OFWAT

Innovation and efficiency gains from the totex and outcomes framework

KPMG LLP and Aqua Consultants LTD

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Contents

Glossary

Totex: Total Expenditure

Capex: Capital expenditure

Opex: Operational expenditure

Repex: Replacement expenditure

Botex: Base total expenditure

AMP: Asset Management Plan

PR19: 2019 Price Review

RUOE: Real Unit Operating Expenditure

EU KLEMS: EU level analysis of capital (K), labour (L), energy (E), materials (M) and service (S) inputs

Ofgem: Office of Gas and electricity Markets

RIIO: 'Revenue = Incentives+Innovation+Outputs'

RIIO T1/GD1/ED1: Transmission (T1), Gas Distribution (GD1) or Electricity Distribution (ED1)

RORE: Return on Regulated Equity

EDPCR: Electricity Distribution Price Control Review

GDPCR: Gas Distribution Price Control Review

TPCR: Transmission Price Control Review

TFP: Total factor productivity

E&W: England and Wales

GIS: Geographic information system

RGF: Rail Freight Group

ODI: Outcome Delivery Incentive

SUDS: Sustainable urban drainage systems

BIM: Building Information Modelling

FOG: Fats, oils and grease

UKWIR: UK Water Industry Research

DEFRA: Department for Environment, Food and Rural Affairs

FCO: Future Concept of Operations

NBIF: National Buried Infrastructure Facility

DSR: Demand side response

M&E: Mechanical and electrical

kWh: Kilowatt hour

PODDS: Prediction and Control of Discolouration in Distribution Systems

PMM: Permanent magnet motors

PV: Photovoltaic

FY: Financial year

CIS: Capital expenditure incentive scheme

NRE: Network-related capital expenditure

NLRE: Non-network-related capital expenditures

DNO: Distribution Network Operator

GDN: Gas Distribution Networks

SWW: Strategic wider work mechanisms

EBSM: Efficiency benefit sharing mechanism

CP: Control Period

BT: British Telecommunications

EBITDA: Earnings before interest, tax and depreciation

DWI: Drinking Water Inspectorate

WaSC: Water and Sewerage Company

WoC: Water only Company

CEGB: Central Electricity Generating Board

OFFER: Office of Electricity Regulation

OFGEM: Office of Gas and Electricity Markets

UK GAAP: UK Generally Accepted Accounting Practice

CAA: Civil Aviation Authority

BOE: Barrel of oil equivalent

CAGR: Compound Annual Growth Rate

FOB: Freight on Board

ASM: Available seat miles

WICS: Water Industry Commission for Scotland

PPP: Public-private partnership

SEPA: Scottish Environment Protection Agency

CMA: Competition and Markets Authority

OECD: Organisation for Economic Co-operation and Development

EMS: Energy, materials and services

ESA: European System of National Accounts

RCV: Regulatory Capital Value

WTW: Water Treatment Works

STW: Sewerage Treatment Works

WwTW: Wastewater Treatment Works

Important notice

This report has been prepared under a private contract dated 9th November 2017 for the Water Services Regulation Authority, Ofwat ('the Beneficiary').

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This report was completed in June 2018 but some minor updates were made to the GD figures in tables 19, 20 and 21 and for SWW in table 12 in Jan 2019 which did not affect the overall conclusions.

Executive summary

Introduction

This study was commissioned by Ofwat, the economic regulator of water and wastewater services in England and Wales, in order to examine the potential impact of the introduction of the totex and outcomes frameworks on innovation and efficiency in the water sector and to comment on how those impacts might change in AMP 7, as well as to comment on the implications of the above for the setting of regulatory efficiency targets.

Scope and objectives

Specifically the study considers two principal research questions:

1. What impact totex and outcomes changes had on efficiency in AMP 6, and what might be their potential impact on future efficiency gains in AMP 7; and

2. What might be the implications of these findings for regulatory policy and the setting of efficiency targets at PR19.

The totex approach and the introduction of incentives based around delivering outcomes for customers are a relatively recent innovation in regulated utilities. Considering their impact is, therefore, a challenging task, given limited data and multiplicity of other factors that could impact efficiency. Totex is a significant change in the treatment of cost performance and recovery, which, combined with outcomes, allows companies greater flexibility to move away from a list of specific schemes agreed by the Regulator towards an approach that allows them to consider alternatives that can deliver the same or better service performance in line with customer preferences. The shift to a totex and outcomes framework in PR14 removed a regulatory barrier to realise additional efficiencies and innovation. This is supported by the case studies provided by the water companies, which provide examples of the transmission mechanisms by which they have been able to use the totex framework to realise greater efficiencies, such as, e.g.:

- Substituting planned capital projects for alternative solutions that deliver equivalent (or better) outcomes at a lower cost;
- Initiatives aimed at reducing the need for future capital projects; and
- Pursuing more innovative technologies and delivery approaches to the same activity, resulting in lower costs.

Sources of evidence for analysis

In deriving the potential impact of the totex and outcomes framework on efficiency, this report reviews three sources of evidence:

- **Exploring and delineating performance due to Totex**: An assessment is made of the levels of cost outperformance in regulated utility networks that have introduced versions of the totex and outcomes framework. Specifically, cost outperformance is compared against regulatory allowances in the controls preceding these changes with levels of outperformance after the changes are introduced.

- **Considering examples of the impact of structural and regulatory change as cross-checks**: Examples of performance gains from other significant changes in both regulated utility sectors and other competitive sectors that demonstrate high levels of capital intensity are compared to the results of the totex performance assessment. These examples focus on the change in real unit operating expenditure (RUOE) as a measure efficiency gains and they are compared against the results of the totex outperformance analysis.
- **Assessing evidence from projects by water companies and the supply chain to inform Totex analysis:** Around 200 project examples have been provided by companies and members of the supply chain in response to a data request. These projects were requested to show the potential impact of the application of the totex and outcomes framework in practice. This project evidence was also used as a point of comparison with the evidence from the totex analysis.

This study focusses on the above sources of evidence, incorporating both top down assessment and a sample of bottom up project evidence. However, limited sources of data and multiplicity of potential other factors at play imply that it is inherently challenging to attribute specific outperformance to either totex or outcomes. There is no data available specifically on the efficiencies generated by these reforms. This means that the analysis has to consider broader data on cost performance for top down analysis and explore to what extent performance could be attributed to totex and outcomes and under what assumptions. For the bottom up analysis, the key question is to what extent identified examples can be extrapolated to all business activities and overall cost performance.

To draw out the implications for regulatory policy setting of the potential efficiency gains during AMP7, total efficiency potential for AMP7 is assumed to comprise of the sum of the following components:

- First, the frontier shift, which is associated with the on-going technological change in the economy and unrelated to the introduction of totex and outcomes framework;
- Second, the benefit and opportunity arising from the totex and outcomes framework over AMP7, which is additional to the frontier shift; and
- Third, other factors affecting performance, which can result in efficiencies as well as inefficiencies, including those under management control and external factors, the impact of which is inherently difficult to disentangle from that the impact of outcomes and totex framework.

This study seeks to isolate, to the extent possible given the data and the adopted approach, the impact from outcomes and totex from a range of other drivers (points 2 and 3 above) and to develop a range for the potential level of total factor productivity improvement during AMP 7 (point 1 above).

To undertake the assessment of TFP, this study uses data from the EU KLEMS dataset for certain sectors which exhibit similar levels of capital and labour intensity to the UK water sector and over certain business cycle periods to inform a range of potential annual efficiency change.

The work on this study began at the end of 2017 and was completed in April 2018. A data request has resulted in extensive examples of specific efficiencies and transmission mechanisms provided by the water companies. Following completion of the preliminary analysis, a workshop was held with water companies, members of the supply chain and Ofwat representatives on the 15th of March 2018, where the initial results were discussed; the industry also provided further helpful evidence and comments at a later date. The comments and evidence raised were then considered in finalising this report.

Advantages and limitations of the data and evidence considered

The approach adopted in this study seeks to make the best use of the available data and has a number of advantages resulting in insightful observations and results, notwithstanding necessary assumptions made.

The totex performance assessment evidence provides levels of real outperformance in a range of sectors (across four network price controls) against cost allowances before and after the introduction of the outcomes and totex framework. It is the only source of real world data on company cost efficiency performance in periods when price controls include outcomes and totex changes.

This has to be considered in the context of the totex and outcomes changes being relatively new reforms, which limits the amount of real observable data on cost performance. Specifically, the research seeks to examine the impact of totex and outcomes in the first and second price control periods following their introduction. There is only one price control that has been completed where similar changes have been introduced and there are no instances where a second price control period is complete. In the case of the water, electricity transmission and gas distribution companies', data is only available for a subset of the current control period. This limits ability to observe impacts over time and requires the use of forecasts to inform the assessment.

The data also focuses on a comparison with the cost allowances set by regulators. These are only as accurate as the models and approaches used, recognising that the process for forecasting costs adequately is inherently challenging. Where allowed costs are not set precisely in line with the real underlying cost functions, this can result in outperformance (or underperformance) that may not be due to real efficiency (or inefficiency).

The cost outperformance data reviewed for this assessment provides only an overall, high level picture of performance; some further detail on the drivers is provided by the companies in their annual performance reports. Whilst this study adjusts outperformance for these factors where possible, where such factors are clearly outside of management control, or where efficiency is not driven by the totex and outcomes framework, there remains a risk that the analysis does not identify or account for all the drivers of outperformance.

The examples of structural and regulatory change and their impact on cost performance can provide a cross-check to the overall efficiency ranges and set an upper bound to efficiency potential based on experience elsewhere, given that they are selected to illustrate such impacts. At the same time, it has to be recognised that the comparative examples contain important differences to the outcomes and totex regime, which might significantly impact the results. The extent to which the changes from these structural and regulatory changes (e.g. introducing competition, changes in ownership, other regulatory reforms, business separation and divestment or cost shocks) represent a similar level of paradigm shift to the introduction of totex and outcomes is open to debate.

Project evidence from companies provides important, real-world evidence of both the transmission mechanism by which the outcomes and totex frameworks drive efficiency improvement and the potential scope for benefits to arise from the framework in certain types of activities. It also provides a strong evidence base on the directional impact of these regulatory changes. At the same time, the sample size of these examples is relatively small (accounting for 3.8% of total AMP 6 spend) and the projects may not constitute a representative sample of companies' overall capital programmes. This means that extrapolating from these examples would involve making strong assumptions about the extent to which the sample is representative of companies' wider totex programmes.

Overall, the approach seeks to make the best use of the available evidence to inform the research questions, including through a variety of diverse sources of evidence, but with some limitations.

Methodology

In order to identify the level of efficiency change arising from the totex and outcomes framework and the potential for this to continue over AMP7, a multi-step approach has been adopted:

1. **Totex performance assessment: Analysis of companies current levels of outperformance on costs under totex and outcomes controls.**

The cost performance of each company was calculated using data from companies' (water and energy) and through comparison of that with companies' allowances at the relevant final determinations. This analysis is presented in section 3. Where price controls are complete, reported costs were used, but for incomplete price controls company forecasts of the overall price review performance were used, including forecasts for RIIO controls and RORE performance data for the water sector for PR19. In these cases the analysis relies on the assumption that forecasts can accurately proxy cost information.

Cost performance figures and allowances were also adjusted for factors clearly unrelated to the totex and outcomes reforms to the extent that these were identified from performance reports and quantified. There are likely to be other examples of exogenous factors either driving efficiency, or increasing costs, which cannot be easily identified.

Efficiency gains were then derived from the outperformance data. This assumed that, after adjusting the data for identified other factors, the regulatory baselines are correct; and the efficiency gains are attributable to the introduction of totex and outcomes as the main factor. This was done through two approaches:

- **Approach 1:** This approach assumed that: efficiency gains revealed during the previous price controls are fully captured in regulatory cost allowances for the next price control period; outperformance during the current price control purely reflects efficiency gains; these efficiency gains are due solely to the change in regulation; and, therefore, all outperformance observed during the price control where the totex and outcomes framework is in place reflects efficiency gains due to the introduction of the framework itself.

  This approach also assumes that all outperformance equates to efficiency, when there are likely to be a range of factors outside of companies' control that might impact on outperformance and that all efficiency is accounted for by the regulatory change. At the same time, there is no evidence to suggest the direction or scale of the impact of these other factors on efficiency and outperformance, or to suggest a bias.

- **Approach 2:** This approach assumed that: there are persistent company-specific factors that lead to a dispersion in cost performance against regulatory cost allowances across the industry; these company-specific factors persist before and after the introduction of totex and outcomes framework; efficiency gains are therefore measured as incremental gains in cost outperformance over the successive price controls; and these efficiency gains are due solely to a change in regulation.

  This approach is subject to the same issues as approach 1 in terms of challenges of identifying the difference between outperformance and efficiency, and the attribution of performance to totex and outcomes versus other factors. However, where there are factors that are persistently driving changes in outperformance and efficiency across adjacent control periods, this approach better controls for such factors than approach 1.

2. The potential for future efficiency gains under a totex control were estimated:

There is no directly observable data delineating the efficiency gains that could be expected over the second totex price control, i.e. AMP7. Therefore, the impact of the framework on the second totex price control was inferred through scenarios and hypothesis.

A range of scenarios were considered based around the two approaches outlined above, including some which assumed that any efficiency benefits arising from the first totex control would continue into the second totex control period and some which assumed that efficiency gains from the framework would decline over the second control. Following evaluation of these scenarios, two specific hypotheses were identified, which reflected each of the approaches previously identified, whilst assuming a lower scope of efficiency gains due to the framework over the second totex control period. In each scenario the impact on efficiency between each of the control periods is based on the experience in electricity distribution, which is the only sector where a similar totex and outcomes framework has been introduced over two price control periods.

The two hypotheses around the impact of the framework on on-going efficiency gains were set as follows:

- **Hypothesis 1:** There have been on-going technology improvements affecting productive efficiency in the wider economy. The on-going technology improvements were also available to the water sector but for the regulatory barriers, which have been addressed by the totex and outcomes framework. The revealed efficiency gains during the first totex control represents both a new, higher rate of on-going technology improvements and a catch-up by the industry to the level of efficiency in the wider economy (as per approach 1). Therefore, the catch-up component has to be separated from the revealed efficiency gains during the first totex control to identify the on-going shift due to the framework.
- **Hypothesis 2:** As per hypothesis 1, but efficiency gains during the first totex control are measured as incremental gains in revealed outperformance between the totex and non-totex price controls (as per approach 2).

Under each of these hypotheses the inter-quartile range was estimated to inform the high and low estimates of the range. Minimum and maximum values were excluded from the ranges estimates to eliminate outliers and cases where other factors (i.e. other than the common factor considered—Totex and outcomes) are likely to drive the results. The variance of the results was then considered and appropriate statistical tests were conducted to test the significance of the findings.

For hypothesis 1 and 2, the levels of outperformance of RIIO ED1 (the second totex and outcomes based price control in electricity distribution) were compared to DPCR4 (the last non totex and outcomes price control) and DPCR5 (the first totex and outcomes price control). The diminishing returns between these controls was then used as a proxy to infer the potential future impacts in AMP7 under hypotheses 1 and 2 and associated diminishing returns from the changes.

3. The analysis was cross-checked against examples of other efficiency events, based on RUOE, in other comparable sectors

Thirteen examples of efficiency gains arising from significant changes in different sectors and contexts were analysed (this analysis is presented in section 4). These examples were selected to represent a range of different sectors including regulated sectors and competitive sectors. The analysis focussed on considering the change in real unit operating expenditure (RUOE) as a measure of efficiency gains both before and after the change. The changes were categorised according to their nature (e.g. introducing competition, separation, regulatory reform, changes in ownership, etc) recognising, at the same time, the differences between these examples and the specific regulatory changes associated with totex and outcomes.

4. A further cross-check was performed based on company case studies that were returned via an information request

Examples of totex in practice from a variety of industry sources were collated through a formal information request that sought example projects showing innovation or efficiency gains as a result of the totex and outcomes framework. An assessment was undertaken into the potential impact of the findings on future efficiency and innovation. This analysis relied on real case studies, data and information provided by industry sources supported by judgement on the significance and replicability of innovation and efficiency in the industry. This analysis is presented in section 2.

In considering the implications for regulatory policy in setting efficiency targets for AMP 7 an analysis of total factor productivity has also been undertaken. The adopted approach to this analysis is similar to that used by a number of regulators in setting frontier shift efficiency assumptions in price controls.

Data from the EU KLEMS database of productivity and growth accounting in the European Union was used to infer range estimates for frontier shift improvement. While TFP estimates based on gross output measures could be more relevant for the purpose of this study, data availability for such a measure is limited. Therefore, this analysis was based on value added measure of output.

TFP is a cyclical variable, influenced by booms and recessions. Therefore, it is typical for productivity studies to look at average TFP growth over a full business cycle. To enhance comparability with other evidence for the water sector, the definitions used in the recent Water UK report[1] have been adopted. Due to data limitations, it is only possible to compute TFP growth for the current business cycle up to 2014. The September 2017 release of EU KLEMS only contains information from 1995 onwards and only for some countries. Therefore, TFP estimates for the first and second business cycle are based on the 2012 release.

The EU KLEMS contains data for different sectors in the economy at different levels of aggregation. The relevant sectors in the EU KLEMS dataset for the E&W water sector are identified based on the nature of the activities performed as defined by Eurostat and the capital intensity of the sector measured by the contribution of labour and capital inputs to the production process. The electricity, gas and water supply and the construction sectors are considered to be the most similar to wholesale activities in the E&W water sector.

Since retail activities include mainly support service activities and other business support activities the relevant sectors in the EU KLEMS dataset are assumed to be professional, scientific, technical, and administrative and support service activities (professional and support services) and retail trade, except of motor vehicles and motorcycles (retail trade). In terms of capital intensity, labour comprises the overwhelming majority of input costs in retailing. Therefore, the analysis also considered labour productivity trends in the two sectors above and an all-industry average labour productivity trend is also reviewed.

Finally, the analysis looked at certain countries specifically driven by the consistency with the UK capital cycle and at the extent of similarities in the regulatory regimes for the chosen sectors. While the 2012 release of the EU KLEMS database contains data from different EU countries, only Belgium (BE), France (FR), Germany (DE), Italy (IT),

[1] Frontier Economics (2017), Productivity Improvement in the Water and Sewerage Industry in England Since Privatisation

Spain (ES) and Netherlands (NL) have data of sufficient detail to carry further analyses. Therefore, the average is taken over these six countries.

In addition to reviewing TFP growth from the relevant sectors in the EU KLEMS dataset, a notional sector performing wholesale activities was constructed by applying labour and capital productivity trends from the electricity, gas and water supply sector to the average capital and labour input mix over different time periods.

Potential impact of totex and outcomes on efficiency in AMP 6 and future efficiency gains in AMP 7

The study considered evidence from the totex performance assessment described earlier and cross checked this evidence with information from other significant changes in other sectors and project evidence provided by companies. These steps are described in more detail below.

Totex performance assessment

The totex performance assessment seeks to compare and contrast levels of cost outperformance before and after the introduction of the totex and outcomes framework. Two measures of cost performance are used in this analysis:

- **Total average performance**—the percentage totex outperformance against regulatory allowed totex over the total duration of the full price control period;
- **Annual incremental performance**—total average performance but expressed as annual incremental change in cost performance, assuming an even spend profile across the duration of the price control.

To illustrate these measures imagine a company with an allowed totex of £100 that actually spent £90 over a five-year price control. This company outperformed the allowed totex by £10, and therefore the cost performance on a total average basis is 10%. That 10% total performance is equivalent to achieving 3.5% annual incremental savings sequentially for each and every year during the price control period.

Table 1 presents totex cost performance of water and energy companies over the first totex price controls for the relevant sector. PR14 figures are cost performance to date adjusted for profiling effect. DPCR5 figures are actual cost performance. RIIO-T1 and RIIO-GD1 figures are based on companies' forecasts of cost performance over the whole price control. Positive figures indicate cost outperformance.

Table 1: Cost performance during first totex controls (total average performance over the period)

Price control	Min	Lower quartile	Median	Upper quartile	Max
PR14	-7.6%	0.0%	3.5%	8.2%	18.9%
DPCR5	-6.2%	4.4%	6.6%	9.6%	15.5%
RIIO-T1	-13.1%	-0.4%	4.7%	7.2%	11.8%
RIIO-GD1	4.1%	9.7%	12.5%	15.8%	17.0%

Source: For PR14, analysis based on the estimate of the impact of wholesale cost outperformance on RoRE as reported by companies in their annual performance reports net of retail outperformance. For energy price controls: Ofgem (2015);

DPCR5 performance report 2010-2015 data table; Ofgem (2017), RIIO electricity distribution annual report 2016-17; Ofgem (2017), RIIO electricity transmission annual report 2016-17; Ofgem (2017), RIIO gas transmission annual report 2016-17; Ofgem (2014), Ofgem (2017), RIIO gas distribution annual report 2016-17

The table shows that companies across sectors have been able to outperform their cost allowances. For PR14 to date, companies have been able to outperform their wholesale cost allowances by 3.5% on a performance over the period basis at the median. The maximum outperformance is 18.9% during the first two years of the price control. For energy, gas distribution companies are projected to outperform their wholesale cost allowances by up to 17%.

The lower quartile to upper quartile range is used to derive an estimate of the potential impact on efficiency from the introduction of totex and outcomes during the first totex price control. This assumes that outperformance equates to efficiency gains. Companies' cost performance rates are adjusted for factors unrelated to totex and outcomes that have been identified and quantified. The symmetry of the selected range around the median is based on the assumption of no directional bias. The range used is wide because of the underlying dispersion of observations, which also suggests that other factors are likely to be at play; this also means that a single number estimate within the range cannot be identified with confidence. The numbers above the upper and lower quartile are excluded because outliers are likely to be driven by other factors.

The dispersion of underlying observations suggests the presence of other factors that might affect efficiency gains, which have not been identified and adjusted for earlier. In particular, the lower quartile of the range is negative. The negative figure would imply that some companies spend more and become less efficient as the result of the introduction of the totex and outcomes framework. This is unlikely to be the case and is more likely a result of other factors that have not been adjusted for. Therefore, the lower end of the estimate of potential efficiency gains that could be attributed to totex and outcomes is capped at 0%. This skews the selected range upwards compared with the underlying data.

Table 2 below provides estimated ranges of potential efficiency gains from totex and outcomes during the first totex price control under the two different approaches to measuring efficiency gains. The first approach attributes all outperformance during the totex price controls to efficiency gains due to totex and outcomes. The second approach attributes the difference in outperformance between the pre-totex and totex price controls to efficiency gains due to totex and outcomes. In addition, both approaches assume the accuracy of regulatory cost models and that similar impacts from the introduction of totex and outcomes occur in different sectors.

Table 2: Ranges of potential efficiency from totex and outcomes during the first totex price control assuming outperformance equates to efficiency gains with a lower bound capped at 0%

Approach	Annual incremental gains (% pa)	Total average efficiency gains (%)
Approach 1	0.0% - 2.7%	0.0% - 7.8%
Approach 2	0.0% - 3.1%	0.0% - 8.9%

Note: This is based on the interquartile ranges presented in Table 1 but with the lower bound capped at 0%.

The analysis suggests that there is a wide range efficiency gains that could be attributed to totex and outcomes across companies as well as across sectors and price controls and over time, under both approaches. This reflects the difficulties in delineating the impact of totex and outcomes, including limitations of the underlying data and the difficulties attributing efficiency to totex and outcomes versus other factors. This is despite the effort to correct the input data for identified other factors, as described earlier.

The novelty of these changes means that there are no precedents of a second totex control, except for electricity distribution networks, on which the impact of the totex and outcomes framework can be directly observed. Therefore, the impact of the framework on the second totex price control necessarily has to be hypothesised and inferred.

A range of different interpretations of the underlying data and corresponding assumptions have been considered and examined. Under some interpretations, it was assumed that there are no elements of catch-up efficiency during the first totex price controls; however, this cannot be supported by evidence. Other interpretations assumed that part of the efficiency gains during the first totex control periods represented catch-up efficiency, which will not persist into the second totex control. However, the totex and outcomes framework is supposed to remove regulatory barriers to efficiency gains that were available and would otherwise have been exploited by the water sector but for the regulatory barriers. Therefore, part of the efficiency gains during the first totex control may represent catch-up efficiency for opportunities that were previously available, but were not exploited until now.

Furthermore, examples of efficiency gains following significant changes (which are discussed in Section 5) are mixed on the longevity of the impact of efficiency gains over time. Some examples exhibit diminishing efficiency gains over the next five year period (e.g. Scottish Water, Openreach separation), while others show increasing gains (e.g. privatisation of electricity distribution and new gas distribution networks). Overall, diminishing efficiency benefits are more common in subsequent periods.

The second totex price control in energy networks, RIIO-ED1, is already underway for the electricity distribution companies. This provides a valuable opportunity to assess whether the increase in efficiency gains would continue to persist after the first totex control.

Table 3 below summarises cost performance on an annual incremental basis for DPCR4 (the pre-totex price control), DPCR 5 (the first totex price control) and RIIO-ED1 (the second totex price control). A positive number indicates cost savings.

Table 3: Comparison of cost performance between ED controls

Price control	Lower Quartile	Median	Upper Quartile	Standard deviation
DPCR4	-0.4%	0.5%	2.1%	2.1%
DPCR5	0.7%	1.6%	2.6%	2.5%
RIIO-ED1	-0.3%	0.3%	1.2%	1.2%
RIIO-ED1/DPCR5	-51.8%	17.8%	45.8%	
RIIO-ED1/DPCR4	78.5%	53.8%	57.1%	

Source: Ofgem(2011), Electricity distribution annual report for 2008-09 and 2009-10; Ofgem(2015), DPCR5 performance report 2010-2015 data table, Ofgem (2017), RIIO electricity distribution annual report 2016-17

Table 3 shows a step reduction in the level of cost outperformance among electricity distribution networks between DPCR5 and RIIO-ED1. For example, the level of upper quartile outperformance observed during RIIO-ED1 (1.2%) is only 45.8% of the upper quartile outperformance observed during DPCR5 (2.6%).

The dispersion of cost performance is also lower during RIIO-ED1 than DPCR5. The standard deviation of cost performance during RIIO-ED1 (1.2%) is less than half of the standard deviation of DPCR5. The narrower dispersion suggests the revealed efficiency gains are realised more consistently across companies, which might be more indicative of a frontier shift, i.e. the on-going shift in efficiency improvements that affect the entire sector. Therefore, the evidence seems to support the hypotheses that part of the efficiency gains during the first totex control represent catch-up efficiency, which will not persist into the second totex control, i.e. hypotheses 1 and 2.

Furthermore, the hypotheses that the observed efficiency gains during the first totex price control would persist into the second totex price control rely crucially on the assumption that the observed totex outperformance is due solely to totex and outcomes. The wide variation in totex outperformance suggests the presence of other factors beyond totex in driving outperformance gains. An approach which takes only part of that outperformance because it assumes catch-up efficiency provides greater scope for outperformance to be explained by any other factors than one which simply attributes all of the outperformance on an ongoing basis solely to the introduction of the totex and outcomes framework. This further supports reducing scope for efficiency gains due to totex and outcomes in the second totex price control.

Because RIIO-ED1 is the only second UK totex price control to date, it is the only source of directly relevant empirical evidence to assess the potential on-going efficiency impact due to the totex and outcomes framework over the second totex price control. This assumes that experience in electricity distribution networks will repeat for the water sector. If the application of the totex and outcomes framework in business planning has been slower in the water sector than in the energy sector, then there may be greater scope for on-going efficiency impact during the second totex water price control. Alternatively, if the application of the totex and outcomes framework in business planning has been faster in the water sector than in the energy sector, then there may be less scope for on-going efficiency impact during the second totex water price control. Given the lack of empirical data to make a quantitative assessment, the analysis relies on observed evidence from RIIO-ED1.

Based on the evidence from RIIO-ED1, Table 4 provides ranges of potential efficiency from totex and outcomes during the second totex control. Overall, the range of annual incremental gains that might be expected during the second totex control is between 0.0% and 1.2% per annum, or 0.0% to 3.7% as an average over the price control period.

Table 4: Ranges of potential efficiency from totex and outcomes during the second totex control as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)	Total average efficiency gains (%)
Hypothesis 1	0.0% - 1.2%	0.0% - 3.7%
Hypothesis 2	0.0% - 1.1%	0.0% - 3.2%

Source: KPMG Analysis

Examples of the impact of structural and regulatory changes on performance

A range of examples of performance improvements in other sectors around significant structural or regulatory changes or events were also reviewed as part of this work. The selected examples were divided into different categories relating to the nature of the changes in regulation, introducing competition, changes in ownership and finally cost or revenue shocks. For each case, changes in unit real operating costs during time periods around the change were measured to identify efficiency improvements.

Table 5 provides a summary of average annual efficiency gain across all cases considered under different time periods. It shows the average performance gain per annum in the five years prior to the shock (T-5 to T-1), the first five years following the shock (T to T+4) and the second five years following the shock (T+5 to T+9). In some cases, there is insufficient data to cover the entire period and hence the average is calculated over the period for which data is available.

Table 5: Summary of examples of reported performance improvements associated with structural or regulatory changes (average, annual change)

Events	T-5 to T	T to T+5	T+5 to T+10
Change in regulatory regime			
Openreach separation	7.6%	8.3%	5.4%
Formation of Scottish Water	NA	6.7%	-1.3%
Manchester airport	2.6%	1.3%	-5.1%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
New gas distribution networks	-1.2%	-0.8%	0.4%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Introduction of competition			
Competition in electricity generation	-4.0%	8.6%	NA
Local loop unbundling	NA	1.7%	1.2%
New gas distribution networks	-1.2%	-0.8%	0.4%
Academic literature		3% to 5%	
Change of ownership			
Formation of Network Rail	NA	9.1%	7.0%
Competition in electricity generation	-4.0%	8.6%	NA
New gas distribution networks	-1.2%	-0.8%	0.4%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Cost/Revenue shock			
UK Oil & Gas price collapse	-14.6%	13.4%	NA
Cost shock - legacy airlines	-0.6%	6.5%	-0.5%
Cost-shock - low-cost airlines	1.7%	2.8%	1.7%
Cost-shock - other airlines	-0.5%	1.8%	3.7%

Source: KPMG analysis, examples are generally based on operating costs. Further detail on all examples can be found in section five of this report.

The introduction of the totex and outcomes framework is likely to be more comparable to the cases of changes in the regulatory regime than to other cases (events). The outcomes and totex change is likely to be less comparable to the introduction of competition where, for example, market sorting effects are introduced, which would not be present in the case of totex and outcomes. Examples of privatisation and change in ownership show instances where new shareholder incentives are introduced to drive management teams to improve efficiency—these might be seen as introducing quite different incentives compared to those introduced by regulators during price controls. Cost and revenue shock examples are also drawn from competitive environments and represent different incentives for efficiency.

Overall, the results from this analysis indicate that major regulatory and structural changes are associated with significant changes in performance, and that the impact of such events is, in many cases, positive. This could be interpreted, under certain assumptions, as indicative of such regime changes and paradigm shifts enabling stronger performance and greater efficiencies being realised by the companies. It is also worth noting that the results from the totex analysis fall within the wide range of examples highlighted on Real Unit Operating Expenditure. However, it is difficult to infer strong conclusions from this comparative analysis, given the different nature of the cases (events) considered and the potential for other factors affecting the performance metrics used in the analysis.

The evidence is also mixed on the longevity of the impact of the documented performance, and, potentially, associated efficiency gains, over time. Some examples exhibit diminishing gains over the next five year period (e.g. Scottish Water, Openreach separation) while others show increasing gains (e.g. privatisation of electricity distribution and new gas distribution networks). Overall, however, diminishing efficiency benefits appear to be common in subsequent periods.

Overall, the evidence suggests a wide range of performance gains associated with incidents of regulatory and structural changes considered; the former might be interpreted as efficiency improvements due to such changes, under certain assumptions. The upper bound appears to be set by Scottish Water where a gain of 6.7% was observed following the merger of regional water companies. Some of the gains may be due to a one-time merger savings.

Project evidence from water companies and supply chain

In this part of the analysis, examples of projects provided by the water companies were compared to the results of the totex analysis. The examples generally support the findings that companies have realised efficiency gains due to the totex and outcomes framework on the basis that the shift in PR14 represented the removal a regulatory barrier to additional efficiency gains and innovation. The case studies provided by the companies suggest a range of different transmission mechanisms underpinning realised efficiencies, for example:

- Substituting planned capital projects for alternative solutions that deliver equivalent (or better) outcomes at a lower cost;
- Initiatives aimed at reducing the need for future capital projects; and
- Pursuing more innovative technologies and delivery approaches to the same activity, resulting in lower costs.

The cost data from 48 of the case studies received from the companies represents a sample of circa 3.8% of the total expenditure in the AMP. This sample was selected specifically to illustrate the effect of Totex on efficiency so is unlikely to be representative of all business activities, but clearly indicates potential for efficiency improvements due to Totex in a variety of different circumstances.

The key findings from this part of the analysis are as follows:

- There are significant savings of up to 100% of totex with an average saving of 35% across the projects over AMP 6 from company responses;
- For some projects companies responses indicated that they are spending more in this control period in order to reduce whole life costs;
- There are projects that could be applied more widely across the sector. For example “ice pigging”, a means to clean water mains, saves significant cost compared to conventional method;
- Several of the case studies with unquantified impact show costs (for example, customer information) with no corresponding demonstrated benefits during this control period, however there is clear potential for these cases to produce savings and/or service improvements in future AMPs.

The responses from the companies indicate that substantial efficiencies as a proportion of project costs have already been realised by adopting the principles of the totex and outcomes framework during AMP6, some of which might be replicable to larger programmes and others that are isolated instances. The totex efficiencies reported to be achieved do not appear to have come at the cost of service levels based on the responses provided.

Table 6 below provides a summary of totex savings based on the information received from the companies across different price controls. The reported savings have been normalised to a 5-year period to reflect a duration of the water price controls.

Table 6: Summary of examples of totex savings by price control

Price Control	Number of detailed case studies received	Average efficiency saving over AMP (%)
Water Resources	8	34.1
Water Network Plus	8	44.4
Wastewater Network Plus	24	39.9
Bioresources	4	-12.0
Retail	1	52.4
Multiple	3	36.8
Total	**48**	**35.4**

Source: Aqua analysis of companies’ replies to Ofwat’s data requests

These case studies alone, when considered together, show an overall totex efficiency of 1.3% of the overall AMP determination (35.4% of the total 3.8% of expenditure that is covered by the projects in the sample). The case studies also clearly show that innovation can play a significant part in enabling the water companies to deliver improved efficiency and suggest that significant efficiencies have been achieved in some instances.

Given that the reported spending on the schemes examined represents less than 4% of companies overall expenditure, and given that the case studies have been selected specifically to illustrate efficiency gains from Totex, the reported gains might not be representative of all of companies' business activities, and, therefore, extrapolating from this data alone would not be appropriate for setting expectations of future savings.

Nonetheless, the case studies corroborate the range of potential efficiency gains that might be expected during the second totex control based on totex performance assessment of 0.0% to 3.7% on an average basis over the whole price control period as shown in Table 4. At the upper end of this range, the case studies represent around 35% of the estimated potential efficiency gains (i.e. 1.3% divided by 3.7%) over AMP7.

Conclusions on the impact of totex and outcomes on efficiency

The overall results from the analysis of totex performance assessment suggest that the range of annual incremental gains due to totex and outcomes that might be expected during the second totex control period, subject to certain important assumptions, could be between 0.0% and 1.2% per annum, or between 0.0% and 3.7% on a total average basis over the whole price control period.

These results have been compared with: (i) performance improvements on Real Unit Operating Expenditure associated with selected regulatory and structural changes in other sectors and with (ii) a range of project examples provided by companies in response to an information request which constitutes around a third of the upper end of the estimated efficiency gains. The 'cross-checks' generally support the hypothesis that totex can unlock significant efficiency gains but also that there are likely to be diminishing returns from the totex framework.

Implications for regulatory policy setting of efficiency targets

The evidence reviewed in this study suggests that the introduction of the totex and outcomes framework allows companies to unlock further innovation and efficiency gains.

When considering setting efficiency targets for AMP 7, it is also important to consider the effect of any shift in the efficiency frontier in the absence of the totex and outcomes framework. Frontier shift represents technological and/or process changes that are expected to occur in the future. It is applied to an estimate of the efficient costs in the base year to project forward efficient costs during the full price control period. In order to estimate frontier shift for AMP7, this report examines the following sources of evidence:

- Total factor productivity in the EU KLEMS dataset; and
- Previous regulatory decisions.

For wholesale activities, EU KLEMS suggests a frontier shift is between 0.4% and 1.3% per annum. Recent TFP growth has been deeply negative for wholesale activities, and it is unclear if productivity will rebound. For retail activities, the frontier shift estimate is 0.8% to 1.8% a year.

The TFP analysis aligns with the levels of previous frontier shift decisions made by regulators in comparable utility sectors.

These TFP results are added to the potential gains from the totex and outcomes framework to understand the potential overall efficiency potential in AMP 7. This approach can be considered appropriate because the methodology for assessing cost outperformance from totex and outcomes compares the level of company outperformance with the allowances made by the relevant regulator at each of the price controls and in each case the regulator already included an adjustment to their allowed costs for frontier shift efficiency. Therefore any outperformance beyond this allowance should already account for this.

Table 7: Ranges of potential efficiency gains from frontier shift, including on-going efficiency impact of totex and outcomes by service as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)			Total average efficiency gains (%)		
	TFP	Totex	Total	TFP	Totex	Total
Results based on hypothesis 1						
Wholesale	0.4 – 1.3%	0.0 – 1.2%	0.4 – 2.5%	1.2 – 3.8%	0.0 – 3.7%	1.2 – 7.4%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%
Results based on hypothesis 2						
Wholesale	0.4 – 1.3%	0.0 – 1.1%	0.4 – 2.4%	1.2 – 3.8%	0.0 – 3.2%	1.2 – 7.0%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%

Source: TFP is based on KPMG analysis of the EU KLEMS datasets, TOTEX is based on Table 4.

Overall, the analysis suggests an indicative range for the potential annual, incremental efficiency savings of 0.4-2.5% per year or 1.2-7.4% total average efficiency gains over the entire AMP. The results based on hypotheses 1 and 2 imply similar ranges. The rest of the evidence examined as part of this study supports various aspects of this analysis as well as some key assumptions (e.g. causality given identified transmission mechanisms, significant magnitude of the impact of the change, generally positive gains, but also wide dispersion of the impact across companies and the existence of diminishing returns over time).

Interpreting the analysis and regulatory policy setting

The results of the analysis as to what efficiency gains water companies might be able to realise going forward from totex and outcomes can help to inform regulatory policy for setting efficiency targets. Within its scope and limitations, it provides useful evidence and analysis for the regulator to consider.

It is important however to bear in mind that the two research questions considered are clearly distinct—the former is an analytical prediction of what might be possible for companies to realise, the latter is a regulatory policy choice, which can be informed (to some extent) by the former as well as a number of other considerations and analysis, regulatory objectives, other evidence, etc. The former cannot be assumed to be the direct answer for the latter.

Total factor productivity

For wholesale activities, EU KLEMS suggests a frontier shift is between 0.4% and 1.3% per annum. For retail activities, the frontier shift estimate is 0.8% to 1.8% a year. Similar TFP analysis has been commonly used amongst regulators in the setting of frontier shift efficiency targets, particularly in relation to wholesale or network activities. Companies who responded to the workshop generally did not challenge the TFP analysis.

Whilst the setting of frontier shift efficiency targets in retail price controls is less common and there may therefore be less regulatory precedent from which to learn, the general principles and approaches should be consistent and the same datasets are used.

The approach in this study also considers labour productivity shift given the relatively lower capital intensity of retail compared to wholesale services. Ofwat may therefore wish to consider an efficiency target for frontier shift from any point in the TFP ranges presented, albeit that they may want to consider their approach to efficiency in the round including, for example their level of ambition, their approach to catch-up efficiency and their views on productivity improvement in the wider economy.

Efficiency gains water companies might be expected to be able to realise going forward from totex and outcomes

The analysis outlined in this study provides an indicative range for the potential efficiency savings for AMP 7 from totex and outcomes of 0.0-1.2% annual incremental efficiency gains. Some of the analysis from which these results are derived and their implications for potential efficiency gains that can be realised by the companies rely on a number of critical assumptions, in particular:

- The lack of bias and accuracy of regulatory cost models, and that the only difference between the totex and non-totex price controls is the introduction of the totex and outcomes framework itself;
- For energy, that the companies accurately predict their cost performance through to the end of the on-going price controls; and for water, that the companies adjust their outperformance for profiling effects on the same basis;
- That there are no other external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis; and that other factors affecting realisable efficiency gains are under companies' control; and
- That the same impacts are seen from totex and outcomes in different sectors.

Therefore when setting regulatory policy, it is important to consider whether these assumptions critically underpinning the specific results can be made with confidence, and in what circumstances, in order to rely on the end results.

The analysis indicates that there is a wide dispersion of efficiency gains that could be attributed specifically to totex and outcomes across different companies, but also across sectors and price controls over time, under any of the hypotheses and approaches used. This means that different companies are likely to be able to realise different efficiency gains due to Totex for various reasons which are difficult to identify. Some of these could be under companies' control and related to performance and others are likely to be external factors beyond companies' control. This means that it is only possible to conclude that potential efficiency gains from Totex will fall within a relatively wide range rather than predict a single number with confidence. This further implies that, by definition, using any one number in the range as a general predictor for potential efficiency gains that every company in the sample would be able to realise would imply a significant unexplained variation from the prediction.

The analysis undertaken does not suggest, overall, any clear bias in the results. Therefore, there are no obvious grounds to suggest that predictions should not be distributed symmetrically, or that they could fall to a greater extent in either the upper, or lower quartile of the range. This also implies that extreme values close to the top or the bottom of the ranges are not good predictors of potential gains and should not be assumed.

Setting regulatory policy

The setting of regulatory policy on efficiency targets is fundamentally a matter for Ofwat to consider in line with their statutory duties as an independent regulator. These decisions may require the use and triangulation of multiple sources of evidence including some, such as the overall approach to cost assessment and recovery or the assumptions in relation to 'catch-up' efficiency, that are beyond the scope of this study. This report provides evidence and analysis as to the potential impact of totex and outcomes on efficiency in the water sector. It could be used, alongside other sources of evidence, to inform that regulatory policy setting but it does not provide a direct and transferrable answer for that policy. Instead, the report represents one source of evidence and analysis to inform those decisions with the strengths and limitations of it clearly established. Below we provide some general observations on regulatory policy setting of efficiency targets based on previous observed regulatory decisions and the analysis and evidence that has been undertaken.

In previous regulatory decisions, where there are uncertainties around the appropriate estimate of efficiency targets, UK regulators have tended to set efficiency targets around the upper quartile of the range or between the central and frontier companies. For example, Ofwat set the capital expenditure baseline for the capital expenditure incentive scheme at the median at PR09. At PR14, Ofwat set efficiency challenge at upper quartile efficiency when estimating the totex cost baseline at PR14. Ofgem also used the upper quartile when setting totex baseline most recently for the RIIO-ED1 price control.

The use of upper quartile by regulators reflects the ambition in providing "stretching efficiency targets"[2] to companies. This also depends on the confidence the regulator has on the quality of its information amongst other factors. For example, Ofgem stated that its use of the upper quartile acknowledged that a part of the difference in costs "relates to factors other than GDNs' relative efficiency (e.g. statistical errors)"[3]. At DPCR5, Ofgem benchmarked network operating costs at the upper third due to greater variability in data.[4]

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[2] Ofwat (2014), Final price control determination notice: policy chapter A2 – wholesale water and wastewater costs and revenues, p.23
[3] Ofgem (2012), RIIO-GD1: Final proposals – Supporting Document – Cost efficiency, p. 7
[4] Ofgem (2009), Electricity distribution price control review final proposals – allowed revenue – cost assessment, p.4

Table 8 shows ranges of potential on-going efficiency targets based on previous regulatory decisions that are based on the median to upper quartile ranges. For frontier shift, the ranges remain 0.4% - 1.3% per annum for wholesale and 0.8% - 1.8% per annum for retail. This is because the ranges are already informed by the average of TFP growth of different benchmark sectors over different time horizons. The use of the average TFP growth reflects the cyclical nature of TFP estimates, on which the frontier shift estimates are derived.

The range for the potential efficiency savings for AMP 7 from totex and outcomes, based on previous regulatory decisions, is 0.2-1.2% annual incremental efficiency gains. The lower bound is based on the median and the upper bound the upper quartile of the range for the potential efficiency gains for AMP7 from totex and outcomes.

Table 8: Ranges of on-going efficiency targets assuming declining benefits from Totex taken as the median to upper-quartile of the range

Control	Annual incremental gains (% pa)			Total average efficiency gains (%)		
	TFP	Totex	Total	TFP	Totex	Total
Wholesale	0.4 – 1.3%	0.2 – 1.2%	0.6 – 2.5%	1.2 – 3.8%	0.6 – 3.7%	1.8 – 7.4%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%

Source: KPMG Analysis

As stated earlier, these estimates rely on a number of critical assumptions including the assumption that outperformance purely reflects efficiency gains and that other factors affecting realisable efficiency gains are under companies' control. There remains a wide dispersion of efficiency gains that could be attributed specifically to totex and outcomes, even when the lower bound is based on the median as per previous regulatory decisions.

The Regulator may wish to set efficiency targets at the upper end of this range if, in its view, the variation in outperformance among companies purely relates to factors related to efficiency that are under companies' control. In other words, the Regulator is confident that the observed efficiency gain at the upper quartile is achievable by all companies. Any differences in efficiency gains are due to the differences in managerial ability in exploiting totex and outcomes.

The Regulator may wish to set efficiency targets below the upper end of the range if, in its view, the variation in outperformance among companies also relates to factors beyond companies' control. Alternatively, the Regulator may wish to consider a lower cost sharing rate (i.e. companies absorbing a lower share of under/outperformance) to acknowledge the uncertainties around the achievability of the efficiency targets towards the upper end of the range.

The Regulator may also wish to consider the setting of efficiency targets in the context of previous regulatory decisions. A review of historical regulatory decisions on frontier shift assumptions suggests a range between 0.7% and 1.1% for AMP7. This represents a point close to the middle of the stated wholesale range in Table 8 and the lower end of the retail range. The evidence reviewed does suggest that there is an increase in efficiency as a result of the introduction of the totex and outcomes framework (including from the totex analysis and also the project evidence for example). Hence the Regulator may consider it appropriate to increase the frontier shift assumption above recent historical levels and select a figure in the top half of the stated total (ie combined TFP and Totex) range.

Given the nature and the scope of this exercise and its reliance on specific sources of data, the Regulator might want to consider other evidence and analysis to inform its regulatory policy and setting of efficiency targets. The complexity of this issue suggests that exploring different sources of data and evidence is important to form a holistic and robust view.

Finally, this study does not consider the broader policy considerations of cost assessment and recovery mechanisms, which is beyond the scope of our work. These mechanisms are likely to represent an important consideration of any regulatory policy setting.

1 Introduction

This study was commissioned by Ofwat, the economic regulator of water and wastewater services in England and Wales, in order to examine the potential impact of the introduction of the totex and outcomes frameworks on innovation and efficiency gains in the water sector and to inform the efficiency assessment for PR19.

1.1 Scope and research questions

The project considers two principal research questions:

1. What impact the totex and outcomes framework changes had on efficiency in AMP 6, and what their potential impact might be on future efficiency gains in AMP 7; and

2. What the implications of these findings might be for regulatory policy and the setting of efficiency targets at PR19.

1.2 Sources of evidence

KPMG and Aqua consultants' approach combines a range of evidence to estimate innovation and efficiency gains from the totex and outcomes framework. Aqua Consultants' work is presented in section 2 and appendices 2 and 3.

The totex approach and the introduction of incentives based around delivering outcomes for customers are a relatively recent innovation in regulated utilities. The framework is a significant change in the regulatory treatment of cost performance and recovery. It removes a previous regulatory barrier and allows companies to take advantage of new and different approaches to delivering outcomes in customers' interests rather than focussing on the delivery of a pre-determined list of schemes. Under the framework companies are incentivised to move away from capex-oriented decision making towards looking at total expenditure.

In deriving the potential impact of the totex and outcomes framework on efficiency, this report reviews three sources of evidence:

- **Exploring and delineating performance due to Totex**: An assessment is made of the levels of cost performance in regulated utility networks that have introduced versions of the totex and outcomes framework. Specifically, cost outperformance is compared against regulatory allowances in the controls preceding these changes with levels of performance after the changes are introduced.
- **Considering examples of the impact of structural and regulatory change as cross-checks**: Examples of performance gains from other significant changes in both regulated utility sectors and other competitive sectors that demonstrate similarities with the water sector in England and Wales, such as having similarly high levels of capital intensity, are compared to the results of the totex

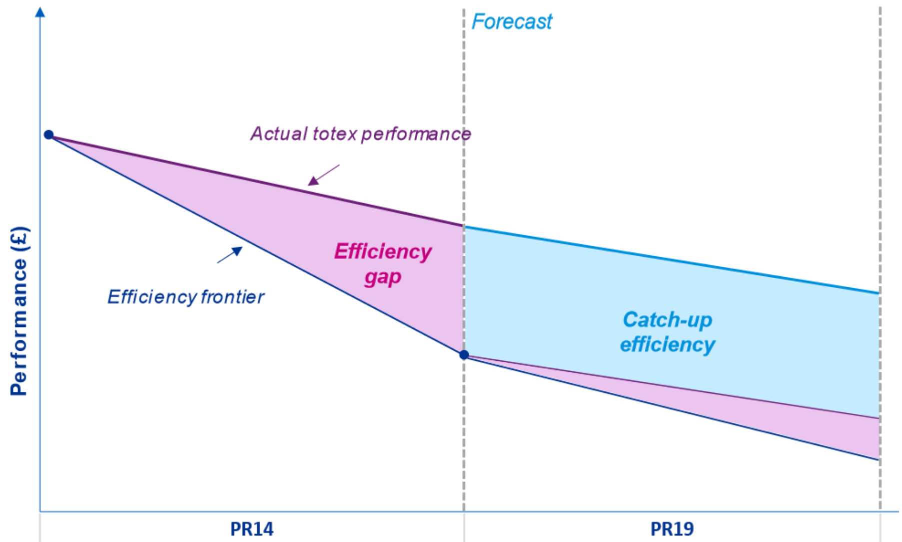
performance assessment. These examples focus on the change in real unit operating expenditure (RUOE) as a measure efficiency gains.

- **Assessing evidence from projects by water companies and the supply chain to inform Totex analysis:** Around 200 project examples have been provided by companies and members of the supply chain in response to an information request. These projects were requested to show the potential impact of the application of the totex and outcomes framework in practice. This project evidence was also used as a point of comparison with the evidence from the totex analysis.

This study focusses on the above sources of evidence, incorporating both top down assessment and a sample of bottom up project evidence. However, limited sources of data and multiplicity of potential other factors at play imply that it is inherently challenging to attribute specific outperformance to either totex or outcomes. There is no data available specifically on the efficiencies generated by these reforms. This means that the analysis has to consider broader data on cost performance for top down analysis and explore to what extent performance could be attributed to totex and outcomes and under what assumptions. For the bottom up analysis, the key question is to what extent identified examples can be extrapolated to all business activities and overall cost performance.

Historically, UK regulators have assessed potential efficiency gains for regulated sectors based upon a combination of 'catch-up' efficiency and 'frontier shift'. The catch-up efficiency accounts for the process by which less efficient firms learn from and 'catch-up' to the most efficient 'frontier' firms. This is informed through comparison of historical company performance often through econometric benchmarking. Cost assessment net of catch-up efficiency represents efficient costs in the base year. Regulators then roll forward efficient costs in the base year through to the end of the price control based on an assumption of frontier shift, i.e. the continued efficiency improvement of the most efficient firms at the frontier. Frontier shift represents technological and/or process changes that are expected to occur in the future. Figure 1 illustrates the distinction between catch-up efficiency and frontier shift.

Figure 1: Simplified representation of catch-up and frontier shift



Source: KPMG

Ofwat intends to use econometric models to set efficient costs in the base year at the frontier for AMP7. This implies that any catch-up efficiency will be captured in cost estimates from the econometric models, and is therefore not a focus in this report.

To draw out the implications for regulatory policy setting of the potential efficiency gains during AMP7, total efficiency potential for AMP7 is therefore assumed to comprise of the sum of the following components:

- First, the frontier shift, which is associated with the on-going technological change in the economy and unrelated to the introduction of the totex and outcomes framework;
- Second, the benefit and opportunity arising from the totex and outcomes framework over AMP7, which is additional to the frontier shift; and
- Third, other factors affecting performance, which can result in efficiencies as well as inefficiencies, including those under management control and external factors, the impact of which is inherently difficult to disentangle from that the impact of outcomes and totex framework.

This study seeks to isolate, to the extent possible given the data and the adopted approach, the impact from outcomes and totex from a range of other drivers (point 3 above) and to develop a range for the potential level of total factor productivity improvement during AMP 7 (point 1 above).

Analysis of total factor productivity: To undertake the assessment of TFP, this study uses data from the EU KLEMS dataset for certain sectors which exhibit similar levels of capital and labour intensity to the UK water sector and over certain business cycle periods to inform a range representing the potential annual efficiency change.

Advantages and limitations of the data and evidence considered

The approach adopted in this study seeks to make the best use of the available data and has a number of advantages resulting in insightful observations and results, notwithstanding necessary assumptions made:

The totex performance assessment evidence provides levels of real outperformance in a range of sectors (across four price-controlled networks) against cost allowances before and after the introduction of the outcomes and totex framework. It is the only source of real world data on company cost efficiency performance during periods when price controls include outcomes and totex changes.

This has to be considered in the context of the totex and outcomes changes being relatively new reforms, which limits the amount of real observable data on cost performance. Specifically, the research seeks to examine the impact of totex and outcomes in the first and second price control periods following their introduction. There is only one price control that has been completed where similar changes have been introduced and there are no instances where a second price control period is complete. In the case of the water, electricity transmission and gas distribution companies', data is only available for a subset of the current control period. This limits ability to observe impacts over time and requires the use of forecasts to inform the assessment.

The data also focuses on a comparison with the cost allowances set by regulators. These are only as accurate as the models and approaches used, recognising that the process for forecasting costs adequately is inherently challenging. Where allowed costs are not set precisely in line with the real underlying cost functions, this can result in outperformance (or underperformance) that may not be due to real efficiency (or inefficiency).

The cost outperformance data reviewed for this assessment provides only an overall, high level picture of performance; some further detail on the drivers is provided by the companies in their annual performance reports. Whilst this study adjusts outperformance for these factors where possible, where such factors are clearly outside of management control, or where efficiency is not driven by the totex and outcomes framework, there remains a risk that the analysis does not identify or account for all the drivers of outperformance.

The examples of structural and regulatory change and their impact on cost performance can provide a cross-check to the overall efficiency ranges and set an upper bound to efficiency potential based on experience elsewhere, given that they are selected to illustrate such impacts. At the same time, it has to be recognised that the comparative examples contain important differences to the outcomes and totex regime, which might significantly impact the results. The extent to which the changes from these structural and regulatory changes (e.g. introducing competition, changes in ownership, other regulatory reforms, business separation and divestment or cost shocks) represent a similar level of paradigm shift to the introduction of totex and outcomes is open to debate.

Project evidence from companies provides important, real-world evidence of both the transmission mechanism by which the outcomes and totex frameworks drive efficiency improvement and the potential scope for benefits to arise from the framework in certain types of activities. It also provides a strong evidence base on the directional impact of these regulatory changes. At the same time, the sample size of these examples is relatively small (accounting for 3.8% of total AMP 6 spend) and the projects may not constitute a representative sample of companies' overall capital programmes; this means that extrapolating from these examples would entail some strong assumptions.

Overall, the approach seeks to make the best use of the available evidence to inform the research questions, including through a list of diverse evidence sources, but with some limitations.

1.3 Methodology

In order to identify the level of efficiency change arising from the totex and outcomes framework and the potential for this to continue over AMP7, a multi-step approach has been adopted:

1. **Totex performance assessment: Analysis of companies current levels of outperformance on costs under the totex and outcomes controls.**

The cost performance of each company was calculated using data from companies' (water and energy) and through comparison of that with companies' allowances at the relevant final determinations. This analysis is presented in section 3. Where price controls are complete, reported costs were used, but for incomplete price controls company forecasts of the overall price review performance were used, including forecasts for RIIO controls and RORE performance data for the water sector for PR14. In these cases the analysis relies on the assumption that forecasts can accurately proxy cost information.

Cost performance figures and allowances were also adjusted for factors clearly unrelated to the totex and outcomes reforms to the extent that these were identified from performance reports and quantified. There are likely to be other examples of exogenous factors either driving efficiency, or increasing costs, which cannot be easily identified.

Efficiency gains were then derived from the outperformance data. This assumed that, after adjusting the data for identified other factors, the regulatory baselines are correct; and the efficiency gains are attributable to the introduction of totex and outcomes as the main factor. This was done through two approaches:

- **Approach 1:** This approach assumed that: efficiency gains revealed during the previous price controls are fully captured in regulatory cost allowances for the next price control period; outperformance during the current price control purely reflects efficiency gains; these efficiency gains are due solely to the change in regulation; and, therefore, all outperformance observed during the price control where the totex and outcomes framework is in place reflects efficiency gains due to the introduction of the framework itself.

This approach assumes that all outperformance equates to efficiency, when there are likely to be a range of factors outside of companies' control that might impact on outperformance and that all efficiency is accounted for by the regulatory change. At the same time, there is no evidence to suggest the direction or scale of the impact of these other factors on efficiency and outperformance, or to suggest a bias.

- **Approach 2:** This approach assumed that: there are persistent company-specific factors that lead to a dispersion in cost performance against regulatory cost allowances across the industry; these company-specific factors persist before and after the introduction of totex and outcomes framework; efficiency gains are therefore measured as incremental gains in cost outperformance over the successive price controls; and these efficiency gains are due solely to a change in regulation.

This approach is subject to the same issues as approach 1 in terms of challenges of identifying the difference between outperformance and efficiency, and the attribution of performance to totex and outcomes versus other factors. However, where there are factors that are persistently driving changes in outperformance and efficiency across adjacent control periods, this approach better controls for such factors than approach 1.

2. The potential for future efficiency gains under a totex control were estimated:

There is no directly observable data delineating the efficiency gains that could be expected over the second totex price control, i.e. AMP7. Therefore, the impact of the framework on the second totex price control was inferred through scenarios and hypothesis. A range of scenarios were considered based around the two approaches outlined above, including some which assumed that any efficiency benefits arising from the first totex control would continue into the second totex control period and some which assumed that there would be a degree of diminishing returns from the framework. Following evaluation of these scenarios, two specific hypotheses were identified, which reflected each of the approaches previously identified, whilst assuming a degree of diminishing returns. In each scenario the impact on efficiency between each of the control periods is based on the experience in electricity distribution.

The two hypotheses around the impact of the framework on on-going efficiency gains were set as follows:

- **Hypothesis 1:** There have been on-going technology improvements affecting productive efficiency in the wider economy. The on-going technology improvements were also available to the water sector but for the regulatory barriers, which have been addressed by the totex and outcomes framework. The revealed efficiency gains during the first totex control represents both a new, higher rate of on-going technology improvements and a catch-up by the industry to the level of efficiency in the wider economy (as per approach 1). Therefore, the catch-up component has to be separated from the revealed efficiency gains during the first totex control to identify the on-going shift due to the framework.
- **Hypothesis 2:** As per hypothesis 1, but efficiency gains during the first totex control are measured as incremental gains in revealed outperformance between the totex and non-totex price controls (as per approach 2).

Under each of these hypotheses the inter-quartile range was estimated to inform the high and low estimates of the range. Minimum and maximum values were excluded from the range estimates to eliminate outliers and cases where other factors (i.e. other than the common factor considered—Totex and outcomes) are likely to drive the results. The variance of the results was then considered and appropriate statistical tests were conducted to test the significance of the findings.

For hypothesis 1 and 2, the levels of outperformance of RIIO ED1 (the second totex and outcomes based price control in electricity distribution) were compared to DPCR4 (the last non totex and outcomes price control) and DPCR5 (the first totex and outcomes price control). The diminishing returns between these controls was then used as a proxy to infer the potential future impacts in AMP7 under hypotheses 1 and 2 and associated diminishing returns from the changes.

3. The analysis was cross-checked against examples of other efficiency events, based on RUOE, in other comparable sectors

Thirteen examples of efficiency gains arising from significant changes in different sectors and contexts were analysed (this analysis is presented in section 4). These examples were selected to represent a range of different sectors including regulated sectors and competitive sectors. The analysis focussed on considering the change in real unit operating expenditure (RUOE) as a measure of efficiency gains both before and after the change. The changes were categorised according to their nature (e.g. introducing competition, separation, regulatory reform, changes in ownership, etc) recognising, at the same time, the differences between these examples and the specific regulatory changes associated with totex and outcomes.

4. A further cross-check was performed based on company case studies that were returned via an information request

Examples of totex in practice from a variety of industry sources were collated through a formal information request that sought example projects showing innovation or efficiency gains as a result of the totex and outcomes framework. An assessment was undertaken into the potential impact of the findings on future efficiency and innovation. This analysis relied on real case studies, data and information provided by industry sources supported by judgement on the significance and replicability of innovation and efficiency in the industry. This analysis is presented in section 4.

In considering the implications for regulatory policy in setting efficiency targets for AMP 7 an analysis of total factor productivity has also been undertaken. The adopted approach to this analysis is similar to that used by a number of regulators in setting frontier shift efficiency assumptions in price controls.

Data from the EU KLEMS database of productivity and growth accounting in the European Union was used to infer range estimates for frontier shift improvement. While TFP estimates based on gross output measures could be more relevant for the purpose of this study, data availability for such a measure is limited. Therefore, this analysis was based on the value added measure of output.

TFP is a cyclical variable, influenced by booms and recessions. Therefore, it is typical for productivity studies to look at average TFP growth over a full business cycle. To enhance comparability with other evidence for the water sector, the definitions used in the recent Water UK report[5] have been adopted. Due to data limitations, it is only possible to compute TFP growth for the current business cycle up to 2014. The September 2017 release of EU KLEMS only contains information from 1995 onwards and only for some countries. Therefore, TFP estimates for the first and second business cycle are based on the 2012 release.

EU KLEMS contains data for different sectors in the economy at different levels of aggregation. The relevant sectors in the EU KLEMS dataset for the E&W water sector are identified based on the nature of the activities performed as defined by Eurostat and the capital intensity of the sector measured by the contribution of labour and capital inputs to the production process. The electricity, gas and water supply and construction sectors are considered to be the most comparable to wholesale activities in the E&W water sector.

Since retail activities include mainly support service activities and other business support activities the relevant sectors in the EU KLEMS dataset are assumed to be professional, scientific, technical, and administrative and support service activities (professional and support services) and retail trade, except of motor vehicles and motorcycles (retail trade). In terms of capital intensity, labour comprises the overwhelming majority of input costs in retailing. Therefore, the analysis also considered labour productivity trends in the two sectors above and at an all-industry level.

Finally, the analysis looked at EU countries as a cross-check. While the 2012 release of the EU KLEMS database contains data from different EU countries, only Belgium (BE), France (FR), Germany (DE), Italy (IT), Spain (ES) and Netherlands (NL) have data of sufficient detail to carry further analyses. Therefore, the average is taken over these six countries.

In addition to reviewing TFP growth from the relevant sectors in the EU KLEMS dataset, a notional sector performing wholesale activities was constructed by applying labour and capital productivity trends from the electricity, gas and water supply sector to the average capital and labour input mix for the England & Water sector over different time periods.

1.4 Timescales

The work on this study began at the end of 2017 and was completed in May 2018. A data request has resulted in extensive evidence and examples of specific efficiencies and transmission mechanisms provided by the water companies. Following completion of the preliminary analysis, a workshop was held with water companies, members of the supply chain and Ofwat representatives on the 15th of March 2018, where the initial results were discussed; the industry also provided further helpful evidence and comments at a later date. The comments and evidence raised were then considered in finalising this report.

[5] Frontier Economics (2017), Productivity Improvement in the Water and Sewerage Industry in England Since Privatisation

1.5 Structure of the report

- Section 2, realising efficiency gains from a change in regime, examines the ‘transmission mechanism’ by which the outcomes and totex changes may drive efficiency improvements as well as project evidence from water companies and members of supply chain;
- Section 3, totex performance assessment, examines totex performance across price controls and seeks to delineate performance due to totex and outcomes;
- Section 4 examines examples of the impact of structural and regulatory change on performance;
- Section 5 examines evidence from historical efficiency gains; and
- Section 6 provides a summary of findings and implications of these findings for regulatory policy and the setting of efficiency targets at PR19.

2 Realising efficiency gains from a change in regime

When Ofwat introduced the totex and outcomes framework it was expected to provide companies with far greater opportunity to promote solutions that deliver outcomes customers wanted at the best value to them.

This section sets out the transmission mechanisms by which Ofwat's totex regime and its focus on outcomes could result in efficiency gains in the sector. Using data provided by companies, examples of projects are provided which demonstrate the transmission mechanisms.

This section then sets out additional detail on real case studies, data and information provided by industry sources supported by Aqua Consultants' opinion and judgement on the significance and replicability of innovation and efficiency in the industry. The aim of this investigation is to provide insight into the opportunity for efficiency and innovation that is afforded by the totex approach utilising a combination of industry case studies, engineering and cost assessment expertise.

2.1 Transmission mechanisms

A frequent criticism of the traditional approach to setting regulatory allowances using separate operating and capital expenditure allowances is that it could lead to a bias for companies to implement capital projects when alternative solutions would be in the best interest of customers.

Such regimes are often combined with an 'outputs' approach to capital expenditure allowances. Under the 'outputs' approach, companies are given allowances to complete specific projects over a given control period.[6] This reduces the flexibility of companies to deviate from agreed solutions during the course of a control period.

PR14 saw the introduction of the totex and outcomes framework, shifting the focus from efficient cost delivery of outputs to efficient delivery of outcomes. Prior to PR14 companies agreed expenditure for significant projects with Ofwat and were incentivised to deliver the specified projects as cheaply as possible. The two key mechanisms by which Ofwat's totex and outcomes framework incentivises totex efficiency compared to previous controls are:

- By focussing on outcomes (rather than outputs) companies have more flexibility over the solutions adopted to achieve a given level of outcomes by allowing companies to deviate from the project they specify in business plans. This flexibility allows companies to choose more cost-efficient solutions to achieving customer outcomes.

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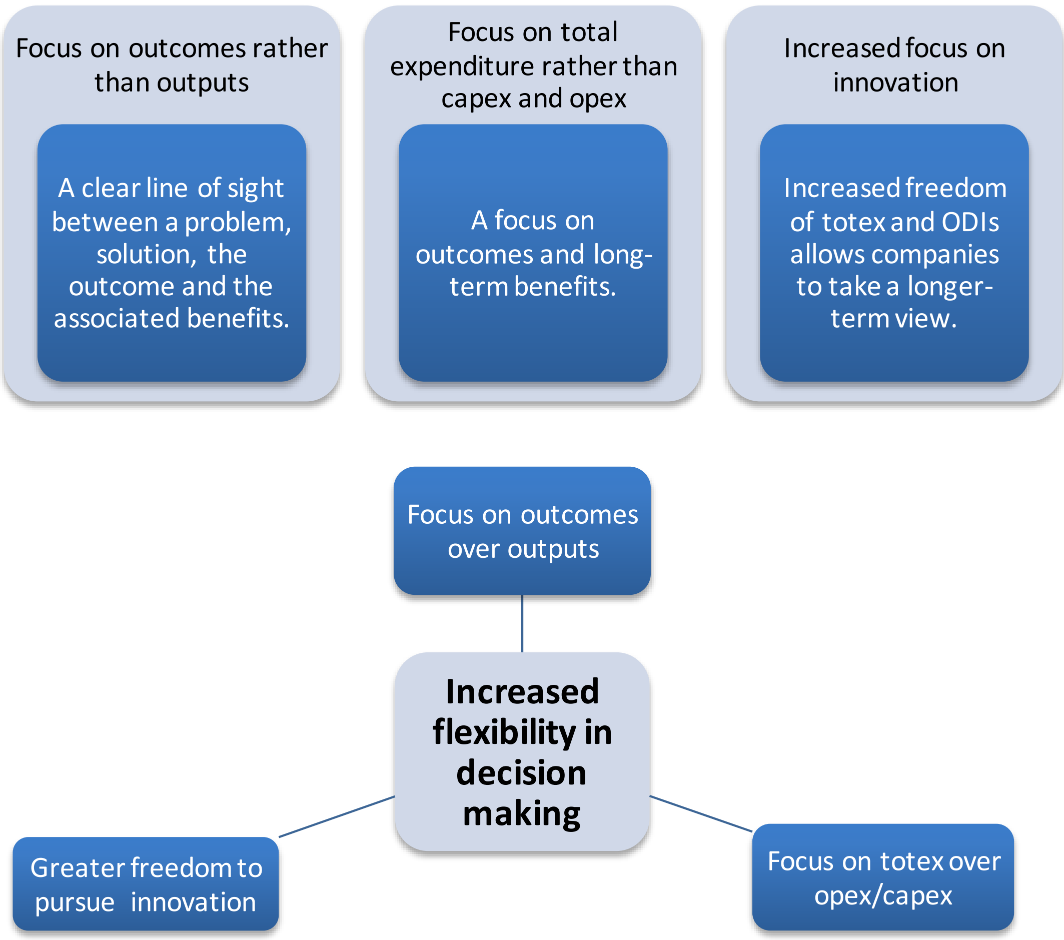
[6] See for example see the discussion in chapter 3 of Ofwat (2009), Future water and sewerage charges 2010-15: Final determinations.

- By focussing on totex the potential bias towards capital solutions is reduced, thus improving allocative efficiency in the sector. Combined with the increased flexibility of the outcomes framework, the totex approach therefore incentivises companies to choose the most whole-life cost-efficient solution to achieving outcomes.

In addition, Ofwat's totex and outcomes regimes have put a strong focus on innovation, which has encouraged companies to look for creative and innovative solutions to delivery. While some innovations may have been adopted without a change in Ofwat's regime, evidence from the workshop and Ofwat's data requests indicates that the outcomes and totex framework has helped to stimulate innovative thinking and make companies more receptive to using new technologies. Therefore, it may be the case that these technologies are being adopted more quickly than would be the case under previous regulatory frameworks.

Figure 2 highlights the key areas of flexibility afforded from the change to totex, as reported by respondents to the data request.

Figure 2: Flexibility reported by companies from the introduction of totex framework



The shift to a totex and outcomes framework in PR14 therefore represents the removal a regulatory barrier to efficiency and innovation. This is supported by the case studies provided by companies, which demonstrate the transmission mechanisms through:

- Substituting planned capital projects for alternative solutions that deliver equivalent (or better) outcomes at a lower cost;
- Initiatives aimed at reducing the need for future capital projects; and
- Pursuing more innovative technologies and delivery approaches to the same activity, resulting in lower costs.

The table below summarises some initiatives being undertaken by companies that demonstrate the effects above. We discuss other examples in more detail in subsequent sections.

Table 9: Examples of projects demonstrating transmission mechanisms

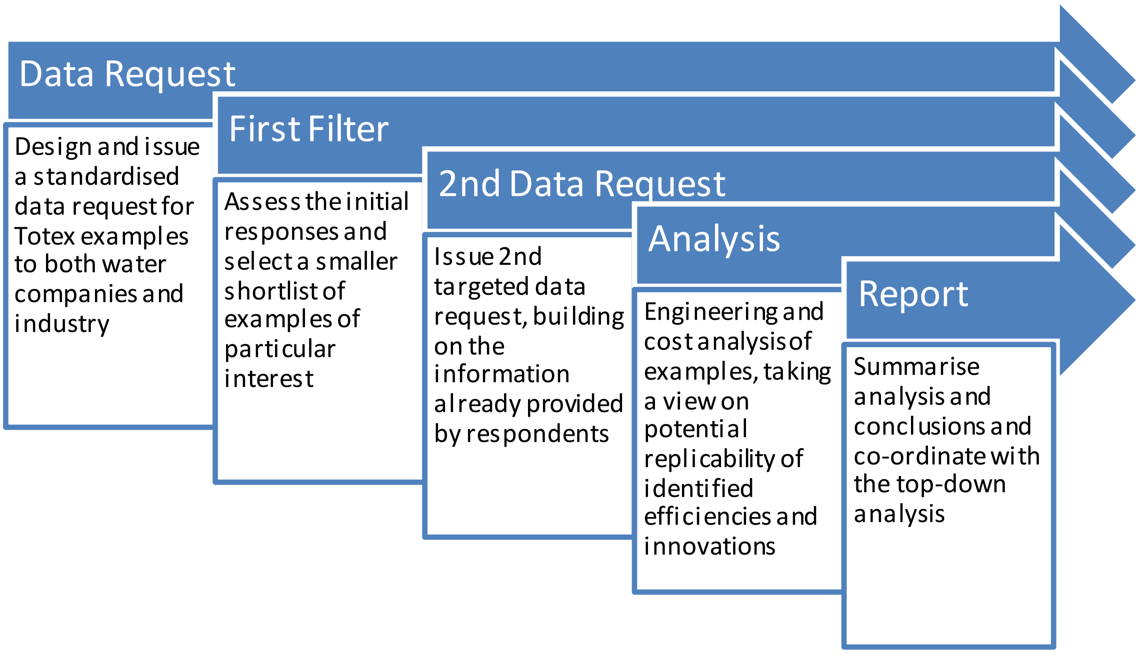
Transmission mechanisms	Examples of company initiatives	Description
Substitution of capital projects for alternative solutions	Coppermills RGF configuration	Installation of a blending option for nitrate reduction in preference to installing a new ion exchange plant.
	Rainscape - Greener Grangetown	Removal of surface water to provide sewerage capacity to allow growth without building new wastewater assets.
Initiatives aimed at reducing the need for future capital projects	EnTrade	Catchment management approaches were optimised through the EnTrade platform. This solution was significantly cheaper than installing nitrogen removal equipment at sewage treatment works.
	'Bin it' campaign	A customer education programme aimed at reducing sewer blockages.
Pursuing more innovative technologies and delivery approaches to the same activity, resulting in lower costs	GIS mapping and inferring the transferred drains and sewers network	The use of existing knowledge about the potential location of 'private' sewers on the basis of house style.
	Kings scholar pond	Use of new materials and techniques to refurbish a sewer.

Source: Aqua Consultants' analysis of company responses to Ofwat's data requests

2.2 Methodology

This section sets out the methodology followed in collecting and analysing the case studies provided by companies. The investigation followed the simplified methodology shown in Figure 3. All quotes provided in this section are obtained from relevant company replies to the data request.

Figure 3: Methodology adopted



Source: Aqua Consultants

The case studies were assessed for the following basic requirements:

- Repeatability – if the case study could be carried out again at the company or in other places or if a 'one-off' opportunity had been maximised.
- Time Horizon – whether the case study had reached a widely deployable state, was under development or was likely to occur in the future; Short, Medium and Long implementation timescales.
- Impact – in terms of the potential to provide greater efficiency.

The constraints of this study are as follows:

- The study is driven by the examples provided by industry. It is only possible to examine what has been reported.
- This is not intended to be a statistical analysis and cannot be interpreted as such due to the limited sample size of case studies and specific project cost data, and

- There is a natural bias in the returned examples from the water companies to provide examples of where they consider the totex approach to have been successful. There may be and likely are examples of where a totex approach has cost companies more, and this may still be the desired result for companies under an ODI approach.

2.3 Project evidence from water companies

2.3.1 Summary from project evidence

Ofwat issued requests for information to the water companies on 28 November 2017 and January 2018 regarding the totex and outcomes framework and the impact of innovation in the Water Industry. This request received replies from 15 companies who returned over 180 case studies. These data requests sought examples of innovative activity by companies making use of the totex and outcomes framework to derive results.

The case studies highlighted several trends, in no order of assessment:

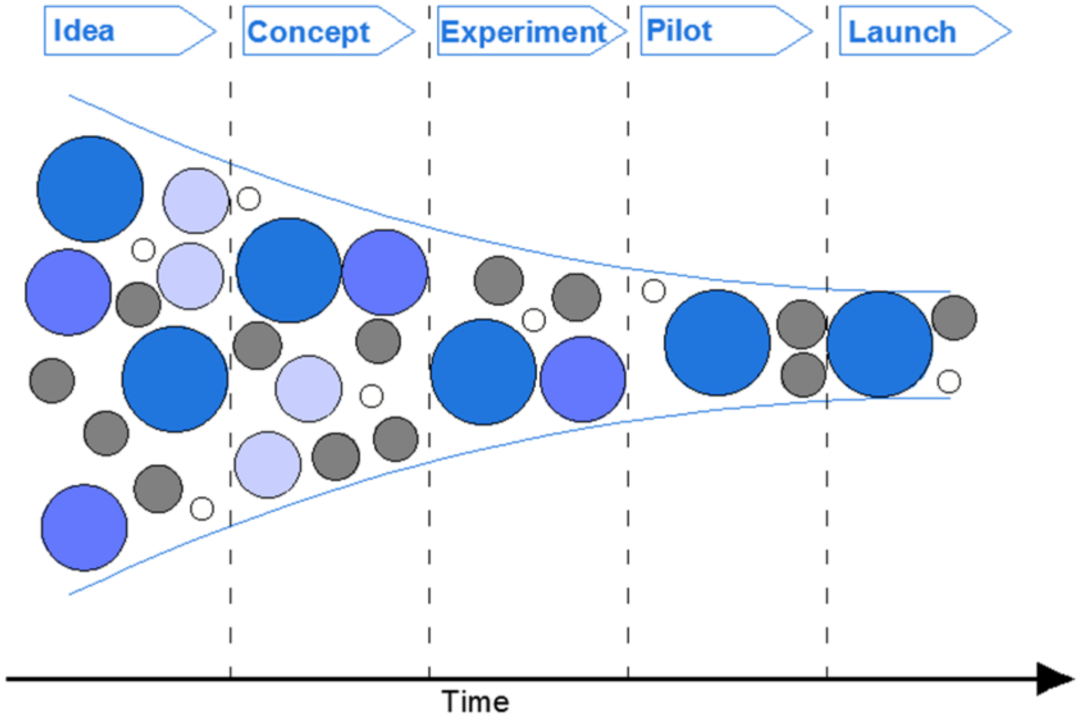
- Water main assessment and leakage reduction;
- “Big Data” and the Internet of Things, giving the ability to apply ‘smart’ solutions, maximising efficiency and optimisation;
- Catchment management enabling capex to be avoided and ‘green’ solutions used;
- Customer education to reduce sewer blockages and water wastage;
- SuDS and other green solutions to reduce sewer flooding and reduce capex; and
- “Innovation Teams” and the inclusion of employee ideas.

The 48 individual case studies provided some interesting data regarding the potential for innovation to provide a significant efficiency. The highest percentage capex efficiency driven by the use of technology, on a surveying and mapping project, is 87%; the overall average reduction for all of the case studies is 35%. The challenge for the water companies is the ability to apply innovation to a significantly larger number of projects such that efficiency increases further. At present there are not sufficient data points to extrapolate the case studies to the PR19 Business Plans; despite there clearly being significant efficiencies to be explored by the companies.

An underlying part of many of the case studies is the use of BIM (Building information modelling), which could be considered as an enabler of efficiency.

The case studies are grouped based on the stages of the case study within the innovation pipeline as illustrated in Figure 4.

Figure 4: Innovation pipeline



Source: Aqua Consultants

2.3.2 Case studies – idea and concept stages

Several of the case studies submitted involve examples that remain in the idea and concept stages. Some have highlighted the development of innovation teams and systems to bring the industry to a position where innovation is seen as business as usual rather than something that is done by others. It has also been noted by some that there are restrictions in place that prevent new products or materials being utilised such as standard specification.

A number of initiatives have centred on customer awareness and education. Examples include:

- Smart meters that enable customers to realise how much water is being used or wasted, schemes called “Green Redeem”, “Smarter Home visits” with other behavioural changes to help customers reduce their water bills;
- Helping customers reduce their water bills; “Vulnerability and Assure tariff”;
- Education to prevent sewer blockages due to the disposal of fats and items such as wet wipes; and

- Northumbrian Water's "Water Rangers" that involves volunteers monitoring public access routes next to streams, rivers, becks, burns and bathing waters across the North East which are prone to pollution.

There are a number of developments associated with leak prevention and detection ranging from the use of water with a higher temperature to minimise winter leakage to the use of sniffer dogs or satellites. Allied with these has been greater emphasis on understanding the cause of the leak/burst with the investment in a "pipe laboratory".

Whilst not quantified the education and water reduction case studies provided suggest that there could be significant efficiency delivered for a small cost. It should be possible to quantify these projects using simple metrics such as a reduction in sewer blockages. These case studies also have other benefits when delivered such as reduced disruption to traffic and the reduced demands on the water network.

A small number of the case studies are clearly at the start of their development phase, showing that there is an ongoing process of development, of these the following appear to have significant potential:

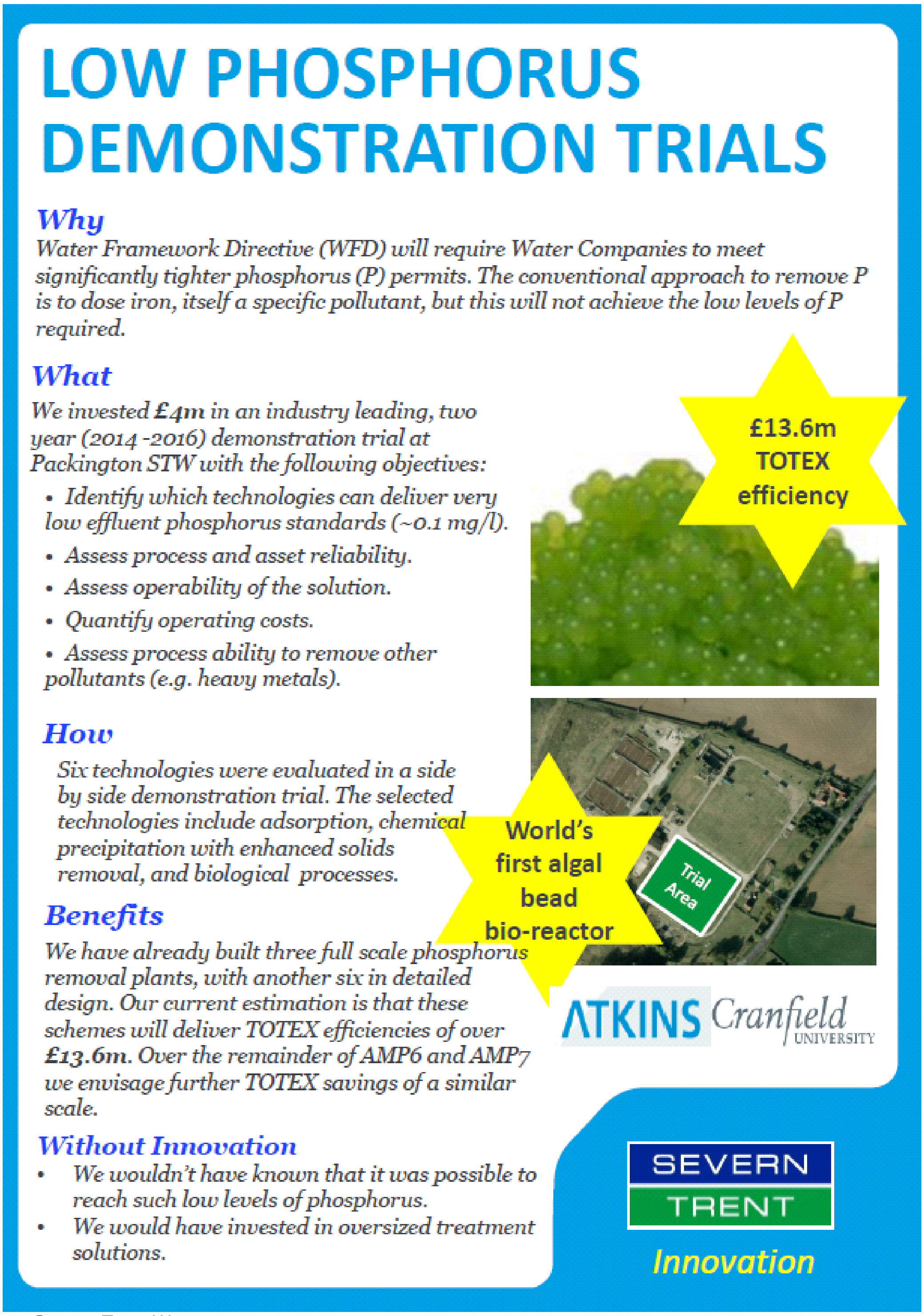
- **Final Effluent re-use:** The re-use of final effluent has been seen as something of a 'holy grail' for many years; an acceptable means of this would be of wide interest across the water industry as this could have a significant impact on the demand on water sources. Only one case study has been supplied for final effluent re-use and this is still in a development stage.
- **'Smart' bacteria that target specific contaminants**: 'Smart' bacteria could have major cost reductions to wastewater treatment if contaminants can be removed within existing process units especially if the bacteria are 'persistent' and re-inoculation is not required.
- **'Bio-augmentation' to tackle FOGs (Fats, oils and Grease):** This could be a means to tackle such problems in the sewerage network as the recently reported Thames Water's "Fatberg".

2.3.3 Case studies – experiment and pilot stages

Several of the case studies submitted involve examples that are in experiment and pilot stages. There are case studies where known engineering problems, such as pressure transients, are being resolved by new methods.

During the present AMP, innovation developed by the water industry, such as the UKWIR low-P trials, shown below in a Severn Trent document, have begun to be applied on a larger basis to solve issues. Other solutions can also be seen to be in development prior to their use being required; such as real time abstraction management to avoid metaldehyde (pesticide used in slug pellets) spikes.

Figure 5: Demonstration of innovation at Severn Trent Water



Source: Severn Trent Water

2.3.4 Case studies – launch

A significant portion of the case studies involves projects that have been through the experiment and pilot stages and are being rolled out across the relevant part of the networks. These case studies are grouped into the relevant price controls and are examined in more details below. .

2.3.4.1 Bioresources

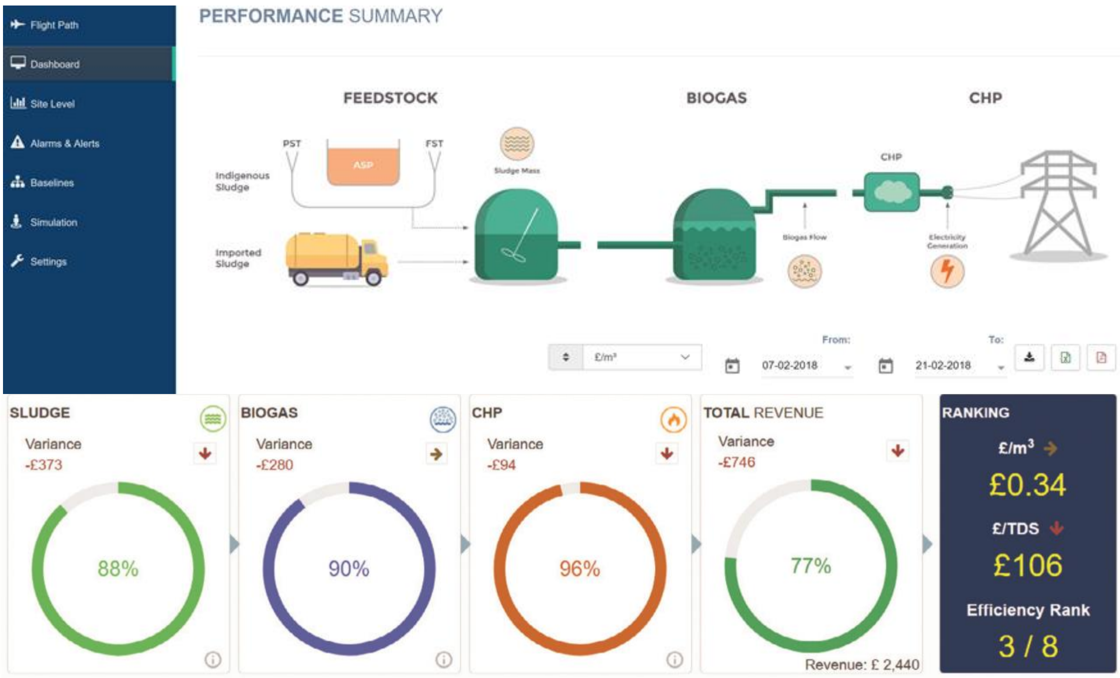
There has been a limited number of case studies submitted in the bioresources price control and these are generally high cost projects with an average value of c£30M.

The schemes submitted are for Thermal Hydrolysis, Advanced Energy Recovery and a plant where the output from the anaerobic digestion can be either gas to grid or electricity maximising the revenue stream.

The total average totex saving on these projects was -12.0%, this is largely driven by a single large capex project. Over a longer period than the AMP the projects all show a positive saving due to the revenues generated by them.

It is also recognised that optimisation of existing anaerobic digestion plants is a key focus area for a number of companies and that advances in technology are enabling low-cost opportunities to identify and optimise performance through near real-time monitoring and process intelligence. South West Water appear to be one of the early adopters based upon a case study in UK Water Projects.

Figure 6: Demonstration of a performance analysis tool at South West Water



Source: South West Water obtained from UK Water Projects available at http://www.waterprojectsonline.com/case_studies/2017/sww_marsh_mills_2017.htm

2.3.4.2 Retail

There was only a single quantified case study submitted in the retail price controls. The majority of the other case studies returned from the water companies relate to water demand reduction and customer education in water usage and, whilst they could have a significant impact, have not been quantified.

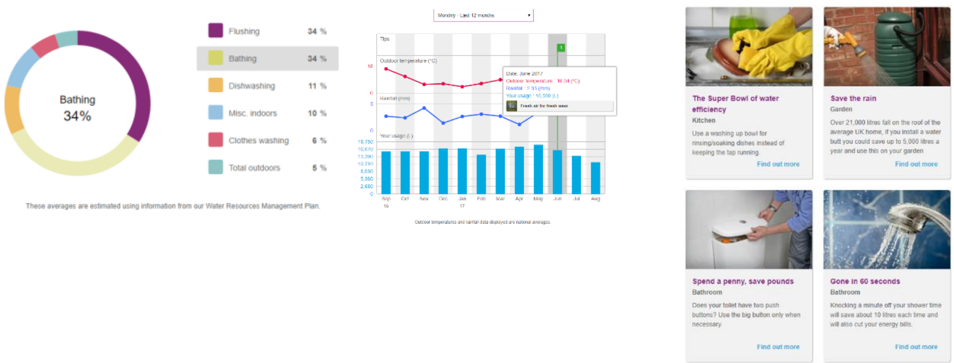
The case study that has been quantified shows a significant saving of opex. In the project an efficiency trial looks to use meter read data in combination with machine learning and behavioural science capabilities to better engage customers with their water usage and to encourage water consumption reduction through providing better information and behavioural "nudges."

Figure 7: Illustrative description of an efficiency trail

Water disaggregation: Educating customers about the average breakdown of their water usage at home, through simple visuals

Meter data: Display of AMR data, with daily update

Tips library: Helping customers take concrete steps towards reducing their water usage, with tailored tips and advice



Source: United Utilities; Customer Online Water Consumption Portal

The percentage of totex saving on this project was over 50%, largely driven by a small opex saving compared to other solutions and the low capex cost to implement the scheme.

Other companies have also used 'nudge' theory to affect the way customers behave, such as South West Water's "Love Your Loo" example.

Figure 8: Overview of the "Love Your Loo" tactics at South West Water

Source: South West Water

2.3.4.3 Wastewater network plus

The wastewater network plus price control has a much larger set of case studies than the others, the average totex saving across these projects is 40%. These case studies fall into similar types of project, demonstrating their potential for repeatability:

- Development of treatment processes – the use of an advanced form of activated sludge;
- Catchment permitting/integrated catchment management – the use of agreements with farmers to control chemicals such as phosphate rather than building treatment systems;
- Smarter catchments – real time control of storm water in a catchment;
- SUDS – 'retro-fitting' sustainable urban drainage systems and greener/water retaining features instead of increasing sewer and pumping capacities;
- Material application and Equipment development – the use of materials such as carbon fibre for sewer strengthening and the introduction of equipment from other industries; and
- Customer education/information – the application of "prevention is better than a cure" to minimise sewer blockages with campaigns such as the 'Bin it'.

A good example of a significant efficiency that likely is not repeatable on a large scale was Yorkshire Water's use of media from redundant biological filters, which produces a sellable product from a waste material.

> *"A programme of Research and Development through AMP5 and delivering benefits in AMP6. The programme established a process for recovery and processing of waste water treatment works biological filter media, enabling the material to be given 'product' status…*
>
> *… 13 hectares of percolating filter beds containing 500,000 tonnes of gravel / blast furnace slag were made redundant. …*
>
> *…. A programme of material testing and environmental impact assessment resulted in the filter bed material being confirmed as a product not a waste."*

2.3.4.4 Water network plus

The water network plus price control has eight case studies. The total average totex saving across these projects is 44.4%.

The case studies in water network plus are noticeably smaller project values than in other price control, the capex largely range from zero to £7M with the exception of one very large project. The high totex savings have been attributed to significant opex savings.

These case studies fall into similar types of project, demonstrating their potential for repeatability:

- Mains cleaning – with mains conditioning or 'ice pigging';
- Leak detection and reduction;
- Pressure transient reduction with new approaches rather than the traditional methods; and
- Smart or adaptive distribution networks.

The use of methods such as 'ice pigging', cleaning water mains with ice, appear to be moving from innovation to business as usual. This technique appears to have substantial cost efficiency when compared to conventional techniques.

2.3.4.5 Water resources

The water resources price control has eight case studies, the total average totex saving across these projects is 34.1%.

A no build example submitted by one company is described as *"We have a capex programme that was included in our PR14 business plan that was designed to remove Metaldehyde from drinking water. We are now close to securing agreement from DEFRA to ban the use of this pesticide, which will remove the need to build new treatment facilities. We are still working through the detail of this and assuring ourselves a potential cancellation of the building programme will not have any adverse effects on drinking water quality. However, if we can avoid this project, we will deliver savings to customers and shareholders through the totex sharing mechanism."*

The use of floating photovoltaic panels on a reservoir is an interesting approach to the use of the water company's facilities and their freedom to pursue innovative solutions. This project showed a totex saving of over 20%.

2.3.4.6 Multiple price controls

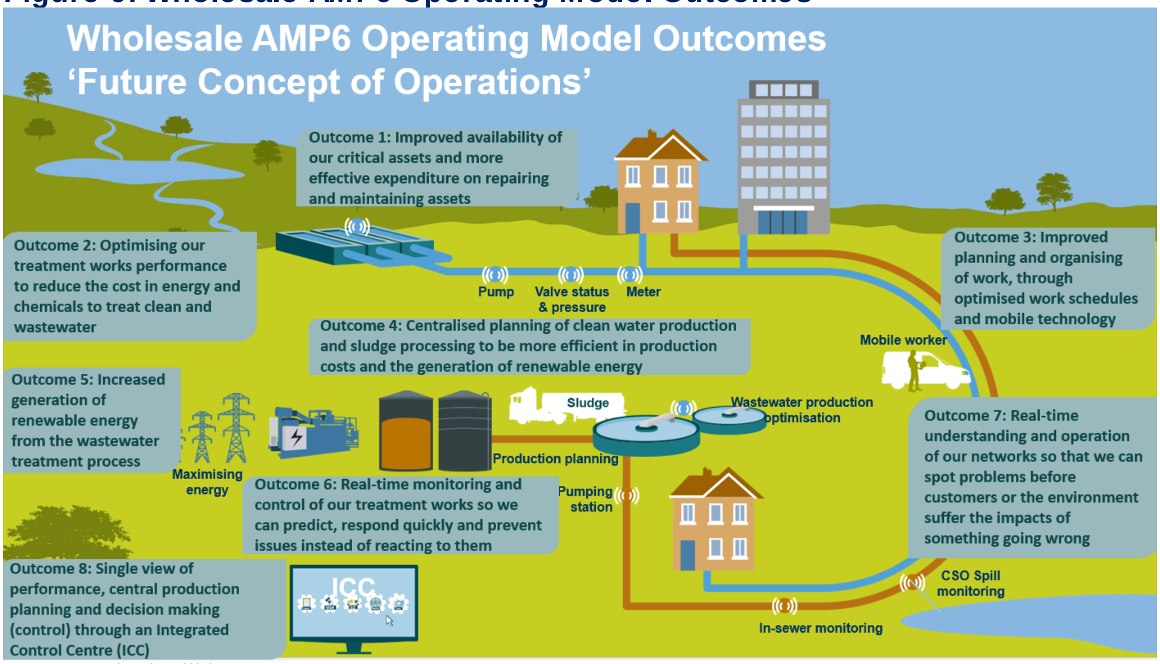
There are three priced case studies in a general category that are relevant across multiple price controls. The total average totex saving across these projects is 36.8%.

United Utilities' Future Concept of Operations (FCO) shows a new way of imagining the water industry as illustrated in Figure 9. The company introduces this concept as:

"We undertook to re-imagine how we deliver operational performance to meet the scale of the service and efficiency challenges we would face in AMP6. The approach we took was analogous to a continuous manufacturing process:

- *Thinking of water and wastewater service as products that are manufactured and delivered to customers*
- *The concept of delivering these products through a continuous manufacturing process - i.e. producing drinking water or treating wastewater to produce sludge for energy and soil fertilisers, which have similarities in continuous production manufacturing sectors*
    - *Manufacturing factories balance investment in the production line with the operational cost of production*
    - *Production plans which take account of marginal costs and optimised production across production lines and production factories"*

Figure 9: Wholesale AMP6 Operating Model Outcomes



Source; United Utilities

2.3.4.7 Summary

Table 10 summarises the case studies in the launch stage supplied by the water companies with information on the costs and efficiencies realised from the projects by price control.

Table 10: Summary of examples of totex savings by price control

Price Control	Number of detailed case studies received	Total average savings (%)	Summary of the scheme innovation
Water Resources	8	34.1	Catchment management, control of potential chemical contamination and adoption of improved efficiency equipment
Water Network Plus	8	44.4	Efficient operation of the network, pressure transient reduction and the adoption of more efficient techniques for mains cleaning.
Wastewater Network Plus	24	39.9	Catchment management, sustainable drainage, customer education and various applications of technology and equipment.
Bioresources	4	-12.0	Maximising gas yields from existing and new equipment and the revenue generated from the generated energy.
Retail	1	52.4	Customer information/education
Multiple	3	36.8	Business management systems and operational concepts
Total	**48**	**35.4**	

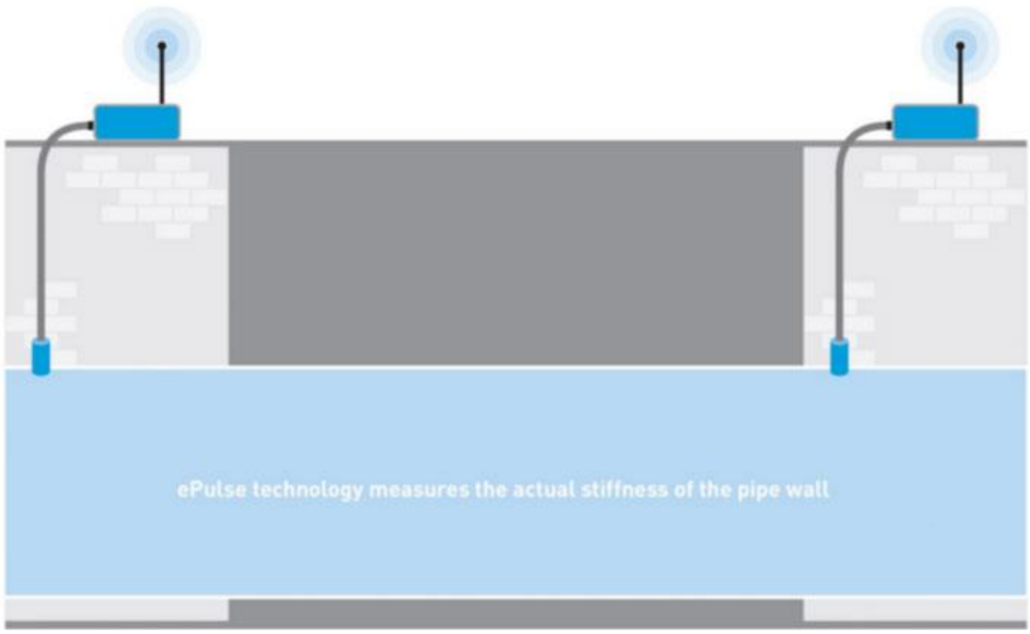
Source: Aqua Consultants' analysis of company responses to Ofwat's data requests

2.3.5 Case studies – medium and longer term deployment

There are several case studies where materials, methods and processes are being developed and appear to have the potential to start to deliver benefits in the medium to longer term.

One of the noticeable areas where it appears innovation is beginning to show benefits is in assessing the condition of underground assets. An example of this is Anglian Water's ePuls which is an acoustic mains condition assessment technique that enables the thickness of pipe walls to be measured without having to physically sample the pipe material in the traditional dig and measure or sample way. This could have a high impact on costs with water companies being able to know the condition of some of their buried assets.

Figure 10: Demonstration of an acoustic mains condition assessment technique at Anglian Water

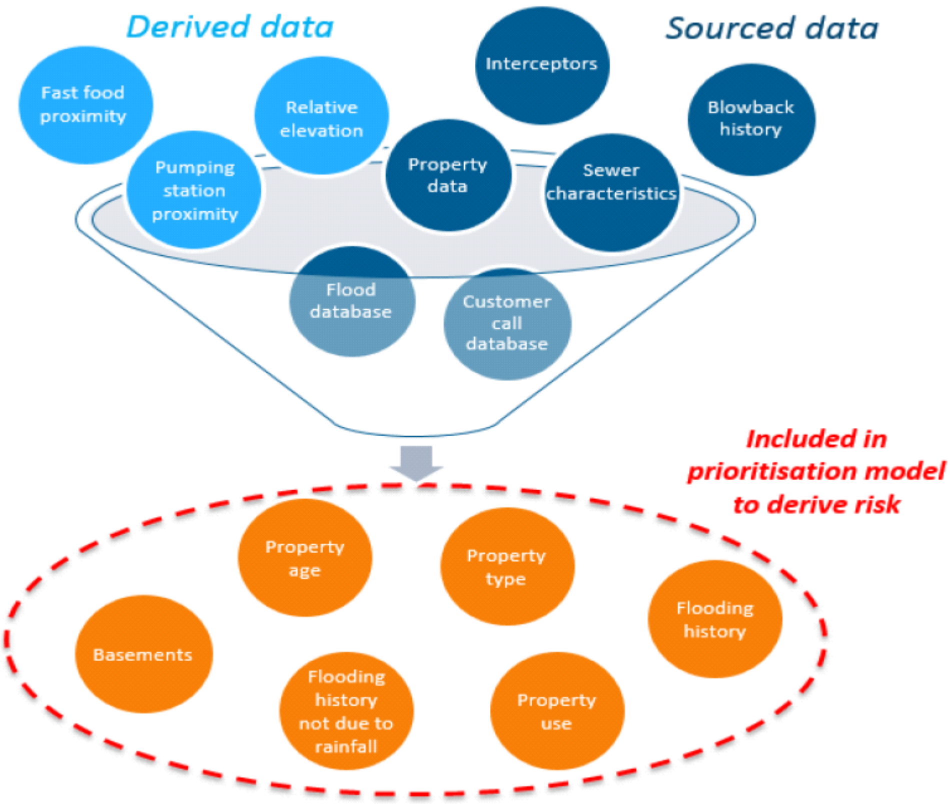


Source: Anglian Water

There are also several approaches being developed to address sewer flooding and management of catchments in real time, instead of constructing additional treatment capacity or SUDS. This has the ancillary benefit of also reducing the potential for flooding to occur. Case studies from Thames Water and South West Water provide some examples. Welsh Water have worked with multiple partners to develop an integrated and sustainable approach to surface water management, to remove surface water from the sewer network, again avoiding the need to build additional capacity.

Thames Water's Sewer flooding - cognitive computing model, described as "*part of a drive to deliver more targeted responses on sewer flooding. A cognitive computing model was created, using leading edge machine learning technology, to identify the key factors that indicate if a particular reactive job is more likely to lead to a flooding incident. Using these factors the model was able to predict which future jobs would be most likely to escalate into a sewer flooding incident.*"

Figure 11: Demonstration of a cognitive computing model



Source: Thames Water

South West Water's "Use of IT Innovation to Help Prevent Pollutions" is similarly described as *"… creating an innovative 'Pollution Prevention' solution to prevent environmental impact from our sewerage operations on coastal and inland watercourses. Pollution events/spills can happen when pipes become blocked, when assets (e.g. pumps) fail or if the system becomes overwhelmed by large volumes of surface water during heavy rain. Reflecting the value we – and our customers – place on minimising such risks and the potential impacts on customers and the environment, our PR14 outcomes and performance commitments embedded our intention to raise our service in this area. There are many factors affecting performance."*

2.4 Evidence from the public domain and members of the supply chain

2.4.1 Members of the supply chain

The supply chain that supports the water industry is a key part in the development of innovative products and systems and many of the case studies supplied by the Water Companies have the benefit of the supply chain's input; in some instances due to confidentiality agreements it has not been possible to credit these inputs.

During the research for this report several members of the supply chain noted that the application of innovation can be delayed or prevented by company's standard specifications, British Standards and other regulations.

The research carried out with the supply chain was with a very small sample of the companies that are active in the water industry covering a range of equipment, process, academia and data technology companies. The following sections are a selection of the responses to the data requests made by the supply chain. They highlight some companies where there is a potential for them to provide efficiency in the short term. They have also been active in the water industry and have played a part in some of the case studies supplied by the water companies.

Hydrosave

Some of the innovations suggested by Hydrosave are at a much smaller scale than those highlighted elsewhere in this report.

A few case studies supplied by the water companies are about projects where transient pressures are being minimised to protect the pipeline assets through valving and control regimes.

What has not been noted in any of the case studies is the ability to monitor the functionality of one of the components of transient suppression the air valves. This monitors if an air valve is not working which would transient pressure or could be leaking if stuck. Hydrosave's SSIREN air valve sensor could be a suitable means of measurement.

Their asset condition monitoring services could be advantageous to water companies, where those companies are endeavouring to understand the condition of buried assets, an area where information appears to be poor.

National Buried Infrastructure Facility (NBIF)

The existing situation regarding buried infrastructure appears to being addressed. Some of the areas that companies are focusing on, based on evidence from the case studies, include:

- Quantifying and measuring the assets' condition;
- Adding systems to extend the serviceability of the buried assets;
- Installing asset monitoring systems; and
- Establishing training facilities for operational personnel.

In addition, the establishment of the National Buried Infrastructure Facility (NBIF) could contribute towards a better understanding of buried infrastructure. The NBIF describes itself as "*a 'one of its kind' facility for research, education and training in buried infrastructure-ground interaction, soil stabilisation and improvement, geophysical sensing, pipeline detection and condition assessment, tunnelling and trenchless technologies*".

IBM

IBM have identified developments that have been applied to other industries that could and are being applied to the water industry. Some of the provided examples include:

- **Call Centre Chat Bots.** Artificial Intelligent robots which interact with customers via chat messaging functions to answer simple customer enquiries.
- **Convergence of Information Technology and Operational Technology**. Growth in new Internet of Things devices is also bringing new ways to capture data.
- **Customer Analytics.** The application of new and more powerful techniques to data to derive insights and allow ability to predict future events and target interventions.
- **Augmented Intelligence.** AI and Cognitive Computing is aiding many businesses to reimagine how insights are derived from sets of data.

Servelec Technologies

Servelec Technologies have highlighted three potential innovations:

- Demand side response (DSR) and dynamic energy tariffs

DSR: Water companies are typically able to rapidly increase or decrease their energy consumption by turning pumps on and off, exploiting their water storage to buffer the impact on customers. Energy companies provide incentives for water companies who can respond to their requirements as needed, such as remuneration or reduction in energy rates.

Dynamic tariffs: Water companies are typically able to defer some pumping to less expensive tariff periods (by using storage) and so can benefit from tariff rates which vary over time. Responses to dynamic tariffs can be made in near real-time.

- Use of artificial intelligence.

'Weak AI' technology is well established and can be implemented cost-effectively without significant risk. FlowSure software uses AI to identify anomalies in flows, pressures, levels, temperatures, etc. to identify leaks, bursts, sewer blockages, impending M&E failures etc.

- Real-time asset optimisation

“Real-time asset optimisation using intelligent edge devices plus top end insights leading to properly informed decision analytics. Asset inspections and maintenance would be targeted more effectively at those assets that are at high risk of failure.

Applications within water companies are starting with higher value and higher criticality pumping equipment."

To illustrate the application of the above technologies Servelec provided the following case studies:

- Portsmouth Water FlowSure Implementation

Portsmouth Water is the latest water supplier to adopt Servelec Technologies' leakage detection software FlowSure following a whole company six-month competitive trial, which detected 322 genuine anomalies, of which 43 where bursts leading to potential annual six-figure net savings.

- Wessex Water New Supply Grid - OptiMISER implementation

Due to be completed in 2018, the water supply grid is a £230 million project that will enable Wessex Water to meet demand in their area for the next 25 years without the need to develop new resources. Started in 2010, the grid when finished will be over 124 miles in length and will be optimised by Servelec Technologies' real-time automated water network control system. Phase 1 was completed in August 2014, when OptiMISER was shown to be providing 10 - 12% savings per annum at key sites, and Wessex Water have been configuring the system themselves to cover the new grid network.

- Towards Enhanced Status: Affinity Water's Quest For Optimal Asset Management

Affinity Water optimised their production and network investment options using Servelec Technologies' PIONEER optimisation tool. The company area was considered as eight distinct 'communities'. The investment plan was optimised to achieve service targets at least discounted cost both at community level and for the company as a whole. This resulted in reduced costs whilst making environmental improvements, tackling leakage and reducing customer interruptions and Ofwat awarding Affinity Water 'Enhanced Status.'

2.4.2 Public Domain Case Studies

In addition to the case studies submitted by the water companies, there are numerous projects highlighted in trade press articles that highlight where innovation has been applied to projects. The breadth of these published case study examples shows how projects can be delivered with the application of innovation in appropriate circumstances. These are listed in the Appendix 2.

2.5 Future innovation opportunities

There were a number of recurring themes in relation to future opportunities for innovation in the water industry. These were not reported as immediately or readily deployable but were considered to offer "game-changing", disruptive change by water companies.

2.5.1 The Internet of Things - IoT

A network of sensors that can be deployed across vehicles, appliances, electronic devices and other objects that are connected to the Internet. Through sensors, software and online connections, these items can exchange data and be controlled remotely in real time.

> *"…this is a very interesting prospect for companies such as ours that serve millions of people and operate over hundreds of sites, some in remote locations.*
>
> *Having real time information on all our assets and processes… would mean that we could **operate as efficiently as possible** and **respond rapidly** to unexpected events.*
>
> *It could also give us a **better understanding of those we serve** – their needs and wants and how they use our service."*
>
> **Wessex Water**

2.5.2 Machine Learning, Predictive Analytics & Artificial Intelligence

This refers to the ability for software programmes to 'learn' from experience and data and to react as a competent person would to a given situation. Weak artificial intelligence is already common place. However, the attainment and deployment of full artificial intelligence is recognised as a significant source of opportunities going forward.

For the water industry this could mean the automation of complex processes, significantly reduced staff costs, enhanced quality and improved consistency of decision making.

One responding company summarised the key applications in the water cycle where machine learning and predictive analytics can bring significant benefits, as follows:

- **Resource management**: Quantitative and qualitative water sources condition forecasting;
- **Networks**: Water demand forecasting and water losses reduction/leakage detection;
- **Asset management**: Predictive maintenance according to reliability and risk analysis;
- **Works and interventions**: Field operations simulation and optimisation;
- **Projects and investments**: Capital investment prioritisation;
- **Billing**: Irregular consumption and fraud detection;
- **Metering**: Sensor location strategy optimisation according to water consumption analysis; and

- **Customer care**: customer satisfaction analysis.

2.5.3 Solar energy and energy cost reduction

This involves conversion of solar energy to heat and electricity, which provides opportunities for water companies to significantly reduce their energy costs.

This technology exhibits rapidly falling cost per unit of energy generated; indeed solar energy cost per watt has already reduced by 100 times since its introduction and is predicted to continue falling at a rapid rate. The point of disruption comes when solar becomes the same or lower cost as energy from local grid supplies.

This offers the potential to reduce the cost of energy, which is a significant proportion of water company's operational costs.

Companies like South West Water have already undertaken widespread roll out programmes for solar, installing small scale solar across 35 sites and one large solar farm which provides all the energy to a nearby water treatment works.

2.5.4 Battery storage

The fast-falling production costs of lithium ion batteries has the potential to disrupt the industry, allowing companies to store energy generated from renewables to enable them to use or export at the most cost/value beneficial periods. The cost per kWh has already halved since 2014 and is predicted to halve again by 2022.

Water companies are already investigating the benefits of adopting battery storage.

2.5.5 Automation / robots

The use of physical or virtual machines that can carry out or assist a wide range of activities, often where exact repetition is required or in hazardous working locations. Example applications include survey robots used to film or scan the inside of sewers, tunnels or water mains.

2.5.6 Building Information Modelling (BIM)

Industry metrics suggest 20% savings in capex are possible with a larger opportunity in the operational phase on the basis that the asset will spend more than 80% of its life in operations. United Utilities reported that this approach will improve their ability to analyse whole life cost and improve totex decision making.

Below are extracts from the Digital Built Britain programme which outline the potential benefits in better service to the customer, better social outcomes and increased productivity.

"The programme is designed to transform how the UK construction industry and operations management professionals approach social and economic infrastructure through digital technology. This includes the way we plan, build, maintain and use that infrastructure, as well as the renewal, replacement and creation of new built assets.

All of this should help people to make better use of built assets, and provide better social outcomes to the challenges of urbanisation and an increasing population. It should also improve the UK's productivity and support growth. "

2.5.7 Digital Twin

A digital twin is a virtual representation of a process, product or service. It is a digital information model that represents a physical asset. This could be an individual asset like a pump or a group of assets like a treatment works. It could also be a network which includes water mains, sewers and assets like pumping stations.

This will provide companies with the opportunity to stress test and trial operational changes and regimes in pursuit of efficiency that would previously have been considered too high a risk or cost.

Digital Twins made it into Gartner Research's top 10 trends for 2017. They predict this approach will be progressively adopted within three to five years.

> *"…This concept is gaining traction in industries such as aerospace and automotive and is often in the top 10 of innovation trends (reference Gartner Research). To exploit this approach within the water industry would be a step change."*
>
> **United Utilities**

2.6 Reported challenges to future efficiency and innovation

Responding companies identified a number of challenges to sustaining future reductions in expenditures and continuing innovation, including:

- The uncertainty and cost implications of Brexit;
- Rising energy costs;
- Increasingly tighter water quality standards;
- The impact of climate change; and
- The public's demand for increased level of service and lower costs.

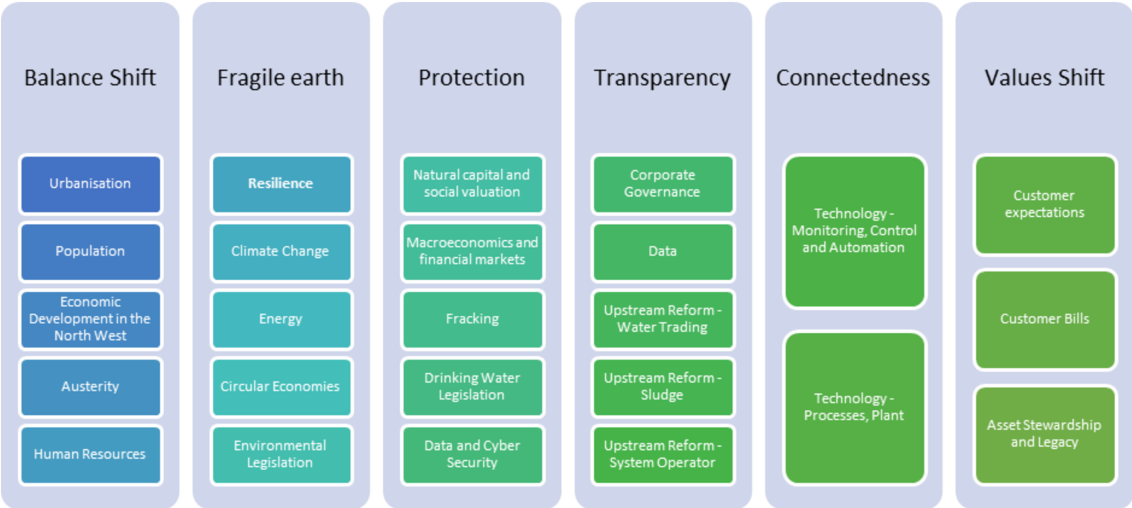
In addition, there is a diverse range of big challenges facing, not only the water industry, but global business as a whole. These big challenges are recognised as the drivers for change. For example, Business in the Community developed a "Forces for Change" framework which recognises these big challenges[7]. The application of this framework by

[7] Business in the Community is a business-led membership organisation as part of the prince's responsible business network

one of the respondent companies, United Utilities, can be seen in Figure 12 which summarises a number of common challenges facing the water industry as a whole.

The solutions to these big challenges will certainly require a greater focus on innovation over efficiency. Innovation can often come at greater upfront cost with no guarantee of future success, therefore the pursuit of disruptive change to meet these big challenges is likely not without risk.

Figure 12: United Utilities interpretation of the Forces for Change Framework



Source: Forces for Change Framework developed by Business in the Community

2.7 Scale of efficiency and innovation for PR19

The tables below show project evidence from water companies by price control. The project evidence are assessed on the following criteria:

- Repeatability – if the case study could be carried out again at the company or in other places or if a 'one-off' opportunity had been maximised.
- Time Horizon – whether the case study had reached a widely deployable state, was under development or was likely to occur in the future; Short, Medium and Long implementation timescales.
- Impact – in terms of the potential to provide greater efficiency.

A large number of project evidence is assessed to have low to medium repeatability for the industry. This reflects the fact that these project are already being deployed by at least some companies in the industry. Where the schemes are already deployed by some companies, they represent catch-up efficiency opportunities for other companies in the industry. This reflects the limitation of the data requests which focus on projects that companies are already implementing as supposed to future opportunities for the sector.

Bioresources

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Flexible energy generation (Bioresources)	A project that provides either gas or electricity to the grid depending on prevailing conditions.	Low	Short Term	Large
Thermal hydrolysis process	Increased benefits from bioresources.	Low	Medium Term	Medium
Advanced Energy Recovery	Increased benefits from bioresources.	Low	Medium Term	Medium

Multiple price controls

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Innovation - SAP Business Transformation programme	The SAP Transformation Programme is deploying the SAP S/4HANA business suite and will ensure Yorkshire Water is connected and integrated across its processes. It will change how the business works, delivering standardised processes and connected data that will allow continuous improvement approach to be taken.	Low	Medium Term	Large
Innovation - Decision Making Framework (DMF)	Systematic decision making.	Low	Medium Term	Medium
Future Concept of Operations (Wholesale)	A change to the way the business is seen and operated.	Low	Long Term	Large

Retail

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Customer online water consumption portal (Retail)	The water efficiency trial looks to use meter read data in combination with machine learning and behavioural science capabilities to better engage customers with their water usage and to encourage water consumption reduction through providing better information and behavioural “nudges”.	Medium	Medium Term	Medium

Wastewater Network Plus

Scheme Title or Reference	Brief Description	Repeatability		Time Horizon		Impact	
EnTrade	Catchment management approaches which were optimised through the EnTrade platform. Other benefits in flood management, biodiversity and reduction in other nutrients and contaminants.	Amber	Medium	Green	Short Term	Green	Large
Catchment permitting	Catchment management for the removal of phosphorous	Amber	Medium	Green	Short Term	Green	Large
Llanelli National Environment Programme Schemes	Catchment approach to spill reduction, linking key assets to spread flow around the catchment during and after heavy rainfall periods.	Amber	Medium	Green	Short Term	Amber	Medium
GIS mapping and inferring the transferred drains and sewers network	The use of existing knowledge about the potential location of 'private' sewers on the basis of house style.	Amber	Medium	Green	Short Term	Amber	Medium
Murton Gap, North Tyneside	The use of surface water separation, online storage and upsized gravity sewers rather than pumped storage.	Amber	Medium	Green	Short Term	Amber	Medium
Pollution reduction programme	The SNIPer system was implemented to provide alerts to asset owners about performance issues at any sewage pumping station. This has enabled attendance at site before a pump failure occurs and intervention to take place.	Amber	Medium	Green	Short Term	Amber	Medium
'Bin it' campaign	A customer education programme aimed at reducing sewer blockages.	Green	High	Amber	Medium Term	Amber	Medium

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Integrated Catchments (Wastewater Network+)	The integrated catchment management approach to address a number of drivers identified in the NEP in a more efficient way delivering greater benefits than a 'construction' approach.	Medium	Medium Term	Large
Wastewater network management (Wastewater Network+)	Improve knowledge, management and performance of the wastewater network by applying an operating model concept on systems thinking.	Medium	Medium Term	Large
Rainscape - Greener Grangetown	Co-operative working with Cardiff Council for the first time to achieve additional resilience for future development in the area.	Medium	Medium Term	Medium
Bucher press	The use of equipment generally used in the food industry in a sewage sludge application.	Medium	Short Term	Limited
Nereda Aerobic Granular Biomass (Wastewater Network+)	The use of a new activated sludge process that develops granular biomass to aid settlement of the sludge in the process unit.	Medium	Medium Term	Medium
Sewer flooding LITE	Improve the customer experience following a sewer flooding incident, as well as removing unnecessary delays and rework	Medium	Medium Term	Limited

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Rainwise	Working with communities and partners to manage the amount of surface water (rainwater from roofs, roads and other hard surfaces) that enters the sewer network to help reduce the risk of flooding to homes and businesses and provide environmental protection	Medium	Medium Term	Limited
Mobile Sludge Dewatering – Reducing Operational Costs	Using mobile equipment to reduce the transportation cost of sewage sludge.	Medium	Medium Term	Limited
Kings scholar pond	Use of new materials and techniques to refurbish a sewer.	Low	Short Term	Limited
Filter Bed Media Recovery and Reuse	Re-use of a 'waste' that became a material of value.	Low	One-off	Large
MRTOI	Real time odour monitoring.	Low	Long Term	Medium

Water Network Plus

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Energy Efficiency	Power generation by gas turbine instead of grid supply.	Medium	Short Term	Large
Ice pigging	Cleaning watermains using ice slurry instead of the traditional techniques. The ice slurry cannot become stuck in the water main.	High	Short Term	Limited
Network Optimisation	Optimising pump scheduling via the effective implementation and utilization of Aquadvanced Energy Distribution Optimization software.	Medium	Medium Term	Medium
Dynamically Adaptive Water Distribution Networks	Collaborative working to improve the resilience, pressure management and operational efficiency of the network, increasing asset life.	Medium	Medium Term	Medium
Reducing the impact of transient pressure in our water networks	Management of pressure transients in water mains.	Medium	Medium Term	Medium
Mains conditioning	The PODDS (Prediction and Control of Discolouration in Distribution Systems) approach to mains conditioning	Medium	Short Term	Limited
Management Innovation - aerial imaging for leak detection, ice pigging adopted.	The use of various techniques to improve efficiency in the water network.	Medium	Medium Term	Limited

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Pressure Transient Training Facility at Glascoed & Sluvad Water Treatment Works	Training facility for operational staff.	Low	Medium Term	Limited

Water resources

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Pesticide removal or DEFRA to remove from market	A no-build solution enabled by working with Defra.	Low	Short Term	Large
Permanent magnet motors (PMM) for boreholes	The use of permanent magnet motor to provide increase efficiency when the existing assets are replaced.	High	Medium Term	Limited

Scheme Title or Reference	Brief Description	Repeatability	Time Horizon	Impact
Coppermills RGF configuration	Install a blending option for nitrate reduction in preference to installing a new ion exchange plant.	Low	Short Term	Medium
Ardley Spillway	Use of new materials in the replacement of a spillway.	Low	Short Term	Limited
Aquadapt	Aquadapt is a software system for real time optimisation and control of water production and distribution systems	Medium	Medium Term	Limited
Floating PV	Using floating photovoltaic cells on a reservoir.	Low	Medium Term	Limited
Lane end nitrate removal	Identify savings relative to more detailed design and cost appraisal of the original design solutions.	Low	Long Term	Limited

Source: Aqua Consultants' analysis of companies' replies to Ofwat's data requests

2.8 Conclusion

The 48 submitted case studies with costing data represent circa 3.8% of capex spend in the AMP. A summary of the findings are:

- The data request made was for a representative sample of projects, yet of those provided there appears to be a bias towards those that can be described as 'good', none of the case studies submitted show a project where risk was encountered. It is not possible to assess this 'optimism' bias based on the data received.
- There are significant savings of up to 100% of totex with an average saving of 35% across the projects over AMP 6 from company responses;
- For some projects companies responses indicated that they are spending more in this control period in order to reduce whole life costs;
- There are projects that could be applied more widely across the sector. For example "ice pigging", a means to clean water mains, saves significant cost compared to conventional method;
- Several of the case studies with unquantified impact show costs (for example, customer information) with no corresponding demonstrated benefits during this control period, however there is clear potential for these cases to produce savings and/or service improvements in future AMPs.
- The responses from the companies indicate that substantial efficiencies as a proportion of project costs have already been realised by adopting the principles of the totex and outcomes framework during AMP6, some of which might be replicable to larger programmes and others that are isolated instances. The totex efficiencies reported to be achieved do not appear to have come at the cost of service levels based on the responses provided.

The conclusions are based on this limited sample of 'innovation' schemes, out of the thousands carried out by the water companies in each AMP.

Table 11 provides a summary of potential totex savings across different price controls. The savings have been normalised to a 5-year period to reflect a duration of the water price controls.

Table 11: Summary of examples of totex savings by price control

Price Control	Number of detailed case studies received	Total average totex saving over 5 years (%)	Summary of the scheme innovation
Water Resources	8	34.1	Catchment management, control of potential chemical contamination and adoption of improved efficiency equipment
Water Network Plus	8	44.4	Efficient operation of the network, pressure transient reduction and the adoption of more efficient techniques for mains cleaning.
Wastewater Network Plus	24	39.9	Catchment management, sustainable drainage, customer education and various applications of technology and equipment.
Bioresources	4	-12.0	Maximising gas yields from existing and new equipment and the revenue generated from the generated energy.
Retail	1	52.4	Customer information/education
Multiple	3	36.8	Business management systems and operational concepts
Total	**48**	**35.4**	

Source: Aqua Consultants' analysis of company replies to Ofwat's data requests

These case studies alone, when considered together, show an overall totex efficiency of 1.3% of the overall AMP determination (35.4% of the total 3.8% of expenditure that is covered by the projects in the sample). The case studies also clearly show that innovation can play a significant part in enabling the water companies to deliver improved efficiency and suggest that significant efficiencies have been achieved in some instances.

At the same time, given that the reported spending on the schemes examined represents less than 4% of companies overall expenditure, and given that the case studies have been selected specifically to illustrate efficiency gains from Totex, the reported gains might not be representative of all of companies' business activities, and, therefore, extrapolating from this data alone would not be appropriate for setting expectations of future savings.

3 Totex performance assessment

Both the water sector in England & Wales ("E&W") and GB energy networks have adopted the totex and outcomes framework as a general concept, albeit the application of the framework differs between the two sectors. A direct examination of companies' expenditures during the totex price controls could provide an indication of efficiency gains resulting from the introduction of the framework.

As a starting point, sub-section 3.1 provides an analysis of company cost performance against cost allowances from price controls before and after the introduction of the totex and outcomes framework. The regulator sets cost allowances such that companies recover efficiently incurred costs, taking into account its view of future ongoing efficiency improvements over the price control. On the assumption that the regulatory cost models are accurate and without bias, then the revealed cost outperformance against regulatory allowances during the price control can be taken as representative of efficiency gains of outperformance is assumed to equate efficiency.

In practice, outperformance against regulatory allowances could be due to additional factors beyond companies' control and unrelated to efficiency. These factors, to the extent they are quantifiable, are removed from the outperformance figures. The impact of non-identified and/or non-quantifiable factors on the results is not certain. This necessarily leads to a wide range of estimates as a result.

Sub-section 3.2 explores two possible approaches in interpreting cost performance observed during the first totex control as a measure of efficiency gains. The two approaches are as follows:

- **Approach 1:** This approach assumed that: efficiency gains revealed during the previous price controls are fully captured in regulatory cost allowances for the next price control period; outperformance during the current price control purely reflects efficiency gains; these efficiency gains are due solely to the change in regulation; and, therefore, all outperformance observed during the price control where the totex and outcomes framework is in place reflects efficiency gains due to the introduction of the framework itself.
- **Approach 2:** This approach assumed that: there are persistent company-specific factors that lead to a dispersion in cost performance against regulatory cost allowances across the industry; these company-specific factors persist before and after the introduction of totex and outcomes framework; efficiency gains are therefore measured as incremental gains in cost outperformance over the successive price controls; and these efficiency gains are due solely to a change in regulation.

  Where there are factors that are persistently driving changes in outperformance and efficiency across adjacent control periods unrelated to the regulatory change, then approach 2 better controls for such factors than approach 1.

Both approaches assume that there are no external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis. In addition, all efficiency is assumed to be accounted for by the regulatory change. Other factors affecting realisable efficiency gains are under companies' control. While these are strong assumptions, is no evidence to suggest the direction of scale of the impact of these other factors on efficiency. Therefore, there are no obvious grounds to suggest that true efficiency gain should not be distributed symmetrically or where they could fall within the range estimate.

The totex and outcomes framework has, in the most part, only been implemented for the first time during the current price control period in both energy and water. Indeed, the two approaches discussed above only infers evidence from the first totex price controls. The quantification of the impact on the on-going efficiency gains of the framework would ideally require a longer-term time series of cost data from companies, which is not available. Therefore, the impact of the framework on on-going efficiency gains has to necessarily be hypothesised and inferred.

Sub-section 3.3 provides two potential hypotheses around the impact of the framework on on-going efficiency gains. The hypotheses are as follows:

- **Hypothesis 1**: There have been on-going technology improvements affecting productive efficiency in the wider economy. The on-going technology improvements were also available to the water sector but for the regulatory barriers, which have been addressed by the totex and outcomes framework. The revealed efficiency gains during the first totex control represents both a new, higher rate of on-going technology improvements and a catch-up by the industry to the level of efficiency in the wider economy (as per **approach 1**). Therefore, the catch-up component has to be separated from the revealed efficiency gains during the first totex control to identify the on-going shift due to the framework.
- **Hypothesis 2**: As per hypothesis 1 but efficiency gains during the first totex control are measured as incremental gains in revealed outperformance between the totex and non-totex price controls (as per **approach 2**).

Both hypotheses rely on the experience in electricity distribution networks, which are currently going through the second totex control, to identify the catch-up component from the on-going shift component. Therefore, it assumes that experience in electricity distribution networks would equally apply to the water sector.

Sub-section 3.4 then draws together evidence from revealed outperformance to draw implications on potential efficiency gains during the second totex control.

Throughout this section, cost performance are reported on two bases:

- **Total average performance**—the percentage totex outperformance against regulatory allowed totex over the total duration of the full price control period;
- **Annual incremental performance**—total average performance but expressed as annual incremental change in cost performance, assuming an even spend profile across the duration of the price control.

To illustrate these measures imagine a company with an allowed totex of £100 that actually spent £90 over a five-year price control. This company outperformed the allowed totex by £10, and therefore the cost performance on a total average basis is 10%. That 10% total average performance is equivalent to achieving 3.5% incremental savings sequentially for each and every year during the price control period.

3.1 Analysis of cost performance against cost allowances

This sub-section provides an analysis of company cost performance against cost allowances from recent price controls within the water and energy sectors.

3.1.1 Water sector

PR14 is the first water price review that adopted the totex and outcomes framework. It was also the point at which the outcomes framework was simultaneously introduced.

PR14 is still in progress with companies having so far reported only their performance for the first two years of PR14 to financial year (FY) 2016-17. As PR14 has not yet finished, comparing outturn totex directly with regulatory cost allowances may misrepresent the genuine efficiency gain. This is due to the timing effect where a company may, for various reasons, adopt a different expenditure profile from the assumed profile at the Final Determination.

In contrast, companies also report their performance in their annual performance reports. The performance reports include companies' estimates of the impact on their return on regulated equity (RoRE) of their cost performance against allowed total expenditures[8], excluding any underperformance or outperformance due to re-profiled expenditure within the current control period. Therefore, the RoRE figures represent genuine additional costs or cost savings relative to the regulatory cost allowances.

Using the RoRE figures, it is possible to estimate companies' cost performance against regulatory allowances on total expenditures, assuming the current level of outperformance will persist through the end of the price control. The steps taken are outlined in Appendix 1. Companies' cost performance include genuine efficiency gains as well as additional factors unrelated to the totex and outcomes framework. Companies' cost performance are adjusted for these additional factors to the extent that they are identified and quantified by companies in their annual performance reports. It is unclear however whether these adjustments are exhaustive. Table 12 provides a summary of adjustments made to companies' cost performance. Negative figures represent adjustments that reduce outperformance.

[8] Companies report RoRE figures that also include the impact of retail cost performance. Companies' RoRE figures are adjusted to strip out retail cost performance.

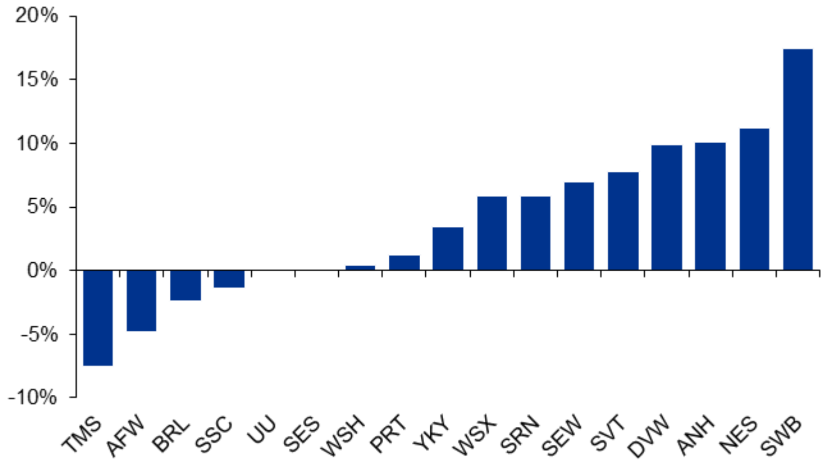
Table 12: Adjustments made to companies' cost performance

Company	Adjustments for	Size of adjustments (£m)
Welsh Water	Renegotiation of the NRW service charge, rates refund received after challenging the 2005 water network assessment, release of provision regarding billing dispute, rates refund	-29.5
Northumbrian	Pension credits, cumulo rate credits	-24.8
Southern Water	Rates rebate, classification of wholesale costs as retail, classification of wholesale costs as non-appointed business	-12.6
Wessex Water	Benign weather conditions during construction	-11.0
Bristol Water	Curtailment gain on the closure of the defined benefit scheme	-3.1
South West Water	Merger synergies (£27m over 5 years converted £5.4m per annum)	-5.4

Source: Companies' annual performance reports

Figure 13 presents companies total average performance against wholesale cost allowances to date. Positive figures represent outperformance against cost allowances. The chart shows that eleven of the sixteen water companies have so far realised cost savings against their wholesale cost allowances.

Figure 13: Companies total average performance against cost allowances



Source: KPMG analysis of companies' annual performance reports

Table 13 shows summary statistics of water companies' cost performance during PR14 to date. Positive values indicate outperformance against regulatory allowances. The table shows a wide dispersion in observed cost performance across companies with a standard deviation almost twice the size of the median. Wide dispersion indicates the presence of other factors driving companies' cost performance. On an annual incremental basis, companies' cost performance rates range between 0.0% and 2.7% a year. The minimum and maximum are not considered as they represent outliers.

Table 13: Cost performance during PR14

Outperformance measure	Min	Lower quartile	Median	Upper quartile	Max	Standard deviation
Total	-7.6%	0.0%	3.5%	7.8%	17.4%	6.5%
Annual incremental	-2.4%	0.0%	1.2%	2.7%	6.3%	2.3%

Source: Analysis based on the estimate of the impact of wholesale cost outperformance on RoRE as reported by companies in their annual performance reports adjusted for factors unrelated to efficiency as quantified by companies.
Note: Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

Table 18 shows summary statistics of water companies' cost performance during PR09, which is the most recent price control prior to the introduction of totex and outcomes framework. Companies' cost performance rates were higher during PR14 (0.0 – 2.7% a year) than during PR09 (-0.6 – 1.9% a year).

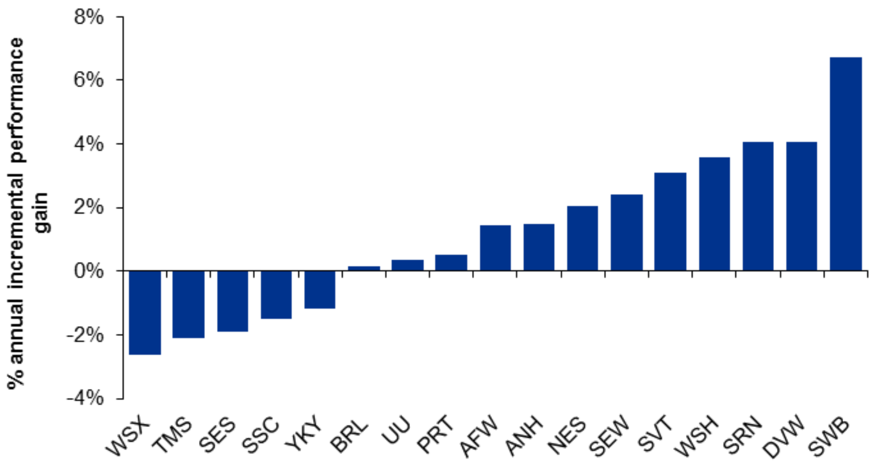
Table 14: Cost performance during PR09

Outperformance measure	Min	Lower quartile	Median	Upper quartile	Max	Standard deviation
Total	-10.8%	-1.9%	-1.1%	5.5%	13.0%	6.0%
Annual incremental	-3.4%	-0.6%	-0.4%	1.9%	4.6%	2.0%

Source: Analysis based on cost performance data obtained from Ofwat.
Note: Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

The increase in the level of outperformance appears broad-based. Figure 14 shows the distribution of changes in the level of cost performance between PR09 and PR14 across companies. A positive number indicates an increase in cost performance. The figure shows that 12 of the companies have increased the level of cost outperformance relative to PR09.

Figure 14: Distribution of changes in the level of cost performance



Source: KPMG Analysis

Table 15 below summarises the changes in the level of cost performance. A positive number implies an increase in outperformance during PR14.

Table 15: Changes in the level of cost performance PR09 vs PR14

Outperformance measure	Min	Lower quartile	Median	Upper quartile	Max	Standard deviation
Total	-7.2%	-3.4%	4.1%	9.0%	18.7%	7.5%
Annual incremental	-2.6%	-1.2%	1.4%	3.1%	6.7%	2.6%

Source: KPMG analysis
Note: Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

The table indicates that companies have increased their cost performance under the price control with the totex and outcomes framework relative to the price control without this framework by -1.2% to 3.1% a year on an annual incremental basis.

The range of outperformance gain across companies is wide reflecting a wide dispersion in companies' cost performance across both price controls.

3.1.2 Energy sector

Ofgem was an early adopter of the totex and outcomes framework, having first introduced the framework in 2004 for the Electricity Distribution Price Control Review 5 (DPCR5). While the totex and outcomes framework as a general concept is common to both the energy and water sectors now, the underlying incentive structures and calibrations are different. This affects the read-across of results from the energy sector to the water sector. Nonetheless, an analysis of evidence from the energy sector could therefore provide valuable insights into the benefits of the totex and outcomes frameworks.

As with the analysis of the water sector, companies' cost performance are analysed both during the price control immediately preceding the introduction of totex (pre-totex price control) with the level of outperformance observed during the totex and outcomes price control (totex price control). Table 16 below provides a summary of the energy price controls used for this analysis and Table 17 summarises principal sources of data.

Table 16: Price controls analysed

Sector	Pre-totex price control	First totex price control	Second totex price control
Electricity distribution	DPCR4	DPCR5	RIIO-ED1
Gas distribution	GDPCR	RIIO-GD1	NA
Energy transmission	TPCR4	RIIO-T1	NA

Source: KPMG Analysis

Table 17: Principal data sources

Price Control	Data sources
GDPCR	End of Period Review of the First Gas Distribution Price Control
DPCR4	Supporting data for Electricity Distribution Annual Report for 2008-09 and 2009-10
DPCR5	DPCR5 Performance Report 2010-2015 Data Table
RIIO-T1	Actuals: ET1 and GT1 Financial Models 2017 Forecast: ET1 and GT1 Annual Reports 2016-17
RIIO-GD1	Actuals: GD1 Financial Models 2017 Forecast: GD1 Annual Reports 2016-17
RIIO-ED1	Actuals: ED1 Financial Models 2017 Forecast: ED1 Annual Reports 2016-17

Source: KPMG Analysis

As RIIO-T1 and RIIO-GD1 are still in progress, some of the cost outperformance observed to date could be due to delays in companies' spending programme. A delay in spending would inflate the level of outperformance in early years of the price control and suppress it towards the end of the price control. Therefore, cost performance for RIIO-T1 and RIIO-GD1 are based on a forecast of cost performance as reported in the RIIO 2016-17 Annual Reports. As DPCR5 has already completed, the cost performance rates are based on actual outperformance as reported on DPCR Performance Report 2010 – 2015.

During the course of this work, Ofgem suggested that the forecasts represent companies' best estimates of their performance throughout the price controls. Ofgem has worked with companies to understand and challenge their forecasts. The forecasts also include the impact from future reopeners, but these reopeners are relatively small for gas and electricity distribution companies.

Companies' cost performance will be driven by two sets of factors, some are related and some are unrelated to the totex and outcomes framework. Companies' cost performance rates are adjusted for these additional factors to the extent that they are identified and quantified by Ofgem in various performance reports. The adjustments may not be exhaustive as there may be other factors that affect efficiency gains but are not quantified. Table 18 provides a summary of adjustments made to companies' cost performance.

Table 18: Adjustments made to companies' cost performance

Price control	Adjustments
DPCR5	Adjustments to baseline revenue allowances for 1) the differences between efficient qualifying expenditures and cost allowances for load-related expenditures and high-value projects; and 2) cost allowances associated with output gaps. These are quantified by Ofgem in its consultation and decision documents on DPCR5 Closeout.
RIIO-ED1	Adjustment for cumulative difference between the level of ex ante cost allowance and the level of cost allowance that would be established if RPEs were updated to actual. This amounts to £204 million in 2016-17 prices. This is quantified in Ofgem's RIIO-ED1 annual reports for 2016-17. Further adjustment to allowances for network reinforcement to align with cost performance observed during DPCR5 [9].
RIIO-T1	Adjustment for cumulative difference between the level of ex ante cost allowance and the level of cost allowance that would be established if RPEs were updated to actual. This amounts to £800 million in 2016-17 prices. This is quantified in Ofgem's RIIO-GT1 and RIIO-ET1 annual reports for 2016-17
RIIO-GD1	Adjustment for cumulative difference between the level of ex ante cost allowance and the level of cost allowance that would be established if RPEs were updated to actual. This amounts to £714 million in 2016-17 prices. This is quantified in Ofgem's RIIO-GD1 annual report for 2016-17

Source: Ofgem (2017), DPCR5 Closeout: decisions on adjustment to allowances; Ofgem (2017), DPCR5 Closeout: Consultation on proposed adjustments; Ofgem (2017), RIIO electricity distribution annual report 2016-17; Ofgem (2017), RIIO electricity transmission annual report 2016-17; Ofgem (2017), RIIO gas transmission annual report 2016-17; Ofgem (2017), RIIO gas distribution annual report 2016-17

[9] The level of outperformance was adjusted to account for differences in forecast demand for load related capex compared to those assumed at the final determination. This reflects the Ofgem position that some of the outperformance on ED1 is related to this. It is entirely possible that demand could increase in the remaining years of ED1 above the levels assumed at the final determination. If this were to occur then the approach would likely understate the level of outperformance that can be attributed to the totex and outcomes framework from this approach, under the assumptions stated.

In addition to the adjustments above, a review of Ofgem's performance reports for the respective price controls reveals that:

- For DPCR5[10], efficiency improvements were the main driver of outperformance. The efficiency improvements were in turn driven by falling unit costs for asset replacement work. However, falling input prices and a drop in work volumes also contributed to outperformance.
- For RIIO-GD1[11], outperformance has so far been driven by lower than expected unit cost on the programme to replace iron mains (repex). This is because companies are replacing a higher proportion of smaller iron mains than forecast for the purpose of setting unit cost allowance, and smaller mains are cheaper to replace. Companies are also realising efficiency gains from using robots for mains replacement, flexible workforces and cloud technologies.
- For RIIO-T1[12], some companies reported efficiency gains due to more optimised asset intervention plans. Outperformance is offset partly by worse than expected asset conditions for some companies.

Table 19 compares companies' cost performance between pre-totex and totex price controls after adjustments as discussed in Table 18. Cost performance are shown on annual incremental basis for the energy sector due to differences in price control duration.

Table 19: Comparison of annual incremental cost performance pre-totex vs totex

Pre-totex Price Control	Lower Quartile	Median	Upper Quartile	Totex Price Control	Lower Quartile	Median	Upper Quartile
DPCR4	-0.4%	0.5%	2.1%	DPCR5	0.7%	1.6%	2.6%
TPCR4	0.0%	2.3%	4.7%	RIIO-T1	-1.0%	-0.3%	0.3%
GDPCR	0.0%	1.4%	2.7%	RIIO-GD1	1.5%	2.0%	2.6%
All energy	-0.3%	1.1%	2.6%	All energy	0.2%	1.6%	2.6%

Source: Analysis of Ofgem (2011), Electricity distribution annual report for 2008-09 and 2009-10; Ofgem (2015); DPCR5 performance report 2010-2015 data table; Ofgem (2017), RIIO electricity distribution annual report 2016-17; Ofgem (2014), Transmission networks: Report on the performance of transmission owners during the regulatory periods TPCR4 and TPCR4RO 2007-08 to 2012-13; Ofgem (2017), RIIO electricity transmission annual report 2016-17; Ofgem (2017), RIIO gas transmission annual report 2016-17; Ofgem (2014), End of Period Review of the First Gas Distribution Price Control (GDPCR1); Ofgem (2017), RIIO gas distribution annual report 2016-17
Note: Figures are adjusted to factors unrelated to efficiency as discussed in Table 18. Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

With an exception of the transmission networks, energy networks have increased their outperformance against regulatory allowances under the totex price controls relative to the pre-totex price controls.

[10] Ofgem (2015), Electricity Distribution Company Performance, p.22
[11] Ofgem (2017), RIIO-GD1 Annual Report 2016-17, p.17
[12] Ofgem (2017), RIIO-ET1 Annual Report 2016-17, p.22-26

Ofgem indicates that transmission networks have relatively large reopeners due to the strategic wider work projects and uncertain costs. Companies' forecasts for RIIO-T1 assume outturn costs matching allowed costs for these reopeners. This reduces forecast cost performance for transmission companies by definition. Forecasts of cost performance among transmission companies may therefore be less relevant from the prospective of measuring efficiency gains.

Table 20 shows the standard deviation of annual incremental cost performance across the different price controls presented in Table 19. As with water, cost performance of energy networks are also widely dispersed. In most cases, the standard deviation of cost performance is larger than the median of the cost performance. RIIO-GD1 is an exception where the standard deviation suggests a relatively tighter distribution around the mean. Wide dispersion is an indication of the presence of other factors driving companies' cost performance.

Table 20: Standard deviation of annual incremental cost performance

Pre-totex Price Control	Standard deviation	Totex Price Control	Standard deviation
DPCR4	2.1%	DPCR5	2.5%
TPCR4	5.7%	RIIO-T1	2.1%
GDPCR	2.2%	RIIO-GD1	0.7%

Source: KPMG Analysis of the underlying data of Table 19
Note: Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

The increase in cost performance appears to be broad based with 15 of the 26 energy networks registering an increase in cost performance between the totex and the pre-totex controls. Table 21 below summarises the changes in the level of cost performance. The statistics shown are calculated based on changes in the level of cost performance at the level of individual companies. A positive number implies an increase in outperformance during the totex controls.

Table 21: Changes in the level of cost performance totex price controls

Network segment	Min	Lower Quartile	Median	Upper Quartile	Max	Standard deviation
Electricity distribution	-3.1%	-1.7%	1.0%	1.9%	3.0%	2.0%
Transmission networks	-9.5%	-3.5%	-1.4%	-0.8%	0.9%	4.5%
Gas distribution	-4.3%	-0.1%	0.6%	1.2%	2.1%	2.0%
All energy	-9.5%	-1.5%	0.4%	1.4%	3.0%	2.7%

Source: KPMG analysis

The table indicates that companies have increased their cost performance by -1.5% to 1.4% a year on an annual incremental basis. The range of outperformance gain across companies is wide reflecting a wide dispersion in companies' cost performance across both price controls.

The extent of the increase in totex cost performance is lower in the energy sector, -1.5% to 1.4% annual incremental, than for the water sector as shown in Table 15 of -1.2% to 3.1% annual incremental. This suggests that either:

- Water companies have been swifter to realising the benefits of totex and outcome frameworks than energy companies; or
- There is greater scope for efficiency gains from totex and outcomes in the water sector than in the energy sector.

However, there is not sufficient information to determine which explanation is more likely for the observed difference between the water and energy sectors.

In addition to cost performance, data are available from the price control financial models to analyse energy companies' responses to the introduction of the totex and outcomes framework by analysing operating expenditures and capital expenditure splits.

The adoption of the totex and outcomes framework is partly in response to the perceived capex bias in regulated industries and to also allow companies the flexibility to adopt the least cost solutions. This step explores whether companies have exploited this flexibility by adopting less capital intensive solutions during the price control than forecast at the final determination. One measure of capex intensity is the capex to totex ratio.

The capex to totex ratio (capex intensity) is calculated using both actual expenditures and allowed expenditures. Actual and allowed capital intensity are calculated for each company for each price control. The difference between the actual and allowed capex intensity measures the level of flexibility deployed by companies. A negative difference indicates that companies have utilised less capital intensive solutions than the level envisaged ex ante. This analysis assumes that operating and capital expenditures enjoy a similar level of efficiency gains during the price control.

Table 22 shows statistics on capex intensity across pre-totex and totex price controls. For RIIO-T1 and RIIO-GD1 the statistics shown are based on companies' total actual expenditures from the beginning of the price control to tariff year end 2016-17. Negative figures indicate that companies preferred solutions had lower capex intensity relative to their allowances.

Table 22: Comparison of capex intensity pre-totex vs totex

Pre-totex Price Control	Min	Average	Max	Totex Price Control	Min	Average	Max
DCPR4	-11%	-4%	2%	DPCR5	-21%	-4%	6%
TPCR5	-7%	-2%	6%	RIIO-T1	-11%	-7%	-1%
GDPCR	1%	6%	19%	RIIO-GD1	-12%	-1%	4%
All energy	-11%	-1%	19%	All energy	-29%	-6%	6%

Source: Analysis of Ofgem (2011), Electricity distribution annual report for 2008-09 and 2009-10; Ofgem (2015); DPCR5 performance report 2010-2015 data table; Ofgem (2017), RIIO-ED1 financial model following the annual iteration process 2017; Ofgem (2014), Transmission networks: Report on the performance of transmission owners during the regulatory *periods TPCR4 and TPCR4RO 2007-08 to 2012-13; Ofgem (2017), RIIO-ET1 financial model following the annual iteration process 2017;; Ofgem (2017), RIIO-GT1 financial model following the annual iteration process 2017;; Ofgem (2014), End of Period Review of the First Gas Distribution Price Control (GDPCR1); Ofgem (2017), RIIO-GD1 financial model following the annual iteration process 2017*

Following the introduction of totex, companies seem to have used the flexibility to reduce capital intensity more than they did under the previous non-totex controls. However the impact on electricity distribution networks, where expenditures under both the pre-totex and totex price controls are based on actual expenditures over the whole price control, appears more limited.

Table 23 shows the distribution of the difference in capex intensity deviation (relative to allowance) when comparing totex and non-totex controls. The results can be interpreted as follows:

- A positive figure would indicate that the company further tilts its spending towards capex; and
- A negative figure would indicate that the company further tilts its spending towards opex.

Table 23: Changes in the level capex intensity

Totex control	Min	Lower Quartile	Average	Upper Quartile	Max
Actual to date performance					
DCPR5 to DPCR4	-9.5%	-4.7%	-0.0%	3.9%	9.8%
RIIO-T1 to TPCR5	-17.5%	-7.3%	-4.4%	1.1%	3.7%
RIIO-GD1 to GDPCR	-15.4%	-14.9%	-7.4%	-3.5%	2.3%

Source: KPMG analysis
Note: Analysis based on actual data up to 2016-17 for RIIO price controls

Using companies' actual to date performance, companies appear to have, on average, moved away from capex intensive solutions during the totex price controls. However, observing the figures in the upper quartile, it can be seen that there are a handful of companies that have increased their capex intensity under the totex control relative to the non-totex control.

3.2 Derivation of efficiency gains from cost performance

This sub-section explores two possible approaches in interpreting cost performance observed during the first totex control as a measure of efficiency gains.

Both approaches assume that there are no external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis. In addition, all efficiency is assumed to be accounted for by the regulatory changes, i.e. the introduction of totex and outcomes. Other factors affecting realisable efficiency gains are under companies' control. While these are strong assumptions, there is no evidence to suggest what the direction or scale of the impact of these other factors on efficiency is. Therefore, there are no obvious grounds to suggest that true efficiency gains should not be distributed symmetrically or where they could fall within the range estimate. This necessarily leads to a wide range of estimates as a result.

Under the first approach (Approach 1), efficiency gains revealed during the previous price control are assumed to be fully captured in regulatory cost allowances for the next price control period. Regulatory cost allowances are set accurately and without bias. Outperformance during the current price control therefore purely reflect efficiency gains. These efficiency gains are due solely to the regulatory change.

However, it may not be appropriate to attribute all of the outperformance observed during the totex and outcomes price controls to efficiency gains because of the following factors:

- **Factor 1:** Outperformance could also be due to circumstances beyond companies' control, beyond those that have been identified and removed from the analysis. These include, for instance, the quality of the efficiency challenge and the robustness of the cost baseline set by the regulator including any forecast allowances, favourable weather reducing maintenance costs and lower demand reducing network reinforcement costs, etc.
- **Factor 2:** Cost analysis does not capture quality improvements, which represent additional efficiency gains.

The presence of factor 1 is evident in the wide dispersion in companies' cost performance across different price controls analysed in sub-section 3.1. Because these other factors are not identified and quantified, the impact of their presence both in terms of the direction and magnitude on estimates of efficiency gains is unclear.

In addition, companies' outperformance over a price control may correlate with their performance over the adjacent price control. For example, a company with high outperformance in the pre-totex control might also achieve high outperformance in the adjacent totex control. Attributing all outperformance during the totex price control to efficiency gains from the totex and outcomes framework would overestimate the framework's benefits.

This leads to the second approach for estimating efficiency gains. There are persistent company-specific factors that lead to a dispersion in cost performance against regulatory cost allowances across the industry. These company-specific factors persist over time. Therefore, efficiency gains are therefore measured as incremental gains in cost outperformance over the successive price controls. These efficiency gains are due solely to changes in circumstances during the price control.

The assumption of perfect correlation of company's performance between the two successive price controls under Approach 2 is a strong one. In practice, there will be other factors that influence companies' ability to outperform their regulatory cost allowances that vary with time. For this reason, assuming outperformance in the previous regulatory period as a proxy for companies' ability to outperform in the current regulatory period may produce a bias to the estimates of efficiency gains.

3.2.1 Approach 1: Outperformance during the totex price control as an estimate of efficiency gains

Under approach 1, outperformance during the current price control is assumed to purely reflect efficiency gains. These efficiency gains are assumed to be due solely to a change in regulation and the introduction of the totex and outcomes framework. Therefore, all outperformance observed during the price control with the totex and outcomes framework reflects efficiency gains due to the introduction of the framework itself.

Table 24 presents cost performance during totex price controls. Cost performance is presented on an annual incremental basis. This allows cost performance from price controls of different durations to be compared.

Table 24: Annual incremental cost performance during totex price controls

Price control	Min	Lower quartile	Median	Upper quartile	Max	Standard deviation
PR14	-2.4%	0.0%	1.2%	2.7%	6.3%	2.3%
DPCR5	-4.1%	0.7%	1.6%	2.6%	4.8%	2.5%
RIIO-T1	-3.1%	-1.0%	-0.3%	0.3%	1.9%	2.1%
RIIO-GD1	0.6%	1.5%	2.0%	2.6%	2.8%	0.7%
All energy	-4.1%	0.6%	1.7%	2.4%	4.8%	2.1%

Source: For PR14, analysis based on the estimate of the impact of wholesale cost outperformance on RoRE as reported by companies in their annual performance reports adjusted for factors unrelated to efficiency as quantified by companies. For energy price controls: Ofgem (2015); DPCR5 performance report 2010-2015 data table; Ofgem (2017), RIIO electricity distribution annual report 2016-17; Ofgem (2017), RIIO electricity transmission annual report 2016-17; Ofgem (2017), RIIO gas transmission annual report 2016-17; Ofgem (2014), Ofgem (2017), RIIO gas distribution annual report 2016-17
Note: Annual incremental figures assume even spend profile and that total average outperformance to persist over the price control period

Table 24 shows that the estimate of efficiency gains on an annual incremental basis during PR14 under approach 1 ranges between 0.0% and 2.7% per annum. The range is based on the inter-quartile range. Minimum and maximum values were excluded from the range estimates to eliminate outliers. The wide range reflects the wide dispersion in companies' cost performance as measured by the standard deviation. The dispersion reflects the presence of other factors affecting that affect efficiency gains which have not been identified.

Given the dispersion of companies' cost performance, a one sample t-test is applied to determine whether the observed cost performance is statistically significant from zero. The one sample t-test relies somewhat on the number of observation points. This makes it unsuitable for testing at transmission networks where there are only four observations. Therefore this test is not applied to transmission networks.

Table 25 provides the results from the one sample t-test. The one-tail P-value measures the probability that the level of cost performance is more than zero. A p-value of less than 0.05 means that the observed level of cost performance is meaningfully different from zero.

Table 25: One sample t-test on annual incremental cost performance

Price control	Number of observations	Average	Standard deviation	One-tail P-Value	Statistically significant at 5% level
PR14	17	1.3%	2.3%	0.03	Yes
DPCR5	14	1.1%	2.5%	0.11	No
RIIO-GD1	8	1.9%	0.7%	0.00	Yes
All energy	26	1.1%	2.1%	0.02	Yes

Source: KPMG Analysis

The table shows that the average outperformance observed during PR14 and RIIO-GD1 are meaningfully different from zero. There is an indication that the average outperformance observed during DPCR5 is also meaningfully different from zero but comparatively less so compared to PR14 and RIIO-GD1.

It is important to note that the test only indicates that efficiency gains over the relevant price controls are unlikely to be zero. It does not indicate that the observed efficiency gains are attributable to the totex and outcomes framework. The attribution problem remains due to the presence of other factors that cannot be controlled for.

3.2.2 Approach 2: Comparative outperformance between the totex and non-totex price controls as an estimate of efficiency gains

The second approach is based on the assumption that there are persistent company-specific factors that lead to a dispersion in cost performance against regulatory cost allowances across the industry. These company-specific factors persist over time. Therefore, efficiency gains are therefore measured as incremental gains in cost outperformance over the successive price controls. These efficiency gains are due solely to changes in circumstances during the price control.

The assumption of perfect correlation of company's performance between the two successive price controls under Approach 2 is a strong one. In practice, there will be other factors that influence companies' ability to outperform their regulatory cost allowances that vary with time. For this reason, assuming outperformance in the previous regulatory period as a proxy for companies' ability to outperform in the current regulatory period may produce a downward bias to the estimates of efficiency gains.

In addition, this approach assumes that the only difference between the totex and the non-totex price controls is the introduction of the totex and outcomes framework. This is unlikely to be the case in practice. Therefore, the analysis begins with an assessment of the cost assessment and recovery approaches across the different price controls. This is to identify other changes in the regulatory approach between the totex and pre-totex controls that are not related to the totex and outcomes framework, and to understand the implications of these on the result. The impact of these other differences unrelated to totex and outcomes has not been quantified and so the magnitude and direction of their impact on efficiency gains is unclear.

As with approach 1, the presence of circumstances beyond companies' control would also widen the potential range of estimates of efficiency gains that could then be attributable to the totex and outcomes framework. Therefore, the analysis under approach 2 begins with an assessment of the cost assessment and recovery approaches.

3.2.2.1 Assessment of the cost assessment and recovery approaches

A high level assessment of the cost assessment and recovery approaches in PR09 and PR14 provides a guide to the comparability of the price controls to allow for an assessment of the benefits of totex.

Water

The pre-totex price control is PR09 which was in place from 1 April 2010 to 31 March 2015. The first totex price control is PR14 which is in place from 1 April 2015 to 31 March 2020.

PR09

At PR09, Ofwat set separate allowances for operating expenditures and capital expenditures.

Allowances for opex were set based on econometric benchmarking targeting frontier shift levels. Ofwat assumed that a company would close 60% of the assessed efficiency gap in operating expenditures to the frontier performance by the end of the price control. Ofwat applied a catch up efficiency glide path where it was assumed that the catch up would happen in equal steps each year for base operating expenditures.

Allowances for capex were set using a cost base comparative assessment approach based on forecast expenditures provided by companies. Ofwat used companies' cost base submissions as the source of data, and targeted a median or representative level of current efficiency.

Ofwat applied operating cost rolling incentives allowing companies to retain any outperformance for the full five-year period. Capex was subject to the capital expenditure incentive scheme (CIS). The baseline was set based on Ofwat's central estimate of efficient capital expenditures as detailed above.

PR14

At PR14, Ofwat used a variety of top-down econometric models of totex and averaged across them. It then set the industry efficient level of costs as the upper quartile and then applied a further challenge based on further additional expected cost savings.

PR14 also saw the menu incentive widened from covering just capex to covering totex. Companies were allowed the flexibility to choose from a 'menu' of cost allowances with different risk-sharing rates. The risk-sharing rate is the proportion of outperformance or underperformance retained by the company.

Assessment

PR14 represents a step change in the way the water sector was regulated. The approach to cost assessment changed from disaggregated cost modelling for opex and capex to top-down totex modelling.

In addition, the definition of efficient cost was changed. Whereas efficient cost was set at the frontier for opex and at the median for capex at PR09, efficient costs were set at the upper quartile for totex at PR14. The separation of retail activities from wholesale expenditure further complicates the comparison of outperformance between PR09 and PR14. While this evidence represents the most directly relevant source of data, the results should be interpreted with caution.

Electricity distribution networks

The pre-totex price control is the Distribution Price Control Review 4 (DPCR4), which was in place from 1 April 2005 to 31 March 2010. The first totex price control was the Distribution Price Control Review 5 (DPCR5), which was in place from 1 April 2010 to 31 March 2015.

DPCR4

Ofgem set separate allowances for opex, network-related capital expenditures (NRE) and non-network-related capital expenditures (NLRE).

Allowances for opex were set based on benchmarking against the upper quartile efficiency level using econometric models. Ofgem allowed no catch-up efficiency glide path for the distribution network operators (DNOs) to achieve the benchmark cost levels.

Allowances for capital expenditures were set based on unit cost benchmarking. The efficient costs were benchmarked on a median rather than the upper quartile, reflecting the quality of data analysed by Ofgem's engineering consultant.

Differential incentives were applied to opex and capex. There was no operating cost rolling incentive, and DNOs retained any outperformance of opex. Capex was subject to a menu-style incentive, where DNOs retain a higher share of any outperformance in exchange for a lower cost allowance and vice versa. The capex menu baseline was set based on a study for Ofgem by external consultants.

DPCR5

Similar to DPCR5, Ofgem set separate allowances for opex, NRE and NLRE. Opex allowances were set based on upper quartile efficiency for indirect costs and upper third (33%) for network operating costs. The difference in benchmark efficiency levels reflects greater variability in the cost data for networking operating costs relative to indirect costs. Ofgem allowed no catch-up efficiency glide path.

Similar to DCPR4, capital expenditures were benchmarked to a median unit cost but large projects exceeding £15m in value were assessed separately.

Unlike DPCR4, a fixed percentage of total expenditures was capitalised into the regulatory asset value with the rest received as “fast money” in the year. Total expenditures, barring excluded menu costs, were subject to the same menu so the same incentive rate applied to capex and opex.

Assessment

DPCR4 and DPCR5 share a similar approach to cost assessments with cost allowances generally set based on upper quartile efficiency. There were also no efficiency glide paths for either controls. The main difference between the two controls is the introduction of the totex and outcomes framework, i.e. the equalisation of incentive rates for opex and capex through the application of a single menu. Therefore, the electricity distribution price control may represent a good proxy for estimating efficiency gains from the totex and outcomes framework.

Gas distribution networks

The pre-totex price control the Gas Distribution Price Control Review (GDPCR), was in place from the 1st of April 2008 to the 31st of March 2013. The first totex price control is the RIIO-ED1 control which is currently in the fourth year of the eight-year control period.

GDPCR

Ofgem set separate allowances for opex, capex and replacement expenditures (repex).

Allowances for opex were set based on benchmarking the efficiency of individual activities within direct and indirect operating cost areas wherever practical. The benchmark was set at the upper quartile efficiency using econometric models. More specific analysis was performed for cost areas where benchmarking was not possible. Ofgem did not allow a catch-up efficiency glide path.

Where possible, capex and repex were assessed based on regression analysis at the upper quartile efficiency using econometric models. Ofgem’s view of efficient capex was supplemented by recommendations from its engineering consultant.

There was no operating cost rolling incentive, and DNOs retained any opex outperformance. Capex and repex were subject to a menu-style incentive. The menu baseline was set 25% of the way between Ofgem’s view of efficient costs and the companies’ forecasts.

RIIO-GD1

Unlike GDPCR, Ofgem set a totex allowance for each company.

Totex allowances were set based on a suite of econometric models both at the top-down totex level and bottom-up individual expenditure areas and activity areas. Benchmarking was done at the upper quartile efficiency. Ofgem's view of efficient costs were based on a simple average for the four preferred econometric models. Ofgem's view of efficient costs was also based on assuming that the companies would close only 75% of the assessed gap between their forecasts and the upper quartile.

Totex was subject to a menu-style incentive. The menu baseline was set at a weighted average between Ofgem's view of efficient costs and companies' forecasts.

Assessment

Both GDPCR and RIIO-GD1 target upper quartile efficiency and assume that companies would close 75% of the gap between their forecasts and the upper quartile efficient costs.

However, Ofgem adopted a different cost assessment approach at RIIO-GD1 than GDPCR1. Namely, GDPCR1 relied on disaggregated models whereas RIIO-GD1 relied on a suite of top-down and bottom-up models. This could have some impact on the comparability of outperformance over the two controls.

Transmission networks

The pre-totex price control the Transmission Price Control Review 4 (TPCR4), was in place from 1 April 2007 to 31 March 2013. The first totex price control is the RIIO-T1 which is in its fourth year of the eight-year control period.

TPCR4 and RIIO-T1 share a number of similarities and are thus discussed here in one section. For both controls, Ofgem assessed each category of costs separately, namely LRE, NLRE, non-operation capex, opex and business support costs. Ofgem generally relied on its engineering consultants to review companies' cost forecasts in forming its view of efficient costs.

For RIIO-T1, large new capital projects are delivered under the strategic wider work mechanism (SWW). The need and funding for these projects are considered during the price control instead of at the price control settlement.

The main difference between TPCR4 and RIIO-T1 is the introduction of the totex menu. At TPCR4, capital expenditures were subject to a 25 percent sharing rate where the companies retained 25 percent of any out/under performance on capex. Companies retained any out/underperformance on opex. In contrast, Ofgem introduced a menu-style incentive for RIIO-T1 covering totex with a sharing rate of around 50%.

Assessment

Without a detailed analysis of the engineering consultant's approach to cost assessment, it is challenging to assess whether the standard of efficient costs adopted were similar for TPCR4 and RIIO-T1. In addition, RIIO-T1 saw not just the introduction of totex but also a menu-style incentive arrangement. The SWW mechanism removes a significant amount of totex from the price control settlement. Relative to gas and electricity distribution price controls, TPCR4 and RIIO-T1 are therefore not as good a proxy for efficiency gains due to totex.

3.2.2.2 Estimates of efficiency gains under approach 2

Table 26 presents changes in the level of cost performance on an annual incremental cost basis. A positive figure indicates that outperformance has increased during the totex price control relative to the non-totex price controls.

Table 26: Changes in the level of annual incremental cost performance totex price controls

Network segment	Min	Lower Quartile	Median	Upper Quartile	Max	Standard deviation
Water	-2.6%	-1.2%	1.4%	3.1%	6.7%	2.6%
Electricity distribution	-3.1%	-1.7%	1.0%	1.9%	3.0%	2.0%
Transmission networks	-9.5%	-3.5%	-1.4%	-0.8%	0.9%	4.5%
Gas distribution	-4.3%	-0.1%	0.6%	1.2%	2.1%	2.0%
Aggregate energy	-9.5%	-1.5%	0.6%	1.4%	3.0%	2.7%

Source: KPMG analysis

Table 26 shows that the estimate of efficiency gains on an annual incremental basis is in the range between -1.2% and 3.1% per annum during PR14. For energy, the analysis of cost assessment and recovery approaches suggests that greater reliance should be placed on evidence from electricity distribution with efficiency gain estimates under approach 2 of -1.7% to 1.9% per annum.

These ranges are based on the lower quartile to upper quartile to reduce the influence of outliers in the results. The wide range reflects the wide dispersion in companies' cost performance as measured by the standard deviation, which is more than twice the median in most cases. In other words, the variation in estimates of efficiency gains is more than the typical level of efficiency gains estimated under this approach.

The dispersion reflects the presence of other factors that affect efficiency gains which have not been identified. In particular, the lower quartile of the range is negative. The negative figure implies that companies spend more and become less efficient as the result of the introduction of the totex and outcomes framework. This is unlikely to be the case. The negative figure is more likely a result of other factors that have not been adjusted and quantified. Therefore, it is appropriate to cap the low end of the estimate of efficiency gains due to totex and outcomes based on approach 2 at 0%.

On this basis, the estimate of efficient gains under approach 2 is in the range between 0.0% and 3.1% per annum.

Statistical tests are applied to test for changes in cost performance at two levels. First, the tests are applied to data at an aggregate level where observations across all network segments (i.e. electricity distribution, gas distribution and energy transmission) are pooled together as one dataset. Second, the tests are applied at the individual network segment level.

Two tests are considered:

- First, the paired sample student's t-test considers whether companies outperform more under the totex controls than the pre-totex controls. However, the Student's t-test relies somewhat on the number of observations. This makes it unsuitable for testing at individual network segment level for transmission networks where there are limited observations. Therefore this test is only applied at the aggregate level and for electricity and gas distribution networks.
- Second, the exact Binomial test considers whether the number of companies outperforming regulatory allowances has increased under the totex controls relative to under the pre-totex controls. The test relies on an exact value statistic which is valid for any sample size. However, the test is a directional test, i.e. whether one quantity is more than another. It is silent on the size of the difference.

To apply the exact Binomial test, a variable was generated that is equal to 1, where the magnitude of outperformance under the totex regime is greater than the outperformance under the non-totex regime(s), and zero otherwise.

Similarly, a variable was generated that is equal to 1 where the magnitude of the delta ratio is more negative under the totex regime, relative to the delta ratio under non-totex regimes, and zero otherwise.

Table 27 provides the results from the paired sample student's t-test. The one-tail P-value measures the probability that the increase in the level of cost performance is more than zero. In other words, the increase in outperformance is meaningfully different and this increased level of outperformance would not be expected if companies continued to outperform as they did under non-totex controls.

Table 27: Paired sample student's t-test on annual incremental cost performance

Price control	Number of observations	Average difference in cost performance	T-statistic	One-tail P-Value	Statistically significant at 5% level
PR14 – PR09	17	1.2%	-1.92	0.04	Yes
DPCR5 – DPPR4	14	0.3%	-0.51	0.31	No
RIIO-GD1 – TPCR4	8	0.2%	0.25	0.41	No
All energy	26	0.2%	0.46	0.33	No

Source: KPMG Analysis

The table shows that the increase in cost outperformance between PR14 and PR09 is meaningfully different from zero. However, evidence from the energy sector is less conclusive. This supports the wide range estimates of efficiency gains.

It is important to note that the test only indicates that efficiency gains over the relevant price controls are unlikely to be zero. It does not indicate that the observed efficiency gains are attributable to the totex and outcomes framework. The attribution remains subject to problem of the presence of other factors that cannot be controlled for.

Table 28 presents the results of the exact binominal test on the increase in cost performance between the totex and non-totex price controls. The mean column measures the proportion (out of 1) of companies in the network segment that have increased their outperformance during the totex control relative to the pre-totex control. The mean would be zero if none of the companies had managed to increase their outperformance.

The confidence interval is computed at the 5% significance level. The confidence interval indicates that there is a 95% chance that the fraction of companies that have increased their outperformance is within the interval. A confidence interval that lies entirely above zero suggests that the probability that none of the companies could increase their outperformance following the introduction of totex is less than 5%. In other words, based on the results below one could conclude that for all segments, at least some companies increased their outperformance. For example, at least 25% in the transmission segment increased their outperformance over the totex price control.

Table 28: Exact Binominal test on the difference in cost performance

Network segment	Mean	Confidence interval	Statistically significant from zero at 5% level
Transmission forecast	0.25	0.01 – 0.81	Yes

Source: KPMG analysis

3.2.3 Revealed efficiency gains during the first totex control

Overall, analysis of companies' performance across the first totex price control, under the assumptions outlined for each stated approach, suggests that efficiency gains during the first totex control is 0.0% - 2.7% per annum under approach 1 and 0.0% to 3.1% under approach 2. On a total average basis, the efficiency gains under approach 1 is 0.0% - 7.8% and approach 2 0.0% - 8.9%.

The range is broad reflecting the limitation of this analysis where efficiency gains are attributed to a single factor, i.e. the introduction of totex and outcomes. The dispersion of companies' cost performance suggests that companies' cost efficiencies are explained by more than a single factor. In so far as the additional factors do not correlate with the introduction of the totex and outcomes framework, the potential range of efficiency gains that could be attributable to the totex and outcomes framework will necessarily be wide.

Table 29: Ranges of potential efficiency from totex and outcomes as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)	Total average efficiency gains (%)
Approach 1	0.0% - 2.7%	0.0% - 7.8%
Approach 2	0.0% - 3.1%	0.0% - 8.9%

Source: KPMG Analysis

3.3 Impact on on-going efficiency gains

The totex and outcomes framework has, in the most part, only been implemented for the first time during the current price control period in both energy and water. Indeed, the estimates of efficiency gains in sub-section 2.2 only provide estimates of efficiency gains from the benefits of the totex and outcomes framework over the first totex price control.

The scope of this sub-section is estimating the impact on potential on on-going efficiency gains that could be expected over the second totex price control, i.e. AMP7, due to the totex and outcomes. There are no precedents of the second totex control, except the electricity distribution networks, on which the impact of the totex and outcomes framework can be directly observed. The quantification of the impact on the on-going efficiency gains of the framework would ideally require a longer-term cost time series from companies, which are not available. Therefore, the impact of the framework on on-going efficiency has to necessarily be hypothesised and inferred.

The totex and outcomes framework is supposed to remove regulatory barriers to efficiency gains that were available and would otherwise have been exploited by the water sector but for the regulatory barriers. In principle therefore part of the efficiency gains during the first totex control may represent catch-up efficiency for opportunities that were previously available but were not exploited until now.

Furthermore, examples of efficiency gains following significant changes (discussed in Section 5) are not clear on the longevity of the impact of efficiency gains over time. Some examples exhibit diminish efficiency gains over the next five year period (e.g. Scottish Water, Openreach separation) while others show increasing gains (e.g. privatisation of electricity distribution and new gas distribution networks). Overall diminishing efficiency benefits are more common in subsequent periods.

In addition, the second totex price control, RIIO-ED1, is already underway for the electricity distribution companies. This provides a valuable opportunity to assess whether the increase in efficiency gains would continue to persist after the first totex control on an on-going basis.

Table 30 below summarises cost performance on an annual incremental basis for DPCR4 (the pre-totex price control), DPCR 5 (the first totex price control) and RIIO-ED1 (the second totex price control). A positive number indicates cost savings.

Table 30: Comparison of cost performance between ED controls

Price control	Lower Quartile	Median	Upper Quartile	Standard deviation
DPCR4	-0.4%	0.5%	2.1%	2.1%
DPCR5	0.7%	1.6%	2.6%	2.5%
RIIO-ED1	-0.3%	0.3%	1.2%	1.2%
RIIO-ED1/DPCR5	-51.8%	17.8%	45.8%	
RIIO-ED1/DPCR4	78.5%	53.8%	57.1%	

Source: Ofgem (2011), Electricity distribution annual report for 2008-09 and 2009-10; Ofgem (2015), DPCR5 performance report 2010-2015 data table, Ofgem (2017), RIIO electricity distribution annual report 2016-17

These results show a step reduction in the level of cost outperformance among electricity distribution networks between DPCR5 and RIIO-ED1. For example, the level of upper quartile outperformance observed during RIIO-ED1 (1.2%) is only 45.8% of the upper quartile outperformance observed during DPCR5 (2.6%). In addition, the dispersion of cost performance is also lower during RIIO-ED1 than DPCR5. The standard deviation of cost performance during RIIO-ED1 (1.2%) is less than a half of the standard deviation of DPCR5. The narrower dispersion suggests the revealed efficiency gains are felt more equally across companies, which is more indicative of an on-going efficiency gain, i.e. the on-going shift in efficiency improvements that affect the entire sector.

Because RIIO-ED1 is the only second UK totex price control to date, it is the only source of directly relevant empirical evidence to assess the potential on-going efficiency impact due to the totex and outcomes framework over the second totex price control. This assumes that experience in electricity distribution networks will repeat for the water sector. If the application of the totex and outcomes framework in business planning has been slower in the water sector than in the energy sector, then there may be larger scope for on-going efficiency impact during the second totex water price control. Alternatively, if the application of the totex and outcomes framework in business planning has been faster in the water sector than in the energy sector, then there may be less scope for on-going efficiency impact during the second totex water price control. Given the lack of empirical data to separate catch-up efficiency from on-going efficiency from cost performance during the first totex price controls, the analysis relies on observed evidence from RIIO-ED1.

The evidence therefore suggests that part of the revealed efficiency gains during the first totex control represents catch-up efficiency where companies catch up with the rest of the economy. Catch-up efficiency will not persist on an on-going basis.

Furthermore, the hypotheses that the observed efficiency gains during the first totex price control would persist into the second totex price control rely crucially on the assumption that the observed totex outperformance is due solely to totex and outcomes. The wide variation in totex outperformance suggests the presence of other factors beyond totex in driving outperformance gains. An approach which takes only part of that outperformance because it assumes catch-up efficiency provides greater scope for outperformance to be explained by any other factors than one which simply attributes all of the outperformance on an ongoing basis solely to the introduction of the totex and outcomes framework. This further supports reducing scope for efficiency gains due to totex and outcomes in the second totex price control.

There are two potential hypotheses around the impact of the framework on on-going efficiency gains over AMP7. The hypotheses are as follows:

- **Hypothesis 1**: The introduction of the totex and outcomes framework allows companies to persistently achieve a higher rate of on-going efficiency improvements. However, the revealed efficiency gains, as measured by the increase in outperformance, (as per **Approach 1**), are partly a result of companies implementing solutions that were available but not implemented prior to totex and outcomes (i.e. catching up) and partly a result of the shift in the on-going efficiency improvements. Therefore, the catch-up component has to be separated from the revealed efficiency gains during the first totex control to identify the impact on totex and outcomes on the rate of on-going shift.
- **Hypothesis 2**: As per hypothesis 1 but efficiency gains during the first totex control are measured as incremental gains in revealed outperformance between the totex and non-totex price controls (as per **Approach 2**).

Hypothesis 1 assumes the definition of efficiency gains as per Approach 1. Approach 1 assumes that efficiency gains revealed during the previous price control are fully captured in regulatory cost allowances for the next price control period. Therefore, all the outperformance observed during the price control with the totex and outcomes framework reflects efficiency gains due to the introduction of the framework itself. On the assumption that the experience in electricity distribution would repeat in the water sector, estimates of potential on-going efficiency gains for the water sector is based on applying the ratio of the outperformance between RIIO-ED1 and DPCR5 directly to the outperformance observed during PR14.

Table 31: Range of potential efficiency from totex and outcomes under hypothesis 1 as annual incremental gains

Description	Lower Quartile	Median	Upper Quartile
DPCR5 cost performance	0.7%	1.6%	2.6%
RIIO-ED1 cost performance	-0.3%	0.3%	1.2%
RIIO-ED1 divided by DPCR5	-51.8%	17.8%	45.8%
X PR14 cost performance	0.0%	1.2%	2.7%
= Hypothesis 1	**0.0%**	**0.2%**	**1.2%**

Source: KPMG analysis

Table 31 shows that the range of potential on-going efficiency gains from totex and outcomes during the second totex control could be in the range between 0% and 1.2% per annum or 0.0% to 3.7% on a total average basis.

The lower quartile to upper quartile range is used to derive the results. The symmetry of the selected range around the median is based on the assumption of no directional bias. The range used is wide because of the underlying dispersion of observations, which also suggests that other factors are likely to be at play; this also means that a single number estimate within the range cannot be identified with confidence. The numbers above the upper and lower quartile are excluded because outliers are likely to be driven by other factors.

Hypothesis 2 assumes the definition of efficiency gains as per Approach 2. Approach 2 takes the increase in a company's outperformance between the pre-totex and the totex price controls reflects the efficiency gains.

On the assumption that the experience in electricity distribution would repeat in the water sector, estimates of potential efficiency gains during the second totex control for the water sector is based on applying the ratio of the outperformance between RIIO-ED1 (the second totex control) and DPCR4 (the pre-totex control) directly to the outperformance observed during PR09. Table 32 shows that the resulting estimates of potential on-going efficiency gains from totex and outcomes during the second totex control.

Table 32: Range of potential efficiency from totex and outcomes under hypothesis 2 as annual incremental gains

Description	Lower Quartile	Median	Upper Quartile
DPCR4 cost performance	-0.4%	0.5%	2.1%
RIIO-ED1 cost performance	-0.3%	0.3%	1.2%
RIIO-ED1 divided by DPCR4	78.5%	53.8%	57.1%
X PR09 cost performance	-0.6%	-0.4%	1.9%
= Hypothesis 2	**-0.5%**	**-0.2%**	**1.1%**

Source: KPMG analysis

The resulting estimates under hypothesis 2 include negative potential efficiency over the second totex price control. As discussed previously, this is a result of the dispersion in companies' cost data which contains elements of other factors affecting cost performance not related to efficiency and/or totex and outcomes. The negative figure implies that companies spend more and become less efficient as the result of the introduction of the totex and outcomes framework. This is unlikely to be the case. The negative figure is more likely a result of other factors that have not been adjusted and quantified. Therefore, the lower end of the estimate of potential efficiency gains that could be attributed to totex and outcomes is capped at 0%, resulting in a range between 0.0 and 1.1% per annum. This skews the selected range upwards compared with the underlying data.

3.4 Conclusion

This section analyses companies' cost performance across price controls from sectors that are subject to the totex and outcomes framework. The analysis of the revealed cost performance during the first totex price controls shows that companies have generally outperformed against regulatory allowances.

Table 33 provides ranges of efficiency gains from totex and outcomes during the first totex price control.

Table 33: Ranges of potential efficiency from totex and outcomes during the first totex price control as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)	Total average efficiency gains (%)
Approach 1	0.0% - 2.7%	0.0% - 7.8%
Approach 2	0.0% - 3.1%	0.0% - 8.9%

Source: KPMG Analysis

These estimates of efficiency gains assume that regulatory cost models are accurate and without bias. Therefore, cost outperformance equates efficiency gains. In addition, it is assumed that the only difference between the totex and non-totex price controls is the introduction of the totex and outcomes framework itself. Therefore, the revealed efficiency gains can be attributable to the totex and outcomes.

Furthermore, the analysis relies on company forecasts and judgements where the price controls are still in progress. For RIIO controls, the analysis relies on the assumption that companies' forecasts can accurately proxy outperformance over the entire period. For the water sector, the analysis relies on the assumption that companies have adjusted for investment profiling effect on their RoRE on a consistent basis and that the achieved outperformance would persist through to the end of PR14.

The estimates above also assumes that there are no other external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis; and that other factors affecting realisable efficiency gains are under companies' control. In practice, there is a wide dispersion in cost outperformance across companies, suggesting that there are additional factors, beyond those which have been quantified and accounted for, that influence companies' performance. This reduces the precision which with the estimates of efficiency gains due to totex and outcomes during the first price control could be made, leading to wide ranges of the estimates.

The totex and outcomes framework has, in the most part, only been implemented for the first time during the current price control period in both energy and water. Indeed, the two approaches discussed above only infers evidence from the first totex price controls. The quantification of the impact on the on-going efficiency gains of the framework would ideally require a longer-term time series of cost data from companies, which is not available. Therefore, the impact of the framework on on-going efficiency gains has to necessarily be hypothesised and inferred.

With RIIO-ED1 being the only second UK totex price control to date, the analysis relies on the observed evidence from RIIO-ED1 under the assumption that the experience with the totex and outcomes framework in electricity distribution networks will repeat in the UK water sector. The approach assumes part of the cost performance during the first totex price controls is catch-up efficiency. It provides greater scope for outperformance to be explained by any other factors than one which simply attributes all of the outperformance on an ongoing basis solely to the introduction of the totex and outcomes framework. A range of different interpretations of the underlying data and corresponding assumptions have been considered and examined. Using evidence from RIIO-ED1 which is the second totex price control for the electricity distribution networks, Table 34 provides ranges of potential on-going efficiency gains from totex and outcomes. This assumes that the experience in electricity distribution would repeat for the water sector.

Under each of these hypotheses the inter-quartile range are estimated to inform the high and low estimates of the range. Minimum and maximum values are excluded from the ranges estimates to eliminate outliers and cases where other factors (i.e. other than the common factor considered—Totex and outcomes) are likely to drive the results.

Table 34: Ranges of potential efficiency from totex and outcomes during the second totex control as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)	Total average efficiency gains (%)
Hypothesis 1	0.0% - 1.2%	0.0% - 3.7%
Hypothesis 2	0.0% - 1.1%	0.0% - 3.2%

Source: KPMG Analysis

Overall, the range of annual incremental gains that might be expected during the second totex control is between 0.0% and 1.2% per annum or 0.0% and 3.7% on a total average basis during the duration of the price control.

4 Examples of the impact of structural and regulatory changes on performance

This section examines examples of unit cost improvements arising from significant changes in different sectors and contexts. A total of 10 examples were analysed. The analysis here focuses on the change in real unit operating expenditure (RUOE) as a measure of unit cost improvements. This differs from the analysis of the water and energy sectors where the focus is on total expenditures. Unit cost improvements on operating expenditures may not necessarily apply to capital expenditures.

The aim of this analysis is to provide an indication of the resultant scale of efficiency improvements following significant changes to regimes. It does so by tracking changes in unit costs around the time of the significant changes. This analysis assumes that unit cost improvements equate to efficiency gains, and that all efficiency gains are attributable to the significant change. It does not attempt to separate out or control for the impact of the changes from other affects such as changes in quality standards, economies of scale and other changes affecting costs beyond managerial control.

The rest of this section presents case studies by sector before providing a discussion of the overall results. All the efficiency gain figures are presented on an annual incremental basis.

4.1 UK Rail

2002: Creation of Network Rail

Network Rail is the owner and infrastructure manager of most of the rail network in England, Scotland and Wales. Between 1994 and 2002, the infrastructure was owned and operated by Railtrack. The Hatfield train crash in 2000 sent Railtrack into financial disarray, with the immediate major repairs undertaken across the whole British rail network estimated to cost in the order of £580m. In October 2002, Network Rail Ltd took over control by buying Railtrack plc while it was in railway administration and, since September 2014, has been classified as a 'public sector body'.

4.1.1 Analysis

Data was collected over the lifetime of Network Rail, from 2003-2017, to determine the reductions in RUOE. The results were used to determine what effect the three shocks detailed above had on the financial performance and efficiency of Network Rail over its lifetime.

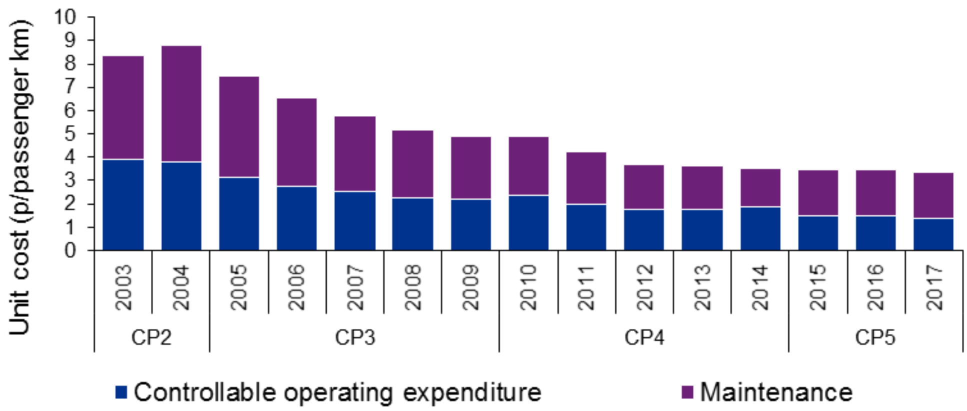
Network Rail's regulatory financial statements provide data on controllable opex, non-controllable opex, and maintenance expenditure. Controllable opex comprises network operations and support costs. Uncontrollable opex comprises traction electricity, industry costs and rates. Maintenance comprises network maintenance.

Non-controllable opex cannot be controlled by Network Rail. It would therefore be misleading to attribute efficiency improvement to non-controllable costs, so this cost category is excluded for this analysis. The remaining costs are combined into controllable costs comprising controllable opex and maintenance. The unit cost is calculated as controllable costs divided by passenger rail kilometres.

4.1.2 Results

Figure 15 shows Network Rail's unit controllable opex and unit maintenance costs over time. In the initial two years of operation, the total unit cost increased as this was a period of reorganisation and running maintenance programmes. Since 2004, there has been a steady overall decrease in unit costs.

Figure 15: Evolution of Network Rail unit costs



Source: KPMG Analysis of Network Rail's Regulatory Financial Statements

Table 35 shows the average change in unit costs in the five years prior to the shock (T-5 to T), the first five years following the shock (T – T+5) and the second five years following the shock (T+5 to T+10). This method was used unless there was not enough data to cover the entire period, in which case the number in brackets indicates the number of years included in the calculation. A positive number indicates declining unit costs.

Following the formation of Network Rail, the unit controllable cost declined by more than 9% a year in the initial five years. The unit controllable cost continued to decline by 7% a year in the subsequent five-year period.

Table 35: Change in controllable costs in different periods per year

Event	T-5 to T	T to T+5	T+5 to T+10
Formation of Network Rail (T = 2002)	NA	9.1%	7.0%

Source: KPMG analysis of Network Rail's Regulatory Financial Statements
Note: The number in brackets indicates the number of years included in the calculation

4.2 UK Telecoms

There have been two shock events in the sector since the turn of the century. These are the local loop unbundling in 2001 and the functional separation of Openreach in 2006.

2001: Local loop unbundling

The EC Local-Loop unbundling regulation came into force in 2001, allowing multiple telecommunications operators to use BT's infrastructure to supply connections to customers' premises. As a result, BT's competitors were able to site their equipment in BT exchanges and connect it to BT loops, providing retail broadband and telephone services to customers.

This event introduced competition into the retail broadband and telephone service markets, which were previously dominated by BT.

2006: Functional separation of Openreach

Ofcom argued that BT had significant market power in the British telecommunications market so, following the Telecommunications Strategic Review carried out by Ofcom, BT agreed to create a separate division, called Openreach. Openreach began operating in January 2006, reporting directly to the BT chief executive, with the aim to provide equal access to BT's local network access. The functional separation allows BT to have greater focus on wholesale costs.

4.2.1 Analysis:

Local loop unbundling

Competitive forces should drive BT to reduce its retail costs to stay competitive with new entrants in the retail broadband and telephone markets. Therefore, the analysis focuses on operating costs as reported for the BT retail segment. BT separates out performance reporting for the BT Retail segment. BT Retail includes retail products and services to the consumer and small to medium-sized business markets.

The unit cost was calculated by taking operating expenditure figures for the BT Retail segment and dividing them by the number of broadband and exchange lines served by BT Retail. The unit cost was then inflated to 2016-17 prices. Where there was a restatement of financial figures, the annual changes in real unit operating expenditure were calculated against the restated figures.

Functional separation of Openreach

Greater managerial focus and public scrutiny associated with the functional separation should lead to more efficiency at Openreach. To this end, operating cost data and exchange line numbers were taken from BT annual reports over the period preceding the separation of BT's wholesale segment to Openreach (2002-05) and following separation (2006-17).

Prior to 2006, opex was calculated as revenue minus EBITDA from the segmented results for BT wholesale division. Exchange lines were taken as the sum of retail and wholesale lines. From 2006 onwards, opex and EBITDA were taken from the segmented results for Openreach.

Opex was then inflated to 2016-17 prices and divided by the line numbers to get a value for real unit cost.

4.2.2 Results

Table 36 shows the average change in unit costs in the five years prior to the shock (T-5 to T), the first five years following the shock (T – T+5) and the second five years following the shock (T+5 to T+10). This method was used unless there was not enough data to cover the entire period, in which case the number in brackets indicates the number of years included in the calculation. A positive number indicates declining unit costs.

Following local loop unbundling, BT Retail's unit cost declined by 1.7% a year in the first five-year period before tailing off to 1.2% a year in the second five-year period.

Following the separation of Openreach, the unit cost declined by 8.3% a year in the first five-year period and 5.4% a year in the second five-year period. This is compared to a decline of 7.6% a year in the five-year period prior to the separation.

Table 36: Change in operating costs in different periods per year

Event	T-5 to T	T to T+5	T+5 to T+10
Local loop unbundling (T = 2001)	NA	1.7%	1.2% (4)
Openreach separation (T = 2006)	7.6%	8.3%	5.4%

Source: KPMG analysis of BT's Financial Statements
Note: The number in brackets indicates the number of years included in the calculation

4.3 England and Wales water sector

The privatisation of the water sector occurred in 1989, where ten previously public regional water authorities in England and Wales were privatised through the sale of assets. At the same time, the Water Services Regulation Authority, or Ofwat, was created in order to economically regulate the privatised water and wastewater industry. In 1990, the Drinking Water Inspectorate (DWI) was set up to monitor water safety and quality.

Since the inception of Ofwat, there have been four full Price Review periods – each running for five years, the first being in 1994. In 2014, the first totex price control was introduced by Ofwat, with the main driver behind the change being to remove the real or perceived bias towards capital expenditure.

4.3.1 Analysis

Frontier Economics was recently commissioned by Water UK to undertake a study into the water sector privatisation in England, specifically looking at the productivity improvement in the water and wastewater industry.

Frontier estimated Total Factor Productivity (TFP) growth achieved by the industry over the period between 1993/94 and 2016/17 on both a quality-adjusted and quality-unadjusted basis.

TFP refers to the residual growth in total output that cannot be explained by the accumulation of the traditional inputs of labour and capital. It is used as a measure of the efficiency of inputs, with an increase in TFP usually resulting from technological improvements.

The quality adjustment is based on average percentage of each company's water supply zones that are compliant with key water quality parameters, relative to the average compliance percentage in 1990. For wastewater, the quality adjustment is based on the average of river quality and bathing water quality for each WaSC.

Table 37 summarises the results from their analysis.

4.3.2 Results

Frontier did not separately identify TFP growth due to frontier shift from TFP growth due to catch-up efficiency. The average TFP growth during the previous business cycle was 1.6% a year with no quality adjustment and 3.2% with quality adjustment.

Table 37: TFP growth based in Frontier's study

	TFP average growth (no quality adjustment)	TFP average growth (quality adjustment)
1994 – 1995	2.9%	3.5%
1996 – 2000 (PR94)	2.2%	4.5%
2001 – 2005 (PR99)	0.7%	2.0%
2006 – 2010 (PR04)	1.4%	2.2%
2011 – 2015 (PR09)	-0.5%	-0.2%
2016 – 2017	-0.2%	0.0%
1994 – 2008 Business Cycle 1	1.6%	3.2%
2009 – 2017 Business Cycle 2	-0.1%	0.1%
1994 – 2017	1.0%	2.1%

Source: Figure 2 of Frontier Economics (2017), Productivity Improvement in the Water and Sewerage Industry in England since Privatisation

Frontier's results include both catch-up efficiency of the sector to the wider economy and frontier shift changes. Initially the recorded TFP average growth was large and it has declined over the time.

The study found that the average TFP growth in the industry since privatisation has been around 1% a year when not adjusted for quality and 2.1% a year when adjusted for quality.

Table 38: TFP growth post-privatisation based in Frontier's study

	T to T+5	T+5 to T+10
TFP average growth (no quality adjustment)	2.9% (1)	2.2%
TFP average growth (quality adjustment)	3.5% (1)	4.5%

Source: Figure 2 of Frontier Economics (2017), Productivity Improvement in the Water and Sewerage Industry in England since Privatisation
Note: The number in brackets indicates the number of years included in the calculation

TFP growth was highest during the initial years of privatisation. In the period before the first price control, there was a big gain in TFP of 2.9%, and 3.5% on a quality adjusted basis. Over the first price control, PR94, TFP grew up to 4.5% a year on a quality adjusted basis. Following PR94, growth slowed and, more recently, the study found negative TFP growth in the industry. On a quality adjusted basis, TFP growth was -0.2% a year during PR09 and 0.0% so far during PR14.

4.4 UK Energy

There have been three shock events in the sector for which data is publicly available for analysis: the privatisation of electricity companies in 1990, the introduction of competition in electricity generation in 1990 and the creation of four new independent gas distribution networks in 2003.

1990: Privatisation and Electricity distribution price control

In 1990, after the Electricity Act 1989, the Central Electricity Generating Board (CEGB) was broken up into four separate companies – generation activities were transferred to PowerGen, National Power and Nuclear Electric (later British Energy), and National Grid Company was created to take on the transmission activities, i.e. the running of the electricity grid. Three further companies were created to manage the electricity generation in Scotland – Scottish Power, Scottish Hydroelectric, and state-run Scottish Nuclear. The twelve area boards were replaced by 12 regional electricity companies, responsible for owning and operating the electricity distribution network in their authorised area.

The Act also established a licensing regime and an independent regulatory body for the industry, OFFER, which has since become the Office of Gas and Electricity Markets (OFGEM). The original distribution price controls were put in place by the government at the time of restructuring, running for five years from 1 April 1990. Responsibility for future price controls was placed under Ofgem, with the first being DPCR1 running from 1995.

1990: Competition in Electricity Generation

Prior to 1989, the CEGB had a monopoly over the generation and transmission of electricity in England and Wales. Accompanying the privatisation of CEGB in 1990 was the creation of the central electricity pool, the wholesale market mechanism through which electricity was traded in England and Wales. This in effect introduced competition in electricity generation.

The pool was a set of rules defining how electricity in the market was to be traded. It was set up as a settlement system to facilitate a competitive bidding process between generators that set the price paid for electricity each half hour of the day and established which generators would run to meet forecast demand.

2003: Creation of four new independent gas distribution networks

In August 2004, National Grid Transco agreed to sell four of its GDNs to third parties, thereby creating four new independent GDNs. These four GDNs are now owned by Wales and West Utilities, Northern Gas Networks and Scotia Gas.

The Gas Distribution Price Control Review 2007-2013 (GDPCR1) was the first price control following the sale of the four GDNs by National Grid Transco in 2005, which allowed Ofgem to set allowed revenue based on meaningful comparisons between the GDNs.

4.4.1 Analysis

1990: Privatisation and Electricity distribution price control

Domah and Pollitt (2001) compiled accounting data for the 12 area boards and their private successors (regional electricity companies) from 1 April 1985 to 31 March 1998. They aggregated the data across the 12 area boards to represent the industry view.

To collect data for operating costs, we used the ‘distribution controllable cost’ in their dataset for the period 1991-1998. Prior to privatisation, the 12 area boards did not report distribution and supply costs separately, therefore we used a proxy to calculate operating costs. We calculated the proportion of supply controllable costs to total controllable costs in 1990-91 and applied this proportion to the total controllable costs prior to the privatisation in order to estimate the controllable distribution costs for those years. All of the operating cost data was then inflated to 2016-17 prices.

The unit cost is defined as controllable distribution costs divided by the volume of electricity distributed.

1990: Competition in Electricity Generation

Newbery and Pollitt (1997) compiled accounting data for the CEGB up until 31 March 1989, the year before the restructuring and privatisation. From April 1991 to 31 March 1996, they collated accounting data for the successor companies of CEGB (PowerGen, National Power, Nuclear Electric and National Grid) to build a hypothetical ‘CEGB’ account. Data for the period between 1 April 1989 and 31 March 1991 was incomplete due to various complications related to the restructuring and privatisation.

We used the data in Newbery and Pollitt's 'The Restructuring and Privatisation of Britain's CEGB' publication (1997). Controllable operating costs are defined as the sum of 'staff costs' and 'materials and services costs'. These were inflated to 2016-17 prices. The unit cost is defined as controllable operating costs per volume of electricity sold.

2003: Creation of four new independent gas distribution networks

Financial data from statutory accounts for Transco and the acquirers of the four GDNs were collated to form a time series of financial data for a hypothetical Transco. Operating costs are defined as turnover less operating profit plus depreciation. Note that under UK GAAP, this measure includes replacement expenditures expensed as opex.

To ascertain the gas distribution unit cost, operating expenditures of the four companies were combined and inflated to 2016-17 prices. The unit cost is defined as operating expenditures per customer connected to a gas distribution network.

4.4.2 Results

Table 39 shows the average change in unit costs in the five years prior to the shock (T-5 to T), the first five years following the shock (T – T+5) and the second five years following the shock (T+5 to T+10). This method was used unless there was not enough data to cover the entire period, in which case the number in brackets indicates the number of years included in the calculation. Positive figures indicate declining unit costs.

Table 39: Change in operating costs in different periods per year

Event	T-5 to T	T to T+5	T+5 to T+10
Privatisation of electricity distribution (T = 1990)	-0.4%(3)	-0.3%	9.9%(4)
Competition in electricity generation (T = 1990)	-4.0%(4)	8.6%	NA
New gas distribution networks (T = 2003)	-1.2%(4)	-0.8%	0.4%(2)

Source: KPMG analysis of data from Newbery and Pollitt (1997), Newbery and Pollitt (2001) and annual reports of Transco, National Grid Gas, Northern Gas Networks, Scotia Gas Networks and Wales and West Utilities
Note: The number in brackets indicates the number of years included in the calculation

Electricity distribution companies increased their cost by 0.3% a year during the first five years following their privatisation. This is a marginal decline compared to an increase of 0.4% a year in the preceding three-year period. The second five-year period coincided with the first electricity distribution price review by OFFER which saw price caps reduced by around 10% per year across the industry. During this period, companies' unit costs declined by 9.9% a year.

Electricity generation companies reduced their cost by 8.6% a year following the introduction of competition in wholesale electricity, compared to an average increase in unit costs of 4.0% a year prior to the reform.

The formation of the four new gas distribution networks also impacted on unit costs. During the period of single ownership, unit costs increased by 1.2% a year. In the first five years following the sales, unit costs still increased but at a slower rate of 0.8% a year. Unit costs declined by 0.4% a year in the subsequent two years following this five year period.

4.5 UK Airports

After the Q4 price control ended in 2008, the CAA concluded that Manchester Airport no longer met the revised criteria established by Government for the airport to be given a price control, therefore it was de-designated from the price control mechanism.

4.5.1 Analysis

Data for this analysis was collected from KPMG's Proprietary Database, which includes data from annual reports and other public sources.

The core operating costs relate to the core aeronautical operating activities of the airport. Core opex is the sum of staff costs, utility costs, maintenance and other core costs. The total was then adjusted to remove specific non-core costs where they could be consistently identified – this included rates/taxes and social security. The resulting adjusted core operating costs were then indexed for inflation to 2016-17 prices.

The unit cost is defined as the adjusted core opex divided by passenger numbers.

4.5.2 Results

Table 40 shows the average change in unit costs in the five years prior to the shock (T-5 to T), the first five years following the shock (T – T+5) and the second five years following the shock (T+5 to T+10). This method was used unless there was not enough data to cover the entire period, in which case the number in brackets indicates the number of years included in the calculation. Positive figures indicate declining unit costs.

Table 40: Change in operating costs in different periods per year

Event	T-5 to T	T to T+5	T+5 to T+10
Manchester airport (T = 2008)	2.6%	1.3%	-5.1%(4)

Source: KPMG analysis
Note: The number in brackets indicates the number of years included in the calculation

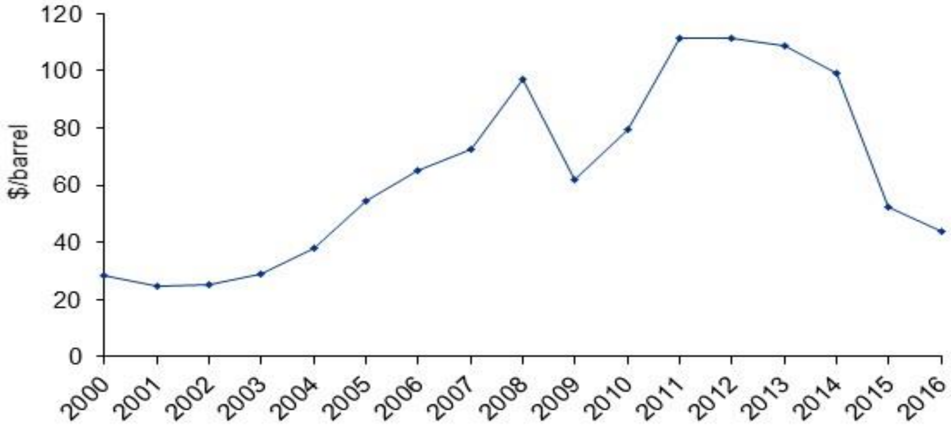
Overall, unit costs declined by 1.3% following the removal of the price cap for Manchester. It is challenging to attribute unit cost trends for airports to any specific change. This is because of factors beyond their controls such as increased security requirements.

4.6 UK Offshore Oil & Gas

From 2002 to 2008, the price of oil saw an unprecedented spike, going from $30/barrel in 2002 to $170/barrel in 2008. Shortly after, the global recession caused demand for energy to drop and so oil and gas prices fell to a low of $40. Economic recovery the following year sent the price of oil back to a high of $111/barrel in 2011 – it hovered around that price until 2014, after which the price once again dropped, this time reaching a low of $32/barrel in 2016.

Figure 16 shows historical prices of Brent crude oil since 2000.

Figure 16: Price of Brent crude oil



Source: U.S. Energy Information Administration

There were a number of factors which contributed to the 2014 drop in oil prices. Firstly, rapid expansion in economies such as China created a great demand in oil in the first decade of the millennium, which began to slow after 2010 – this slow in demand had significant price ramifications on oil due to the scale of China's population. Another contributing factor to this price fall was the increase in oil production by countries such as the US and Canada, spurred by high oil prices – as a result of this local production, supply increased enough for the US and Canada to cut their oil imports sharply, driving prices downward.

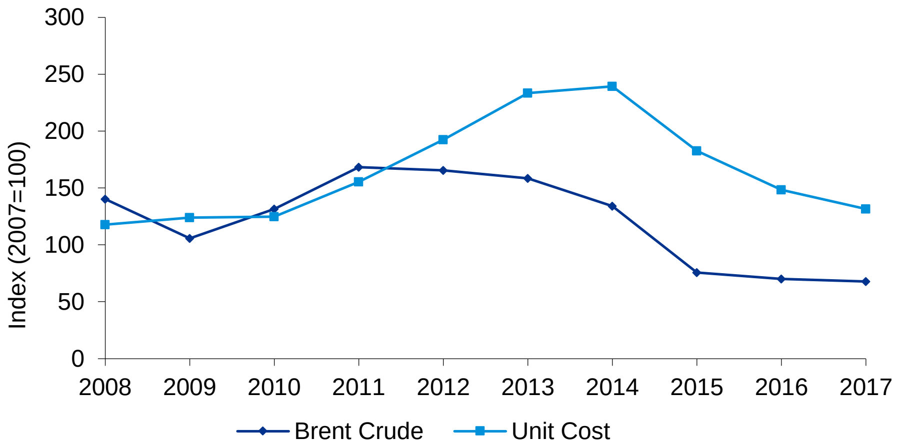
4.6.1 Analysis

Data for this analysis was extracted from Annual Economic Reports as published by UK Oil and Gas. Production cost, in $/barrel of oil equivalent (boe), from the Annual Economic Reports over the period 2007 to 2017 were inflated to 2016-17 prices.

4.6.2 Results

The general trend shows that the pattern in real operating unit costs largely follows Brent crude oil prices as shown in Figure 17. This correlation can be shown through the Compound Annual Growth Rate (CAGR) analysis where in the periods 2007-2011, Brent crude prices and unit cost increased by an average of 13.9% and 11.6% year-on-year respectively, and in the period 2014-2017, Brent crude prices and unit cost decreased by an average of 20.3% and 18.1% year-on-year respectively.

Figure 17: Brent crude oil price vs unit cost



Source: KPMG analysis

Prior to the collapse in oil price in 2014, production costs were rising by 14.6% a year in the five-year period to 2014. Since 2014 the price of Brent crude declined by 20% a year while production costs declined by 13.4% a year. This reflects a combination of producers' ability to boost productivity through higher throughput and decommissioning of loss-making wells.

Table 41: Change in operating costs in different periods per year

Event	T-5 to T	T to T+5	T+5 to T+10
UK Oil&Gas price collapse (T = 2014)	-14.6%	13.4% (3)	NA

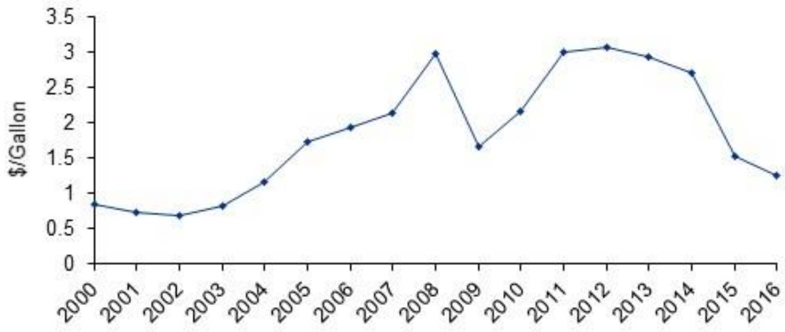
Source: KPMG analysis of Annual Economic Reports published by UK Oil & Gas

4.7 US Airlines

Oil prices rose sharply during the period between 2002 and 2008 – price per barrel went from $30 in 2002 to $170 in 2008. One of the worst affected industries was the aviation industry due to its reliance on jet fuel as one of the main inputs. Traditionally, fuel costs were less than 15% of airline operational costs, however during the oil price spike, this more than doubled on an industry-wide basis, and was even greater for airlines with low labour costs.

Figure 18 below shows that jet fuel price rose from $0.69/gallon in 2002 to $2.96/gallon in 2008, an increase of 331% over the period. The result of this price spike was that many airlines were not able to fully pass on the fuel costs to passengers, so their losses became substantial – in the first six months of 2008, 25 airlines went out of business.

Figure 18: Jet fuel spot price (FOB)



Source: U.S. Energy Information Administration

4.7.1 Analysis

This analysis relies on the information from Global Airline Industry Program at the Massachusetts Institute of Technology. The database contains revenue and cost data for 16 major US airlines. Of the 16 airlines, the breakdown was:

- Seven full-service (legacy) airlines: these are airlines that focus on providing a wide range of pre-flight and on-board services, including different service classes and connecting flights;
- Five low-cost airlines: airlines that focus on cost reduction in order to implement a price leadership strategy on the markets they service; and
- Four 'other' airlines.

Some of the airlines have been acquired since the database began.

This analysis is on airlines' system operating expenditure per unit of production, excluding fuel costs. Nominal data for the total operating expense from Global Airline Industry Program are converted to 2016 prices using the US Consumer Price Index. This value is then divided by the number of available seat miles (ASM), which is a measure of an airline flight's passenger carrying capacity, equal to the number of seats available multiplied by the number of miles flown.

4.7.2 Results

Between 2002 and 2006, jet fuel prices rose by 165%. Airlines across the spectrum from legacy to other reduced their non-fuel costs. Legacy airlines reduced their non-fuel unit costs by 6.5% a year. Low-cost and other airlines reduced their non-fuel unit costs by 2.8% and 1.8% respectively, reflecting their leaner cost base.

Between 2007 and 2011, jet fuel rose another 55%. However, legacy airlines instead saw their non-fuel unit costs increased by 0.5% a year. In contrast, low-cost and other airlines continued to reduce their non-fuel unit costs, albeit at a slower rate for low-cost airlines.

Table 42: Change in non-fuel operating costs in different periods per year

Type of carrier	T-5 to T	T to T+5	T+5 to T+10
Cost shock - legacy airlines (T = 2002)	-0.6%	6.5%	-0.5%
Cost-shock - low-cost airlines (T = 2002)	1.7%	2.8%	1.7%
Cost-shock - other airlines (T = 2002)	-0.5%	1.8%	3.7%

Source: KPMG analysis of the Global Airline Industry Program Database

4.8 Scottish Water

Scottish Water was founded in 2002 by a merger of West of Scotland Water Authority, East of Scotland Water Authority and North of Scotland Water Authority. This occurred under the Water Industry (Scotland) Act 2002 and resulted in the company being wholly owned by the Scottish Government.

Scottish Water operates under the regulation of the Water Industry Commission for Scotland (WICS), a regulator established in 2005, who are responsible for the price setting process taking place every six years, and also for facilitating competition in the Scottish water industry – In April 2008, Scotland opened up water and wastewater retail services to competition for all non-household customers under the Water Services etc. (Scotland) Act 2005.

4.8.1 Analysis

Scottish Water's annual reports were used to collect data over the period from 2003-2017. Base totex (botex) was used to calculate the unit cost – this was calculated by subtracting PPP charges and SEPA service charges from opex, and summing the result with capital maintenance. Botex for Water and Wastewater services was then added to obtain the total botex for the company and this was inflated to 2016-17 prices.

Botex was used since reporting prior to 2007 did not sufficiently segment opex. The unit cost is defined as the total botex divided by the total number of connected properties.

4.8.2 Results

From 2002 to 2007, unit botex decreased steadily - in the four years following Scottish Water's formation, total unit botex decreased by an average of 6.9% year-on-year. From 2007, unit botex started to increase up until 2010, where it began to steadily decrease again. Between 2007 and 2011, the unit botex increased by an average of 2.5% year-on-year.

Table 43: Change in unit botex in different periods per year

Event	T to T+5	T+5 to T+10
Formation of Scottish Water	6.9%	-2.5%

Source: KPMG Analysis of Scottish Water's annual returns

4.9 Other studies

In considering the scope for efficiency improvement, particularly after the introduction of a significant change to the regulatory framework, such as totex and the use of greater incentives, it may be instructive to review the extent to which the introduction of competition or the deregulation of utilities or other comparative sectors has resulted in a significant level of productivity improvement.

An interesting summary of this evidence can be found in the CMA paper 'Productivity and competition A summary of the evidence', 2015.

Table 44: Summary results from comparative studies

Study	Sector, timescale and approach	Suggested incremental gains from competition
Zhang,Parker and Kirkpatrick, 2005	Electricity generation 1985-2003 in developing countries. Impact of competition on labour productivity econometric analysis	1.1% to 3% p.a.
Nickell,1996	147 UK companies 1972 –1986.Impact on TFP growth when firms face 5 or more competitors.	3.8% to 7.1% p.a.
Nickell, 1997	700 UK companies 1972–1986. TFP growth in more competitive environments.	3.8% to 4.6% p.a.
Maher and Wise, 2005	Impact of competition into UK electricity and gas in 1990s.	10%+ a year productivity growth in 1990s
Gortand Sung, 1999	Comparative analysis of TFP growth in competitive US telecoms market versus regional monopolies.	TFP growth rates found to be between 7 and 14 times higher in competitive markets.
Miccoand Serebrisky, 2004	Impact of changes in air transport and de-regulation on productivity and efficiency.	Introduction of 'open skies' agreements found to reduce transport costs by 8%.
Holmes and Schmitz, 2010	Summarise evidence from other studies of industries that have seen a change in their competitive environment.	Nearly all studies reviewed suggest that increases in competition led to increases in industry productivity.

Source: KPMG analysis

Studies generally site three key sources of the efficiency improvement from the introduction of competition or the reduction of regulation or market power resulting in increased rivalry between firms. A summary is provided in Table 45.

- 'Within-firm' effects-the impact of competition on the incentive for efficiency within firms/on management teams.
- 'Across-firm', 'market-sorting' or 'external restructuring' effects-the impact of more efficient firms increasing their market share and forcing out less efficient firms.
- 'Innovation' or 'dynamic efficiency' effects-the impact of competition on incentives for innovation.

Whilst 'within-firm' and 'innovation' competition is more directly attributable to the introduction of totex, an 'across-firm' effect cannot be materialised in the regulated industry – in this case, the suggested incremental gain due to competition of 3%-5% cited in Table 44 is likely to be higher than the factual case.

Table 45: Summary results from comparative studies

Study	Sector, timescale and approach	Suggested incremental gains from competition
Within-firm effects		
Bloom and Van Reenen, 2010	Cross-country survey of more than 6,000 firms	Strong competition boosts management practises.
Nickell, Nicolitsas and Dryden, 1997	Empirical survey of 580 UK manufacturing companies	Competition is substitutable for other disciplining devices e.g. financial pressure or shareholder pressure.
Across-firm effects		
Harris and Li, 2008	Analysis of extent of between firm versus within firm effects	79% of UK productivity growth occurs from across-firm effects.
Disney, Haskeland Heden, 2003	Review of UK manufacturing from 1980-1992	50%of labour productivity and 80-90% of TFP growth occurs from across-firm effects.
Baldwin and Gu, 2006	Review of Canadian manufacturing 1979-99.	Around 70% of productivity growth is attributed to higher productivity firms gaining market share.
Scarpetaet al,2002	Study of TFP across 10 OECD countries in 1980s and 1990s.	Across-firmeffects or market sorting accounts for 20-40% of TFP growth across OECD countries.
Innovation		
Blundell, Griffith and VanReenen, 1995	Analysis of 375 firms listed on the London Stock Exchange, 1972-1982.	Dominant firms tend to innovate more and industry concentration dampens innovation. However in more concentrated markets innovation in aggregate will fall.

Source: KPMG analysis

This study is seeking to review the evidence for efficiency improvement arising from changes to the regulatory framework which seek to reduce regulatory controls (e.g. moving to totex) and increase market-like incentives (e.g. outcomes). Hence these changes are not the same as introducing competition, in particular the changes will not introduce across-firm or market sorting effects as regulated water networks will continue to be regional monopolies. However they may introduce within-firm effects or increase levels of innovation.

4.10 Discussion of examples of unit cost changes over time from significant changes

Table 46 provides a summary of examples of efficiency improvements in this section. The examples are divided into four major categories:

- Change in regulatory regime: This includes an introduction of economic regulation, changes in the regulatory framework, introduction of new incentives and calibrations of the regulatory regime.
- Introduction of competition: This includes an introduction of third party network access, creation of new markets and comparative competition.
- Change of ownership: This includes change in ownership from public to private, private to public and private to private.
- Cost/revenue shock: This includes instances where competitive sectors experience significant cost of revenue shocks.

The categorisation is based on a high level review of the nature of the changes associated with the events. The scale and scope of changes varies from one example to another even within the same grouping.

Some examples may feature in more than one category. For example, the privatisation of electricity distribution is featured under both the first category and the third category because it involves a change in ownership from public to private as well as the change in regulatory regime due to the imposition of the price control. This highlights the difficulties with attributing unit cost declines to a particular effect or a change.

Within the change in regulatory regime category, the examples show real unit operating costs decline from -0.8% to +8.3% per year in the first five years following the event. Within this category, Openreach saw a large reduction in unit costs of 8.3% per year, but this follows a reduction of 7.6% a year before the change so the incremental impact of the separation on unit costs is likely to be smaller.

Within the introduction of competition category, the examples show real unit operating costs decline from -0.8% to +8.6% per year in the first five-year period. The largest reduction of 8.6% is associated with the introduction of competition in electricity generation. However, this change coincided with the privatisation of electricity generating companies. The results in this category are consistent with those found in our review of comparative studies.

Within the change of ownership, the examples show changes in unit costs of -9.1% to +0.3%. The formation of Network Rail led to the largest reduction in unit costs which followed on into the second five-year period although at a reduced rate. In contrast, the second five-year period of the new gas distribution networks saw companies reduce their costs at a faster rate, i.e. 0.4% reduction a year vs an increase of 0.8% a year in the first period.

In the cost/revenue shock categories, companies showed their ability to reduce unit costs at a fast rate immediately following the shock. Oil and gas companies cut their production costs by more than 13% a year, while airlines showed varying rates of cost cutting. Overall, the range is 13.4% to-1.8% per year.

Table 46: Summary of examples of reported performance improvements associated with structural or regulatory changes (average, annual change)

Events	T-5 to T	T to T+5	T+5 to T+10
Change in regulatory regime			
Openreach separation	7.6%	8.3%	5.4%
Formation of Scottish Water	NA	6.7%	-1.3%
Manchester airport	2.6%	1.3%	-5.1%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
New gas distribution networks	-1.2%	-0.8%	0.4%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Introduction of competition			
Competition in electricity generation	-4.0%	8.6%	NA
Local loop unbundling	NA	1.7%	1.2%
New gas distribution networks	-1.2%	-0.8%	0.4%
Academic literature		3% to 5%	
Change of ownership			
Formation of Network Rail	NA	9.1%	7.0%
Competition in electricity generation	-4.0%	8.6%	NA
New gas distribution networks	-1.2%	-0.8%	0.4%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Cost/Revenue shock			
UK Oil & Gas price collapse	-14.6%	13.4%	NA
Cost shock - legacy airlines	-0.6%	6.5%	-0.5%
Cost-shock - low-cost airlines	1.7%	2.8%	1.7%
Cost-shock - other airlines	-0.5%	1.8%	3.7%

Source: KPMG analysis of regulatory accounts, financial statements and public reports.

The introduction of the totex and outcomes framework is likely to be more comparable to the cases of changes in the regulatory regime than to other cases (events). The outcomes and totex change is likely to be less comparable to the introduction of competition where, for example, market sorting effects are introduced, which would not be present in the case of totex and outcomes. Examples of privatisation and changes in ownership show instances where new shareholder incentives are introduced to drive management teams to improve efficiency—these might be seen as introducing quite different incentives compared to those introduced by regulators during price controls. Cost and revenue shock examples are also drawn from competitive environments and represent different incentives for efficiency.

Overall, the results from this analysis indicate that major regulatory and structural changes are associated with significant changes in performance, and that the impact of such events is, in many cases, positive. This could be interpreted, under certain assumptions, as indicative of such regime changes and paradigm shifts enabling stronger performance and greater efficiencies being realised by the companies. It is also worth noting that the results from the totex analysis fall within the wide range of examples highlighted on Real Unit Operating Expenditure. However, it is difficult to infer strong conclusions from this comparative analysis, given the different nature of the cases (events) considered and the potential for other factors affecting the performance metrics used in the analysis.

The evidence is also mixed on the longevity of the impact of the documented performance, and, potentially, associated efficiency gains, over time. Some examples exhibit diminishing gains over the next five year period (e.g. Scottish Water, Openreach separation) while others show increasing gains (e.g. privatisation of electricity distribution and new gas distribution networks). Overall, however, diminishing efficiency benefits appear to be common in subsequent periods.

Overall, the evidence suggests a wide range of performance gains associated with incidents of regulatory and structural changes considered; the former might be interpreted as efficiency improvements due to such changes, under certain assumptions. The upper bound appears to be set by Scottish Water where a gain of 6.7% was observed following the merger of regional water companies. Some of the gains may be due to a one-time merger savings.

5 Evidence from historical efficiency gains

5.1 Previous regulatory decisions on frontier shift assumptions

A number of UK regulators apply a two-step approach to forming ex ante expenditure allowances for regulated companies:

- The first step typically involves forming an estimate of efficient expenditure for a base year based on a suite of top-down benchmarking models and bottom-up cost models using historical cost information (modelled costs).
- The second step involves the regulators rolling the base year efficient cost forward by applying frontier shift and/or catch up efficiency assumptions to derive final expenditure allowances.

Table 47 provides a summary of recent UK regulatory decisions on frontier shift assumptions. Frontier shift from one sector may not necessarily be applicable in another sector due to differences in input mix and technology potential. However, it could provide an indication of general frontier shift in an economy.

Table 47: Previous regulatory decisions on frontier shift assumptions

Sector	Price Control	Period	Frontier shift assumption per year
Non-totex Controls			
Water	PR94	1995-2000	1.0% for capex and opex
	PR99	2000-2005	1.4% for base opex and capital maintenance (CM)
			2.1% for enhancement (EN) opex and capex
	PR04	2005-2010	0.6%/0.9% for base opex water/wastewater
			0.9%/1.5% for EN opex water/wastewater
			0.3%/0.5% for CM water/wastewater
			0.45%/0.75% for EN capex water/wastewater
	PR09	2010-2015	0.25% for base opex water and wastewater
			0.38% for EN opex water and wastewater
			0.40% for All capex water and wastewater
	PR09 CMA	2010-2015	0.90% for opex and 0.4% for capex
Energy	DPCR4	2005-2010	1.50% for opex only
	TPCR4	2007-2013	1.50% for opex only
	GDPCR1	2008-2013	1.4% for opex
			1.5% for mains reinforcement
			2.0% for repex
Rail	CP4	2009-2014	0.2% for controllable opex
			0.7% for maintenance and renewals
	CP5	2014-2019	0.3% for total expenditure
Airports	HAL Q6	2014-2021	1.0% for opex
Royal Mail	FD 2006	2006-2010	1%-1.5% for opex
Totex Controls			
E&W Water	PR14	2015-2020	None (but benchmarking models included a time trend to capture dynamic efficiencies)
	PR14 CMA	2015-2020	1.0% for totex
NI Water	PC15	2015-2021	0.9% for opex and 0.6% for capex
Energy	DPCR5	2010-2015	1.0% for totex
	RP5	2012-2017	1.0% for opex
	RIIO-T1	2013-2021	1.0% for opex and 0.7% for capex and repex
	RIIO-GD1	2013-2021	1.0% for opex and 0.7% for capex and repex
	RIIO-ED1	2015-2023	0.8% - 1.1% for totex

Source: Final determination documents of the relevant price controls

In general, it can be observed that for both non-totex and totex controls regulators applied the frontier shift to opex assumptions. The opex frontier shifts can be considered to be separate from any capex assumptions, which is possible because regulators previously set opex and capex allowances independently. This means that the reported opex frontier shift targets do not preclude the regulator from setting separate capex frontier shift assumptions.

Specifically for the non-totex controls, the regulators applied greater frontier shifts for capex rather than opex assumptions. Moreover, the water sector regulatory precedents demonstrate that Ofwat set separate water and wastewater frontier assumptions for the majority of the non-totex controls, except for PR09 when both capex and opex assumptions where merged for water and wastewater services.

More recently, the introduction of the totex controls changed the trend from greater shifts in capex to opex efficiencies. For totex price controls, Ofgem's average frontier shift target for opex is circa 1.0% compared to circa 0.7% for capex.

5.1.1 Conclusion

A review of previous regulatory decisions on frontier shift assumptions reveals that frontier shift has been declining over time across all sectors. This reflects diminishing opportunities for improvements in frontier shift.

Overall, this review suggests a frontier shift assumption in a range between 0.7% and 1.1% for AMP7 based on the recent totex price controls.

5.2 Total factor productivity improvements

Total factor productivity (TFP) measures the portion of output that cannot be explained by the amount of inputs used in the production process. TFP growth indicates a more efficient use of existing inputs.

TFP growth represents a good benchmark for efficiency improvements under the totex and outcomes framework. This is because it captures the overall efficiency with which labour and capital inputs are jointly used together in the production process. It aligns with the totex and outcomes framework where regulators provide companies with incentives to choose the optimal input mix that maximise the benefits for customers.

In addition, previous regulatory decisions on frontier shift have tended to consider TFP growth as a source of evidence for potential productivity improvements. However, those studies have tended to use TFP growth to estimate efficiency improvements for operating expenditure. This reflects the regulatory framework where the allowed operating and capital expenditures are assessed separately. The totex and outcomes framework removes that distinction and thus TFP growth could be considered for total expenditure.

5.2.1 Background on TFP estimation

TFP growth is the change in the level of output that cannot be explained by the change in the amount of inputs used in production. At the highest level therefore TFP analysis requires data on inputs and outputs.

There are two approaches to measure outputs:

- The **gross output** approach measures the total output of an industry.
- The **value added** approach excludes intermediate inputs in the production process from the output. Intermediate inputs are inputs that are used up in the production

process. An example of an intermediate input in the water sector include energy used for the purpose of pumping water across the network.

TFP growth based on value added does not consider productivity gains from better use of intermediate inputs. It is based on the notion that labour and capital are the two dominant drivers of productivity. It assumes that intermediate inputs are used in the production process constantly and uniformly overtime.

The OECD[13] acknowledges that a gross-output-based TFP is the most appropriate measure of technical change in an industry. This is because it considers the role of intermediate inputs in deriving productivity. In addition, TFP estimates based on the value added approach will be systematically higher than TFP estimates based on a gross output approach.[14]

However, gross output measures are sensitive to intra-industry flows of products. An example is when an industry has gone through a separation of retail activities from wholesale activities. Prior to the separation, gross output would count only retail products to final customers. Post separation however gross output would count wholesale outputs and retail outputs as two separate outputs.[15]

Inputs are generally organised into five major input factors, namely: capital (K), labour (L), energy (E), materials (M) and services (S). Energy, materials and services (EMS) represent intermediate inputs in the production process. There are often issues with data availability on the quantity of EMS inputs.[16]

While TFP estimates based on gross output measures could be more relevant for the purpose of this study, data availability for such a measure is limited. Therefore, this analysis is based on the value added measure of output.

TFP is a cyclical variable, influenced by booms and recessions.[17] Therefore, it is typical for productivity studies to look at average TFP growth over a full business cycle.

5.2.2 Data sources

The EU KLEMS is a database of productivity and growth accounting in the European Union. It is funded by the European Commission, and is developed by a consortium of 15 organisations from across the EU.[18]

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[13] OECD (2011), Measuring Productivity OECD Manual, p.18
[14] Australian Government Productivity Commission (2003), A Comparison of Gross Output and Value-Added Methods of Productivity Estimation, p. 5
[15] OECD (2011), p. 31
[16] The Conference Board (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, p.1
[17] Malley et al. (1998), The Interaction Between Business Cycles and Productivity Growth: Evidence from US Industrial Data.
[18] http://ec.europa.eu/eurostat/web/eu-klems

The most recent release was in September 2017. It contains data from 28 European countries over the time period from 1995-2015 for most countries and industries. The UK data series however only begins from 1998 and so does not cover a full business cycle. Longer historical series are obtained from the 2012 release, which contains data from 10 EU countries with data going back to 1970 for some countries.

The September 2017 release contains a number of methodological changes compared to the 2012 release. These include, for example, revisions for consistency with the new European System of National Accounts (ESA 2010) and the change in the source for capital stocks data. As a result, we rely on the September 2017 release dataset only for the current incomplete business cycle. The analysis on previous complete business cycles is based on the data from the 2012 release.

The EU KLEMS includes the following variables which we have used in our analysis:

- Volume indices for the industry's output on a value added basis (volume indices on a gross output basis are only available in certain releases of the dataset and only for some countries);
- Volume indices for labour and capital inputs (volume indices on EMS inputs are only available in certain releases and only for some countries);
- Data on the value of capital and labour inputs used (the value of EMS inputs are only available in certain releases, for some countries); and
- TFP volume index on the value added basis.

5.2.3 Approach and methodology

Average annual TFP growth is calculated over different time periods for different countries and sectors in the EU KLEMS dataset.

5.2.3.1 Time period

Productivity is a cyclical variable and so, where possible, should be considered over full business cycles. The definition of business cycles is not precise with different sources providing different definitions. For example, the Water UK report on productivity improvement in the water and sewerage industry[19] defined business cycles as follows:

- The first business cycle from 1982 – 1991;
- The second business cycle from 1994 – 2008; and
- The current (incomplete) business cycle from 2009 to 2015.

[19] Frontier Economics (2017), Productivity Improvement in the Water and Sewerage Industry in England Since Privatisation

On the other hand, CEPA in its report on scope for improvement in Network Rail efficiency[20] defined the following business cycles based on HM Treasury:

- 1972-1978;
- 1978-1986;
- 1986-1997; and
- 1997-2006.

Business cycles may vary from one country to the next even for countries within the same economic area. To enhance comparability with other evidence for the water sector, we have adopted the definitions in the Water UK report. Due to data limitation, it is only possible to compute TFP growth for the current business cycle up to 2014.

The September 2017 release of EU KLEMS only contains information from 1995 onwards and only so for some countries. Therefore, TFP estimates for the first and second business cycle are based on the 2012 release.

5.2.3.2 Relevant sectors

The EU KLEMS contains data for different sectors in the economy at different levels of aggregation. The relevant sectors in the EU KLEMS dataset for the E&W water sector are identified based on:

- nature of activities performed by the sector as defined by Eurostat; and
- sector capital intensity as measured by the contribution of labour and capital inputs into the production process.

Wholesale activities

In terms of the nature of activities across the sectors in the EU KLEMS dataset, the electricity, gas and water supply and the construction sectors are the most similar to the wholesale activities in the E&W water sector.

The electricity, gas and water supply sector includes water supply, sewerage, waste management and remediation activities as well as electricity, gas, steam and air conditioning supply. The construction sector includes construction activities for buildings and civil engineering works as well as civil engineering works for water projects and sewage systems.[21] Both sectors partially include activities currently performed by the E&W water sector. They are therefore considered to be relevant for the analysis of wholesale activities frontier shift.

In terms of capital intensity, Table 48 shows the contribution of labour and capital inputs for the water sector in England and Wales for each wholesale water value chain element

[20] CEPA (2012), Scope for Improvement in the Efficiency of Network Rail's Expenditure on Support and Operations: Supplementary Analysis of Productivity and Unit Cost Change, p.28
[21] Eurostat (2006), NACE Rev. 2 Statistical Classification of Economic Activities in the European Community

based on companies' financial reports in 2015/16 and 2016/17. Labour input is measured as total employment costs. Capital input is measured as the sum of capital maintenance charges and nominal return on RCV.

Table 48: Contribution of labour and capital services

	Water resources	Water plus	Wastewater plus	Bio resources	Wholesale All
Capital	83.7%	79.8%	85.0%	79.3%	82.3%
Labour	16.3%	20.2%	15.0%	20.7%	17.7%

Source: KPMG analysis of companies' financial reports

The four wholesale value chain elements share similar levels of capital intensity. This finding supports applying a single frontier shift across all wholesale activities.

Table 49 shows the average contribution of labour and capital services of the top 5 sectors with the highest capital input share over the second business cycle from 1994 to 2008.

Table 49: Contribution of labour and capital services by UK industry 1994-2008

Sector	Labour Share	Capital Share
Real estate activities	6.9%	93.1%
Mining and quarrying	15.6%	84.4%
Electricity, gas and water supply	32.8%	67.2%
Coke and refined petroleum products	43.8%	56.2%
Telecommunications	54.4%	45.6%

Source: KPMG Analysis of EU KLEMS 2012 Release based on labour compensation and capital compensation series.

The real estate activities sector and mining and quarrying sectors have the most comparable levels of capital intensity to water and sewerage wholesale activities. However, outputs for the real estate activities sector comprise mainly outputs related to owner occupied housing where outputs are measured as inputs. Thus productivity is zero by definition[22], making the sector not suitable for an efficiency analysis and is thus not considered to be a relevant comparator for wholesale activities.

The analysis of capital intensity shows that there are no sectors in the EU KLEMS dataset that are perfectly comparable to wholesale activities. Therefore, in addition to the sectors identified above, a notional sector performing wholesale activities is constructed by applying labour and capital productivity trends from the electricity, gas and water supply sector to the level of capital intensity of the wholesale activities as shown in Table 51. This approach assumes that the observed capital intensity for wholesale activities represents the optimal mix of inputs. It further assumes that the wholesale activities have

[22] Timmer et al (2007), EU KLEMS Growth and Productivity Accounts Version 1.0

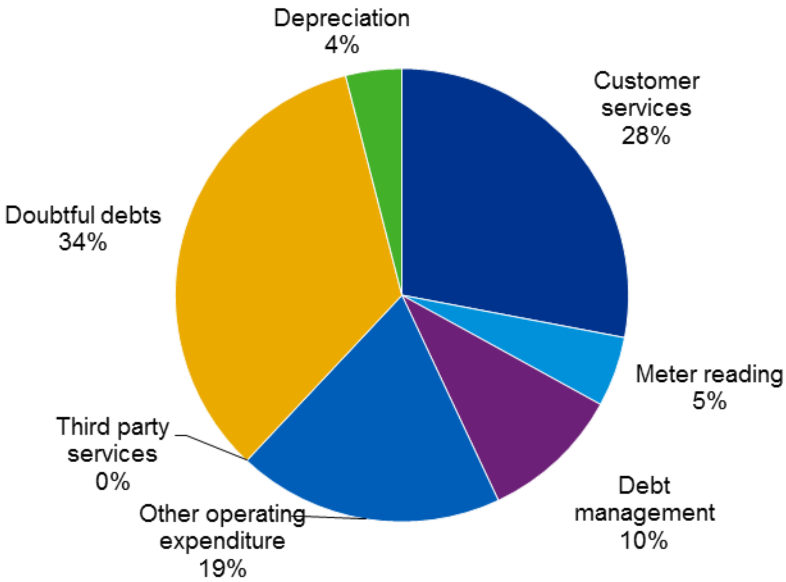
similar labour and capital productivity trends as the electricity, gas and water supply sector.

Capital productivity growth is calculated as the change in the volume of capital inputs relative to the change in the volume of gross value added volume outputs. Labour productivity is calculated as the change in the volume of labour inputs relative to the change in the volume of gross value added volume outputs. Both data sets are obtained from EU KLEMS.

Retail activities

Retail activities in the water sector comprise mainly of labour costs and doubtful debts. Figure 19 shows retail cost decomposition by key expenditure groups.

Figure 19: Household retail cost stack



Source: Ofwat

Doubtful debts do not represent an input into the production of water retail services. Excluding doubtful debts, the majority of the retail inputs are customer services, meter reading and debt management. The definition for these costs as provided in Ofwat's regulatory accounting guideline are as follows:[23]

- Customer services are costs associated with billing, payment handling, donations, vulnerable customer schemes, enquires and complains and investigatory visits,

[23] Ofwat (2017), RAG 4.07 – Guideline for the table definitions in the annual performance report

- Debt managements are costs associated with the management of debt recovery including monitoring of outstanding debt; and
- Meter reading are costs associated with ad hoc reading requests, cyclical reading, reading queries and read processing costs, managing meter data plus supervision and management of meter readers.

The definitions above suggest that retail activities include mainly support service activities and other business support activities. On this basis, the relevant sectors in the EU KLEMS dataset are:

- Professional, scientific, technical, and administrative and support service activities (professional and support services): This sector is dominated by professional services but also includes travel agency and tour operators and other business support activities. This could be said to represent some elements of water retail services such as meter reading and customer services; and
- Retail trade, except of motor vehicles and motorcycles (retail trade): This sector represents the resale of new and used goods to the general public for personal or household consumption. This represents the main function of water retailers.

In terms of capital intensity, labour comprises the overwhelming majority of input costs as illustrated in Figure 19. Therefore the analysis also considers labour productivity trends in the two sectors above. In addition, an all-industry average labour productivity trend is also relevant for retail activities on the assumption that labour inputs into retail activities are generally interchangeable with labour inputs into other sectors in the economy.

5.2.3.3 Relevant countries

TFP growth can be influenced by a number of country-specific factors, including:

- **Difference in the capital cycle**: EU KLEMS does not adjust capital for utilisation. This assumption might not hold for countries that are undergoing large capital investment programmes, as they may take time to fully utilise the new capital assets. As a result, TFP growth will be artificially low for those countries. Therefore, a comparison must account for the capital cycle across countries.
- **Difference in regulatory regime and liberalisation**: Studies have shown that countries undergoing a change in regulatory regime and liberalisation generally observe a higher productivity improvement in the immediate period following the change. Therefore, a comparison must account for differences in the status of regulatory regime and liberalisation across countries.

For these reasons, TFP growth in the UK represents the most directly relevant productivity benchmark for the UK water sector. Nonetheless, it is still useful to refer to evidence from other European countries, which are presented as averages across countries to reduce the impact of country-specific factors, as a cross check.

While the 2012 release of the EU KLEMS database contains data from different EU countries, only Belgium (BE), France (FR), Germany (DE), Italy (IT), Spain (ES) and Netherlands (NL) have data of sufficient detail to enable further analyses. Therefore, the average is taken over these six countries.

5.2.4 Estimates of TFP growth for wholesale activities

Table 50 shows average TFP growth across the five sectors we consider are relevant for wholesale water activities by country and business cycle.[24]

Table 50: Average TFP growth per annum by business cycle

Sector	1982-1991	1994-2008	1982-2008	2009-2014
UK				
Mining and quarrying	-2.6%	-2.0%	-0.4%	-10.8%
Electricity, gas and water supply	2.0%	0.9%	1.3%	-3.3%
Coke and refined petroleum products	-1.3%	-0.7%	-0.6%	-7.8%
Construction	2.2%	0.0%	1.2%	1.6%
Telecommunications	-0.6%	8.1%	4.6%	-0.8%
EU ex UK				
Mining and quarrying	1.6%	-1.0%	0.1%	-0.5%
Electricity, gas and water supply	1.7%	0.9%	0.9%	-2.8%
Coke and refined petroleum products	-3.7%	-4.6%	-4.4%	NA
Construction	1.4%	-0.8%	-0.1%	-1.1%
Telecommunications	NA	5.3%	NA	2.0%

Source: KPMG Analysis of EU KLEMS 2012 and 2017 releases
Note: NA means data are missing in more than one country. For telecommunications, Belgium has been excluded from the 1994-2008 figure due to the lack of data.

For electricity, gas and water supply, TFP growth from completed business cycles in the UK over different time periods range from 0.9% over the second business cycle to 2.0% over the first business cycle. Average TFP growth across the five other EU countries range from 0.9% over the second business cycle to 1.7% over the first business cycle. Longer term averages over two completed business cycles are 1.3% for the UK and 0.9% for the five other EU countries.

Construction in the UK registers a similar range of TFP growth from 0.0% during the second business cycle to 2.2% during the first business cycle. The EU average TFP growth for this sector is lower from -0.8% during the second business cycle to 1.4% over the first business cycle. Longer term averages over two completed business cycles are 1.2% for the UK and -0.1% for the five other EU countries.

Other capital intensive sectors show varying level of TFP growth over the business cycles. Commodity sectors including mining and quarrying and coke and refined petroleum products have generally registered successive declines in productivity. However, TFP in commodity sectors is driven largely by commodity prices. When prices are low, operators shut loss making sites, leading to higher unutilised capacity and lower

[24] Annual growth values have been calculated using a linear approximation of compound annual growth. Therefore, small differences could be obtained if an alternative formula is used.

TFP growth. This is different in the water sector where capacity utilisation is largely insensitive to prices, so their TFP growth are less relevant for the water sector.

Telecommunication registered relatively large TFP growth during the most recent complete business cycle (1994-2008) for the UK and the EU average. This is a reflection of rapid technological change in the sector where existing assets (e.g. copper wires) can be used to deliver more services. This is unlikely to be the case for the water sector so TFP growth in the telecommunications sector is also less relevant for the water sector.

With the exception of the UK construction sector, TFP growth during the current incomplete business cycle have been significantly lower relative to average TFP growth observed over the two previous complete business cycles. The systematic decline in TFP reflects the impact of the economic recession on output growth. The recession has a negative impact on TFP growth because the EU KLEMS methodology does not adjust TFP for capacity utilisation, which will be lower during a recession. Thus, it is important for TFP analysis to be conducted over the entire business cycle to avoid introducing the impact of cyclicality in the productivity estimate. For this reason, more emphasis should be placed on the results from complete business cycles.

Notional sector performing wholesale activities

In addition reviewing TFP growth from the relevant sectors in the EU KLEMS dataset, a notional sector performing wholesale activities is constructed by applying labour and capital productivity trends from the electricity, gas and water supply sector to the average capital and labour input mix over different time periods.

Table 51 shows average growth in capital and labour productivity over time from the EU KLEMS dataset. Capital productivity is calculated as the growth in the volume index of gross value added less the growth in the volume index of capital services. Labour productivity is calculated as the growth in the volume index of gross value added less the growth in the volume index of labour services.

Table 51: Capital and labour productivity trends in electricity, gas and water supply

Electricity, gas and water supply (% per year)	UK				Average EU ex UK*			
	1982-1991	1994-2008	1982-2008	2009-2014	1982-1991	1994-2008	1982-2008	2009-2014
Capital	1.5%	-0.3%	0.3%	-4.7%	NA	0.5%	NA	-3.5%
Labour	3.0%	3.4%	3.4%	-1.4%	NA	1.4%	NA	-1.4%

Source: KPMG analysis of 2012 EU KLEMS based on the volume indices for gross value added, capital services and labour services.
Note: This does not include Belgium due to the lack of capital and labour services data.

Table 52 shows the contribution of labour and capital inputs for the wholesale activities based on water companies' financial reports in 2015/16 and 2016/17. Labour input is measured as total employment costs. Capital input is measured as the sum of capital maintenance charges and nominal return on RCV.

Table 52: Contribution of labour and capital services – E&W wholesale

	Wholesale All
Capital	82.3%
Labour	17.7%

Source: KPMG analysis of companies' financial reports

Table 53 shows the resulting estimates growth for the notional sector performing wholesale activities. The TFP growth estimates are lower when adjusted for wholesale-specific capital-labour input mix. This is because a combination of higher capital intensity in wholesale activities relative to the average electricity, gas and water supply sector and subdued capital productivity (see Table 51) which has been consistently lower than labour productivity in the UK and across other major developed economies.[25]

Table 53: TFP growth of a notional sector performing wholesale activities

(% per year)	1982-1991	1994-2008	1982-2008	2009-2014
UK	1.8%	0.4%	0.9%	-4.1%
Average EU ex UK	NA	0.7%	NA	-2.2%

Source: KPMG Analysis of EU KLEMS 2012 and 2017 releases
Note: Average for EU countries (excluding UK) exclude Belgium due to lack of data

Discussion and implications

The evidence in aggregation indicates a historical frontier shift for wholesale activities in a range between 0.4% and 1.3% per annum. This is based on the following evidence:

- TFP growth from the two complete business cycles in the UK electricity, gas and water supply sector has been 0.9% - 2.0% per annum. The long run average over the two business cycles is 1.3% per annum;
- TFP growth from the two complete business cycles in the UK construction sector, which includes civil engineering works for water projects and sewerage systems, has been 0.0% - 2.2% per annum. The long run average over the two business cycles is 1.2% per annum; and
- TFP growth from the two complete business cycles in the notional wholesale sector, which is constructed based on the actual labour-capital input mix of wholesale activities of water companies in the UK, wholesale water sector, has been 0.4% - 1.8% per annum. The long run average over the two business cycles is 0.9% per annum.

The 0.4% to 1.3% per annum is also consistent with data from the average of the six EU countries considered. The EU-average TFP growth from the two complete business

[25] See discussion for example in OECD (2008), OECD Compendium of Productivity Indicators 2008

cycles in the electricity, gas and water supply sector and the construction sector have been 0.9 – 1.7% and -0.8% - 1.4% per year, respectively.

TFP growth has been negative across sectors during the current incomplete business cycle due to a recession. The recession has a negative impact on TFP growth because the EU KLEMS methodology does not adjust TFP for capacity utilisation, which will be lower during a recession. The volatility in capacity utilisation is less relevant for wholesale activities where demand is less sensitive to economic growth. For this reason, more emphasis should be placed on the results from complete business cycles.

5.2.5 Estimates of frontier shift for retail activities

Table 54 shows average TFP growth across the two sectors relevant for retail water activities by country and business cycle.

Table 54: Average TFP growth per annum by business cycle by relevant sector and country

	1982-1991	1994-2008	1982-2008	2009-2014
Professional and support services				
United Kingdom	-0.6%	1.3%	0.5%	2.6%
Average EU ex UK	-2.1%	-1.8%	-1.9%	-0.4%
Retail trade				
United Kingdom	2.5%	-0.5%	0.8%	-1.4%
Average EU ex UK*	2.2%	0.2%	0.9%	NA

Source: KPMG Analysis of EU KLEMS 2012 and 2017
Note: Average EU ex UK figures for retail trade do not include Belgium due to the lack of data in the EU KLEMS dataset

TFP growth in the professional and support services sector and the retail trade sector have been volatile over time. In addition, there seems to be no correlation in the rate of TFP growth between two sectors. It would therefore seem inappropriate to base frontier shift estimates for retail on TFP growth from a particular sector or a particular time period.

Table 55 shows average labour productivity growth for the three sectors relevant for retail water activities by country and business cycle.

Table 55: Average labour productivity growth per annum by business cycle by relevant sector and country

	1982-1991	1994-2008	1982-2008	2009-2014
Professional and support services				
United Kingdom	0.6%	2.4%	1.4%	1.7%
Retail trade				
United Kingdom	3.3%	1.3%	2.1%	0.2%
Total industries				
United Kingdom	1.8%	1.6%	1.8%	-0.3%

Source: KPMG Analysis of EU KLEMS 2012 and 2017

These labour productivity growth figures have not been adjusted for the change in capital intensity over time. The substitution of labour for capital affects labour productivity figures because, all else constant, fewer labour inputs would be required to produce the same amount of outputs. Therefore, these is an assumption that retail activities would be able to match the capital substitution trends observed by the comparable sectors.

Discussion and implications

The evidence in aggregation indicates a historical frontier shift for retail activities in a range between 0.8% and 1.8% per annum. This is based on the following:

- The long run average TFP growth over two business cycles for both the professional and support services and retail trade in the UK is between 0.5% and 0.8%;
- The long run average labour productivity growth over two business cycles for UK professional and support services, retail trade and total industries is between 1.4% and 1.8%; and
- The fact that the long run average is preferred over data from a particular sector or a particular period due to the volatility in TFP growth and labour productivity growth.

The 0.8% to 1.8% per annum is also consistent with data from the average of the six EU countries considered. The EU-average TFP growth from the two complete business cycles in the professional and support services and retail trade sectors is -1.9% to 0.9% per annum.

6 Summary of findings and implications for regulatory policy

This study was commissioned by Ofwat, the economic regulator of water and wastewater services in England and Wales, in order to examine the potential impact of the introduction of the totex and outcomes frameworks on innovation and efficiency in the water sector and to comment on how those impacts might change in AMP 7, as well as to comment on the implications of the above for the setting of regulatory policy. Specifically the study considers two principal research questions:

1. What impact the totex and outcomes changes have had on efficiency in AMP 6, and what might be their potential impact on future efficiency gains in AMP 7; and

2. What might be the implications of these findings for regulatory policy and the setting of efficiency targets at PR19?

The totex approach and the introduction of incentives based around delivering outcomes for customers are a relatively recent innovation in regulated utilities. Considering their impact is, therefore, a challenging task, given limited data and the multiplicity of other factors that could impact efficiency.

Totex is a significant change in the treatment of cost performance and recovery, which, combined with outcomes, allows companies greater flexibility to move away from a list of specific schemes agreed by the Regulator towards an approach that allows them to consider alternatives that can deliver the same or better service performance in line with customer preferences. The shift to a totex and outcomes framework in PR14 removed a regulatory barrier to realise additional efficiencies and innovation. This is supported by the case studies provided by the water companies, which provide examples of the transmission mechanisms by which they have been able to use the totex framework to realise greater efficiencies, such as, e.g.:

- Substituting planned capital projects for alternative solutions that deliver equivalent (or better) outcomes at a lower cost;
- Initiatives aimed at reducing the need for future capital projects; and
- Pursuing more innovative technologies and delivery approaches to the same activity, resulting in lower costs.

6.1 Assessing the current impact of the totex and outcomes changes on efficiency in AMP 6 and the potential for future efficiency in AMP 7

In deriving the potential impact of the totex and outcomes framework on efficiency, this report reviews three sources of evidence:

- **Exploring and delineating performance due to Totex**: An assessment is made of the levels of cost outperformance in regulated utility networks that have introduced versions of the totex and outcomes framework. Specifically, cost outperformance is compared against regulatory allowances in the controls preceding these changes with levels of outperformance after the changes are introduced.

- **Considering examples of the impact of structural and regulatory change as cross-checks**: Examples of performance gains from other significant changes in both regulated utility sectors and other competitive sectors that demonstrate high levels of capital intensity are compared to the results of the totex performance assessment. These examples focus on the change in real unit operating expenditure (RUOE) as a measure efficiency gains and they are compared against the results of the totex outperformance analysis.
- **Assessing evidence from projects by water companies and the supply chain to inform Totex analysis:** Around 180 project examples have been provided by companies and members of the supply chain in response to a data request. These projects were requested to show the potential impact of the application of the totex and outcomes framework in practice. This project evidence was also used as a point of comparison with the evidence from the totex analysis.

This study focusses on the above sources of evidence, incorporating both top down assessment and a sample of bottom up project evidence. However, limited sources of data and a multiplicity of potential other factors at play imply that it is inherently challenging to attribute specific outperformance to either totex or outcomes. There is no data available specifically on the efficiencies generated by these reforms. This means that the analysis has to consider broader data on cost performance for top down analysis and explore to what extent performance could be attributed to totex and outcomes and under what assumptions. For the bottom up analysis, the key question is to what extent identified examples can be extrapolated to all business activities and overall cost performance.

6.1.1 Totex performance assessment

Table 56 provides ranges of efficiency gains during the first totex price control under two different approaches to measuring efficiency gains. The first approach attributes all outperformance during the totex price controls to efficiency gains. The second approach attributes the difference in outperformance between the pre-totex and totex price controls to efficiency gains.

Table 56: Ranges of efficiency gains during the first totex price control assuming outperformance equates to efficiency gains with a lower bound capped at 0%

Approach	Annual incremental gains (% pa)	Total efficiency gains (%)
Approach 1	0.0% - 2.7%	0.0% - 7.8%
Approach 2	0.0% - 3.1%	0.0% - 8.9%

Source: KPMG Analysis

These estimates of efficiency gains assume that regulatory cost models are accurate and without bias. Therefore, cost outperformance equates efficiency gains. In addition, it is assumed that the only difference between the totex and non-totex price controls is the introduction of the totex and outcomes framework itself. Therefore, the revealed efficiency gains can be attributable to the totex and outcomes.

Furthermore, the analysis relies on company forecasts and judgements where the price controls are still in progress. For the RIIO controls, the analysis relies on the assumption that companies' forecasts can accurately proxy outperformance over the entire period. For the water sector, the analysis relies on the assumption that companies have adjusted for investment profiling effect on their RoRE on a consistent basis and that the achieved outperformance would persist through to the end of PR14.

The estimates above also assume that there are no other external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis; and that other factors affecting realisable efficiency gains are under companies' control. In practice, there is a wide dispersion in cost outperformance across companies, suggesting that there are additional factors, beyond those which have been quantified and accounted for, that influence companies' performance. This reduces the precision with which the estimates of efficiency gains due to totex and outcomes during the first price control could be made, leading to wide ranges of the estimates.

The totex and outcomes framework has, in the most part, only been implemented for the first time during the current price control period in both energy and water. Indeed, the two approaches discussed above only infer evidence from the first totex price controls. The quantification of the impact on the on-going efficiency gains of the framework would ideally require a longer-term time series of cost data from companies, which is not available. Therefore, the impact of the framework on on-going efficiency gains has to necessarily be hypothesised and inferred.

The evidence suggests that part of the revealed efficiency gains during the first totex control represents catch-up efficiency where companies catch up with the rest of the economy. Catch-up efficiency will not persist on an on-going basis.

Furthermore, the hypotheses that the observed efficiency gains during the first totex price control would persist into the second totex price control rely crucially on the assumption that the observed totex outperformance is due solely to totex and outcomes. The wide variation in totex outperformance suggests the presence of other factors beyond totex in driving outperformance gains. An approach which takes only part of that outperformance because it assumes catch-up efficiency provides greater scope for outperformance to be explained by any other factors than one which simply attributes all of the outperformance on an ongoing basis solely to the introduction of the totex and outcomes framework. This further supports reducing scope for efficiency gains due to totex and outcomes in the second totex price control.

Because RIIO-ED1 is the only second UK totex price control to date, it is the only source of directly relevant empirical evidence to assess the potential on-going efficiency impact due to the totex and outcomes framework over the second totex price control. This assumes that experience in electricity distribution networks will repeat for the water sector. If the application of the totex and outcomes framework in business planning has been slower in the water sector than in the energy sector, then there might be greater scope for on-going efficiency impact during the second totex water price control. Alternatively, if the application of the totex and outcomes framework in business planning has been faster in the water sector than in the energy sector, then there might be less scope for on-going efficiency impact during the second totex water price control. Given the lack of empirical data to separate catch-up efficiency from on-going efficiency from cost performance during the first totex price controls, the analysis relies on observed evidence from RIIO-ED1. Evidence from RIIO-ED1, which is the second totex price control for the electricity distribution networks, is used to separate on-going efficiency from catch-up efficiency, Table 57 provides ranges of potential on-going efficiency gains from totex and outcomes under the assumption that the experience of electricity distribution would repeat for the water sector. Overall, the range of annual incremental gains that might be expected during the second totex control is between 0.0% and 1.2% per annum or 0.0% and 3.7% on a total average basis during the duration of the price control.

Table 57: Ranges of potential efficiency from totex and outcomes during the second totex control as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)	Total average efficiency gains (%)
Hypothesis 1	0.0% - 1.2%	0.0% - 3.7%
Hypothesis 2	0.0% - 1.1%	0.0% - 3.2%

Source: KPMG Analysis

The analysis undertaken does not suggest, overall, any clear bias in the results. Therefore, there are no obvious grounds to suggest that predictions should not be distributed symmetrically, or that they could fall to a greater extent in either the upper, or lower quartile of the range. This also implies that extreme values close to the top or the bottom of the ranges are not good predictors of potential gains and should not be assumed.

6.1.2 Examples of the impact of structural and regulatory changes on performance

A range of examples of performance improvements in other sectors around significant structural or regulatory changes or events were also reviewed as part of this work. The selected examples were divided into different categories relating to the nature of the changes in regulation, introducing competition, changes in ownership and finally cost or revenue shocks. For each case, changes in unit real operating costs during time periods around the change were measured to identify efficiency improvements. Table 58 provides a summary of average annual efficiency gain across all cases considered under different time periods. It shows the average performance gain per annum in the five years prior to the shock (T-5 to T-1), the first five years following the shock (T to T+4) and the second five years following the shock (T+5 to T+9). In some cases, there is insufficient data to cover the entire period and hence the average is calculated over the period for which data is available.

Table 58: Summary of examples of reported performance improvements associated with structural or regulatory changes (average, annual change)

Events	T-5 to T	T to T+5	T+5 to T+10
Change in regulatory regime			
Openreach separation	7.6%	8.3%	5.4%
Formation of Scottish Water	NA	6.7%	-1.3%
Manchester airport	2.6%	1.3%	-5.1%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
New gas distribution networks	-1.2%	-0.8%	0.4%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Introduction of competition			
Competition in electricity generation	-4.0%	8.6%	NA
Local loop unbundling	NA	1.7%	1.2%
New gas distribution networks	-1.2%	-0.8%	0.4%
Academic literature		3% to 5%	
Change of ownership			
Formation of Network Rail	NA	9.1%	7.0%
Competition in electricity generation	-4.0%	8.6%	NA
New gas distribution networks	-1.2%	-0.8%	0.4%
Privatisation of electricity distribution	-0.4%	-0.3%	9.9%
Water privatisation (no quality adjustment)	NA	2.9%	2.2%
Water privatisation (quality adjustment)	NA	3.5%	4.5%
Cost/Revenue shock			
UK Oil & Gas price collapse	-14.6%	13.4%	NA
Cost shock - legacy airlines	-0.6%	6.5%	-0.5%
Cost-shock - low-cost airlines	1.7%	2.8%	1.7%
Cost-shock - other airlines	-0.5%	1.8%	3.7%

Source: KPMG analysis of regulatory accounts, financial statements and public reports.

Overall, the results from this analysis indicate that major regulatory and structural changes are associated with significant changes in performance, and that the impact of such events is, in many cases, positive. This could be interpreted, under certain assumptions, as indicative of such regime changes and paradigm shifts enabling stronger performance and greater efficiencies being realised by the companies. It is also worth noting that the results from the totex analysis fall within the wide range of examples highlighted on Real Unit Operating Expenditure. However, it is difficult to infer strong conclusions from this comparative analysis, given different nature of the cases (events) considered and the potential for other factors affecting the performance metrics used in the analysis.

The evidence is also mixed on the longevity of the impact of the documented performance, and, potentially, associated efficiency gains, over time. Some examples exhibit diminishing gains over the next five year period (e.g. Scottish Water, Openreach separation) while others show increasing gains (e.g. privatisation of electricity distribution and new gas distribution networks). Overall, however, diminishing efficiency benefits appear to be common in subsequent periods.

Overall, the evidence suggests a wide range of performance gains associated with incidents of regulatory and structural changes considered; the former might be interpreted as efficiency improvements due to such changes, under certain assumptions. The upper bound appears to be set by Scottish Water where a gain of 6.7% was observed following the merger of regional water companies. Some of the gains may be due to a one-time merger savings.

6.1.3 Project evidence from water companies and supply chain

The cost data from 48 of the case studies received from the companies represents a sample of circa 3.8% of the total expenditure in the AMP. This sample was selected specifically to illustrate the effect of Totex on efficiency so is unlikely to be representative of all business activities, but clearly indicates potential for efficiency improvements due to Totex in a variety of different circumstances.

The key findings from this part of the analysis are as follows:

- There are significant savings of up to 100% of totex with an average saving of 35% across the projects over AMP 6 from company responses;
- For some projects companies responses indicated that they are spending more in this control period in order to reduce whole life costs;
- There are projects that could be applied more widely across the sector. For example "ice pigging", a means to clean water mains, saves significant cost compared to conventional method;
- Several of the case studies with unquantified impact show costs (for example, customer information) with no corresponding demonstrated benefits during this control period, however there is clear potential for these cases to produce savings and/or service improvements in future AMPs.

The responses from the companies indicate that substantial efficiencies as a proportion of project costs have already been realised by adopting the principles of the totex and outcomes framework during AMP6, some of which might be replicable to larger programmes and others that are isolated instances. The totex efficiencies reported to do not appear to have come at the cost of service levels based on the responses provided.

Table 59 below provides a summary of totex savings based on the information received from the companies across different price controls. The reported savings have been normalised to a 5-year period to reflect a duration of the water price controls.

Table 59: Summary of examples of totex savings by price control

Price Control	Number of detailed case studies received	Total average totex saving over 5 years (%)
Water Resources	8	34.1
Water Network Plus	8	44.4
Wastewater Network Plus	24	39.9
Bioresources	4	-12.0
Retail	1	52.4
Multiple	3	36.8
Total	**48**	**35.4**

Source: Aqua Consultants' analysis of companies' replies to Ofwat data requests

These case studies alone, when considered together, show an overall totex efficiency of 1.3% of the overall AMP determination (35.4% of the total 3.8% of expenditure that is covered by the projects in the sample). The case studies also clearly show that innovation can play a significant part in enabling the water companies to deliver improved efficiency and suggest that significant efficiencies have been achieved in some instances.

At the same time, given that the reported spending on the schemes examined represents less than 4% of companies overall expenditure, and given that the case studies have been selected specifically to illustrate efficiency gains from Totex, the reported gains might not be representative of all of companies' business activities, and, therefore, extrapolating from this data alone would not be appropriate for setting expectations of future savings.

Nonetheless, the case studies collaborate with the range of potential efficiency gains that might be expected during the second totex control based on totex performance assessment of 0.0% to 3.7% on a total average basis as shown in Table 57. At the upper end of this range, the case studies represent around 35% of the estimated potential efficiency gains (i.e. 1.3% divided by 3.7%) over AMP7.

6.1.4 Conclusions on the impact of totex and outcomes on efficiency

The overall results from the analysis of totex performance assessment suggest that the range of annual incremental gains due to totex and outcomes that might be expected during the second totex control period, subject to certain important assumptions, could be between 0.0% and 1.2% per annum, or between 0.0% and 3.7% on a total average basis over the price control.

These results have been compared with: (i) performance improvements on Real Unit Operating Expenditure associated with selected regulatory and structural changes in other sectors and with (ii) a range of project examples provided by companies in response to an information request. The 'cross-checks' generally support the hypothesis that totex can unlock significant efficiency gains but also that there are likely to be diminishing returns from the totex framework.

6.2 The implications of these findings for regulatory policy setting of efficiency targets at PR19

To draw out the implications for regulatory policy setting of the potential efficiency gains during AMP7, total efficiency potential for AMP7 is assumed to comprise of the sum of the following components:

- First, the frontier shift, which is associated with the on-going technological change in the economy and unrelated to the introduction of totex and outcomes framework;
- Second, the benefit and opportunity arising from the totex and outcomes framework over AMP7, which is additional to the frontier shift; and
- Third, other factors affecting performance, which can result in efficiencies as well as inefficiencies, including those under management control and external factors, the impact of which is inherently difficult to disentangle from the impact of the outcomes and totex framework.

This study seeks to isolate, to the extent possible given the data and the adopted approach, the impact from outcomes and totex from a range of other drivers (point 3 above) and to develop a range for the potential level of total factor productivity improvement during AMP 7 (point 1 above).

The evidence reviewed in this study suggests that the introduction of the totex and outcomes framework allows companies to unlock further innovation and efficiency gains.

When considering setting efficiency targets for AMP 7, it is also important to consider the effect of any shift in the efficiency frontier in the absence of the totex and outcomes framework. Frontier shift represents technological and/or process changes that are expected to occur in the future. It is applied to an estimate of the efficient costs in the base year to project forward efficient costs during the full price control period. In order to estimate frontier shift for AMP7, this report examines the following sources of evidence:

- Total factor productivity in the EU KLEMS dataset; and
- Previous regulatory decisions.

For wholesale activities, EU KLEMS suggests a frontier shift of between 0.4% and 1.3% per annum. Recent TFP growth has been deeply negative for wholesale activities, and it is unclear if productivity will rebound. For retail activities, the frontier shift estimate is 0.8% to 1.8% a year.

The TFP analysis aligns with the levels of previous frontier shift decisions made by regulators in comparable utility sectors.

These TFP results are added to the potential gains from the totex and outcomes framework to understand the potential overall efficiency potential in AMP 7. This approach can be considered appropriate because the methodology for assessing cost outperformance from totex and outcomes compares the level of company outperformance with the allowances made by the relevant regulator at each of the price controls and in each case the regulator already included an adjustment to their allowed costs for frontier shift efficiency. Therefore any outperformance beyond this allowance should already account for this.

Table 60: Ranges of potential efficiency gains from frontier shift, including on-going efficiency impact of totex and outcomes by service as annual incremental and total average efficiency gains

Control	Annual incremental gains (% pa)			Total average efficiency gains (%)		
	TFP	Totex	Total	TFP	Totex	Total
Results based on hypothesis 1						
Wholesale	0.4 – 1.3%	0.0 – 1.2%	0.4 – 2.5%	1.2 – 3.8%	0.0 – 3.7%	1.2 – 7.4%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%
Results based on hypothesis 2						
Wholesale	0.4 – 1.3%	0.0 – 1.1%	0.4 – 2.4%	1.2 – 3.8%	0.0 – 3.2%	1.2 – 7.0%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%

Source: KPMG Analysis

Overall, the analysis suggests an indicative range for the potential annual, incremental efficiency savings of 0.4-2.5% per year or 1.2-7.4% total average efficiency gains over the entire AMP. The results based on hypotheses 1 and 2 imply similar ranges. The rest of the evidence examined as part of this study supports various aspects of this analysis as well as some key assumptions (e.g. causality given identified transmission mechanisms, significant magnitude of the impact of the change, generally positive gains, but also wide dispersion of the impact across companies and the existence of diminishing returns over time).

6.2.1 Interpreting the analysis and regulatory policy setting

The results of the analysis as to what efficiency gains water companies might be able to realise going forward from totex and outcomes can help to inform regulatory policy for setting efficiency targets. Within its scope and limitations, it provides useful evidence and analysis for the regulator to consider.

It is important however to bear in mind that the two research questions considered clearly distinct—the former is an analytical prediction of what might be possible for companies to realise, the latter is a regulatory policy choice, which can be informed (to some extent) by the former as well as a number of other considerations and analysis, regulatory objectives, other evidence, etc. The former cannot be assumed to be the direct answer for the latter.

Total factor productivity

For wholesale activities, EU KLEMS suggests a frontier shift is between 0.4% and 1.3% per annum. For retail activities, the frontier shift estimate is 0.8% to 1.8% a year.

Similar TFP analysis has been commonly used amongst regulators in the setting of frontier shift efficiency targets, particularly in relation to wholesale or network activities. Companies who responded to the workshop generally did not challenge the TFP analysis.

Whilst the setting of frontier shift efficiency targets in retail price controls is less common and there may therefore be less regulatory precedent from which to learn, the general principles and approaches should be consistent and the same datasets are used.

The approach in this study also considers labour productivity shift given the relatively lower capital intensity of retail compared to wholesale services. Ofwat may therefore wish to consider an efficiency target for frontier shift from any point in the TFP ranges presented, albeit that they may want to consider their approach to efficiency in the round including, for example their level of ambition, their approach to catch-up efficiency and their views on productivity improvement in the wider economy.

Efficiency gains water companies might be expected to be able to realise going forward from totex and outcomes

The analysis outlined in this study provides an indicative range for the potential efficiency savings for AMP 7 from totex and outcomes of 0.0-1.2% annual incremental efficiency gains. Some of the analysis from which these results are derived and their implications for potential efficiency gains that can be realised by the companies rely on a number of critical assumptions, in particular:

- The lack of bias and accuracy of regulatory cost models, and that the only difference between the totex and non-totex price controls is the introduction of the totex and outcomes framework itself;
- For energy, that the companies accurately predict their cost performance through to the end of the on-going price controls; and for water, that the companies adjust their outperformance for profiling effects on the same basis;
- That there are no other external factors affecting outperformance beyond those that have been quantified and adjusted for in the analysis; and that other factors affecting realisable efficiency gains are under companies' control; and
- That the same impacts are seen from totex and outcomes in different sectors.

Therefore when setting regulatory policy, it is important to consider whether these assumptions critically underpinning the specific results can be made with confidence, and in what circumstances, in order to rely on the end results.

The analysis indicates that there is a wide dispersion of efficiency gains that could be attributed specifically to totex and outcomes across different companies, but also across sectors and price controls over time, under any of the hypotheses and approaches used. This means that different companies are likely to be able to realise different efficiency gains due to Totex for various reasons which are difficult to identify. Some of these could be under companies' control and related to performance and others are likely to be external factors beyond companies' control. This means that it is only possible to conclude that potential efficiency gains from Totex will fall within a relatively wide range rather than predict a single number with confidence. This further implies that, by definition, using any one number in the range as a general predictor for the potential efficiency gains that every company in the sample would be able to realise would imply a significant unexplained variation from the prediction.

The analysis undertaken does not suggest, overall, any clear bias in the results. Therefore, there are no obvious grounds to suggest that predictions should not be distributed symmetrically, or that they could fall to a greater extent in either the upper, or lower quartile of the range. This also implies that extreme values close to the top or the bottom of the ranges are not good predictors of potential gains and should not be assumed.

Regulatory policy setting

In previous regulatory decisions, where there are uncertainties around the appropriate estimate of efficiency targets, UK regulators have tended to set efficiency targets based on the central to upper quartile of the range. For example, Ofwat set the capital expenditure baseline for the capital expenditure incentive scheme at the median at PR09. At PR14, Ofwat set efficiency challenge at upper quartile efficiency when estimating the totex cost baseline at PR14. Ofgem also used the upper quartile when setting totex baseline most recently for the RIIO-ED1 price control.

The use of upper quartile by regulators reflects the ambition in providing “stretching efficiency targets”[26] to companies. This also depends on the confidence the regulator has on the quality of its information. For example, Ofgem stated that its use of the upper quartile acknowledged that a part of the difference in costs “relates to factors other than GDNs’ relative efficiency (e.g. statistical errors)”[27]. At DPCR5, Ofgem benchmarked network operating costs at the upper third due to greater variability in data.[28]

Table 61 shows ranges of potential on-going efficiency targets based on previous regulatory decisions. For frontier shift, the ranges remain 0.4% - 1.3% per annum for wholesale and 0.8% - 1.8% per annum for retail. This is because the ranges are already informed by average of TFP growth of different benchmark sectors over different time horizons. The use of the average TFP growth reflects the cyclical nature of TFP estimates, on which the frontier shift estimates are derived.

The range for the potential efficiency savings for AMP 7 from totex and outcomes, based on previous regulatory decisions, is 0.3-1.3% annual incremental efficiency gains. The lower bound is based on the median and the upper bound the upper quartile of the range for the potential efficiency gains for AMP7 from totex and outcomes.

[26] Ofwat (2014), Final price control determination notice: policy chapter A2 – wholesale water and wastewater costs and revenues, p.23
[27] Ofgem (2012), RIIO-GD1: Final proposals – Supporting Document – Cost efficiency, p. 7
[28] Ofgem (2009), Electricity distribution price control review final proposals – allowed revenue – cost assessment, p.4

Table 61: Ranges of on-going efficiency targets assuming declining benefits from Totex taken as the median to upper-quartile range

Control	Annual incremental gains (% pa)			Total average efficiency gains (%)		
	TFP	Totex	Total	TFP	Totex	Total
Wholesale	0.4 – 1.3%	0.2 – 1.2%	0.6 – 2.5%	1.2 – 3.8%	0.6 – 3.7%	1.8 – 7.4%
Retail	0.8 – 1.8%	NA	0.8 – 1.8%	2.4 – 5.3%	NA	2.4 – 5.3%

Source: KPMG Analysis

As stated earlier, these estimates rely on a number of critical assumptions including the assumption that outperformance purely reflects efficiency gains and that other factors affecting realisable efficiency gains are under companies' control. There remains a wide dispersion of efficiency gains that could be attributed specifically to totex and outcomes, even when the lower bound is based on the median as per previous regulatory decisions.

The Regulator may wish to set efficiency targets at the upper end of this range if, in its view, the variation in outperformance among companies purely relates to factors related to efficiency that are under companies' control. In other words, the Regulator is confident that the observed efficiency gain at the upper quartile is achievable by all companies. Any differences in efficiency gains are due to the differences in managerial ability in exploiting totex and outcomes.

The Regulator may wish to set efficiency targets below the upper end of the range if, in its view, the variation in outperformance among companies also relates to factors beyond companies' control. Alternatively, the Regulator may wish to consider a lower cost sharing rate (i.e. companies absorbing a lower share of under/outperformance) to acknowledge the uncertainties around the achievability of the efficiency targets towards the upper end of the range.

The Regulator may also wish to consider the setting of efficiency targets in the context of previous regulatory decisions. A review of historical regulatory decisions on frontier shift assumptions suggests a range between 0.7% and 1.1% for AMP7. This represents a point close to the middle of the stated wholesale range in Table 61 and the lower end of the retail range. The evidence reviewed does suggest that there is an increase in efficiency as a result of the introduction of the totex and outcomes framework (including from the totex analysis and also the project evidence for example). Hence the Regulator may consider it appropriate to increase the frontier shift assumption above recent historical levels and select a figure in the top half of the stated total (ie combined TFP and Totex) range.

Given the nature and the scope of this exercise and its reliance on specific sources of data, the Regulator might want to consider other evidence and analysis to inform its regulatory policy and setting of efficiency targets. The complexity of this issue suggests that exploring different sources of data and evidence is important to form a holistic and robust view.

Finally, this study does not consider the broader policy considerations of cost assessment and recovery mechanisms, which is beyond the scope of our work.

Appendix 1: Approach to derive outperformance from RORE

The derivation of cost performance for water companies during PR14 based on the reported return on regulated equity follows the following steps:

- **Step 1**: Obtain the reported impact of wholesale totex outperformance against allowances from companies' annual performance reports. Where companies combine retail with wholesale totex outperformance in their RoRE calculation, retail impact is stripped out based on information provided in the relevant annual performance reports.
- **Step 2:** Multiply the wholesale totex outperformance impact on RoRE (in basis points) by the average year regulated equity at the final determination to derive the value of the post-tax rewards due to outperformance. Average year regulated equity value is taken from PR14 final determinations.
- **Step 3**: Divide the pre-tax reward amount by one minus the headline tax rate of 20% to derive the pre-tax amount.
- **Step 4**: Divide the post-tax reward amount by the cost sharing rate to convert the pre-tax reward amount into outperformance amount.
- **Step 5**: Obtain totex allowances from the final determination but adjusted for companies' final menu choices.
- **Step 6**: Divide the outperformance by the adjusted totex allowance to derive the totex outperformance percentage

Appendix 2: Public Domain Case Studies

There are numerous projects in trade press articles that highlight particular innovations. These are listed in Table 62 below.

Table 62: Examples of public domain case studies

Project	Description and source
The Pioneer Optimiser	Investment optimisation model over multiple service and cost constraints. http://www.waterprojectsonline.com/case_studies/2017/affinity_pioneer_optimiser_2017.htm
Wastewater Treatment Works Rationalisation	Totex-based decision making used in the scheme and the potential for it being used elsewhere. http://www.waterprojectsonline.com/case_studies/2017/dcww_wwtw_rationalisation_2017.htm
Nereda® in Ireland	One of the major innovation in wastewater treatment that is being applied at present. http://www.waterprojectsonline.com/case_studies/2017/irish_nereda_2017.htm
BIM4Water	Better information management in the water industry. http://www.waterprojectsonline.com/case_studies/2017/bim_2017.htm
Pipelines in Wastewater Treatment Projects	The services that can be provided by the supply chain, enabling more efficient projects to be delivered. http://www.waterprojectsonline.com/case_studies/2017/saint_gobain_pipelines_2017.htm
ReGenerator® Technologies	A development of a new treatment process. http://www.waterprojectsonline.com/case_studies/2017/sweco_regenerator_2017.htm
Retford STW	Used of pre-fabrication to address safety issues. http://www.waterprojectsonline.com/case_studies/2017/severn_trent_retford_2017.htm
Shirebrook STW	Innovation in the integration of technologies to meet ultra-low phosphorus discharge consent for a sewage treatment work. http://www.waterprojectsonline.com/case_studies/2017/severn_trent_shirebrook_2017.htm
Hoplands Farm WTW	Totex-based decision making for contact tank replacement, highlighting the benefits of contractor early engagement. http://www.waterprojectsonline.com/case_studies/2017/sew_hoplands_farm_2017.htm

Outwoods Reservoir	Project highlighting the benefits of the collaboration between the Client and Contractor. http://www.waterprojectsonline.com/case_studies/2017/ssw_outwoods_2017.htm
Marsh Mills WwTW	Optimisation of anaerobic digestion. http://www.waterprojectsonline.com/case_studies/2017/sww_marsh_mills_2017.htm
Advanced Thermoplastic Solutions	Use of thermoplastic civil engineered chambers for structure and pipework of treatment works. http://www.waterprojectsonline.com/case_studies/2017/pipex_thermoplastics_2017.htm
Volute Disc Press	High efficiency dewatering and thickening technology for sludge treatment. http://www.waterprojectsonline.com/case_studies/2017/evergreen_volute_2017.htm
Whitburn Spill Reduction	Reduction of surface water entering the combined sewer to reduce pumping and treatment costs and increase sewer capacity. http://www.waterprojectsonline.com/case_studies/2017/northumbrian_whitburn_2017.htm

Source: Aqua Consultants' research

Appendix 3: Example Water Company Case Studies

Northumbrian Water's GIS Mapping

This case study highlights the benefits of using a combination of knowledge and technology and whilst being relatively small has had a large impact on part of the business.

GIS mapping and inferring the transferred drains and sewers network

"When we assumed responsibility for an estimated 13,500km of transferred drains and sewers, information on the historic infrastructure was sparse. Following an extensive exercise to try and discover all the maps and plans that we could from local authorities and councils we estimated we had just 5% coverage. In addition there was very little information available on the make-up of the assets: materials, size of pipe etc.

The obvious approach appeared to be traditional surveying but we calculated it would take around 15 years to collect the missing information. It would also be expensive, costing £10million in the first five years alone.

We worked hard to find a more innovative approach that would provide the answers we needed at a lower cost and in a shorter time so we explored options for a digital solution, eventually choosing 1Spatial and their solution built around the 1Integrate product. Its approach was to use available information to develop a set of data rules that filled in the data gaps. We used 1Spatial's rules-engine technology to convert the knowledge of our experts into repeatable rules. For example, a rule might state that a property of a given age and construction would have a sewer of a particular type and location.

The rules were developed to create important attributes including: location, construction material, direction of flow and usage (i.e. what actually flowed through a given pipe), and they were validated against the results of tradition surveys of representative sample areas.

Mapping the TDS network sooner is enabling better customer service and more informed investment and maintenance plans. The key benefit for our customers is faster understanding and resolution of any issue - we now know what is in the ground. When a customer calls us, we can get more quickly to the possible sources of the problem.

The decision to take a rules-based, data-driven, agile approach has dramatically reduced both the time and cost of the project, delivering a map of the whole transferred network in just two years, for £1.25 million (compared to the original planned cost for the first five years, this represents an 87% saving). Our on-going iterative approach was the most novel feature - constantly developing and enhancing the rules is what set us apart from other utilities that have used a rules–based application. We are developing our approach further by complimenting it with aerial survey data to identify manhole covers and further improve the confidence level of the inferred map."

The work has been featured in trade press, and presented at conferences.

Thames Water's Kings Scholar Pond

This project demonstrates a successful combination of technology

Innovation – Kings Scholar Pond

Background

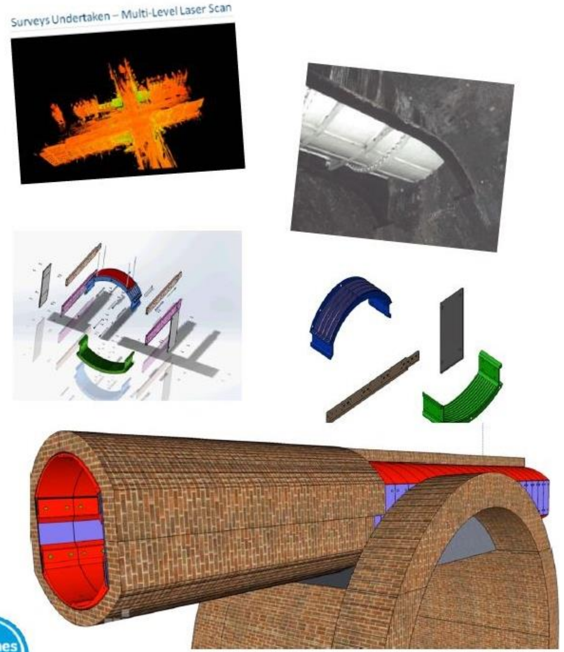
- Deteriorating Victorian sewer asset posing risk of failure and associated consequences located in central London

Approach

- Fully line the affected section with a 'self-supporting' high specification pipe liner using carbon fibre materials to limit the additional loading on the bridge structure.
- Using Digital Tools including; Laser Scanning, 3D model build & Digital Rehearsals
- Minimising construction works through off-site solution - utilsing Carbon Fibre 'Jigsaw Puzzle' solution

Benefits

- Avoided need for extensive construction work on busy central part of London
- Solution meant components could be delivered and installed through existing manhole and sewer network
- Environmental, Customer, Efficiencies etc



Thames Water

9

Severn Trent Water's FOG Reduction

This R & D project could be replicated at numerous locations

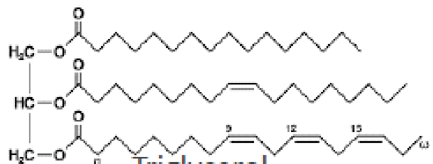
REDUCING BLOCKAGES

FOG (FATS OILS & GREASES) MITIGATION IN OUR SEWERS

£2m annual saving if successful

Why

We have 46,000 blockages in our sewer network each year, which equates to one every two kilometres. FOG is mostly generated by food service establishments and causes blockages which lead to internal and external flooding, pollutions and odour issues for our customers.



Triglycerol

How?

A Bio-Augmentation solution is dosed into the sewer, and breaks down the FOG through metabolic decoupling. This is totally new and innovative not only to Severn Trent but to the UK Water industry.

Following a successful trial, 11 units have been installed and commissioned; including sewage treatment works, pumping stations, longer sewer lengths, restaurants and motorway service stations, which all suffer from FOG issues.

BEFORE AFTER

Benefits

If the trials continue to be successful then through reduced occurrences of blockages caused by FOG, savings of £2m per annum can be achieved, assuming roll-out to 50 sites over 5 years. This does not include additional benefits from avoidance of ODI penalties, operational call-outs and pollution fines.

Without Innovation

A systematic trial would not have been conducted to prove the technology. There was an internal lack of belief that this technology could work, and the systematic trial disproved this belief.

SEVERN TRENT

Innovation

Wessex Water's Entrade

This project has been highlighted from several similar catchment management projects.

Data	Description
Project Summary and need for project	Poole harbour is a notable waterbody with numerous environmental designations. However, nitrogen in the harbour can promote the growth of algae under certain conditions, which, in turn, can adversely affect biodiversity. In 2008 we installed nitrogen removal at Poole sewage treatment works, reducing our nitrogen discharge by 927 tonnes every year so that our contribution fell to 15% of the annual inflow of nitrogen into the harbour. This came at a cost of £12 million and annual running costs of £0.5m. We could go further with nitrogen removal at upstream sites, such as Dorchester sewage treatment works where 40 tonnes of nitrogen could be removed each year, costing around £6m to install and £0.4m each year to operate. However, environmental regulators and others have agreed that we can try out alternative methods to prevent 40 tonnes of nitrogen entering Poole harbour annually by 2020. Part of our response is Entrade. This is an online nutrient trading system that we have devised, which is a UK-first initiative that works as an online reverse auction
Technical Details	Farmers place bids for payment to grow cover crops over winter, or switch from arable to grass. EnTrade estimates the nitrogen saved by each bid offered, based on the crop type and sowing date. This in turn indicates the most cost effective ways of meeting our targets.
Baseline, selected and delivered Capex, Opex, totex, Whole Life Cost/NPV (and the basis on which they have been calculated)	Total costs for catchment management approach in Poole Harbour is approximately £350,000 per year. In comparison, a nitrate treatment works at Dorchester STW would require £6 million capital costs with an on-going operational cost of £0.4 million.
Benefits to Water Company	From the first series of auctions we have found that the combined cost to deliver nutrient reductions is nearly one third less than previous catchment management work and less than a quarter of the cost to add nitrogen removal at Dorchester sewage treatment works. The trial also created a market price for nitrogen reductions – in itself an interesting development.
Benefits to customers (including, where available on a whole-life/NPV basis)	Nitrogen removal at Dorchester sewage treatment works would cost around £6m to install and £0.4m each year to operate
How this is being applied to other areas of the business	As well as further nitrogen auctions, we want to see whether EnTrade can be used for biodiversity, phosphorus and sediment management and also influence investment decisions and allocation of funding to different activities that affect the health of river catchments.

	As well as using EnTrade within Wessex Water, we have partnered with Natural England on one auction and sold a user licence to United Utilities for nitrogen leaching prevention in Cheshire. Environmental regulation does in some instances hamper our ability to use the Entrade approach to deliver the required improvements. In AMP7 for instance we will be required to build a nitrate treatment works at Wareham at a cost of £5 million, despite the fact this in our view this could be delivered much more cheaply through a catchment management approach.
Do you consider the scheme/project to be innovative and why?	This is the first implementation in the UK of an online reverse auction for environmental purposes.
Describe how you collaborated on the project and with whom (customers, suppliers, other water companies	**Regulators** Discussion with the Environment Agency and Natural England to allow sufficient time to trial this alternative approach. Natural England acting as a co-buyer with Wessex Water on one auction **Farmers** Farmers are the sellers of service via EnTrade
Where is the scheme in the project development life cycle	EnTrade is in full implementation, having been built in 2015 and trialled first in summer 2016.
How are you evaluating whether to progress the scheme/whether it is net beneficial?	EnTrade allows near-instant evaluation of each auction, notably: - The estimated nitrogen leaching avoided that was available through the farmers' bids - The £ cost per kg of nitrogen avoided Farmers send photographs as evidence of agreed measures being carried out and our catchment advisers are able to provide further on-the-ground verification. Other benefits are based on the avoided cost of conventional end-of-pipe treatment.