow predicted for next time step,
A_{Next} River Abstraction predicted during the next time step
R_{Next} Return to River predicted during the next time step

Modelling abstractor behaviours

Abstractor decisions are modelled to represent their changing ability to access abstracted water as water levels change on a day to day basis following changes in rainfall. Their resultant decisions depend on the profit they make from their use of water and the options they have to reduce their need for water (e.g. changing their production choices). The economics of their use of water has been determined from a number of sources.

The EA and Natural Resources Wales hold information about all live abstraction licences held in England and Wales. This includes maximum annual and maximum daily abstraction limits. This database provides an indication of the purpose or purposes for which the water is abstracted and the location of the abstraction point or points associated with the licence. Details of actual abstractions (volumes, location and discharges) are recorded in ledgers by the EA and Natural Resources Wales. This provided initial information on how abstractors use water.

Engagement with real abstractors, and with abstractor representatives, was then crucial, in helping understand the challenges abstractors face, what drives decision making around water in their industry, and how they might respond to new constraints and opportunities. This was supplemented with information gathered from workshops and one to one consultations, information from experts, from the behavioural literature and about responses to similar changes in the UK and overseas. Information about product prices, production costs, supply and demand was required to establish the context within which decisions about water are made. These were sourced from data sources such as business surveys, market reports and manuals, as well as the consultations.

Modelling the future

Key sources of future uncertainty are climate and socio-economic change, so the four climate and four socio economic scenarios in the EA Case for Change (see Box 2) analysis were used. The four climate change scenarios were selected from a national assessment of seasonal changes in river flows and groundwater levels for the 2050s to reflect a reasonable range of a wider set of scenarios. These are designated:

- Scenario A - less significant change in flows; and

- Scenarios C, G and J, greater changes in flows at different locations.

Four socio-economic scenarios were used which are summarised in Box 6:

- "Sustainable behaviour";
- "Local resilience";
- "Innovation"; and
- "Uncontrolled demand".

Box 6: Short descriptions of the Socio-economic scenarios

Scenarios are a tool for thinking about different possible futures. The Environment Agency developed its original scenarios in 2006 to explore uncertainties relating to future water demand and highlight issues or potential options. The 2012 versions of the scenarios are the refreshed 2050 socio-economic scenarios for water resources and quality. They were revisited and reviewed given recent world events and on-going shocks to the socio-economic system to ensure they were robust and fit for purpose. The following summarises the four scenario narratives used in the modelling.

'Innovation' - ***"Our scientists and technologists can solve the problems of environmental damage through their ideas and innovation"***
In response to a stagnating economy, the government chooses to drive the UK into a large scale wave of industrial investment in sustainable technologies, attempting both to kick-start the economy and avoid an impending wave of resource shortage. The result is a world in which sustainable behaviour is 'designed in' to urban and social life. One consequence is a 'corporatist' world, in which the interests of business and government are aligned.

'Uncontrolled demand' -***"The rich shall inherit the earth – because we're worth it"***
Political and economic systems were dominated by the interests of the wealthy, and as a result, they were able to shrug off protests designed to provoke a rethink of prevailing political and economic models. Increasing resource shortage meant that previous patterns of polarisation between the rich and poor intensified. The top 20% continue to consume without moderation, while the less affluent people are squeezed, relying on handed down products and poorer infrastructure. Security, water, energy and health move from being publicly provided to being increasingly privatised, with minimal basic provision levels supplied for all.

'Local resilience' - ***"It is better to have fewer wants than greater resources"***
Sustained political and economic crises of the 2010s were not successfully resolved, leaving the UK in a low-growth world despite the best efforts of politicians. Rationing and unwillingness for countries to work together made the UK turn inwards, and local regions focus more on how to solve their own problems. The direction of economic innovation has been away from international financial flows and finance, concentrating on helping money circulate locally to support local and regional economies. Consumption is less intensive and more focused on local services than expensive (often imported) manufactured products.

Sustainable behaviour' - ***"We can cut out resource use through new ways of managing our societies and our relationships"***
With growth hard to find, government focused on social welfare as the way to keep citizens content, while environmental disasters in the 2010s provoked international engagement with the low carbon agenda, and tighter regulations. Consumers choose to be green, pushed along by more regulation, which makes products reflect the full costs, including the pollution, they cause. The sense of a collective project and collective action around environmental protection for social welfare means they are happier to trust the government to legislate for the national good. There is a greater role for public management, also driven by infrastructure costs that are unattractively high for private sector firms.

Aggregation

Seven catchments were chosen initially to be as representative as possible of the agent types and hydrological conditions following extensive analysis of the range of catchments and consultation with stakeholders. Subsequently initial analysis suggested that one catchment, the Tees, would not provide representative results due to its link to the Kielder dam. Of the remaining six catchments, it has only been possible to complete modelling of four to date. However, we feel there is enough evidence to inform consultation at this stage, and work to complete the remaining two continues, and will inform further analysis (including for any final stage impact assessment). For this consultation impact assessment, we have only counted benefits from catchments where analysis suggests that the case studies can be considered representative. Hence for instance, the catchment case studies do not include a significant population of thermal electricity generation abstractors, so the potential costs and benefits of reform to that sector have not been quantified.

A spreadsheet-based "aggregation model" reads the ABM outputs and scales up the results for all catchments in England and Wales. It is designed to explore whether the benefits of full (enhanced)

implementation in only a proportion of catchments, outweighs the broader costs associated with minimum (basic) implementation nationally. It does this by calculating each catchment as a weighted average of the 4 modelled catchments based on the sectoral mix. This is explained further in Box 7. Around 20% of catchments were not considered suitable to be a weighted average of the 4 catchments and are therefore neutral to the reform option and claim no net benefits from reform.

In a 'run' of the aggregation model each catchment is classified into one of three types, according to the flow chart in Figure 2. Basic catchments undergo basic reform only. This results in some administrative costs and benefits, but any additional costs and benefits arising from the introduction of full trading reforms under Current System Plus or Water Shares are not applicable in these catchments. "Enhanced (Trading)" catchments undergo enhanced reforms. As well as the administrative costs and benefits they are also able to achieve the full benefits from trading reforms possible under Current System Plus or Water Shares. "Enhanced (Env)" catchments are assumed to require more administrative reform than Basic catchments due to their high environmental sensitivity, but the full trading reforms are not implemented because the benefits of potential trading are not estimated to outweigh the costs of facilitating trading such as establishing pre-approval rules for trades in that catchment.

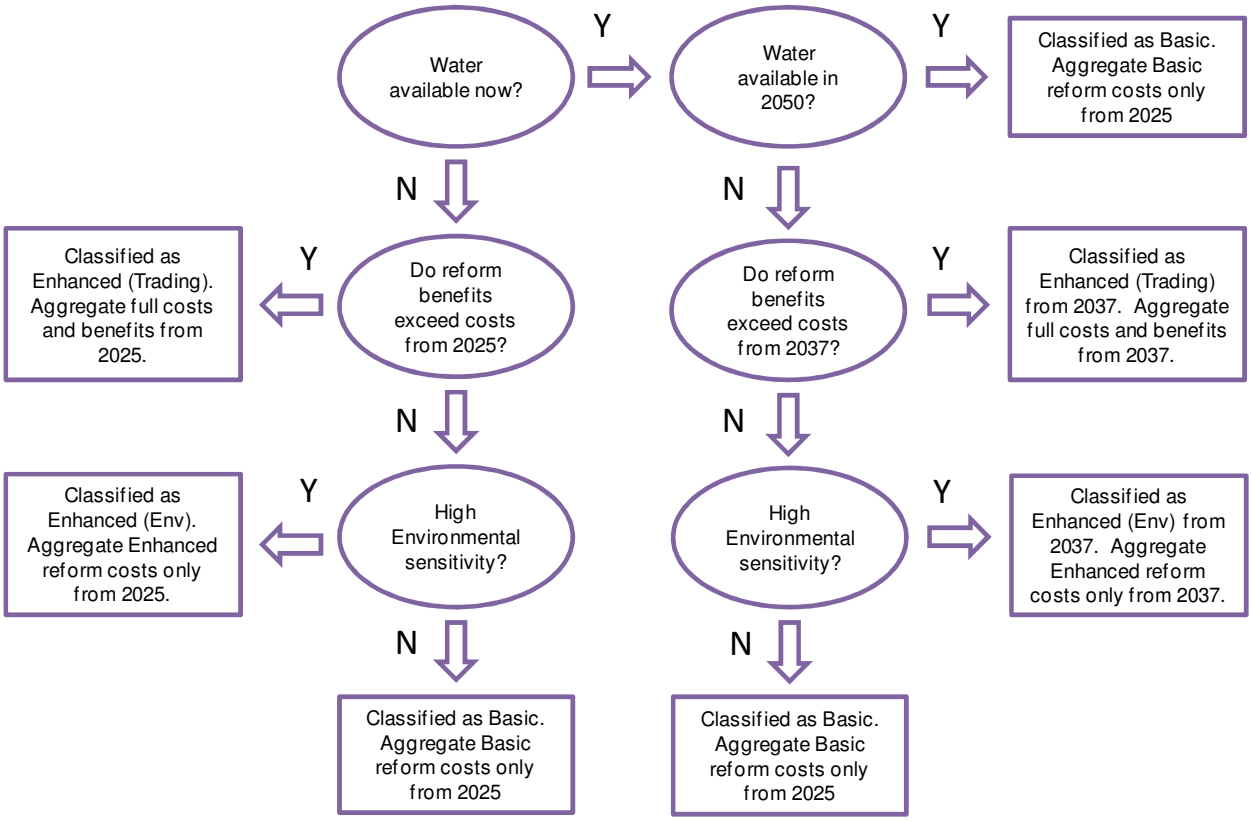
Box 7: Calculating the weighted averages

If 3 catchments are modelled and the benefit per m^3 of water abstracted was £1 in Catchment 1, £2 in Catchment 2 and £3 in Catchment 3, we could take a straight average of these three numbers (= £2 per m^3) and assume that this benefit per m^3 of water abstracted applied to all the other catchments.

However, the level of benefit will depend not only on the amount of water abstracted per year, but also a number of other factors. The most significant of these is expected to be the mix of different sectors in the catchment. For example, in the ABM model we observe trading occurring between agricultural agents; therefore we would expect a catchment with a high proportion of agricultural abstractors to have higher benefits from trading.

The weightings are calculated by matching the total sectoral split across the catchment, giving greater weight to the results from modelled catchments that have a similar split of agents to the catchment under consideration. So for example, if Catchment 1 is dominated by agriculture but Catchment 2 is dominated by PWS, a catchment in the aggregation model that is also dominated by PWS would have a higher Catchment 2 weighting percentage and a lower Catchment 1 weighting percentage.

Figure 2: Catchment classification flowchart



In general a much higher percentage of catchments in England are classified as Enhanced compared to the situation in Wales, reflecting the higher water availability in Wales. The least dry climate scenario across the country as a whole is Scenario A, so more catchments remain classified as "Basic". Climate scenarios G and J are the driest, and these are the scenarios with the greatest number of corresponding "Enhanced" catchments under the Water Shares option.

The numbers of catchments classified as each type by 2050 are shown in the table for the best and worse cases for each reform option.

Table 2: Numbers of catchments classified as basic or enhanced by 2050

Catchment classification	Best case		Worse case	
	Current System Plus	Water Shares	Current System Plus	Water Shares
England*				
Basic	36	37	36	37
Enhanced (Trading)	34	31	20	15
Enhanced (Env)	4	6	18	22
Wales*				
Basic	11	11	9	9
Enhanced (Trading)	5	5	3	3
Enhanced (Env)	3	3	7	7

* For 22 catchments in England and 1 catchment in Wales, it was not possible to calculate benefits for inclusion in the aggregated results however administrative costs or savings were included. The table shows the numbers of catchments in each class for which it was possible to include the full range of costs and benefits.

Monetised cost and benefits

Overview of monetised costs and benefits

We use the mid-point value between the best and worst case to represent the best estimate. Table 3 shows the discounted costs and benefits in 2013 prices. The reforms are modelled over a 25 year period, to be consistent with climate change and socio economic scenarios.

Table 3: Summary of mid-point discounted costs and benefits (£m)

ENGLAND		Current System Plus	Water Shares
Costs	Transition costs to Government	18.7	20.5
	TOTAL COSTS	**18.7**	**20.5**
Benefits/ Cost Savings	Change in production gross margin for business	0.5	1.5
	Administration cost savings for Government	80.3	71.9
	Administration cost savings for business	36.3	35.9
	Adaption cost savings for business	191.7	194.4
	TOTAL BENEFITS	**308.7**	**303.7**
NET PRESENT VALUE		**290.1**	**283.1**

WALES		Current System Plus	Water Shares
Costs	Transition costs to Government	2.3	3.0
	Administration costs for Government	6.1	9.1
	TOTAL COSTS	**8.4**	**12.1**
Benefits/ Cost Savings	Change in production gross margin for business	0.2	-0.2 (represents a cost)
	Administration cost savings for business	1.2	1.0
	Adaption cost savings for business	22.3	25.0
	TOTAL BENEFITS	**23.7**	**25.8**
NET PRESENT VALUE		**15.3**	**13.7**

[Note: due to rounding the combined figures do not always total precisely]

Transition costs to Government

These are assumed to occur in Year 0, which represents 2025. These are the costs that fall to the Environment Agency and Natural Resources Wales as a result of moving the existing abstraction licences into a new system. Water Shares is slightly more expensive to implement as it requires more extensive development of rules for pre-approval of trades, a system to predict water availability over allocation periods and more work in changing existing volumetric licences into shares.

Administration costs to Government

These are incurred from Year 0 through to Year 24. For England, the annual operating costs under both current system plus and water shares are expected to be lower than the baseline operating costs. These reductions are mainly driven by replacing a very complex and expensive mechanism for identifying and investigating potentially harmful individual abstractions, with a simpler mechanism of catchment reviews. Furthermore the reform options tend to reduce the need to change abstraction constraints in a catchment as they tend to reduce risks to the environment.

In Wales however, the operating costs under current system plus and water shares are higher than the current system base case resulting in an average annual administrative cost. Wales' costs are higher as there are fewer licences in Wales that could be subject to the complex and expensive mechanisms of the current system, hence there is less money to be potential saved by switching to a reformed System.

Administration costs to business

These are incurred from Year 0 through to Year 24. These are the changes in administrative costs to business associated with the introduction of Basic or Enhanced reform in each catchment. Modelling suggests that the annual operating costs under both current system plus and water shares are expected to be lower than the current system base case operating costs, so again the net effect of reform is a cost saving rather than a cost increase.

Change in adaption costs to business

These are incurred from Year 0 through to Year 24. This is the change in capital investment (and associated operating costs) incurred in the catchments as agents seek to balance supply and demand as the climate changes over time.

The main driver is the change in investment profile made by the regulated water companies. Under some circumstances the more efficient use of water in the catchment under current system plus or water shares when compared to the baseline can result in a water company being able to make less future investment, or delay the investment from one year to another, while still balancing supply and demand. This generates an NPV benefit for the water company[13] that should ultimately feed through into lower prices for customers, but we have not attempted to estimate this second round effect. In other cases water companies are able to engage in the abstraction market, for example by selling licences to agricultural and industrial abstractors and replacing the water for their regulated customers by bringing forward investment options.

The change in the 25 year profile of additional capital and operating costs under current system plus or water shares compared to the baseline is converted into an equivalent annual figure for the modelled catchments, and it is these values that are scaled up to all 116 catchments to determine the national change in adaptation costs. The circumstances of each water company across the country are quite different to each other.

This category also includes investments made by other abstractors such as for the construction of new water storage reservoirs on farms.

Change in production gross margin for business

These are incurred from Year 0 through to Year 24. These benefits are driven by increased access to high river flows and abstraction trading. Trading allows the purchasing business to generate additional profits above the cost of the trade. It is important to note the trading benefits reflect actual increases in profit to businesses and exclude transfers (i.e. sales values of rights from buyers to sellers).

The significance of these benefits to the overall national NPV figures varies depending on the scenario and catchment.

Variation of results between best and worst cases

The following tables show the discounted figures for the best and worst case. For each scenario below we have identified the main factors underpinning the costs and benefits.

[13] The catchment models include the costs of investments in the years in which they occur. These costs are then discounted to calculate the net present value (NPV). Hence if an investment is put back a year, the NPV of that cost will reduce as it will be discounted by an extra year.

Best case

Table 4 shows the discounted figures for climate change scenario C and socio-economic scenario Sustainable Behaviour.

Table 4: Scenario: C-Sustainable Behaviour (£m)

ENGLAND		Current System Plus	Water Shares
Costs	Transition costs to Government	18.4	20.3
	TOTAL COSTS	**18.4**	**20.3**
Benefits/ Cost Savings	Change in production gross margin for business	7.3	21.5
	Administration cost savings for Government	81.1	72.4
	Administration cost savings for business	36.3	35.9
	Adaption cost savings for business	358.4	358.4
	TOTAL BENEFITS	**483.1**	**488.2**
NET PRESENT VALUE		**464.6**	**467.9**

WALES		Current System Plus	Water Shares
Costs	Transition costs to Government	2.2	2.9
	Administration costs for Government	5.4	8.4
	Change in production gross margin for business	0.6	0.6
	TOTAL COSTS	**8.2**	**11.9**
Benefits/ Cost Savings	Administration cost savings for business	1.1	0.9
	Adaption cost savings for business	36.1	41.5
	TOTAL BENEFITS	**37.2**	**42.4**
NET PRESENT VALUE		**29.0**	**30.5**

[Note: due to rounding the combined figures do not always total precisely]

The 'Sustainable Behaviour' socio-economic scenario sees demand for the public water supply remain fairly constant. The 'C' climate change scenario is unusual in being relatively wetter in the eastern side of the country, compared to other scenarios; nevertheless the Cam and Ely Ouse and Stour catchments are both predicted to be short of water by 2025. The Usk catchment is also expected to be short of water by 2050. The Hampshire Avon however is expected to have water available throughout the modelling period.

Less than 35% of the catchments for which benefits could be estimated are categorised as Enhanced (Trading) in 2025. By 2050 this has risen to around 40% of catchments. Less than 10% are categorised as Enhanced (Environmental) by 2050 (see Table 2).

Most of the Net Benefits arise from adaptation cost savings to business and this comes largely from the water companies being able to defer capital expenditure under the reform options. Some reservoir building is observed and generally low levels of trading. The exception is in Cam and Ely Ouse where there is significant permanent licence trading activity under Current System Plus compared to the current system, with the agriculture sector the biggest buyer of licences. Under water shares there are also a number of significant permanent licence transfer trades occurring but there is also significant activity in the short term multi-lateral allocation market, with most trades from agriculture to agriculture.

Overall the benefits from changes in production gross margin are small. Increases in administration costs in Wales also contribute to the reduction in net benefits in this scenario.

Worst case

Table 5 shows the discounted figures for climate change scenario G and socio-economic scenario unconstrained demand.

Table 5: Scenario: G-Unconstrained demand (£m)

ENGLAND		Current System Plus	Water Shares
Costs	Transition costs to Government	18.9	20.8
	Change in production gross margin for business	6.3	18.4
	TOTAL COSTS	**25.3**	**39.2**
Benefits/ Cost Savings	Administration cost savings for Government	79.6	71.4
	Administration cost savings for business	36.3	35.9
	Adaption cost savings for business	24.9	30.3
	TOTAL BENEFITS	**140.8**	**137.6**
NET PRESENT VALUE		**115.5**	**98.4**

WALES		Current System Plus	Water Shares
Costs	Transition costs to Government	2.4	3.1
	Administration costs for Government	6.8	9.7
	TOTAL COSTS	**9.2**	**12.8**
Benefits/ Cost Savings	Change in production gross margin for business	1.1	0.2
	Administration cost savings for business	1.2	1.0
	Adaption cost savings for business	8.6	8.6
	TOTAL BENEFITS	**10.8**	**9.8**
NET PRESENT VALUE		**1.6**	**-3.0**

[Note: due to rounding the combined figures do not always total precisely]

The 'Uncontrolled Demand' socio-economic scenario has the highest demand growth for the public water supply, and the 'G' climate change scenario is relatively dry. While both Hampshire Avon and Usk are predicted to have water available in 2025 all the modelled catchments will be short of water by 2050.

In England around 30% of the catchments for which benefits could be estimated are categorised as Enhanced (Trading) in 2025. By 2050 this has risen to around 46% of catchments. Less than 10% are categorised as Enhanced (Environmental) by 2050 (see Table 2).

Most of the Net Benefits arise from savings in administration costs, with modest adaptation cost savings arising mainly, as for the Best Case (Scenario C & Sustainable Behaviour), from the Public Water Supply deferring capital expenditure.

As in the Best Case, the most significant levels of trading are seen in Cam and Ely Ouse.

In Wales, all catchments are categorised as Basic in 2025. By 2050, 37% of catchments for which benefits can be estimated are categorised as Enhanced (Environment) under both reform options and just 16% as Enhanced (Trading). The small additional benefits arising from positive changes in production gross margin for business, administration and adaptation cost savings for businesses under Enhanced (Trading) reform are very similar to the additional costs to Government of administering the reforms in Wales.

Catchment Narratives

The catchment models can provide additional insights into the drivers underpinning non-administrative costs and benefits, and we have provided some additional information derived from consideration of the catchment models later in Box 8 and Box 9.

Box 8: The catchment case studies under C-Sustainable Behaviour

The Stour catchment: is predicted to be short of water by 2025 although public water supply demand growth between 2025 and 2050 is relatively flat. Current System Plus reform is cost beneficial so the catchment is classified as Enhanced from 2025. The average annual net benefit (undiscounted, and excluding transition costs) is estimated to be £1.5 million. Around 90% of the net benefit (£1.3 million) is due to a reduction in the equivalent annual investment required by water companies, with 6% due to an increase in production and 4% due to administrative cost savings. Trading activity is not very significant. The catchment is also classified as Enhanced from 2025 under Water Shares. The average annual net benefit is very similar, around £1.5 million, with 90% of the net benefit again due to a reduction in water company investment. The increase in production contributes 7% of the net benefit and administrative costs savings contribute 3%. Most trading activity in the short term multi-lateral allocation market is from agriculture to agriculture or from agriculture to horticulture. There is a small increase in the number of agricultural and horticultural reservoirs being built.

The Hampshire Avon catchment: is predicted to have water available in 2025 and in 2050. It is therefore classified as Basic, and the average annual net benefits of around £90k arise purely from administrative cost savings.

The Cam and Ely Ouse catchment: is predicted to be short of water by 2025. However, the ABM model predicts a net cost to the catchment if Current System Plus reform were to be implemented from 2025 of around £0.3 million (annual average, not discounted, excluding transition costs). As in the Stour example, the water companies are able to defer capital expenditure resulting in an equivalent annual saving of around £0.5 million, but this is offset by loss of profit on production, especially in the agricultural sector. There is also greater investment in reservoir capacity. There is significant trading activity under Current System Plus compared to the current system (permanent licence transfers), with the agriculture sector the biggest buyer of licences. Because Current System Plus reform results in a net cost in this case, in the Aggregation model the Cam and Ely Ouse catchment would fail the cost: benefit test and would remain as a Basic catchment. The situation is similar under Water Shares, with a net cost to the catchment if reform were to be implemented from 2025 of around £0.4 million annual average. There is a saving in the equivalent annual investment required by the water companies of around £0.2 million but this is offset by a loss of profit on agricultural production. As with Current System Plus, there are a number of significant permanent licence transfer trades occurring but there is also significant activity in the short term multi-lateral allocation market, with most trades from agriculture to agriculture.

The Usk catchment: has water available in 2025 but is predicted to be short of water by 2050.

Current System Plus reform is cost beneficial so the catchment is classified as Enhanced from 2037. The average annual net benefit (undiscounted, and excluding transition costs) is estimated to be £1.6 million, and all of the benefit is because the water companies are able to defer capital expenditure, resulting in an equivalent annual saving of around £1.6 million. There is very little net impact on the other sectors in the catchment, although administrative costs increase by around £40k. There is very little trading observed.

The average annual net benefit with Water Shares reform is estimated to be £1.9 million. The saving in equivalent annual water company investment is £2.1 million, but profit on production is reduced by £0.1 million. There is a small amount of activity in the short term multi-lateral allocation market, with most trades from agriculture to agriculture.

Box 9: The catchment case studies under G-Uncontrolled Demand

The Stour catchment: is predicted to be short of water by 2025 and demand for the public water supply continues to grow strongly between 2025 and 2050. The PWS demand growth results in more significant trading activity between water companies under both Current System Plus and Water Shares, resulting in more permanent licence transfers and an increase in capital investment under both policy options compared to the current system. The gain in production profits from non-PWS trading are not sufficient to make reform cost beneficial overall however, so the Stour catchment remains classified as Basic by the aggregation model under both Water Shares and Current System Plus.

The Hampshire Avon catchment: is predicted to have water available in 2025 but be short of water by 2050. Demand for the public water supply continues to grow strongly between 2025 and 2050. Current System Plus reform is almost cost neutral. The water companies are able to defer capital expenditure, resulting in an equivalent annual saving of around £0.4 million, but this is offset by a reduction in production profit of the same amount. Water Shares reform is cost beneficial so the catchment is classified as Enhanced from 2037. The average annual net benefit (not discounted, and excluding transition costs) is estimated to be £0.2 million, most of the benefit arises from water companies deferring capital expenditure.

The Cam and Ely Ouse catchment: is predicted to be short of water by 2025 and demand for the public water supply continues to grow strongly between 2025 and 2050. Current System Plus reform is cost beneficial so the catchment is classified as Enhanced from 2025. The average annual net benefit (not discounted, and excluding transition costs) is estimated to be £0.2 million. Water companies are able to defer capital expenditure which results in an equivalent annual saving of around £0.4 million, which is offset by a reduction in production profit of £0.2 million. There is a greater investment in agricultural reservoir capacity compared to the current system, and quite a high level of trading activity with water companies trading for permanent licence transfers with other water companies and with the agricultural sector. Water Shares reform is also cost beneficial, so the catchment is classified as Enhanced from 2025. The average annual net benefit is very similar to Current System Plus (around £0.2 million), but the permanent transfer of licences from agriculture and industry to the water companies is greater so the net effect is an equivalent annual saving of £0.9 million by the water companies offset by a reduction in production profit of £0.7 million. There is a considerable volume of short term allocation trading, with most trades from agriculture to agriculture.

The Usk catchment: has water available in 2025 but is predicted to be short of water by 2050. Demand for the public water supply continues to grow strongly between 2025 and 2050. The Usk is one of only 3 catchments in Wales classified as Enhanced from 2037 under this scenario, which explains why reform can be cost beneficial in the Usk but marginal for Wales as a whole. For Current System Plus, the average annual net benefit (not discounted, and excluding transition costs) is estimated to be £0.7 million. Around 95% of the net benefit is due to a reduction in the equivalent annual investment required by water companies, with 5% due to an increase in production profit. Water Shares reform is also cost beneficial, with almost 100% of the net benefit due to water company savings, but the average annual net benefit is reduced to £0.6 million because of the higher administration costs. There is a very low level of trading in permanent licence transfers but some short term allocation trading, mostly from agriculture to agriculture.

Net Present Values over 25 years

Table 6 shows the net present values for England and Wales combined. We use the mid-point value between the best and worst case to represent the best estimate. Current System Plus is found to result in a higher net present value over 25 years (of around £8.5m) for England and Wales combined.

Table 6: NPV (£m) – Best Estimate

ENGLAND AND WALES		Current System Plus	Water Shares
	Low Estimate	117.1	95.3
	High Estimate	493.7	498.4
NET PRESENT VALUE (best estimate)		**305.4**	**296.9**

[Note: due to rounding the combined figures do not always total precisely]

The results indicate that the NPV for reform is likely to be positive and in the range £95m to £499m over 25 years. This is the range for Water Shares (the most variable option in terms of economic performance), so the range for Current System Plus is contained within this.

In England the administrative cost of operating a reformed water abstraction licensing system is lower than it is under the current system. This is primarily due to

- the introduction of electronic licenses, and
- a reduction in the number of investigations required to manage local environmental damage.

The costs of implementing Enhanced reforms to allow trading are higher than Basic reform and will only be introduced where the benefits of trading are expected to outweigh the costs. The numbers of catchments falling into the Basic or Enhanced category depends on both the reform option and the scenario combination under consideration. On average we find about half of the catchments in England fall into the Enhanced category by 2050.

In general, when the financial benefits of reform are high for a particular sector of the economy in the catchment models, these become the dominant contributors to the overall NPV figures estimated by the Aggregation Model. When the financial benefits are marginal, it is the administrative cost savings that become more significant.

In Wales a much higher percentage of catchments are classified as Basic, reflecting higher water availability and therefore less need for trading[14]. In addition, administrative cost savings are lower relative to England because there are fewer investigations required in Wales under the current system. Overall, administrative costs increase in Wales. So the case for reform in Wales depends on whether the benefits in a particular scenario outweigh the increase in administrative costs.

The modelling demonstrates that reform can provide benefits in a number of ways, and (depending on the catchment and scenario combination) different factors become more or less important:

- The removal of seasonal restrictions (summer/winter licences) and the provision of “bonus water” at times of high flows:
    - allows agents access to more water
    - provides additional flexibility for agents to manage their annual water allocations through water scarce periods
    - enables agents to make better use of existing reservoirs, and makes building new reservoirs more attractive;

[14] Under most scenario combinations, none of the Welsh catchments have a cost benefit case for becoming Enhanced (Trading) catchments from 2025. Thus, trading benefits do not start until 2037.

- The reduction of barriers to trade (in particular enabling some trades to be pre-approved) makes it easier for agents with spare water to trade it with those who have a need. We see evidence in the model that this:
    - increases the total volume of water that is being used for economic benefit
    - allows water to move to those who can generate more economic benefit from it
    - enables some Public Water Supply (PWS) companies to buy abstraction rights and thus delay high cost infrastructure projects
    - enables other PWS companies to sell abstraction rights and replace these with earlier implementation of low cost infrastructure projects;
- Periodic allocation of water (under Water Shares):
    - explicitly clarifies how much water can be abstracted in the next period and allows agents in the model to identify how much water they need or have spare, which enables them to trade from a position of knowledge
    - increases short term trading, which maximises the water being used for economic benefit, and helps agents to manage short-term high demand/low supply situations better and hence achieve higher levels of overall production.

Limitations in the results

The above findings are subject to a number of caveats. Most importantly, we are almost certainly under-estimating the net benefits from reform and from Water Shares in particular. The main limitations are as follows:

Aggregation

The Aggregation Model runs are only based on four ABM catchment models: Stour, Hampshire Avon, Cam and Ely Ouse and Usk.

- Not all of the 116 catchments in England and Wales can be adequately represented as a weighted average of these four catchments. Where such representation was not judged to be appropriate, the net benefits arising from increases in production value or decreases in adaptation costs were excluded, although it was possible to still include the changes in administration costs. The combined effect of these two limitations is that we are currently underestimating the benefit of reform in approximately 20% of the catchments;
- Without the Trent and Derwent model included it has not been possible to include any benefits to the non-hydro power generation sector.

Following this consultation IA, further case studies of the Trent and Derwent, and Dee catchments will be examined to ensure the analysis for the final IA includes a very large catchment or basin and the power sector, a key abstractor.

The Aggregation Model reflects the water availability, level of abstraction and mix of abstractors in each catchment, but it still assumes that the four modelled catchments are an unbiased representation of all 116 real catchments. This is more likely to be true in scenarios that are generally dry everywhere in the country (e.g. Scenarios G and J), but is less likely to be true in scenarios that are much wetter in some parts of the country than others (e.g. Scenario C).

The Aggregation Model assumes that all cost and benefit elements can be scaled from the 4 catchments to the whole of England, and separately Wales. Adaptation costs to business are generally dominated by PWS impacts. As there are only a very few water companies in each catchment, and their plans are sometimes different in nature, this assumption is less likely to be reliable for this element of the costs.

The Aggregation Model assumes the Environment Agency and Natural Resources Wales will be making decisions on where to implement enhanced benefits based on perfect knowledge of how the future will unfold. This will not be the case and in some circumstances they may make the wrong decision leading to loss of potential benefits or additional unnecessary costs.

The Abstractor Behaviour Model

There is no obvious marked difference between the NPVs estimated for the two reform options (Current System Plus and Water Shares) in these initial results. In general Current System Plus performs better than Water Shares, but the differences are small. This may suggest that any additional benefits under Water Shares accruing from the improved flexibility of the system are not outweighing:

- the additional costs, or
- the effect on water availability of the policy's improved responsiveness to drier conditions.

However, these results must be treated with caution as we believe that the model is currently under-reporting the level of trading that might be expected under Water Shares, due to an inherent bias against the trading of shares that we have identified in the complex interactions between agents and their assessment of water reliability, which results in agents not trading as much once licences have initially been reduced, as they are doing in Current System Plus. It has not been possible to resolve this effect for this impact assessment. Thus a small increase in the benefits of trading under Water Shares would make it the preferred option in a number of scenario combinations.

The results for an individual catchment are sometimes dominated by the impact of a small number of economically significant agents. In some cases we have excluded the results for particular agents where we believe that they do not reflect real phenomena, but are rather an artefact of the modelling. As the behaviour of the agents affects other agents in the model, it is difficult to say what effect this has on the overall results. It is important that key agents are identified and their set-up and emergent behaviour in the model exposed to particular scrutiny; this process is on-going.

For the purposes of modelling we have assumed that in order to prevent environmental deterioration the quantity of water reserved for the environment in 2025 is maintained for the entire modelling period to 2050. This is a simplification of a more complex process. In reality environmental requirements could be adjusted to:

- support habitats' adaptation to the impacts of a changing climate and
- maintain access to water for abstraction.

While adjustments to environmental protection limits would change the quantity of water reserved for the environment (reducing this in a drier climate*), it would not deteriora*te the balance of the needs of the environment compared to abstraction.

The potential impact of adopting a moving environmental protection limit is not easy to anticipate at this stage. It will produce economic benefits to agents, as they will have access to more water, but this would be true for all options so their relative performance may not change. Hence the impact on the case for reform would not be clear.

Where possible, these limitations have been subject to sensitivity analysis as described in Annex F.

Non-monetised costs and benefits

Benefits to the Environment

No attempt has been made to monetise the benefits to the environment that result as all the options are designed to achieve the same environmental outcomes set in legislation. However the options could differ in how quickly and effectively they achieve these outcomes and an attempt has been made to model this in the catchment cases studies which include indicators of risks to the environment. Initial analysis of results suggest that in all catchment case studies the reform options perform better in preventing risks to the environment with option 2 tending to perform best. This is due to the better links between allowed abstraction and flows and the more efficient process of changing catchment abstraction regulation reducing delays to protecting the environment.

However there are significant challenges in modelling the processes for changes in licences and the measurement of environmental risk is quite simplistic given that this is not an ecological model. The indicators of environmental risk also do not take into account the potential for flow requirements to meet environmental objectives to change as the climate changes and ecosystems adapt. This results in the

catchment case studies showing increasing risks to the environment as the climate changes under all options. This is partly an effect of time lags in the modelled approach to constraining abstraction as the climate changes so responses never catch-up with the following climate changes. In actual practice, assessments could be made of future risks and the implications of climate change would be factored into constraints in abstraction to meet environmental objectives. Further work will be done to improve modelling and assessment of environmental risks under different options prior to the final impact assessment.

Other non-monetised costs and benefits

Option 0- Do nothing/Current system

Costs

This option carries no upfront implementation costs as it is a continuance of the existing system. However, over time unexpected costs could arise due to the inherent problems of the current system set out previously. The uncertainty around time-limited licences and the licence modification process for users could lead to inefficient business planning and investment, particularly to manage risks of climate change. There may also be costs incurred by new users of the system.

Benefits

This option is a known system to abstractors, hence provides benefits of certainty and familiarity.

Option 1: Current system plus

Costs

A key element of this option is facilitation of trading markets. There are risks of unintended impacts due to such things as market abuse and distortion. We have not costed these but have investigated international case studies of market development in other sectors. We are beginning to explore options for market regulation and will work further on these options with stakeholders following consultation.

There may also be costs for abstractors in better understanding their water needs and the value of water to them, which we have not monetised.

Benefits

This option offers broad non-monetised benefits for all from increasing flexibility to adapt to a range of climate change outcomes. Businesses may be able to diversify their income by developing a business in water management. The facilitation of competition in the water industry due to easier access to abstraction of new entrants could increase the economic benefits of upstream competition. There are also benefits to non-abstractors and the rural economy from more efficient use of water.

Option 2: Water shares

Costs

This option delivers even greater facilitation of trading markets. There are therefore greater risks of unintended impacts due to such things as market abuse and distortion. We have not costed these but have investigated international case studies of market development in other sectors. We are beginning to explore options for market regulation and will work further on these options with stakeholders following consultation.

There may also be costs for abstractors in better understanding their water needs and the value of water to them, which we have not monetised.

Benefits

This option offers greater non-monetised benefits than option 1 for all from increasing flexibility to adapt to a range of climate change outcomes. This could provide greater investment certainty for abstractors

than option 1 as they would be guaranteed a proportion of available water through their shares. Anecdotal evidence from Australian irrigators suggests that the share system provides an improved basis for abstractors to plan and invest. Hence it is expected that this option may provide for a more flexible and responsive system in the longer term which more robust to future climate impacts.

One-In-Two-Out Methodology

Under the reform options, business can achieve cost savings when compared to the baseline. This comes from a saving in the administration costs, along with saving as a result of adaption changes under the options, for both water companies and other abstractors who can build reservoirs.

Under both options more trading can occur. This is a regulatory change which is permissive in nature as abstractors are not forced to trade. We can assume that abstractors will only enter into a trade if it is cost-beneficial to them. We have included elements from behavioural economics in the results, such as inertia, which ultimately assumes not everyone is rational which will limit the amount of trading that occurs. The profits as a result of trading have been quantified and have been included in the one-in-two-out analysis.

Both reform options will be considered as an 'IN' as the proposed options involve regulation. However this should be treated as being 'Zero Net Cost' for the purposes of On-In-Two-Out as there is an overall benefit to business. This was calculated using the latest BIS impact assessment calculator[15] to derive the Equivalent Annual net cost to business in 2009 prices. Table 8 shows that businesses can achieve a cost saving in both England and Wales under both reform options.

Table 8: Net cost to business per year (EANCB on 2009 prices) (£m)

		England	Wales	England and Wales Combined
Option 1 Current System Plus	G- Uncontrolled Demand	-2.65	-0.52	-3.17
	C-Sustainable Behaviour	-19.45	-1.77	-21.22
	Best Estimate(Mid Point)			**-12.20**
Option 2 Water Shares	G-Uncontrolled Demand	-2.31	-0.47	-2.78
	C-Sustainable Behaviour	-20.11	-2.02	-22.13
	Best Estimate(Mid Point)			**-12.46**

[Note: due to rounding the combined figures do not always total precisely]

Small and Micro Business Assessment

Context

Water abstraction has a significant number of Small and Micro Businesses. While the largest volume of abstraction is by water and power companies, the agriculture sector has the largest number of abstraction licences. Agricultural businesses tend to be mostly SMBs - around 94.5% SMB. This means that a significant proportion of licences, 17,436 out of 21,280 or 82%, are likely to be owned by SMBs- see Table 9. It is important to note that some SMBs, such as large horticultural farms, can be very significant users of water which bears no relationship to their number of employees.

Following the Water Act 2003, the UK Government deregulated a significant number of small volume abstractors, below 20m^3/d, to reduce the administrative burden on small operators while still protecting other abstractors and the environment. These were predominantly rural groundwater abstraction licences for agricultural and domestic purposes. For context, 20 m3 is 20,000 litres and is a significant amount of water per day for an individual business. This is enough to supply more than 130 people's daily water demand for domestic uses or just under 60 households. Alternatively it would be enough water for a herd of around 140 dairy cows.

[15] https://www.gov.uk/government/publications/impact-assessment-calculator--3 (Expires 27th September 2013)

In considering reform options, we reviewed whether this level of deregulation remained appropriate and looked at evidence on impacts of the previous deregulation. We concluded that increasing the level of deregulation to any significant extent would be likely to create risks of derogation to regulated abstractors. Particularly as water scarcity increases and its traded price, there is a risk that numbers of unregulated abstractions could increase substantially affecting the available water to regulated abstractors. There could also be a risk to the environment. Hence we have focused reform on modernising the regime including the administrative processes so it is generally easier to use for all abstractors including SMBs.

Table 9: Analysis of licences held by SMBs

Number of abstraction licences in force by purpose: England and Wales (2011), DEFRA ENV15 statistics	Number of licensed	Likely % of SMBs[16]	Number of SMB licences estimated
Electricity supply industry (c)	519	56.0	291
Public water supply	1,617	56.0	906
Other industry	3,896	56.0	2,182
Fish farming, cress growing, amenity ponds	685	95.4	653
Spray irrigation (a)	10,330	95.4	9,855
Agriculture (excl. spray irrigation)	2,992	95.4	2,854
Other	210	56.0	118
Private water supply	1,031	56.0	577
Total	21,280		17,436

Impacts

The impacts on SMBs will be in line with the impacts on business more generally, identified in the monetised and non-monetised sections of this Impact Assessment. Overall SMBs should experience benefits although some may not have the capacity to exploit trading benefits. Having said that, to date farmers and growers have been the most active traders of water and trading provides the opportunity for SMBs to diversify their businesses into water management. They will certainly all experience the benefits of improved administration systems, such as water accounts.

Current reform options do potentially include some immediate direct costs to abstractors. In enhanced catchments smart meters will be required to allow the better regulation of water to deliver the benefits of reform. While larger businesses would also be affected by the cost of metering, the estimated cost of £850 per smart meter is likely to be easily absorbed in large organisations. For SMBs, their size and resource constraints could mean that this had a greater relative impact. However as the requirements for new smart meters will be limited to enhanced catchments, the impact is on less than 50% of SMBs. Furthermore this estimate assumes that an abstractors' current meter can't be easily upgraded to be 'smart' and does not assume a bulk buying approach which could be organised. We will investigate these issues further following consultation.

Another area of impact could be the transition to a new system, which may cause administrative burden and cost abstractors time and effort to adapt to. As SMBs are smaller organisations, this could also have a greater relative impact.

[16] Percentages taken from the BIS "Business Population Estimates for the UK and Regions 2012" dataset.

Options to mitigate impacts

Exemption: The default mitigation is exemption. Exempting all SMBs from regulation is likely to have undesirable environmental impacts, as the size of business does not correlate to amount abstracted and hence the risks to the environment. For example irrigators can be major users at times of dry weather and low river flows posing significant risks to the environment if not regulated. While there are still a significant number of agricultural and other SMB licences left, all remaining licences will be over the $20m^3/d$ threshold. Exemption is also is likely to prevent businesses from gaining benefits from trading. Therefore, this is not a feasible mitigation for this policy.

Other mitigations which are likely to be considered in the detailed policy and regulation development include:

Specific information campaigns or user guides, training and dedicated support for smaller businesses: This mitigation could help with the administrative burden of transitioning to the new system. We will engage with SMBs as part of transition, to ensure that there are user guides, training and dedicated support services which help explain the changes, and support SMBs through the transition period. We are likely to engage with SMBs and their representatives in the development of this material, building on the engagement with SMBs throughout the development of this policy.

Partial exemption and varying requirements: This mitigation could be used to reduce the impact of meters. We could exempt SMBs from the requirement to have an upgraded meter. However, both this and exemptions from other areas such as online accounts would have disbenefits. SMBs would lose out on enhancements like soft landings on their HOFs and short-term trading from not having a meter, or more easily manageable administration of their licence or share by not having an online account.

Next steps

These potential impacts are conditional on policy decisions which are still in development. There will be more in depth assessment of these impacts in the final policy and regulation development process. It is also important to note that the intention of this reform is to modernise and develop more risk based and lower cost regulation overall. This principle will help to ensure that the impact on business, and in particular SMBs, is lower cost and proportionate.

Risks and assumptions

The modelling involved the integration of hydrological models with a bespoke abstractor behaviour model (ABM). It was therefore necessary to make a number of simplifications and these are detailed in Annex D, along with the likely impact on the results due to any changes to these assumptions. A summary of sensitivity analysis surrounding some key assumptions is set out earlier in the main body of this Impact Assessment.

Rationale and evidence that justify the level of analysis used in the IA

The ABM approach was chosen instead of traditional top down economic modelling following workshops with experts and an open tendering process with a wide range of proposals. Annex A also details the evidence gathering process that has gone on for this consultation impact assessment detailing the drivers determining the chosen methodology. This was considered appropriate due to the complex nature of the abstraction system involving both hydrology and a large number of abstractors, and the uncertainties surrounding the future. Given the significance of these reforms for the long-term and the complexity of the system to be modelled, we have invested substantially in bespoke models and extensive stakeholder interaction. Following this consultation IA, we will be examining further case studies of the Trent and Derwent, and Dee catchments. This will ensure the analysis for the final IA includes a very large catchment or basin and the power sector, a key abstractor.

Wider impacts

The wider areas which are likely to be impacted by the proposed reforms are detailed below. The scale of these impacts will be investigated through consultation.

Economic / Financial

We can expect a positive impact on competition from these proposals, as both the Current System Plus and the Water Shares options are designed to increase the amount of water traded and also facilitate new entrants to the market. As part of the modelling work we will look to identify what sectors are most affected. We can expect a potential impact on small, micro and start-up businesses, which have been considered as part of the Small and Micro Business Assessment. Wider impacts are unclear but may generally not be that significant given that there are the overall abstractor sector is not that large. The most significant benefit may be the synergies with upstream water industry reform in England, further facilitating new entrants.

Social

There is expected to be a positive impact on rural areas, as these are the areas which are most likely to abstract and trade water. Specifically, water scarce rural areas in the south-east and east of England are most likely to gain the greatest benefits from the proposals due to the barriers to trading within a catchment being removed. This will need to be taken into account when designing any trading system.

Environmental

The proposals are designed to reduce the risk that the environment suffers as a result of the abstraction of water. The quality of ecosystems should improve, as it will allow for better management of unsustainable abstractions and over-abstracted catchments. The proposals also aim to help manage and mitigate the predicted effects of climate change.

There may be some impacts on the landscape if the proposals are successful in incentivising the construction of infrastructure that supports resilience, such as reservoirs. Better management of flows may have a minor positive impact on the degree of water pollution.

The impact on the emission of Greenhouse Gases is expected to be minimal but needs to be explored further.

Summary and preferred option with description of implementation plan.

There is no preferred option in this impact assessment as the current evidence does not adequately distinguish between the two reform options and we also want to promote an open and broad consultation, including collecting views and any new evidence to further the analysis done so far. Further work is required on the evidence base including modelling of two further catchment cases studies which importantly cover the power sector. The next step is a public consultation on our proposals in December 2013. We aim to legislate early in the next Parliament. We expect that reforms will be implemented towards the early 2020s. The Welsh Government will consider its position in respect of reform, post the December 2013 consultation.

Annex A: Evidence gathering and methodology

Options development

The objective of the options development phase was "to develop a shortlist of feasible abstraction reform options to support the goals set out by the UK government in the Water White Paper". To achieve this goal the project team built on potential reforms identified whilst developing the case for change. These were gathered from internal and external workshops as well as previous engagement with experts. After compiling previous work we set up workshops, initially attended by internal Environment Agency and Environment Agency Wales (now Natural Resources Wales) staff and later attended by external water experts to review our thinking and continue to shape our ideas. To identify potential options and good practice more widely, we commissioned an analysis of different international approaches from AEA; research on the Australian water management system from Professor Mike Young, and international case studies of market formation and development from NERA Economic Consultancy:

International examples

To understand what we could learn from approaches to abstraction regulation internationally, the reform team commissioned a review which focused on countries where we could learn the most, focusing particularly on countries where changes have been made to abstraction management[17]. The most useful findings from this review were around the Australian approach to abstraction regulation which contributed significantly to the water shares option.

Australian Abstraction Regulation

To learn more about the Australian approach, we worked with Professor Mike Young from Adelaide University who published two papers. The first focused on lessons to be learned generally from abstraction reform in Australia and other leading edge international practice. [18] This recommended a reform approach which significantly informed the development of the Water Shares option. The second focused on the Gwydir catchment in Australia which shares more characteristics with catchments in England and Wales than the examples previously reviewed[19]. The latter of these two reports also helped understand the likely regulatory costs of implementing abstraction reform.

Market development and regulation

Stakeholders have raised concerns about the possible consequences of reforms which promote a more market-based approach to water abstraction management. Within this context, NERA Economic Consulting were commissioned to review the experience of transitions to market-based approaches in selected other sectors and countries. The work took the form of case studies to draw out lessons that may be relevant for water abstraction from the experiences of how other markets were both developed and regulated. These covered a wide range of experiences, such as Individual Transferable Quotas (ITQs) in New Zealand and Iceland's fisheries, airport slots trading in the United States, emissions trading in the European Union, trading of gas transport capacity rights in the United States, and measures to improve liquidity in the market for spot electricity price hedging instruments in New Zealand. The report for this project has now been published[20]. This will inform further consideration of these issues.

To ensure we could manage all the abstraction reform ideas emerging from international reviews, internal and external engagement and technical support from experts, the team developed a conceptual

[17] Review of international abstraction regulation, AEA Technology plc for Defra (2012)

[18] Towards a generic framework for the abstraction and utilisation of water in England and Wales, Professor Mike Young (2012) http://www.ucl.ac.uk/environment-institute/research/ei_fellowship_report

[19] Australian case study project: the Gwydir river catchment, Professor Mike Young and Christine Esau (2013) http://randd.defra.gov.uk Project Code WT1504

[20] A Cross-Sector and Cross-Country Review of Approaches to Transitioning to Markets, Nera (2013) http://www.nera.com/67_8142.htm

framework that linked potential individual reforms (components) to key abstraction reform functions. This made it possible to combine different components to meet the functions required of an abstraction regulation system in different ways and therefore construct a range of options.

In some instances the process of developing options consistently favoured some approaches over others. For example, review conditions were consistently favoured over time limits as the way of making changes to licences whilst balancing long term flexibility and regulatory certainty. To ensure the project gathered evidence on how abstractors respond to a broad range of regulatory approaches, it was agreed that we should test three options that span the range of tools available. Interpretation of the options modelling would then inform which elements work best under which circumstances and support decisions around reform. The reform options identified were an enhanced version of the current system, a system of 'water shares', and an administered pricing option. While the first two were considered feasible and are discussed in detail below, the final option was found to be counter to UK Government tax policy, and had significant technical issues. For these reasons it was ruled out- more detail can be found under 'Other Options Considered' – and the impacts were not modelled.

AMEC provided expert support to the technical development of the abstraction reform options including how the options should be represented and differentiated between in the modelling work. This involved applying agreed rules to define the licence conditions to transition into the model as well as translating the conceptualisation of the options into model inputs.

Options assessment

Developing an evidence strategy to assess the impacts of reform options was a major challenge. We needed to explore how options might perform under different future scenarios of climate and socio-economic change over a reasonably long period, taking into account both the detail of particular hydrological systems, and an England and Wales overview. We also needed to capture the range of behaviours of different abstractors under different scenarios and uncertainty.

Following consideration by the Project Board and a workshop with experts, we developed a broad approach based on:

- Working with abstractors to understand how they used water and changes in water availability would impact on them;
- Developing a number of catchment case studies with different hydrological and abstractor types covering different areas of the country;
- Examining a period of 25 years soon after reform implementation up to 2050. This is the period for which we had reasonably detailed future climate and socio-economic scenarios; and
- Aggregating up from catchment case studies to England and Wales based on an understanding of the key factors affecting the impacts of options in catchments.

Box 10: Workshops

There were 3 phases of engagement with abstractors for the Risk Solutions Project: sector workshops, catchment case study workshops with local abstractors, and a final phase of multi-sector workshops.
The purpose of the first phase was to understand how potential changes might affect different abstracting sectors, understanding how they currently use water and how this might change with future scarcity, and how they might respond to water markets and changes to licensing systems.
The second phase involved workshops with abstractors in the seven original case study catchments which introduced the different potential reform options, explored how policy reform might affect abstractors and how they might operate their abstraction in response both as individuals and working together.
The final phase involved four multi-sector workshops which allowed stakeholders an opportunity to influence the reform options before they were finalised for public consultation and to help the design of the consultation by testing the new multi-media ways of explaining the options.

With this broad approach, we went out to tender following an extensive information exercise to facilitate the development of consortia covering the range of expertise and ensure we got the best possible proposal for detailed evidence approaches.

As a result, we selected a consortium led by Risk Solutions which involved hydrological, economic, social and agent based modelling expertise. This project used an integrated hydrological and behavioural modelling approach to develop catchment case studies. The modelling to achieve this was carried out between February 2012 and September 2013 by a consortium comprising Risk Solutions, HR Wallingford, London Economics, Wilson Sherriff and Vivid Economics. AMEC worked with the Environment Agency to represent future abstraction licences and regulatory conditions under the reform options and provided support troubleshooting early model outputs. Additional expertise was provided by Mott Macdonald, ADAS, Cranfield University, Simon Less Consulting, The Centre for Ecology and Hydrology, The British Geological Survey and Blackwell Water Consultancy.

The model examined how well the options performed between 2025 and 2050 in terms of producing economic value and protecting the environment. Both the process of building the model (thinking through how each option should be represented in the model and how the various actors may respond) and examination of results emerging from the modelling, informed the design of the options.

During the evidence gathering, the ARAG steering group was involved in the evidence process, our core model was subject to scrutiny from a peer review panel and informed by workshops with local and sectoral stakeholders (see Box 10).

Option assessment also drew upon work by external consultants URS to understand the administrative costs of the different options; and top down economic modelling by Vivid Economics to provide an additional perspective on potential option benefits:

Administrative Costs

The Environment Agency commissioned URS to develop a spreadsheet tool to allow for flexible analysis of the administrative costs and costs to abstractors from the reform options.

The needs of each option were assessed to understand the actions and systems would be required to run it. Data on how much each of these actions and systems would cost was determined by considering increases or decreases in these costs gathered from a variety of sources, including market quotations from experts, the 2012 published accounts of the Environment Agency and experience of Environment Agency and Natural Resources Wales staff of operating the current abstraction regulation system. As this work was undertaken before 1 April 2013, references to Environment Agency include information held by Environment Agency Wales, which now forms part of Natural Resources Wales.

Top-down modelling

The model is a set of calculations and code in excel which can compare a trading policy option with no trading, considering a variety of water availability and demand scenarios. This model provides a top down approach which looks nationally and further detail can be found in Annex E.

Annex B: Detailed descriptions of options considered

Option 0 - Do nothing/Current system

Summary

The current system uses daily and annual abstraction limits and hands off flows to control abstraction, maintain environmental protection and protect the rights of downstream abstractors. Water trading is possible but uncommon and not dynamic enough to meet short term changes in demand. Most licences have no end date and can be varied if losses are compensated for in many cases. Charges are set to recover management costs and are not designed to react to water availability.

Linking Abstraction to water availability

As water has become scarcer, licences have been issued with progressively more restrictive conditions such as hands off flows. These are specified river flows or levels at which abstraction must stop. Around a quarter of licences, generally those issued more recently, include conditions which crudely link the amount of water that can be taken to water availability.

Some licences are restricted to winter or summer use only. Winter use licences are generally used to give access to winter high flows to fill reservoirs, while summer licences generally provide access to low flows for irrigation.

Trading water within catchments

Abstraction trading is possible but not straightforward or quick. Each individual trade is subject to 3 month approval procedures by the regulator and abstractors have to find willing trading partners independently. Short term trades are generally not feasible under standard procedures due to the slowness of the system. Trading is currently rare.

Making licence changes

Licences are generally changed if they are unsustainable. Demonstrating that a licence is unsustainable (removing more water than the environment is able to cope with) requires investigation. If required, permanent licences can be amended voluntarily under section 51 of the Water Resources Act (1991) or compulsorily under section 52, with compensation paid in some cases for resulting losses. Compensation is funded by the Environmental Improvement Unit Charge (EIUC), a tax on abstractors. Licence changes cannot be made until the full compensation amount has been collected. To keep the burden on abstractors down, this has to be collected over a number of years, and therefore licence changes can take years to fund.

New licences and licence variations have been time limited since 2001. These typically require renewal after 12 years. At the end of the time limit there is a presumption that the licence will be renewed unless the abstraction is damaging the environment, the abstractor no longer has a reasonable need for the water or is not using the water efficiently. Licences granted before 2001 are unlikely to be time limited and therefore not subject to the renewal process.

Administrative approach

Regulatory tools

The administration of this system is based on paper licences. Abstractors are informed of changes to their HOFs by phone call, text or letter. There are annual and daily limits on the volume which can be abstracted.

Charging

In option 0, abstractors are charged for the size of volume allowed by their licence, with the exception of spray irrigators who can opt to use a two part tariff that includes a volumetric component. Generally the fixed price of abstraction is low (significantly below the value of the water to the abstractor). Abstraction charges vary according to the season an abstractor is permitted to operate in, whether they abstract from a supported source and how consumptive they are (assessed using standard estimates of the consumptiveness of different sectors).

Regulatory threshold

All of the options apply to all abstractors wishing to take more than $20m^3$ per day.

Application to different catchments

Under this option, the use of regulatory tools varies at the margins across England and Wales according to local requirements and the different characteristics of catchments but there is no systematic approach to variation.

Option 1: Current system plus

Summary

The current system plus option aims to refine the current system to make it more flexible and capable of supporting abstractors as they adapt to the impacts of climate change. This option uses the current annual and daily volumetric abstraction controls, and hands off flow conditions from the current system. However, it aims to refine these tools to improve the link between water availability and abstraction including removing seasonal restrictions. All licences would be permanent but subject to transparent and risk based catchment reviews to protect the environment. It also makes it easier for abstractors to trade water. In line with the other reform option, the more sophisticated aspects of this would only be used in 'enhanced' catchments where water was scarcer.

Linking abstraction to water availability

Allowed abstraction would be linked to water availability more closely by:

- Replacing seasonal conditions with flow based conditions allowing, for instance, surface water abstractors who previously had winter licences access to high flows at all times of the year;
- Allowing any surface water abstractor to take additional water at the highest flows;
- Enhancing hands off flow conditions that apply to surface water abstractors so that abstraction controls are more gradually imposed;
- Introducing a regulatory minimum level at very low flows so that all abstraction is gradually restricted as flow levels approach this level with no abstraction being allowed when flows are lower than this level; and
- Allowing total licensed abstraction from groundwater to respond to long term changes in groundwater recharge by varying total groundwater abstraction from an aquifer, and spreading this change across relevant abstractors, in response to change in long term average patterns of recharge.

Trading water within catchments

Low risk water trades would be pre-approved so some trades would be processed almost immediately. Due to the limitations of the current water accounting system, the majority of trades that could be pre-approved would be low risk temporary trades. From surface water these would typically involve abstractors selling to abstractors downstream. In groundwater these would typically involve trades that move abstraction away from sensitive receptors, such as wetlands, to lower risk locations. The system

would inform all abstractors which trades were pre-approved to facilitate trading. A system would be introduced to make it easier for abstractors who want to buy or sell water to get in contact. At present, this is envisaged as a trading platform- see the section on system requirements below.

Making licence changes

All abstraction licences would have the same status rather than some being permanent and others time-limited. None would be time limited but the regulator would be able to change abstraction conditions if published environmental conditions are breached due to current abstraction conditions. Abstractors would be given notice of any such changes. Where changes are made and abstractors are given appropriate notice, abstractors would not be compensated for changes to the conditions that determine how much they can abstract. Improving the link between water availability and abstraction should reduce the likelihood of breaching environmental conditions. The regulator would maintain the right to intervene at any time should abstraction cause serious environmental damage. For modelling purposes, we have assumed that reviews take 6 years to decide on required action from being triggered and 6 years notice is given to abstractors before changes are implemented, effectively 12 year period from identification of a risk of change being needed to implementation.

Administrative approach

Regulatory tools

Under option 1 regulatory tools are split into three main elements. These are:

- Site-specific permits
- Catchment abstraction rules
- Water Account

Site specific permits are a prerequisite for abstraction and include local conditions that apply to abstraction, for example, the requirement to have a certain type of fish screen (to prevent fish from getting into the water being abstracted) on an abstraction point. They also detail the maximum daily abstraction limit possible from that site. These permits ensure that local sensitivities are not overlooked and allow conditions to be tailored to local requirements.

Catchment abstraction rules documents include conditions specific to the catchment, such as trading rules, standard hands off flow conditions and review conditions. Detailing the rules in one place allows them to be applied transparently and consistently. It also makes trading easier and clarifies environmental requirements.

The water account details how much each abstractor can abstract over a set period, for example, over one year. Separating the periodic abstraction constraint from local conditions and catchment conditions enables water to be traded quicker and more simply.

Charging

Charging would be based on a combination of the size of the licence and actual use, and charges would more accurately reflect both how much water is returned to the environment (consumptiveness) and how reliable an abstraction licence is.

Regulatory threshold

All of the options apply to all abstractors wishing to take more than 20m^3 per day.

Application to different catchments

Where there are competing demands for water between abstractors and water ecosystems are sensitive, there will be a greater need to facilitate trading and regulate flows to protect the environment, both of which requires a more sophisticated and costly approach to abstraction regulation. This cannot be justified where there is no water scarcity. To reflect this, we have split the reform option into universal components which will have to be in place regardless of the type of catchment, and enhanced

components, which will only be put in place where there are likely to be economic and/or environmental benefits. Hence some catchments will only have basic components whereas others will have enhanced components. The main extra components in enhanced catchments are:

- Abstractors have access to additional high flow water;
- Hands off flows and the regulatory minimum level controls on abstraction are gradually implemented rather than being crude on/off mechanisms in basic catchments; and
- Pre-approval rules are developed to facilitate trading.

The first two of these components are implemented in all enhanced catchments, but pre-approval rules are only developed in catchments where there is a demand for trading. In order to allow these enhanced components to function, abstractors in these catchments may be required to have smart meters compatible with Environment Agency and Natural Resources Wales telemetry systems.

Over time, environmental conditions or levels of demand for trading may change, and decisions can be made to introduce enhanced components to catchments. For modelling purposes, catchments have been split into five groups; those only requiring the basic (universal) components over 25 years, those requiring either the environmental enhancements or all the enhanced components for the full 25 years and those which introduce either environmental enhancements or fully enhanced components after 12 years. This classification is driven by levels of water scarcity under different climate change scenarios and estimated benefits from trading compared to the costs of introducing enhanced components.

Option 2: Water shares

Summary

The water shares option centrally embeds the principle that abstractors have a share in the available water resource rather than an absolute allowance whatever the water resources available. For a particular period, assumed to be a fortnight for surface water abstractors in the modelling, abstractors receive a water allocation based on water availability and depending on the reliability and size of their share in a particular resource (see Box 11). This creates the potential to implement a more systematic approach to accounting and managing water in rivers to reflect the variability in their flows and facilitate shorter-term and more types of trading. Because groundwater levels are slower to respond to changes in availability annual allocations are issued to groundwater abstractors that only change slowly in response to long term changes in groundwater recharge.

This system includes many of the changes proposed in the current system plus, for example:

- Linking abstraction to water availability by moving from seasonal to availability-based conditions;
- separating and simplifying licence conditions;
- introducing usage charging more widely; and
- introducing a more consistent way of changing abstraction conditions.

Box 11: Shares

A share is a right to a proportion of the water available in the catchment. The actual volume of water is defined by an allocation in a given period, which sets out what that proportion allows you to abstract during that period. An abstractor may own shares equivalent to 10% of the water available in that catchment. That 10% could provide 10,000m3 in a wet period, but the allocation may be shrunk to 8,000m3 or 6,000m3 during a dry period where flows have dropped.

Allocations define how much water an abstractor can use during a fixed period of time and are uninterruptible. For the purposes of modelling the options, we have trialled fortnightly allocations. However we are aware that this may not be the right duration and that the appropriate duration may vary in different catchments

Shares would be grouped by reliability. For example, more reliable shares allow abstraction at both lower and higher flows and less reliable shares allow abstraction only at higher flows. These groups of shares may allow abstractors to tailor their portfolio of shares so they can abstract at different flows as required

Shares would be initially allocated based on previous water usage. The exact details of this process are to be finalised, but will comply with the transition principles set out in the 'Policy Objective' section.

The approach to groundwater is the same under this option and option 1 aiming to facilitate pre-approved low risk trades and to allow total abstraction from an aquifer to adapt to long term changes in recharge.

Linking abstraction to water availability

By varying allocations, abstractors can take more when more is available and less when less is available. In this system, because the volume of water that can be abstracted is linked to the volume available shares would not be modified. Instead, fortnightly allocations will allow for responsive reductions or increases in abstraction to meet flows and environmental conditions. In water shares, the restrictions on maximum daily allowances can be relaxed as the allocation system provides extra control over abstraction levels during allocation periods. For the purposes of modelling, it has been assumed that restrictions on daily abstraction are twice the level of current system and current system plus.

Trading Water within catchments

Under this option it will be possible to pre-approve trades up stream as well as downstream due to improved water accounting. It will also be possible to facilitate short-term trading during the period of allocation. So a wider range of trades will be possible with lower transaction costs than with the current system or current system plus. Because the long term right to a proportion of water is separated from the short term right to abstract a specific volume of water, abstractors can make short term trades by trading in allocations, or by transferring water through 'put and take' trading (putting water into a river from a reservoir or other storage mechanism to be taken out further downstream) without impacting their long term entitlements. There will then be a market in both short-term allocations and in long-term shares. This will be facilitated by a system, such as a trading platform, in the same way as Option 1.

Making changes to licences

This will happen through a review system in a very similar way to the one in Option 1. However, changes would be made to the rules for setting allocations rather than to the number of shares held by abstractors. As there is a stronger linkage between flows and abstraction in this option, changes should be required less often than under current system plus.

Administrative approach

Regulatory tools

Under option 2, water shares, regulatory tools are split into the same three main elements as option 1. These are:

- Site-specific permits
- Catchment abstraction rules
- Water Account

Water accounts would include periodic allocations and shares. Catchment rules would set out how allocations are determined.

Charging

Charging would be based on a combination of the size of the licence and actual use, and charges would more accurately reflect both how much water is returned to the environment (consumptiveness) and how reliable an abstraction licence is in a similar way to option 1

Regulatory threshold

All of the options apply to all abstractors wishing to take more than 20m^3 per day.

Application to different catchments

As with option 1, water shares can be implemented in a more or less sophisticated way depending on demand for trading and environmental sensitivity of catchments. In actual fact there are a wide range of potential designs in terms of, for instance, the periods for allocation and the pre-approval of different

types of trades. For the impact assessment, we have assumed two versions as with option 1, basic and enhanced. In the enhanced version:

- Allocations are more closely linked to flows; and
- Pre-approved trading rules are developed.

The first of these components are implemented in all enhanced catchments, but pre-approval rules are only developed in catchments where there is a demand for trading.

As with option 1, in order to allow these enhanced components to function, abstractors in these catchments may be required to have smart meters compatible with Environment Agency and Natural Resources Wales telemetry systems.

Over time, environmental conditions or demand for trading may change and as with option 1, decisions can be made to introduced enhanced components to catchments. The same approach to classification of catchments has been taken as option 1.

Transition

How the transition to a new system is managed is a key area of importance for implementing a new abstraction management system. The transition principles, set out in the Policy Objective section, will be consistent across the reform options. Various factors will need to be taken into account before we change existing licences to move them into a new system. These include:

Proportionate implementation

As discussed above, the reform options can be implemented in a basic or enhanced version depending on the demand for trading and the environmental sensitivity of catchments. At transition, an initial assessment will be made for each catchment as to what version of the chosen reform option is appropriate and will provide most benefits given the costs.

Available water

Because abstraction reform aims to increase the proportion of licensed water that can be used through facilitating trading, it is critical that only the water that is genuinely available above environmental limits is allocated in the reformed system. If more water was allocated initially than was available this could lead to environmental deterioration and breach our obligations under the Water Framework Directive. This means that where catchments are over licensed it will not be possible to transfer full licensed volumes into the new system. For the purposes of the impact assessment, we have assumed in the catchments enhanced to facilitate trading that abstractors will receive an amount based on recent average use, generally assessed over the last 6 years, plus 20 per cent of their licensed amount capped by licence volume. This will be considered and finalised during the policy development period post-consultation.

Previous licence conditions

The UK Government has committed to taking into account previous abstraction licences as well as water usage when moving to a new system. The reliability of access to water in the reform options has been set to be comparable to the reliability of current licences.

Compensation

As per the transition principles, we do not intend to fund compensation for any losses individual abstractors incur in the change to a new system. However, losses are unlikely in most cases as we are seeking to provide existing licence holders with volumes very similar to what they currently use with similar reliability.

System requirements

Online accounts and catchment conditions

In option 0, abstraction licences are written documents. Under the two reform options, paper licences would be replaced with an electronic water account that would track licensed quantities or shares and allocations, and individual conditions such as HoFs, online.

Historic abstraction conditions, such as the basis for hands off flows, would be standardised and detailed in a set of catchment abstraction rules. Local permits would hold any site-specific requirements and would be a prerequisite for any regulated abstraction.

Metering

Currently there is no legal requirement to have accredited meters on abstractions. However, accredited smart meters may be essential or highly desirable in the reformed system. In option 0, abstractors have to record meter readings frequently. For those abstractors with a two-part tariff for spray irrigation, taking a daily meter reading is part of their charging agreement[21]. In Option 1, catchments using the enhanced tools will require frequent recording and reporting of abstraction data. In option 2, the two-weekly allocation and trading period which we are currently considering would require abstractors to record or report their readings every two weeks. The level of reporting required is likely to be proportionate to the size of abstraction and potential risk. For the impact assessment, we are assuming that in all enhanced catchments abstractors would have to have smart meters linked to telemetry systems.

Trading platforms

For both reform options, the modelling assumes that the Environment Agency and Natural Resources Wales provide a trading platform, to make it easier for trading to happen. The platform would act as a central market place for abstractors in England and Wales to inform them of what trades are pre-approved, allow them to link to other abstractors and register their trades within their catchment.

It is also assumed that private sector brokers would emerge to facilitate bilateral and multilateral trading. Estimates of likely broking charges have been made of 3% of the value of trades for sellers and 1.5% for buyers. These are based on market rates for comparable trading markets and experience in Australia.

[21] Top tips for complying with your water abstraction licence, Environment Agency (2011) http://www.environment-agency.gov.uk/static/documents/Business/water_abstraction_Top_tips_July2011.pdf

Annex C: ARAG Stakeholder Members

John Adlam – Dove Associates

Philip Burston – Royal Society for the Protection of Birds

Andy Limbrick – Energy UK

Adam Comerford – Canal and Rivers Trust

Luke DeVial – Wessex Water

Sarah Mukherjee – Water UK

Rose Timlett/Lucy Lee – World Wildlife Fund

David Bellamy – Food and Drink Federation

Chris Brett - Inter Hydro Technology Ltd (British Hydropower Association)

Susanne Baker – EEF: The Manufacturers Association

Nicola Owen – Mineral Products Association

Derek Holliday – Country Land and Business Association

Jackie Coates – Chemical Industries Association

Debbie Stringer – Confederation of Paper Industries

Paul Hammett - National Farmers Union

David Bassett - British Trout Association

Andrew Gurney – Farmers Union Wales

Ian Brown - Welsh Water

Simon Wood – EDF Energy

Annex D: Key assumptions and simplifications

The modelling used involved integration of hydrological models (complicated systems in their own right) with a bespoke abstractor behaviour model (ABM). Catchments are generally large areas (from 1000 to over 8000km^2), with a large number of abstractors.

The ABM has been designed to capture the behaviour of a wide range of different types of abstractor, with different requirements for water and different capacities to respond effectively to changing water availability and the abstraction reforms. New agents will arrive in the catchments and others leave prior to, and during, the modelling period. There are a large number of agents, producing a wide range of products each with a number of options for how and when they may respond to the various drivers of change. It was necessary to make a number of simplying assumptions which are detailed below.

Hydrological modelling

Groundwater modelling

The simplified approach to groundwater modelling in the hydrological models means that:

- There is only one estimate of the groundwater level across each Ground Water Management Unit, which generally covers an area greater than 50 km^2.
- Fluctuations in groundwater levels will not be fully represented across the Groundwater Management Units

Water levels in aquifers tend to change more slowly than flows in rivers. The rate of the water level change in the aquifers for each Groundwater Management Unit is unlikely to be accurately represented. Depending on local conditions groundwater abstractors may be able to abstract more or less water than they would be able to in practice owing to the coarseness of the groundwater model.

Sensitivity around environmental requirements

The quantity of water reserved for the environment in the catchment models (the no go below flow limit) is based on a key requirement of the Water Framework Directive to prevent deterioration of the ecological status of the environment. The Environmental Flow Indicator (EFI) is the threshold used to indicate where flows are sufficient to support the environment. Where current actual flow is above the EFI, this sets the limit on available water for more abstraction in the modelling. Where current flows are below the EFI, abstraction is prevented from increasing further.

For the purposes of modelling it is assumed that to prevent deterioration, the quantity of water reserved for the environment in 2025 is maintained for the entire modelling period to 2050. This is a simplification of a more complex process. In reality the EFI could be adjusted as specific evidence on the ecological needs of catchments evolves. But more significantly, it could be adjusted in future to support habitats adaptation to the impacts of a changing climate and maintain access to water for abstraction. Whilst adjustments to the EFI would change the quantity of water for the environment (reducing this in a dryer climate), it wouldn't deteriorate the balance of the needs of the environment compared to abstraction.

It has not been possible to model precisely the future possible evolution of environmental thresholds without also modelling the complex relationship between local ecological requirements and hydrology. As result, the quantity of water reserved for the environment in the catchment models is likely to overestimate environmental requirements within the dryer climate change future scenarios.

Behavioural modelling and decision making

Characterising agents

It was of course not possible to model every agent in each catchment precisely. We could not fully represent the complexity of their production processes or accurately model the economics of their operations. Instead we made a number of simplifying assumptions. For example, we identified a series of generic products or services in each sector and assumed production was confined to these. Further

we had to impute the levels of current production of these products from estimates of the amount of water required per unit of production and the amount of water currently abstracted by each agent. We also had to impute the location and nature of agricultural businesses that may become abstractors in the future. While these are major simplifications it has provided us with a rich mixture of different type of abstractor, delivering different products or services with different requirements for water and different levels of price sensitivity providing us with a suitable test bed for the options.

Non-Public Water Supply agent decisions

We assume that non-Public Water Supply (non-PWS) agents must accept the market price for their output (i.e. they are *price takers*). That is, there is no dependency between the amount of output an agent produces and the unit price of their output (so they can increase or decrease production without affecting the price). This means, for example, that if an individual agent experiences an increase in input costs that is specific to them they cannot pass this on to their customers through an increase in prices. This would reflect the position in a very competitive market. Note however, that if there are general increases in input costs that are experienced by all non-PWS agents in a particular sector, then this will cause prices in those final product markets to rise.

PWS long term (investment) decision making

Over the modelling period to 2050, our PWS agents take decisions about how to invest in water resource management schemes in a way that is intended to broadly follow the approach that water companies in England and Wales are currently required to take in their Water Resource Management Plans (WRMPs). At a workshop with the water industry in January 2013 there was broad acceptance that this was a sensible approach given that there was no way of knowing now how companies might be required to take these decisions in future.

The main difference between our modelled approach and the approach the companies actually undertake is that the companies are required to undertake a Strategic Environmental Assessment (SEA) of options chosen for potential implementation. We do not model this process. We note however that we use company options from the feasible options list and in many cases these have already been screened for environmental impacts, though we recognise that this is not the same as a full SEA.

Also PWS investment strategies are typically focused around Water Resource Zones (WRZs), the regions within which PWS companies manage their water resources. While we model PWS decisions at the WRZ level, we need to incorporate these outcomes into our catchment level models as the latter define the principal regions in which trading of water abstraction rights can occur. WRZs generally do not correspond with catchments. We have therefore had to scale PWS abstractor responses within the WRZs to represent the overall impact in the associated catchments.

Modelling the options

Modelling trading

The trading mechanism needs to work in the necessarily complex policy scenarios involving trading across trading units in the catchment. For the current version of the model we have focussed on developing a trading mechanism that seems to work with a reasonable level of effectiveness, rather than trying to develop a mechanism that would maximise the volume (or value of trades) in real world trading. The mechanism has not been tested using economic experiments or other methods. We have assumed that the trading mechanism does not introduce any barriers to trading, other than a value for transaction costs, and in modelling the outcome of trading we have assumed that there is no collusion in the market, or any anti-competitive practices. Our view is that the mechanism is more likely to over-estimate the volume and value of trades achievable in practice than to under-estimate them.

Aggregation modelling

The basic assumption at the heart of the aggregation modelling is that the benefit of reform in each catchment across England and Wales can be estimated from the benefits calculated for each case study catchment on the basis of the amount of water abstracted and the mix of sectors present in each sector. In reality a large number of other factors will affect the level of benefits.

Top down modelling

The top down model is designed to be very simple. The most significant simplification is the lack of consideration of hydrology in the model. In water resources, spatial relationships are very important, but they also bring complexity. So for this simple model, most of the richness of hydrological and spatial relationships has had to be put aside. All trades between abstractors are allowed within single catchments in the model. This will significantly overstate the trades that would naturally be allowed in practice and therefore the benefits of reform. This modelling has not distinguished between the reform options.

Interpreting results

Simplification has been necessary as described above. However it is important to remember the aims of this work. We are not trying to accurately reproduce catchment and abstractors' behaviour, but to understand how different potential abstraction reforms will operate in practice and the impacts they might have, to inform the design of the new system. This means that, for example, detailed modelling of all aspects of the hydrogeology is not necessary, provided the main features of the system that will drive abstraction behaviours are captured.

The fundamental challenge has therefore been to ensure that the principal drivers are identified and represented appropriately within the model and that the impact of the remaining assumptions and uncertainties are explored either through uncertainty and sensitivity analysis, or when interpreting the results.

Identifying emergent behaviours

By simulating the simultaneous operations and interactions of multiple agents with the different policy options within changing climate and socio-economic conditions, the ABM is able to model complex systems behaviours that may emerge when many individual elements of a system interact together following relatively simple rules. This emergent system behaviour may lead to unanticipated impacts (both good and bad).

Simulating real-life decision making processes

In the ABM non-Public Water Sector agents are not represented as purely profit maximising, in the same way as they would be in a traditional economic model. Agents do not take decisions (such as determining their output level) in order to generate the maximum theoretically feasible level of profit. Although agents do take expected profit into account in their decisions, many agents act in a variety of 'sub-optimal' ways identified from the behavioural economics literature and through our consultations. For example:

- Agents use 'rules of thumb' to specify the range of production levels and the investment options that they will consider
- They exhibit delays in their decision making (compared to optimum timing of decisions), for example in the timing of their investment decisions.
- Some agents imitate their peers rather than calculating their own optimum strategies
- *Satisficing behaviour* (i.e. targeting satisfactory profits rather than maximum profits) is reflected in the behaviour of some agents
- Agents' decision making may change depending on their recent experience.

Modelling the options

The construction of the ABM has involved an on-going dialogue between the team designing the options and the modellers. This has served two purposes:

- It has helped ensure that the key differences in the options are captured in the model – the mechanistic modelling of interactions at individual abstractor and time step level makes this possible; and

- It has imposed a level of discipline, and depth of quality, in thinking about how the options will work in practice at the individual abstractor level, that it would be hard to replicate in any other way.

Exploring findings from a range of perspectives

Different stakeholders will have different interests and will raise different questions about reform. Many of these can be explored within the model and illustrated using narratives derived from the model – this is a great benefit of this type of approach.

Annex E: Top Down Modelling Results

The model estimates the economic value generated by improving water trading in the UK, known as the 'gains from trade', to be in the order of £100 million per year (undiscounted) in dry years. Dry years occur with a frequency of around one year in four or five. The gains from trade are lower in normal or wet years.

These gains from trade arise solely from exchanges of water between abstractors and are small relative in the value of water in use, in the order of less than 1 per cent of the value of water in use. This is because the amounts of water changing hands are small, again less than 1 per cent of total abstracted volumes. The explanation for these low figures is that only abstracters that place low value on water are willing to sell their rights, although this result depends on the assumptions made about relative values of water.

Public water supply-demand balance investments can generate additional value, enabling additional water to be sold to other abstractors. The estimates of the benefits from these investments suggest that they could be an order of magnitude higher than the basic gains from trade. These figures indicate that, in some places, it may be desirable to build new infrastructure as demand increases and as a means of adapting to climate change.

Future demand and climate are uncertain. Circumstances in which the gains from trade are largest, demand growth and a dry climate, lead to gains about double the central estimate. The opposite circumstances lead to estimates about half the central estimate.

The model shows that at the values of water assumed for various types of user, public water supply is the principal buyer of water from other abstractors. The estimated gains from trade are sensitive to the assumed values of water for the various users, especially for public water supply. The estimates of the value of water in the literature are few and wide ranging, and the values for water used in the model are highly uncertain.

The other main limitations include:

- the limitations of the model structure that assumed that all water can be traded by all parties in the model, without geographical restriction, across a catchment, but without inter-catchment interactions. The first overstates of the number of permitted trades and gains from trade, and the second may under- or over-state trades;
- the absence of data on volumes and costs for catchment-specific public water supply investment options, such as reservoirs, and non-public water supply investments, such as on-farm storage;
- the quality of the abstraction licensing data; and the need to use supply options from only four catchments and apply them to all of England and Wales.

Annex F: Quality assurance of the model results

The process of quality assurance has been on-going throughout model development and testing.

However, the factors that drive the results are complex, with many possible interactions and pathways being possible. All of these require careful checking. There is no simple subset of drivers that explain the results at the aggregated level. Instead, it appears to be the specific circumstances of the individual catchments and its agents that provide the explanation in many cases. This means that in order to ensure that all aspects of the quality assurance process are completed, it will be necessary to undertake a fuller range of sensitivity analyses than has currently been completed.

Work is therefore still on-going, as the impact of varying input parameters or elements of the modelling is explored, and the results carefully examined at agent, catchment and aggregation level to see whether:

- the various simplifications in the model (around agents, behaviours, and the options) are interacting together in a sensible way;
- the emergent behaviour that the model produces are plausible;
- any unrealistic results have a significant impact on the results and therefore must be changed.

To support this process our researchers have developed a number of tools that help focus model checking activities by, for instance, identifying agents that have a particularly significant impact on the results. An example of a set of agents that presented a particular challenge is non-profit-maximising agents such as canal operators. Methods of representing these agents more realistically in the modelling have been developed and implemented.

A number of sensitivity analyses have been carried out, generally on a small number of scenario combinations. A long list of potential sensitivities was identified with the help of project board members and the peer reviewers. A final list of sensitivity runs was then prioritised, to focus on investigating the limitations of the modelling and to understand their potential impact on the emerging results for this initial impact assessment. This included the impact of explicitly modelling behaviours such as social interactions in the model – as this is a key feature of the agent based approach, which differentiates it from many, more traditional top down approaches.

Sensitivity Analysis

The results of a number of sensitivity tests carried out to-date are described below.

Economic Growth Rates

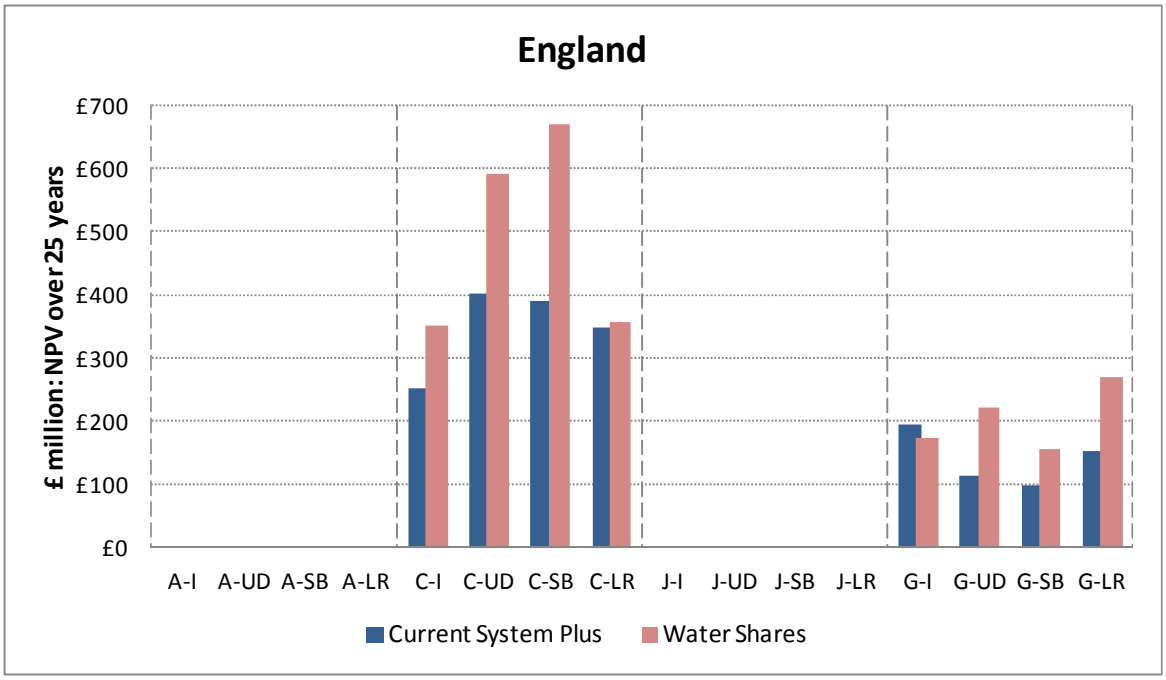
The absolute level of the benefit is sensitive to assumptions made about the maximum levels of growth that agents can achieve. Growth is a function in the model of decisions made by agents (which in turn are influenced by a wide range of factors including estimates of product prices under each of the socio-economic scenarios). However, constraints on growth such as physical or funding constraints are not explicitly included in the model. To account for this the model assumes that no individual agent can grow more than 3% a year (year on year, not accounting for inflation). Most of the agents grow at a rate below this, and many face negative growth, hence the 3% growth doesn't get applied very often. While 3% may be appropriate at sector level, it doesn't reflect the ability for individual agents to grow more rapidly than this. Also agent growth at higher rates may act as a surrogate for new agents entering the market. For these reasons we investigated the sensitivity of increasing the maximum rate to 10% per year.

Figure 3 and **Figure 4** show the illustrative results of this analysis for England and Wales, respectively, shown as new levels of overall absolute Net Present Value. While there is generally a small increase in the overall benefit of reform in England under Current System Plus there are some scenarios where the benefit is reduced slightly (Scenarios are represented on the horizontal axis; the notation indicates climate scenario followed (after a hyphen) by socio-economic scenario). This is usually caused by growing agents making decisions about water which then result in changes in PWS investment sequencing. These changes tend to involve moving large value investments forwards or backwards by one or two years, and introduce a certain amount of noise to the NPV calculations. However the

additional flexibility of the system under Water Shares is observed to produce significant extra benefits in all scenarios considered so far, with average 25-year NPVs benefits under Water Shares almost doubling. Overall Water Shares becomes the more attractive policy in almost all the scenarios.

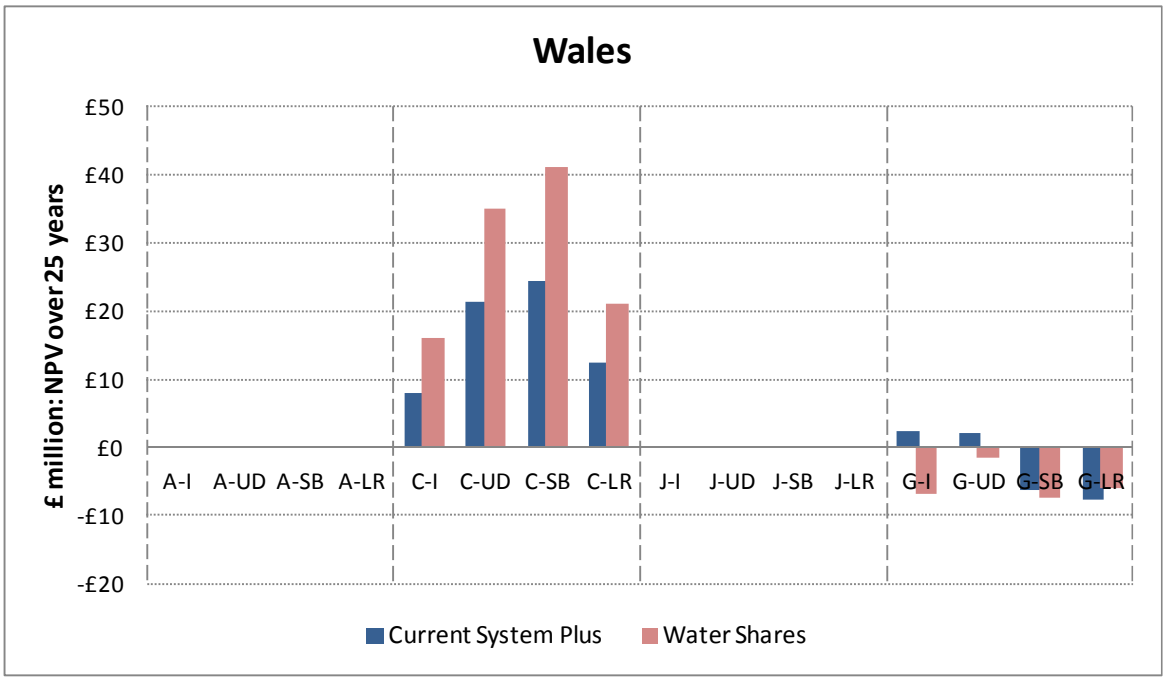
While there is a similar story in Wales, the case for reform still remains marginal with some scenarios continuing to show disbenefits, albeit reduced somewhat compared to the initial analysis.[22]

Figure 3: Illustrative Impact of increased growth rates on reform benefits for England



Key : Letter before hyphen is climate change scenario: A involves less significant change in climate (and hence flows); C, G or J involve greater changes in climate at different locations. **Letters after hyphen are socio-economic scenarios**: Innovation (I); Uncontrolled demand (UD); Sustainable Behaviour (SB); Local Resilience (LR) (**See page 25 for more on the scenarios**)

Figure 4: Illustrative Impact of increased growth rates on reform benefits for Wales



Key to x-axis notation in Figures 3 and 4: Letter before hyphen is climate change scenario: A involves less significant change in climate (and hence flows); C, G or J involve greater changes in climate at different locations. **Letters after hyphen**

[22] With so many catchments classified as basic in Wales (e.g. low water scarcity) there are fewer opportunities for benefits to accrue from the improved economics and therefore costs still outweigh benefits in many scenarios

It is difficult to decide what an appropriate 'base case' value should be for this parameter. This will be subject this to more extensive sensitivity testing and discuss further with experts and the peer reviewers. As with all analysis in this impact assessment, views are welcomed as part of consultation (please see the consultation document for particular questions on the analysis).

Agent Behaviours

One of the principal (and innovative) elements of the modelling approach adopted in this project has been the consideration of abstractor behaviour. Agents are modelled as making decisions in order to achieve profitability, but the level to which they act with complete economic rationality can be varied.

Thus while agents do take expected profit into account when they make decisions about production levels and future investment and adaptation options, agents can be modelled as acting in a number of sub-optimal ways, such as:

1. Only considering a sub-set of production levels and the investment options
2. Accepting satisfactory profits, and being reluctant to change until overall profitability is threatened
3. Imitating peers rather than calculating their own optimum strategies
4. Making decision based on their most recent experience rather than with a longer term perspective, and
5. Being unwilling to sell unused water even if there was economic advantage to do so.

In the initial model runs it was assumed that agents are fully rational in their willingness to engage in trading and would:

- sell unused water, and
- be prepared to reduce production if the selling the water was more economically advantageous.

However, assumptions in areas 1-4 were adopted, that will generally lead to many agents not trying to economically optimise their decision making. Instead, most agents will only consider changing behaviour if they are starting to be loss making ('loss aversion'); otherwise they continue doing what they are currently doing, but are influenced to consider change if other (more innovative) agents are being successful with a different product or strategy.

This sensitivity test explored the impact of assuming that the majority of agents are more autonomous and economically rational, and are prepared to more regularly consider the most profitable product selection and production volumes. In reality, agents are likely to learn over time - it should be noted that the modelling assumes does not fully factor for this. If they are followers, the choices are biased toward the choices others have made. The behavioural patterns do not change, but the choices made by innovative agents do change over time, and so actual agent behaviour does vary over time.

An increase in the level of economic rationality assumed has limited effects on the NPVs under Current System Plus in England. However, there is significant increased economic benefit under Water Shares, and this reform option becomes the more attractive option in the majority of scenarios considered so far (see Figure 5). There is a similar effect in Wales, although the case for reform still remains marginal (Figure 6).

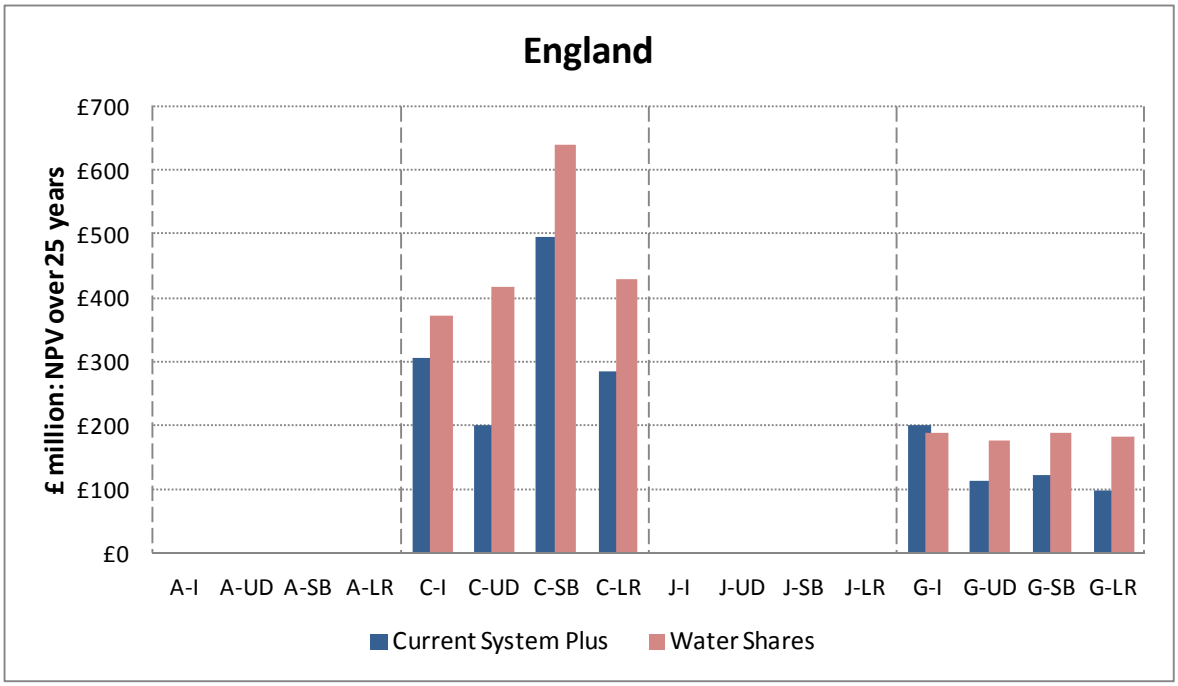


Figure 5: Impact of increased economic rationality on reform benefits for England

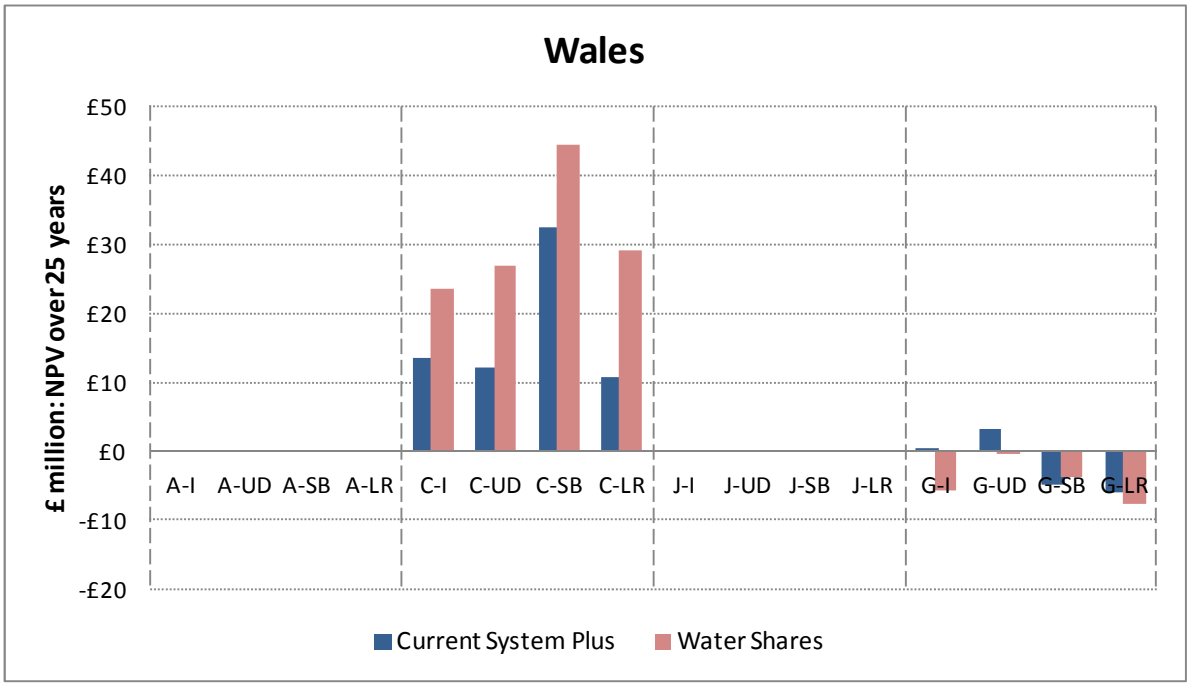


Figure 6: Impact of increased economic rationality on reform benefits for Wales

Key to x-axis notation in Figures 5 and 6: Letter before hyphen is climate change scenario: A involves less significant change in climate (and hence flows); C, G or J involve greater changes in climate at different locations. **Letters after hyphen are socio-economic scenarios**: Innovation (I); Uncontrolled demand (UD); Sustainable Behaviour (SB); Local Resilience (LR) (**See page 25 for more on the scenarios**)

Trading Inertia

At present the modelling includes some assumptions about how easy trading will be under each policy option.

Short-term trading (over a period of a few weeks) is only considered to be possible under Water Shares. Further, selling/ leasing of shares under Water Shares is considered to be easier to arrange and facilitate than selling/leasing of licences under Current System Plus. However, the existence of pre-established low-risk trade rules under both reform policies is considered to be far more effective at enabling trading than under Current System.

Without reform, trading is considered to be quite difficult to arrange, with agents needing to overcome considerable inertia in order to find others willing to trade licences and achieving agreement from the EA or NRW for the trade to occur.

These differences are included in the modelling by:

1. Limiting possible trading partners under Current System to those in the same sector, or within 50km of each other
2. Inserting a fixed economic cost that each trading agent needs to overcome (which varies between policies). This effectively increasing the price a seller is willing to accept, and reduces the price a buyer is willing to pay, and in turn reduces the likelihood of successful matches being made in the market. The inertia values selected at present are intended to represent the legal and management costs associated with arranging trades, but also the inertial costs associated with the perception of additional difficulty. They are smallest for Water Shares, and largest for Current System.

In general these inertial costs suppress the number of small volume trades since the costs are more material compared to the absolute value of the water being traded. Further work is still needed to explore the models' sensitivity to these assumptions.

Aggregation scaling

Aggregated results for England and Wales are compiled by scaling up the costs and benefits observed in the four modelled catchments. The final outputs are sensitive to a number of assumptions in the scaling process.

In particular:

1. Annual average costs and benefits from the four catchment models are combined (using a weighted average approach) to generate figures that are considered representative of each of the 116 real catchments.
2. Each catchment is assumed to have the most beneficial policy applied to it correctly and in a timely fashion by the Environment Agency and Natural Resources Wales

The sensitivity of the aggregation results to variations in the annual average costs and benefits has been explored by varying the two components with the largest uncertainty:

- Annual adaptation costs[23]
- Production gross margin[24]

Figure 7 shows the effect of varying the calculated adaptation costs by ±20%. Figure 8 shows the impact of varying calculated production gross margin by ±20%. The central bars on the charts show the 25-year NPV benefit for the base case scenario. The purple boxes show the range over which these NPVs vary in response to the applied sensitivity test. Overall results are much more affected by variations in adaptation costs than gross margin, and these are generally only material in the representative high case scenario (C-Sustainable Behaviour or C-SB). This reflects the fact that when there are significant benefits arising from reform one of the largest contributions comes from being able to delay capital investment projects through improved water availability and resource management.

[23] The most significant adaptation costs are associated with PWS investment options. These are drawn from published Water Resource Management Plans, but a number of simplifications and assumptions have had to be made when considering how and when options might be selected. Further, in some instances we have had to extrapolate beyond existing WRMPs to estimate demand and supply curves and likely future options.

[24] Each agent is modelled as manufacturing/growing one or more products. Production costs are modelled as varying with production volumes. Income is derived from selling the product for the current market price. Production gross margin is the aggregated profits from all agents, which are influenced by changes in water costs, market prices and each agent's ability to access water under the various policies.

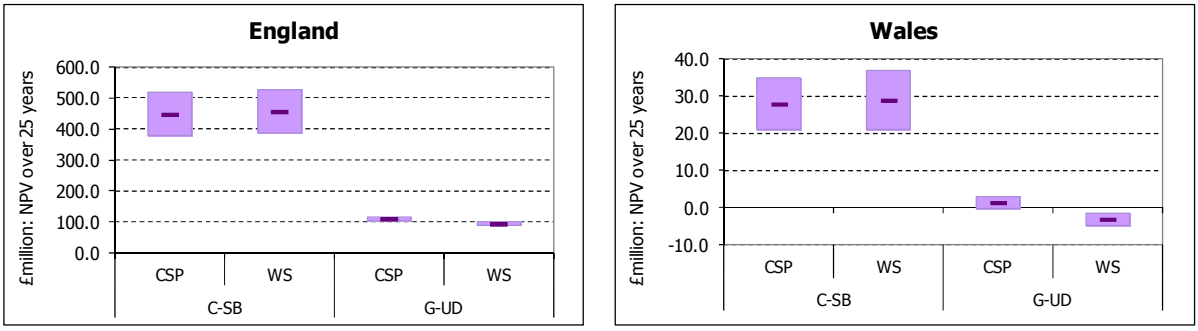


Figure 7: Impact of 20% variation in adaptation costs on reform benefits in England and Wales

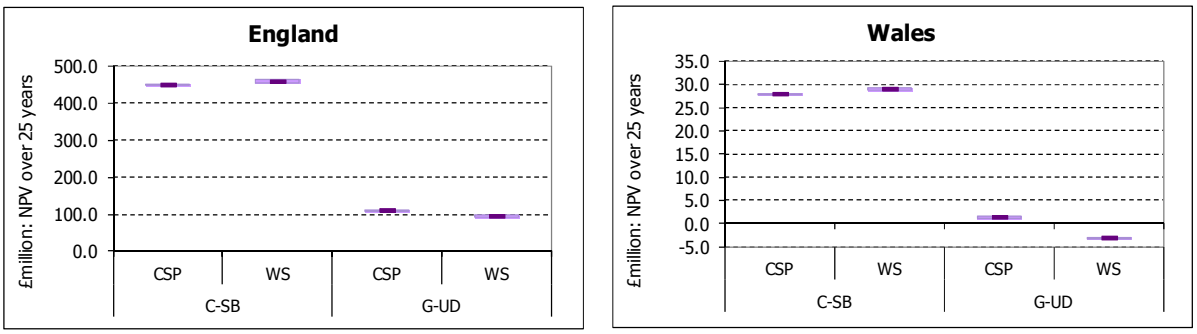


Figure 8: Impact of 20% variation in production gross margin on reform benefits in England and Wales

Aggregation sensitivity

One further limitation of the aggregation model methodology is that it assumes the regulator has perfect knowledge of whether reform will be cost beneficial in a catchment, just before the decision is taken on whether to implement Basic or Enhanced reform. In reality the wrong decision could sometimes be taken, so a catchment may see net benefits that are smaller than predicted or even net costs.

In order to test the sensitivity of this assumption the aggregation model was re-run, but allowing catchments to be classified as Enhanced even if this would result in net costs of up to and including £200k per year on average, this being the typical size of losses that are currently excluded with 'perfect' decision making. The results are summarised in Table 7 below for England (the sensitivity test makes very little difference for Wales).

Table 7: Sensitivity test results for imperfect decision making on catchment reform

Scenario and policy option	England	
	NPV £ million	Change from base NPV
C-Sustainable Behaviour - Current System Plus	438	-2%
C-Sustainable Behaviour - Water Shares	446	-2%
G-Unconstrained Demand - Current System Plus	85	-23%
G-Unconstrained Demand - Water Shares	73	-22%

Table 7 shows that the G-Unconstrained Demand scenario is quite sensitive to the assumption of perfect decision making. This is because this scenario has more catchments classified as Basic with assumed perfect knowledge of the cost-benefit case, so there is more potential for incorrectly implementing Enhanced reform to result in lower net benefits.