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anglianwater

Our PR24 Enhancement Strategies

Part 3: A carbon neutral business

October 2023

PR24 Enhancement Strategies Part 3: A Carbon neutral business

A carbon neutral business

1 Overview

1.1 Overview

This document sets out the enhancement investments that we propose to make to help us achieve the ambitions set out in our Strategic Direction Statement. These investments related specifically to our ambition to be a carbon neutral business. We've looked at how our whole business, across both water and water recycling can contribute to this ambition. Through our six capitals approach we have accounted for the carbon impact that all of our enhancement investments are likely to make. The enhancement strategies set out in this document refer to investments which are included in our plan specifically to reduce greenhouse gas emissions (section 2) and take a circular economy approach to how we use sludge (section 3).

1.1.1 Guide to our enhancement strategies

Each of the enhancement strategies align to costs presented in our data table submissions. The table below sets out how each section of our enhancement proposals presented in this document maps to enhancement cost tables.

Table 1 Our PR24 'A Carbon Neutral Business" Enhancement Strategies

Enhancement strategy	Costs data table references
Greenhouse gas reduction	CWW3.177-CWW3.179 (Greenhouse gas reduction (net zero))
Sludge	CWW3.137-CWW3.139 (Sludge storage - Cake pads / bays / other; (WINEP/NEP)) CWW3.143-CWW3.145 (Sludge treatment - Thickening and/or dewatering; (WINEP/NEP)) CWW3.146-CWW3.148 (Sludge treatment - Other; (WINEP/NEP)) CWW3.162-CWW3.164 (Sludge enhancement (growth)) CWW3.185-CWW3.186 (Bioresources Resilience) CWW3.187-CWW3.188 (Bioresources - Non WINEP cake pads) CWW3.189-CWW3.190 (Bioresources - IED and Reg changes)

The structure of each individual enhancement strategy is aligned to Ofwat's enhancement criteria set out in chapter A1 of appendix 9 of the Final Methodology (Setting expenditure allowances). The table below sets out how each sub-heading maps across to the enhancement criteria. Our enhancement strategies should should be read alongside chapter 7 Driving cost efficiency of our business plan which sets out an overview of how we have approached our enhancement investment plan overall.

Table 2 Enhancement strategy structure

Enhancement strategy sub-section heading	Enhancement assessment criteria
Delivering for the long term	**A1.1.1 Need for enhancement investment**
Investment context	a) Is there evidence that the proposed enhancement investment is required (ie there is a quantified problem requiring a step change in service levels)? This includes alignment agreed strategic planning framework or environmental programme where relevant.
Scale and timing	b) Is the scale and timing of the investment fully justified, and for statutory deliverables is this validated by appropriate sources (for example in an agreed strategic planning framework)?
Interaction with base expenditure	c) Does the proposed enhancement investment or any part of it overlap with activities to be delivered through base, and where applicable does the company identify the scale of any implicit allowance from base cost models?

Enhancement strategy sub-section heading	Enhancement assessment criteria
Long term context (historic)	d) Does the need and/or proposed enhancement investment overlap or duplicate with activities or service levels already funded at previous price reviews (either base or enhancement)?
Long term context (future)	e) Is the need clearly identified in the context of a robust long-term delivery strategy within a defined core adaptive pathway?
Customer support	f) Where appropriate, is there evidence that customers support the need for investment (including both the scale and timing)?
Cost control	g) Is the investment driven by factors outside of management control? Is it clear that steps been taken to control costs and have potential cost savings (eg spend to save) been accounted for?
Unlocking greater value for customers, communities and the environment	**A1.1.2 Best option for customers**
Option consideration	a) Has the company considered an appropriate number of options over a range of intervention types (both traditional and non-traditional) to meet the identified need?
Cost-benefit analysis	b) Has a robust cost-benefit appraisal been undertaken to select the proposed option? Is there evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-party technical assurance of the analysis provided?
Environmental and social value	c) In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when proposing a best value option over a least cost one?
Investment benefit	d) Has the impact (incremental improvement) of the proposed option on the identified need been quantified, including the impact on performance commitments where applicable?
Managing uncertainty	e) Have the uncertainties relating to costs and benefit delivery been explored and mitigated? Have flexible, lower risk and modular solutions been assessed - including where forecast option utilisation will be low?
External funding	f) Has the scale of forecast third party funding to be secured (where appropriate) been shown to be reliable and appropriate to the activity and outcomes being proposed?
Direct procurement	g) Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?
Customer view	h) Where appropriate, have customer views informed the selection of the proposed solution, and have customers been provided sufficient information (including alternatives and its contribution to addressing the need) to have informed views?
Cost efficiency	**A1.1.3 Cost efficiency**
Developing costs	a) Is it clear how the company has arrived at its option costs? Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?
Benchmarking	b) Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?

Enhancement strategy sub-section heading	Enhancement assessment criteria
	d) Is there compelling evidence that the additional costs identified are not included in our enhancement model approach? e) Is there compelling evidence that the allowances would, in the round, be insufficient to account for evidenced special factors without an enhancement model adjustment? f) Is there compelling econometric or engineering evidence that the factor(s) identified would be a material driver of costs?
Assurance	c) Does the company provide third party assurance for the robustness of the cost estimates?
Customer protection	**A1.1.4 Customer protection**
	a) Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed or reduced in scope? b) Does the protection cover all the benefits proposed to be delivered and funded (eg primary and wider benefits)? c) Does the company provide an explanation for how third-party funding or delivery arrangements will work for relevant investments, including how customers are protected against third-party funding risks?

Naturally, some of the information we highlight is relevant to more than one of these enhancement criteria, and so each enhancement investment should be read as a whole. In some sub-sections we go beyond the specific enhancement assessment criteria to provide additional relevant context where needed. For example, in some 'Long-term context (historic)' sections, we highlight not just the expenditure from previous price reviews, but also the activities and/ or performance delivered in previous AMPs.

2 Greenhouse Gas Reduction

Overview

- For many years we have been at the forefront of carbon reduction in the water industry. Our PR24 investments have been developed to deliver on our SDS ambition to be a carbon neutral business, as well as to align with our Net Zero Routemap[1] and our Long-Term Delivery Strategy (LTDS) and address areas with both the biggest carbon liability and the greatest opportunity for carbon reductions. The scale and diverse range of the enhancement investments delivers carbon savings in AMP8 whilst setting the trajectory for effective delivery in AMP9 and beyond.
- We will invest £153m to reduce process emissions at 17 of our largest Water Recycling Centres, replacing 12 HGVs, 26 tractor units, four hook-lifts and four tippers with electric equivalents, and three gas-to-grid projects

Table 3 Investment Summary

PR24 costs (£m)	
Capex	152.4
Opex	0.5
Totex	152.9
Benchmarking	
Method	Market testing of costs
Results	Cost quotations from the market have been embedded into our investment costs
Customer Protection	
Price Control Deliverable	Net Zero - tonnes of greenhouse gases removed
Ofwat data table	
CWW3.177-CWW3.179	Greenhouse gas reduction (net zero)

2.1 Delivering for the long term

2.1.1 Investment context

The world faces a climate emergency resulting from the emission of greenhouse gases leading to a warming of the planet and changing climates across the world. The importance of tackling this challenge has been reflected at global and national levels, with the 2015 Paris Agreement setting the global ambition to limit global temperature increases to well below 2°C above pre-industrial temperatures, and in 2019, the UK government committed to reducing national greenhouse gas emissions to net zero by 2050 and in 2021 the UK enshrined a new target in law to reduce emissions by 78% by 2035[2]. To achieve these aims it is vital that individuals, governments and businesses play their part; without action the climate emergency could evolve into a climate disaster.

To play our part in national and international efforts to limit global temperature rise to less than 2°C (and ideally less than 1.5°C) by the end of the century, in 2019 we committed, alongside all water companies in England, to reach net zero carbon by 2030[3]. This commitment relates to our operational emissions - those over which we have greatest control. Our CEO Peter Simpson is one of the co-sponsors of this ambitious target, described by:

Nigel Topping UK's High Level Climate Champion as"one of the most significant steps taken by the industry anywhere in the world".

This approach, and our proposals for Net Zero enhancement investment are in line with the Anglian Water purpose "To bring environmental and social prosperity to the region we serve through our commitment to Love Every Drop". The region in which we operate across the east of England is both the driest and lowest which makes it exceptionally vulnerable to the effects of climate change including longer, hotter summers and warmer, wetter winters. As the world continues to warm the effects of climate change build, these negative effects will continue to be felt across our region and highlights the urgency of delivering carbon emissions reductions.

We want to avoid locking unnecessary carbon in our assets now so that we can continue to operate in a net zero operating environment in 2030 and by 2050 - benefiting future customers as well as the customers of today. Achieving and

1 Net Zero routemap
2 https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
3 Water companies Net Zero 2030 Routemap and Anglian Water's net zero strategy to 2030

maintaining net zero in a changing climate will be a key challenge for everyone and we need to recognise the importance of joined-up investment planning for climate change mitigation and adaptation.

For many years Anglian Water has been at the forefront of carbon reduction in the water industry. Our decarbonisation journey began in 2010, when we first set ambitious goals to reduce our operational and capital carbon emissions, at a time when measuring and managing capital (embedded) carbon - the carbon in our assets and what we build - was unheard of.

Historically our focus on delivering operational carbon savings has been:

- through sustainable design for new build and maintenance activities,
- year on year investment in energy efficiency of our existing asset base,
- through the delivery of renewable energy generation schemes such as solar PV arrays and
- through the electrification of our car and small van fleet.

This has been achieved through efficiencies delivered through base funding or, in the case of our PV installations, though non-regulated activities. Focus on these areas will continue in AMP8 through base funding and through investments from our non-regulated business.

However, in line with both the Water UK and the Anglian Water Net Zero Carbon Routemaps [4]Net Zero enhancement funding is now required to take **transformational steps on 'non electricity' emissions** - elements of our carbon emissions where current approaches cannot deliver the required change and areas where Anglian Water, and most other water companies, have not previously concentrated.

The focus of our net zero enhancement investments are process emissions, that is nitrous oxide nitrous oxide and methane CH_4 (methane) emissions released primarily from the wastewater treatment process, the export of biogas to the gas grid and the decarbonisation of our Heavy Goods Vehicles (HGVs) which currently represent around 70% of our transport emissions.

Ofwat's methodology has been followed with Carbon Accounting Workbook (CAW) v17 used to calculate the carbon savings afforded by interventions to reduce process emissions. The CAW uses an emissions factor to calculate nitrous oxide emissions. Work by the Intergovernmental Panel on Climate Change (IPCC) and other water companies in the UK and overseas suggests that nitrous oxide emissions may be higher than currently reported in the CAWv17. IPCC data suggests that nitrous oxide emissions may in fact be around 4 times larger than currently reported in the CAW[5]. It is likely that this increased IPCC emissions factor (currently supported by Defra) will be adopted in due course; the nitrous oxide reductions we are currently targeting to achieve through enhancement spend are likely to be up to 4 times greater if the updated emission factor were applied.

Therefore, the **carbon savings per £ spent are likely to be 4 times greater**than currently set out in our enhancement investments for nitrous oxide emissions. This increase in reduction would also be accompanied by an increase in baseline emissions, highlighting further the importance of the issue and the size of the challenge to be addressed.

In addition, the CAW currently does not fully account for all methane emissions arising from the sludge treatment process with some elements of methane reduction fully accounted for, some partly accounted for whilst others remain unaccounted for. However, in assessing the baseline emissions position, and reduction potential for scope 1 emissions, only those emissions included within the CAW have been included.

The investments proposed will deliver methane emission reductions and whilst a small proportion of the reductions are not currently accounted for in the CAW, they are valid in efforts to reduce emissions and progress decarbonisation.

Whilst we are proposing a range of net zero carbon enhancement investments, we continue other pioneering carbon reduction approaches which compliment these proposed investments and demonstrates our wide-ranging commitment to delivering reduced carbon emissions.

As part of our plan we are proposing a bespoke performance commitment for lower carbon concrete assets [6]. Concrete is a carbon intensive material that is used throughout our asset base due to its high strength, long lifetime, and ability to form many different structures. This performance commitment measures the percentage reduction in the carbon emissions associated with the concrete used in the construction of our capital assets. This will be achieved through avoiding and reducing our use of concrete, as well the use of 'lower carbon concrete' materials. This will require us to work with and invest in our supply chain to make innovative approaches and techniques widely available across our dispersed asset base. The knowledge and insight we generate will be truly sector leading. We have already reduced our capital carbon by over 63% since 2010. We recognise there is a relationship between costs and carbon, with the principle of 'lower cost lower carbon' applying to the early stages of implementations. However, given our previous efforts over previous AMPs we have taken the easy wins and the low

4 https://www.anglianwater.co.uk/siteassets/household/environment/net-zero-2030-strategy-2021.pdf
5 IPCC
6 For full details please read our outcomes data table commentary section 1.22.

hanging fruit, further reductions on this element of capital (embedded) carbon will be hard won. Our approaches to capturing and managing data for robust reporting will also be valuable looking ahead to PR29.

Innovation Fund: Triple Carbon Reduction

We have led the Ofwat Innovation Fund Triple Carbon Reduction' project which uses electrolysis powered by renewable electricity to produce Hydrogen and Oxygen[7]. The Hydrogen is stored and exported to be used as fuel whilst the Oxygen is used in aeration in the wastewater treatment process. It is hoped that the use of Oxygen instead of air will reduce the amount of energy required to power the aeration pumping systems and reduce the amount of nitrous oxide released as consequence of the wastewater treatment process. In this way the project aims to reduce carbon in three ways; displacing fossil fuels using Hydrogen, reducing the energy requirements for aeration and reducing nitrous oxide emissions. The outcomes of the project will be valuable in the development of the Hydrogen economy and for investment decisions at PR29 and beyond.

Innovation Fund: Whole Life Carbon

Our Ofwat innovation fund Whole Life Carbon in design project builds on the current PAS2080 carbon standard and its philosophy that reducing carbon reduces cost, and supports the industry in delivering its Public Interest Commitment to reach net zero carbon by 2030.[8]It will also enable the water sector and its value chain to make informed decisions based on data insight and visualisations. To go beyond existing frontier performance requires innovation in combining visualisation of carbon and cost hotspots integrated with cost models and existing engineering platforms. This will allow engineers to challenge designs and optimise solutions to reduce both carbon and cost as they visualise impacts in real time.

There are three categories of GHG reductions where enhancement investment is needed in AMP8 to work towards net zero goals:

1. process emissions reductions,
2. biomethane export to the gas grid and
3. Heavy Goods Vehicles (HGV).

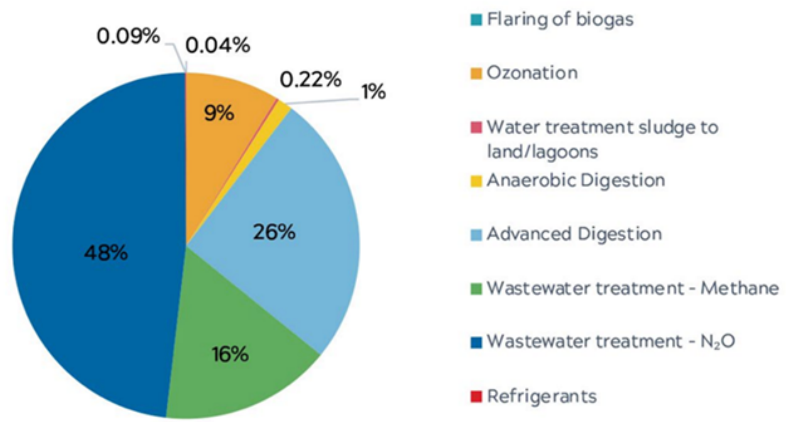
7 [Triple Carbon Reduction - Ofwat Innovation Fund (challenges.org)]
8 [Enabling Whole Life Carbon Design - Ofwat Innovation Fund (challenges.org)]

Process emissions currently account for approximately 25% of our carbon emissions whilst emissions from vehicles make up approximately 10%. Gas to grid schemes allow for much greater carbon savings than achieved through the current CHP process.

Process emissions

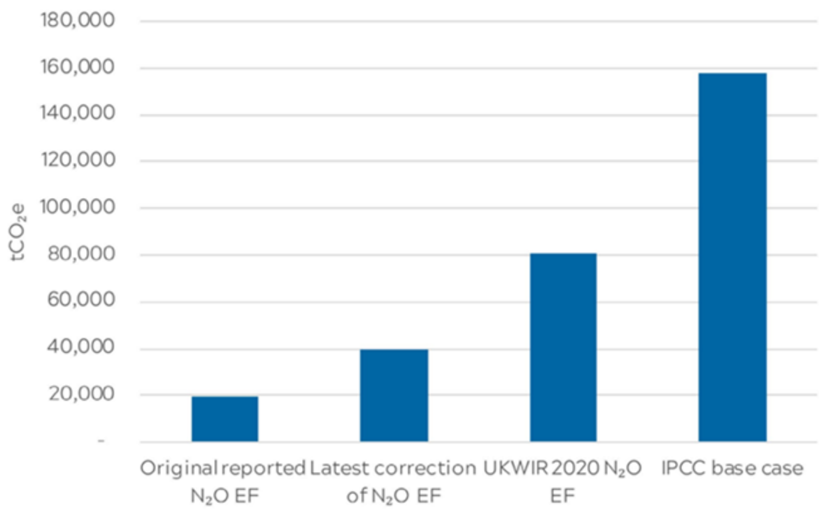
Greenhouse gases (GHG) in the form of methane and nitrous oxide, generally referred to as process emissions, are generated through the water treatment and water recycling process. The proportion of process emissions in our operations, as reported in the Carbon Accounting Workbook (CAW) in 2020/21, are shown in the figure below. This highlights that the majority of ourprocess emissions arise from our water recycling and sludge treatment activities. Water-related process emissions account for just under 10 per cent of our overall process emissions and the predominant source is from the ozonation treatment process.

Figure 1 Our process emissions in our operations, as reported in the Carbon Accounting Workbook in 2020/21



We recognise the latest science and available data is revealing the true extent in the baseline of process emissions from wastewater treatment, and whilst variable, they appear to be in line with factors published by the IPCC for nitrous oxide. If applied, the proportion of process emissions of our overall total operational emissions is even more significant, and is illustrated in the graph below.

Figure 2 Calculated carbon savings (following CAW v17)



Ofwat's methodology has been followed with Carbon Accounting Workbook (CAW) v17 used to calculate the carbon savings (as highlighted above).

To gain granular detail of emissions on operational sites, an increase in the measurement and monitoring is required, with a collaborative approach between government, regulator and companies. Knowledge and data sharing has been ongoing both within the sector and wider global organisations. Examples include UKWIR, Spring and the recently established Community of Practice for process emissions.

Given that just over 90% of our process emissions are from the wastewater treatment process, **our AMP8 enhancement programme focusses on the GHG emissions from Water Recycling Centres (WRCs) and Sludge Treatment Centres (STC).**

Biomethane export to the gas grid

Biomethane export to the gas grid will deliver large scale carbon emission reductions when compared to the CHP installations they will replace. In addition, these CHP installations which we propose to replace with gas to grid schemes are at the end of their operational lifetime. As set out in our net zero strategy gas to grid affords an opportunity to deliver large carbon savings over a long timeframe.

9 https://www.ipcc.ch/report/sixth-assessment-report-cycle/

Gas to grid schemes are not a difficult engineering challenge to resolve, the challenge is economic and therefore enhancement investment is required to deliver the carbon reduction benefits.

As discussed the gas to grid schemes replace CHP installations which will be at the end of their operational life. **Our enhancement costs have been calculated by including only those costs above that of replacing the CHP.**

Heavy Goods Vehicles

Given geography and operational requirements, we use HGVs to move sludge around our region. These HGVs are diesel powered and therefore carbon intensive and currently represent around 10% of our annual carbon emissions. Currently there are few diesel HGV alternatives at a comparative cost and therefore enhancement funding is required to deliver a step change in HGV emissions.

2.1.2 Scale and timing

The most recent UN IPCC AR6 synthesis report [9] highlighted that the world is already on track to exceed 1.5C of warming in the 2030s. Delaying action until after 2030 would significantly increase the risk of exceeding the 2°C target specified in the Paris agreement. It is particularly important that those sectors that have a feasible plan to significantly reduce carbon emissions in the 2020s can deliver those strategies at pace, recognising that there are sectors of the economy for which there is recognition that reaching net zero will take longer than this.

In the wider economy, sectors that require large amounts of heat in their production such as metals and cement manufacture will likely be amongst the later sectors to reach net zero., Whilst we and the UK water sector consumes large amounts materials and concrete in constructing and maintaining our assets - with the associated embedded carbon emissions. It is important that we play a leading role in delivering carbon reductions through the use of lower carbon concrete approaches, with those sectors such as ours that have the capability to deliver greenhouse gas reductions sooner, to do so.

Our investments have been developed to align with the our Net Zero Routemap ([net-zero-2030-strategy-2021.pdf (anglianwater.co.uk)](net-zero-2030-strategy-2021.pdf)) and our Long Term Delivery Strategy (LTDS) net zero sub strategy and address our carbon 'hot spots' - that is those areas with the both the biggest carbon liability and the greatest opportunity for carbon reductions. The scale and diverse range of the enhancement investments delivers carbon savings in AMP8 whilst setting the trajectory for effective delivery in AMP9 and beyond. The level of investment that we have included in AMP8 strikes a balance in delivering carbon savings and value to our customers, and being deliverable and affordable in the context of our overall plan whilst building knowledge and understanding to contribute at PR29 to deliver further reductions to carbon emissions.

Whilst from a carbon and climate change perspective it would be optimal to deliver all net zero enhancement investments as soon as possible and therefore in the first year of AMP8 , this is not feasible in terms of deliverability. Consequently, our investments are timed across the AMP with those gas to grid schemes which deliver the largest carbon savings occurring early in the AMP.

It is worth noting that our net zero enhancement investments will not 'solve' the net zero carbon problem - they will not deliver a net zero carbon Anglian Water but will deliver carbon reductions, providing a strong position to build upon the outcomes of the programme in AMP9 and beyond.

2.1.3 Interaction with base expenditure

These enhancement investments deliver GHG reductions above those that we will achieve through our base allowances.

For standard enhancements, we have included investments under other sub-strategy areas where there is a benefit to both greenhouse gas emissions and the primary enhancement driver. This strategy focusses on enhancement investments where the primary driver is to reduce operational greenhouse gas emissions.

We have ensured that carbon costs and benefits are embedded in the consideration of options across our enhancement programme. Any investments from other parts of the enhancement programme which contribute to our net zero ambition are reflected in those respective enhancement strategies. This enhancement strategy focusses on those material investments for the purpose of reducing greenhouse gas emissions which are not covered by base or other enhancements. The table below summarises how the expenditure for net zero investments is treated in our Plan. Our net zero-specific enhancements focus most substantially on reducing process emissions, switching our Heavy Goods Vehicles (HGVs) to lower carbon fuel and gas to grid.

Table 4 GHG reduction activities split between base, net zero specific enhancement expenditure, and enhancement expenditure captured in other enhancement strategies

Base	Standard enhancement (part of other strategies)	Net zero-specific enhancement (this strategy)
Implementing energy efficiency measures	Greenhouse gas reductions from our approach to delivering wider environmental and social value across our enhancement programme.	Developing understanding of, and reducing nitrous oxide emissions
Implementing energy storage solutions		Introducing electric HGVs into our fleet
Procuring all remaining grid electricity through green tariffs or sleeving renewable power to our sites		Switching CHP generation capacity to operate as biomethane upgrade plants
Replacing small vehicles with electric equivalents		Developing understanding of, and reducing methane emissions
Switching our gas oil demand to hydrotreated vegetable oil		Feasible options including solar modules on small operational sites
Development of hydrogen strategy		

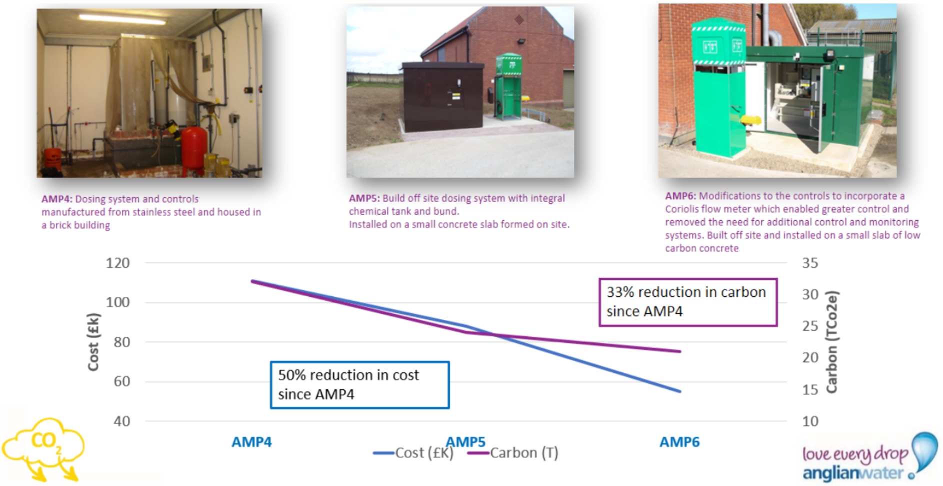
CHP replacement costs

One area where there is an interaction of enhancement expenditure with base is our biomethane to the grid investments. As part of this we will be replacing existing CHP engines, four of which will have reached the end of their asset life and would have been replaced as part of base capital maintenance (and so there is an implicit allowance for this within Ofwat's botex models). We have therefore removed the CHP replacement costs of £4.89 million from this investment to ensure that any implicit base allowance is not included in our enhancement request. We have calculated this by assuming like for like replacement of the existing engines using our cost models.

2.1.4 Long term context (historic)

We have been at the forefront of carbon reduction in the water industry. Our decarbonisation journey began in 2010, when we first set ambitious goals to reduce our operational and capital (embedded) carbon emissions, at a time when measuring and managing capital carbon - the carbon in our assets and what we build - was unheard of. With a committed leadership and a determined supply chain, by 2023 we reduced capital carbon by 63 per cent in our capital programmes from our original 2010 baseline. Through AMP6 we also reduced operational emissions by 34 per cent from a baseline set in 2014/2015.[10] These whole life carbon reductions have already benefited our customers through driving additional capital expenditure (capex) and operational (opex) efficiencies. These were set out as part of our PR19 business plan - the image below shows an example of this from our PR19 ortho dosing case study.

Figure 3 Standard Product Evolution: Carbon and Cost



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Working with Government and leading businesses through our role in the Green Construction Board, we helped develop and in March 2023 supported the revision to the world's first standard for managing carbon in infrastructure (PAS 2080), which is now being used nationally and internationally. We have also achieved platinum status on ISO 14064, the international standard for the quantification and reporting of greenhouse gases.

Our long-term focus and planning on greenhouse gas reductions means we are not going into AMP8 and beyond from a standing start, and opportunities to make significant progress towards net zero with cheaper solutions are limited. Where there are lower cost solutions and/or solutions that deliver co-benefits to other areas of the plan these are reflected in our base costs and other enhancement investment areas.

Our net zero enhancement investments focus on process emissions, switching our HGV fleet to low carbon fuels and gas to grid. In each case, there hasn't been a clear economic or commercial rationale for reducing emissions as part in previous AMPs and as these represent a step change in performance there is a need for enhancement investment in these areas at PR24

2.1.5 Long term context (future)

The challenges and opportunities we face in achieving our carbon reduction aims out to 2050 remain broadly in line with those we identified when we developed our net zero 2030 strategy back in 2021: process emissions, emissions from HGVs and gas to grid schemes. In addition, we can now add in chemicals, not a focus in 2021 and until APR 2023, not a focus of carbon emissions for Ofwat.

Whilst we have made excellent progress towards achieving net zero the path to 2030 and ultimately 2050, it is not straight forward and we face a number of challenges:

- **Growth in our region** - Increasing population growth in our region means that the volume of water we abstract, treat, supply and recycle continues to increase which has further implications on the amount of energy and chemicals we use and the amount of emissions we generate.
- **Increasingly tighter environmental consents** - Increasingly tighter environmental consents have also increased the intensity of our energy consumption in both the water and water recycling processes further adding to the emissions that we are seeking to address. It also means that we must use increasing volumes of chemicals to treat water to a higher standard and to treat emerging contaminants.
- **Scientific developments in emissions measurement** - As discussed earlier, the emissions factor currently employed for nitrous oxide emissions is likely to change upwards. Considering nitrous oxide investments alone, this increase in emissions factor does not affect our investment profile since whilst the

10 This includes decarbonisation of the electricity system
11 Please note the cost in this graph is material supply cost only

emissions will increase, so too will the carbon benefit of every nitrous oxide emission reduction scheme delivered. However, a change in emissions factor will alter the balance of solution types we invest in to reach our overall net zero target - in this case since the carbon benefit for nitrous oxide schemes will increase, it pushes the mix of investments further towards nitrous oxide schemes rather than other carbon emission reduction schemes. This is one development that we are currently aware of and have taken into consideration in the development of our LTDS, however we are certain there will be further developments in climate science which will challenge the approach we take to achieving net zero. There is also a similar development of understanding of and reporting of emissions from treatment chemicals. This has been leading to a lack of consistency in reporting of emissions across the sector in part driven by the Carbon Accounting Workbook (CAW) used by companies not being comprehensive (i.e. not covering all chemicals used) and by the emissions factors in the CAW requiring update. This is particularly relevant as programmes such as WINEP become materially larger and there remains uncertainty around treatment processes for new and emerging pollutants.

- **Developments in technology** - developments in technology are both a challenge and opportunity for the delivery of our net zero strategy. Whilst technological developments offer us new ways of tackling challenges, the tremendous pace of technological developments in the area of CO_2e emissions reductions also means that we will need to constantly review our strategy to ensure that the combination of strategic investments we are making is still the most appropriate as there is a risk that previously favourable approaches are no longer the best solutions.

The challenge of achieving net zero requires us and the wider industry to think and operate differently. Our journey to carbon neutrality to date has not only been inward looking, we have also supported the system-wide decarbonisation of our region through initiatives such as exporting waste heat to greenhouses in our region. Working collaboratively with wider stakeholders we will be seeking to utilise emerging but proven technologies (such as this) across our business including to help us tackle the challenges we face and we will be investing in trials and pilots including with other organisations.

The strategic enhancement investments we have identified (where the primary driver is the reduction of greenhouse gas emissions) that comprise a key part of our net zero strategy out to 2050.

Our LTDS net zero sub strategy sets out our low regret strategic interventions that reduce our operational emissions, primarily through the management of our process emissions, investment in lower carbon chemicals for our treatment processes, investment in gas to grid schemes and the transition of our HGV fleet to low carbon emission alternatives. [12]

2.1.6 Customer support

We have engaged with customers through multiple channels to understand the range of views on the scale and timing of our investments to achieve net zero. Our PR24 priorities engagement work highlighted that future customers rank reducing our carbon footprint as the second most important priority for the business, compared to a general view from customers that reducing carbon footprint is the 13th top priority for spend allocation 18 priority areas. We have therefore sought to balance these priorities as part of our net zero enhancement strategy, with prioritising the 'lower hanging fruit' greenhouse gas reduction investments in previous AMPs and delivering greenhouse gas reductions from our wider enhancement programme before seeking additional greenhouse gas reduction specific investments.

We have therefore used our customer and stakeholder engagement, alongside our own technical expertise, considerations around how our net zero strategy fits within the LTDS, and affordability and deliverability concerns to consider the extent to which greenhouse gas reduction enhancement investment is required at PR24. The investment we have proposed, focussing on process emissions, biomethane to the grid and HGV fuels, strikes the right balance. Going further and faster on reducing process emissions, and investing more in AMP8 is an option, but this would add to affordability pressures for our customers and not strike the right investment prioritisation highlighted in our customer engagement. Investing less than this would not be sufficient in light of the pressing need to take action on to reduce greenhouse gas emissions in the near term.

2.1.7 Cost control

Actions to reduce process emissions and converting HGVs to low carbon fuel supplies are focussed purely on the need to reduce greenhouse gas emissions. This need is outside of management control as a global concern and a national priority which is written in to legislation. Whilst there isn't a statutory requirement on Anglian to deliver these investments in AMP8, not to do so would hinder our ability to support the UK to achieve net zero outcomes, and go against the recognition that the later action is taken on climate change, the greater the cumulative impact over time.

12 For more detail on our LTDS net zero sub strategy, please refer to Section 2.2.7 in our LTDS.

This is something that we have recognised for multiple AMPs and we have sought to control costs by prioritising the 'low-hanging fruit' of methods to reduce our greenhouse gas emissions, for example by focussing first on those areas where carbon benefits align with cost benefits, and incorporating greenhouse gas reduction benefits into other parts of our enhancement programme. The investment put forward as part of this net zero-specific enhancement strategy reflect the investments which are required to be delivered as part of PR24 reflective of these cost control measures.

2.2 Unlocking greater value for customers, communities and the environment

2.2.1 Option consideration

Our enhancement investment choices, and the long list of options from which the enhancement investments have been selected, have been aligned with those reviewed and listed in the Ofwat 'Net Zero Technology Review' (https://www.ofwat.gov.uk/wp-content/uploads/2022/08/Net_Zero_Technology_Review.pdf).

We have considered a broad range of options to reduce greenhouse gas emissions including the following. We set out where we deemed these options to be feasible for meeting the identified need through our optioneering process:

Table 5 Optioneering for greenhouse gas emissions

No.	Option	Description	Unconstrained	Feasible
1	Gas-to-grid	Converting CHP engines at end of life to permit to inject into gas network -- increase carbon benefit from putting straight into the network & decarbonising gas network (displacing fossil fuels)	Yes	Yes
2	Switching HGV fleet to liquid natural gas fuel	Switching to the use of LNG fuelled HGVs	Yes	
3	Hydrogen generation and the provision of refuelling centres	Using water to produce hydrogen and then provide this hydrogen as fuel to replace fossil fuels	Yes	
4	Switching HGV fleet to electricity	Using electricity to power HGVs	Yes	Yes
5	Fleet (car and van) replacement	Replacing diesel small vehicle fleet vehicles with electric vehicles	Yes	Yes - Feasible option to be delivered from base
6	Nitrous oxide monitoring and real time control	Installation of monitors and controllers	Yes	Yes
7	Aeration changes to reduce nitrous oxide	Optimising dissolved oxygen concentrations	Yes	Yes
8	Membrane Aerated Biofilm Reactor (MABR)	Adding membrane media to existing tank supporting biofilm growth	Yes	Yes
9	Ammonia recovery or treatment from digested sludge	Cover tanks and treat off gas, ammonia from liquor pathfinder	Yes	Yes
10	Methane emission reductions	Minimise leakage and maximise harvesting and utilisation	Yes	Yes
11	Renewable energy PV	Development of PV arrays at AW sites delivering private wire power	Yes	
12	Renewable energy Wind	Development of wind turbines at AW sites delivering private wire power	Yes	

No.	Option	Description	Unconstrained	Feasible
13	Renewable energy Hydro	Recognising topography consraints of the AW region, development of hydro generation schemes delivering private wire power	Yes	
14	Utilisation of 'waste' heat	Provision of 'waste' heat to non-Anglian Water users to displace fossil fuel use	Yes	
		For 1, 6, 7, 8 and 9 whilst these solutions are feasible on some sites (and therefore included within our plan) they are not feasible at all sites. For 5 this is base investment and not NZ enhancement For 11, PV has been included as feasible in this table because in the data table (CWW22 and CW21) it is a 'feasible' and not 'selected' NZ enhancement investment		

This methodology has resulted in a range of best available nitrous oxide solutions which Jacobs have worked with global specialists to review and integrate. These proven solutions focus on:

- optimisation of process control - a step change in asset operation to minimise nitrous oxide emissions and maintain energy efficiency.
- maximising denitrification, lowest nitrous oxide emissions result when compared with BAU
- Proactive asset health remedial work - not BAU capital maintenance but accelerating sector progress to a new normal which allows much more resilient, better operated facilities (for example proactive diffuser assessment and optimisation for our vast aeration assets)
- Digital futures - supported by high quality process information. As yet, digital twins and soft sensor solutions are not proven nitrous oxide mitigation strategies in any global work. Enhanced process control will support the development of these further but our programme is founded on the evidence base at present which is for robust monitoring, process operation and enhanced or advanced process control regimes. As early instigators of Ammonia-based Aeration Control (ABAC) in the UK sector, we will optimise our legacy systems for nitrous oxide mitigation in line with proven experience globally (Denmark, Australia, Switzerland).

This approach has driven a focus on proven options which have evidence of technical or cost effectiveness. These are well summarised in Ofwat Net zero technologies reports [13], the recent Defra rapid evidence assessments (which Jacobs led) (as shared by Defra on 30th January 2023) and the latest EA review work which compares different environmental permits in terms of whole life cycle GHG emissions.

This focus on proven solutions supported by good science is in the best interests of customers and is supported by the evidence. The solutions proposed are realistic without over-optimistic mitigation reductions which are unsupported by technology providers.

However, the enhancement investments proposed will not result in full abatement in AMP8, as we do not feel that this is technically and financially feasible and will compromise the effectiveness of future work.

The solutions proposed are additive and support flexibility and asset resilience. Indeed in producing the list of enhancement investments we selected from a longer list of potential interventions. These potential investments have been included as feasible investments detailed in data table CWW22 which could be taken forward if decided by Ofwat. Our programme is ambitious, but evidence based - founded on consistent proven solutions and it will be delivered collaboratively to enhance learning by the sector.

As discussed in section 1, our proposed net zero enhancement investments concentrate on three areas of carbon emission reductions: process emissions reductions (both nitrous oxide and methane), biomethane export to the gas grid and HGVs.

Nitrous Oxide process emissions

As discussed in above it is possible that an increased emission factor associated with nitrous oxide emissions may be adopted. This reflects the uncertainty around nitrous oxide emissions which extends beyond the emissions factor through to their productions and the approaches employed to reduce the emissions. As a consequence the innovations and technologies available to deliver reductions are immature.

13 https://www.ofwat.gov.uk/publication/net-zero-technology-review/

In order to develop a more mature approach to nitrous oxide reductions during AMP8 it is critical to explore a number of different investment approaches such that lessons can be learnt, data gathered and assessments made as to effectiveness. These learnings can then be accelerated in AMP9 and beyond.

Whilst these learnings will be valuable into the future, our proposed enhancement investments will also deliver carbon savings in AMP8. **We are proposing 19 nitrous oxide reduction enhancement investments which will deliver cumulative carbon savings across AMP8 of 5043.25 tonnes and 4143 tonnes per annum when all schemes are fully operational.**

As per our Net Zero Routemap, nitrous oxide emissions will be our largest source of emissions in 2030 and as the emissions factor associated with these emissions will likely increase, further increasing the size of the problem. It is our view that our proposed enhancement investments will reduce emissions, contribute to the knowledge base of Anglian Water and the water sector more widely and, if not taken forward, represent a large, missed opportunity in delivering change. The size of the prize should be embraced now.

In developing our approach to nitrous oxide enhancement investments we asked Jacobs to undertake a study into nitrous oxide reductions.Jacobs are leading experts in this field having authored the Ofwat Net Zero technologies report which included approaches to reducing nitrous oxide emissions, co-chairing the UK and Ireland Process Emissions CoP (of which Anglian Water are a founding member) and chairing the IWA Climate Smart Utilities working group which highlights the best available evidence globally for nitrous oxide monitoring and mitigation.

The study delivered a set of ambitious, but science driven, approaches that are proven, cost-effective solutions. The baseline and nitrous oxide reductions (reported as CO2e) was calculated using the Carbon Accounting Workbook (CAW v17) factor as per the Ofwat methodology. It possible that in due course this emissions factor is changed to be in line with the value proposed by the IPCC and supported by Defra. This emissions factor is a fourfold increase of that currently in the CAW v17. If this is the case then emissions reductions would increase broadly 4 times per £ invested.

In order to gain a more detailed estimation of the relative source and magnitude of nitrous oxide from wastewater, screening of our Band 6 sites has been undertaken. This reviewed and assessed nitrous oxide production 'risk factors' evident from operational data from the sites, including dissolved oxygen (DO), plant loading and sludge liquors, partial nitrification and denitrification. The assessment is in line with guidance included in a UKWIR report, outlining operational conditions that may trigger nitrous oxide production and emissions[14].

The approach employed screened and prioritised higher emissions sites and developed solutions to reduce emissions of nitrous oxide. This was achieved using the following methodology:

- The largest 49 Anglian Water sites were identified. These sites serve a population equivalent of 4,674,800, over 60% of our total wastewater population.
- Nitrous oxide emissions from these sites were estimated using site online operational data (ammonia, Dissolved Oxygen (DO), flows, aeration system operational conditions etc) and Cobalt Water (Jacobs partner) Artificial Intelligence (AI) driven machine learning tool.
- Poor performing sites were identified based on analysis of online DO data and percentage time each site was operating within low and high DO emission factors (linked to higher nitrous oxide generation per gram ammonia treated)
- Best scientific knowledge and practice was then applied to select the sites with the highest nitrous oxide emission potential (predicted nitrous oxide emissions and population served) and high benefit to cost ratio.
- Prioritisation was then applied on a site-by-site basis, to provide site specific mitigation measures:
- The biological treatment processes used, their configuration and nitrification / denitrification performance.
- The impact of ammonia rich liquor returns from bioresources plant to the main biological treatment processes.
- The aeration equipment age, condition, air flowrate and potential Oxygen Transfer Efficiency (OTE)

From this analysis, and our own nitrous oxide monitoring in place at four sites to better understand emissions, a prioritised list of sites was produced, containing the greatest opportunities for N_2O emissions reduction potential. Each site was then reviewed, and an options appraisal developed, considering specific treatment and asset type e.g. nitrifying activated sludge with fine bubble diffused aeration, against a list of potential interventions. Many of the options reviewed are listed in the 'Net Zero Technology Review' (https://www.ofwat.gov.uk/wp-content/uploads/2022/08/Net_Zero_Technology_Review.pdf).

Where it is worthwhile, several investments are outlined at the same site in order to drive the best solution considering overall nitrous oxide mitigation and the efficiency or marginal abatement cost of the investment. Emission monitoring and real time control is included at each site where further investment is proposed as it provides the foundation of understanding and reduction.

14 https://ukwir.org/quantifying-and-reducing-direct-greenhouse-gas-emissions-from-waste-and-water-treatment-processes-1

Proposed investment outlined below has been focussed on sites with the activated sludge process where nitrification is carried out. Carbonaceous non-nitrifying plants and extended aeration plants have not been prioritised at this stage due to the lower emission reduction potential that exists in this process configuration. We are currently engaged in collaborative research to better understand nitrous oxide emissions from the trickling filter process, and whilst this process type is significant in our asset base, we are not proposing investment until they are better understood, and potential mitigation options are developed.

Nitrous Oxide monitoring and real time control (RTC)

Our existing monitoring programme (trial monitors installed at Cambridge, Cotton Valley, Cliff Quay and installing at Whitlingham) and knowledge from other studies has shown that accurate, continuous nitrous oxide monitoring of treatment processes will allow insight and understanding into patterns of production and enable identification of operational changes to mitigate. Combined with monitoring other operational parameters (Dissolved Oxygen, flow, load etc), an optimised operating regime can be developed and implemented using an advanced process control system. Long term monitoring will be essential to maintain the optimisation, calculate the benefit, and also to develop a more accurate understanding of emissions over time, informing future emissions reduction and deriving an accurate emission factor for the sector when reviewed alongside data from other sites. The exact specification of the number of monitors and controllers varies depending on site specific factors such as the number of lanes/phases of treatment process at each site.

Aeration changes including anoxic zones and aeration systems

A shortlist of sites suitable for process enhancement investment to enable further reduction in emissions beyond monitoring and RTC, has been developed through the screening analysis. Typically, a constraint has been identified during this work that cannot be overcome by operational changes alone, and process modification is required to reduce the nitrous oxide risk factor and enable a potential reduction to be realised. This investment will be stacked with nitrous oxide monitoring and process control. Insights from our own monitoring, collaboration with other global utilities, and scientific data from literature have demonstrated the importance of the nitrification/denitrification stages in wastewater treatment and operational dissolved oxygen concentrations to be paramount in determining nitrous oxide production and emission.

Investment in this category is targeted to modify or fortify existing treatment process to provide further emissions reduction. This includes provision of less air in some processes and extending anoxic zones or conversely, provision of more air at some sites with aeration process redesign. Our analysis from our own monitoring and from other studies has demonstrated that existing process design and engineering of aeration design for treatment compliance and energy efficiency may not always be optimum for process emission minimisation. This group of investment will establish retrofit options to optimise emission reduction without impacting treatment compliance and attempt to minimise compromising energy efficiency (e.g. from ammonia based dissolved oxygen control where DO level are suppressed during periods of low load).

Membrane Aerated Biofilm Reactor (MABR)

Membrane Aerated Biofilm Reactors (MABR) is one of the most promising technologies that may offer a significant and transformational reduction in nitrous oxide emissions from wastewater treatment, with the drastically lower emissions than conventional activated sludge process, some reporting 80-90% reduction[1], and other studies approximately 50% reduction[2]. This is achieved by adding membrane media into the existing tank supporting biofilm growth and a hybrid system to be established. Oxygen is supplied directly to the biofilm through the membrane, and an oxygen concentration gradient develops across the biofilm enabling simultaneous nitrification and denitrification, and a sink for nitrous oxide. In addition, the increased oxygen transfer efficiency of a MABR will result in a reduction in energy consumption compared with a conventional activated sludge process.

MABR could also offer further potential for emissions reduction, by treating the lower residual nitrous oxide contained in the aeration exhaust air flow, eliminating the need for expensive and cumbersome process covers and presenting a more effective option with multiple benefits. The potential to capture and treat the exhaust air from MABR is being investigated within the Triple Carbon Reduction project, led by Anglian Water and funded from the first round of the Water Breakthrough Challenge[15 16].

Ammonia recovery or treatment from digested sludge centrate

In contrast municipal wastewater treatment, digested sludge centrate is characterised by significantly higher ammonia concentration (40 to 50 times higher than domestic wastewater) and much lower volume to treat. A high specific emission of nitrous oxide per mass of nitrogen in the wastewater has been reported from the literature and as seen in own monitoring, has led to emissions from centrate treatment becoming an emission hotspot and a priority. Selected investments to mitigate include:

- Cover process tanks and treat off-gas at our four existing Liquor Treatment processes at Sludge treatment centres

15 https://www2.mst.dk/Udgiv/publications/2020/08/978-87-7038-216-8.pdf and https://pubmed.ncbi.nlm.nih.gov/37567125/
16 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4363572

- New sludge liquor treatment plant established at our largest sludge treatment centre, designed and operated to minimise nitrous oxide emissions from outset, including covering and treating nitrous oxide in off-gas. Currently the centrate is returned to the existing wastewater treatment works
- Ammonia from Liquor recovery pathfinder, building on the Ammonia Recovery Innovation project funded under the Innovation in Water Challenge, we are supporting and led by Northumbrian Water

Methane reductions

Mott MacDonald undertook the analysis into methane reductions. Mott MacDonald are experts in the water sector in general and have expertise in both methane assessment methodologies, participating in the ongoing development of the CAW to better assess methane emissions, and in methane emission reduction approaches.

The study highlighted that the CAW currently does not fully account for all methane emissions arising from the sludge treatment process with some elements of methane reduction fully accounted for, some partly accounted for whilst others remain unaccounted for. However, in assessing the baseline emissions position, and reduction potential for scope 1 emissions, only those emissions included within the CAW have been included.

Going forward an improved methane and nitrous oxide calculation methodology would allow for a more granular understanding of these emissions and assist with the development of solutions.

The study has delivered a set of recommended robust interventions with emission reductions calculated with the vast majority fully accounted for in the CAW. It is our view that the reductions proposed will deliver methane emission reductions and whilst a small proportion of the reductions are not currently accounted for in the CAW, they are valid in efforts to reduce emissions and progress decarbonisation.

Anglian Water has ten dedicated sludge treatment centres (STC), co-located on our some of our largest WRC's.

In identifying the sites to consider potential reduction in methane emissions, a long list of sites based on annual sludge treated and population equivalent was produced. This list comprised of fifteen sites which were a combination of six sludge thickening sites (STS) and ten sludge treatment centres (STC). Following a site-by-site review, the long list was reduced to a short list of eight sites.

The short-list comprised of the eight STCs where advanced anaerobic digestion (AAD) (thermal hydrolysis, and biological hydrolysis (Monsal EEH, and Helea HpH)) is practised. The STS sites were discounted, as it was considered that the potential for reducing methane losses wouldn't be cost effective compared with the STCs given the significantly lower methane production rates pre-digestion. Therefore, the sites that offered the most efficient potential for reducing methane losses were the eight AAD STCs (Great Billing, Cotton Valley, Whitlingham, Cliff Quay, Pyewipe, Colchester, Basildon, and King's Lynn).

The approach to reducing methane losses has been to maximise its collection and utilisation in combustion plant such as combined heat and power (CHP) and heat boilers:

- Minimise leakage
- Maximise methane harvesting and utilisation.
- Optimise connection of methane generating plant to the biogas system
- Extraction of dissolved methane using vacuum degassing, and transfer to the biogas system
- Treat and/or abate residual methane.

The methane emissions associated with secondary digestion and fugitive emissions were taken forward for the application of mitigating technologies. These are only covering Scope 1 emissions.

The emissions associated with secondary digestion were split into two options (or 'scenarios'); where possible, the secondary digesters are to be connected to the biogas system, where vacuum degassing, flash aeration and odour control are utilised ('Option 1'). If it is not practical to connect the secondary digestors directly to the biogas system ('Option 2'), vacuum degassing is installed between the primary and secondary digester (intermediate vacuum degassing), the secondary digester is covered and aerated (equivalent to flash-aeration), and the off-gas is similarly abated in a two-stage odour control unit. A summary of how each technology is applied through these arrangements is listed in the table below:

Table 6 Application for technology to scenarios

Methane losses associated with anaerobic digestion and buffer storage	Technology	Baseline methane emissions (average, $kgCH_4$ /trawDS)	% reduction (lower range)	% reduction (upper range)	Final methane emissions , lower range reductions ($KgCH_4$/trawDS)	Final methane emissions, mid-range reductions ($KgCH_4$/trawDS)	Final methane emissions, upper range reductions ($KgCH_4$/trawDS)	Comment
Fugitive emissions	LDAR (leak detection and repair)	1.30	44	70	0.73	0.56	0.39	Reported values in the Journal of Petroleum Technology
	PVRV (Pressure vacuum relief valve)	Included in above - combined solution						Combined solution - PVRV upgrade will reduce uncertainty of efficacy of LDAR
Secondary digestion - option 1	PDST (Post-digestion storage tank) upgrade	2.00	100	100	0	0	0	Assumes covering tanks and collecting methane will reduce emissions to zero
	Vacuum degassing	0.28	25	100	0.21	0.11	0	Assumed values relating to dissolved methane
	Flash aeration	0.11	Up to 100	Up to 100	0.08	0.04	0	Assume all residual methane is stripped
	OCU (Odour control unit) upgrade	0.05	0	50	0.05	0.04	0.03	From dissolved methane in dewatering liquors, suggestion is that stripped methane to OCU will lay between low-medium loss
Secondary digestion - option 2	PDST (Post-digestion storage tank) upgrade	2	0	0	0	0	0	Fugitive losses prevented due to covering, but emissions will occur downstream of PDST

This methodology allowed for the development of solutions specific to particular sites. These solutions were developed in the context of existing full scale or demonstration plants across the UK or Europe to ensure viability and deliverability. Solutions have been assessed on a potential range of emissions reductions available. Where this range exits we have adopted a value in the lower range to ensure no over-estimations

Gas-to-grid

Decarbonisation of heat networks is considered to be one of the more challenging aspects to be addressed in order to meet national net zero targets. Our bioresources asset base through the production and upgrading of our biogas to biomethane for injection into gas networks offers significant benefits in support this aim and also our own net zero targets.

We have considered all of our ten sludge treatment centres (STC) where we currently use our biogas to generate heat and power via CHP engines for conversion to biomethane and gas injection to grid. The options assessment included a review of the asset condition and remaining life on the existing engine fleet, date at which existing renewable obligations schemes close and viability of obtaining a gas grid connection for export of biomethane into the grid. Through this exercise we have identified three of our sites - Cottonvalley, Great Billing and Whitlingham for transition in AMP8. The enhancement expenditure is net of base capital maintenance that would have been required to replace those engines on the selected sites that would reach end of life.

£4.87m funding from base in lieu of like for like replacement one engine at Cotton Valley and three at Great Billing which would all reach the end of their serviceable lives within the AMP. Possible transition of our remaining STC sites from CHP to gas to grid are included on the feasible options list. Again, these costs exclude those associated with CHP replacement.

We have also undertaken an assessment via the supply chain of the most appropriate technology for biogas upgrading. This involved a number of meetings and interviews with the supply chain, including suppliers of upgrading equipment, operators and potential off-takers for the biomethane and any other value add products. The conclusion was that at this time membrane upgrading plants are best suited to meet this need and also open up potential future opportunities for carbon capture of CO2. The CO2 capture is not included in our enhancement case at this time but this does present a potential future revenue opportunity as markets develop, this could include capture for beneficial use in other industries or as capture and storage.

The three gas to grid schemes will be integrated as a wider renewables strategy from the sites that are separate to this enhancement case, but we assume that the renewable electricity benefits we currently receive from the CHP engines will be offset with solar or other renewable sources.

HGVs

We understand that emissions from our HGV fleet, primarily generated by moving sludge between our numerous treatment plants to our STC's is a difficult area to decarbonise. Given the near ubiquity of diesel HGVs in the market and the additional costs associated with a move away from diesel this is a challenge which cannot be addressed without enhancement spending.

As other areas of our operation decarbonise, the proportion of our emissions from our HGV fleet will increase to around 16% in 2030. As a consequence, we have undertaken analysis of the available non-fossil fuel HGV alternatives and developed an approach which will deliver a lower carbon solution.

Working with both our framework vehicle providers and companies outside of our framework we have identified which options are available to support our ambitions to reduce the carbon impacts of our HGV fleet.

Alternate fuels that have been identified as ready for use currently and within the next investment cycle are Biomethane (CNG & LNG), Electric & HVO. Hydrogen fuel cell technology has been identified as a possible 'range extender' however energy input vs. output performance of c.20% has lead us to view the Hydrogen fuel cell as a high cost, low efficiency option that we would not have a clear need for given our mileages. As we move past 2030 it is possible the technology and costs associated with Hydrogen will change to make this technology more economically viable.

In order to identify the most effective low carbon alternatives we have used a cost calculator incorporating capital and operational costs for our specific vehicles types and for the annual mileage for our vehicles. These broad mileages are dependant on specific work activity but are around 100,000Kms annually for each vehicle.

We have modelled our routes across vehicle types with each of the above technologies and found the best £ invested per T/CO2 saved benefit to exist on an electric drivetrain, this includes benefits on maintenance, servicing and parts.

Bulk tippers have been chosen as the most suitable vehicle type, as have opportunities for overnight charging as our rapid charging infrastructure becomes established, and routes of around 300Kms/day which is within real world range forecasts after 5 year battery degradation and shown to be outperformed by existing early adopters of the technology

All of the above proposed enhancement investments are categorised as 'selected' in data table CWW22. In addition, we have also included some 'feasible' schemes. These feasible schemes are further gas to grid schemes, nitrous oxide reductions and solar photovoltaics (PV) investments. We have also included a 'feasible' PV investment in data table CW21

Solar Photovoltaics (PV)

PV affords a cost-effective way of delivering renewable energy on or adjacent to our sites. Previously in AMP6 and in AMP7 we have worked with external financiers to develop, construct, own and operate solar PV installations across our estate. We then procure this energy. However, we have large numbers of smaller sites which are below the size threshold that has been commercially viable for us and our investment partners. Should we be successful in securing capital for this programme, we will develop up to 400 solar installations across our water recycling and water asset base (equating to 20 GWh's of renewable energy) utilising both roof and ground mounted installations to provide renewable energy behind the meter at our sites.

Despite the methodology employing the best available science it is clear that there is still uncertainty about nitrous oxide production and mitigation approaches. In light of this uncertainty, our enhancement investment includes a range of alternatives which will deliver cost effective reductions but also offer insight into their effectiveness. This learning can then be employed in future investment cycles to deliver further reductions.

Our programme is ambitious but evidence based - founded on consistent proven solutions and it will be delivered collaboratively to enhance learning by the sector. It is supported by our leadership of the Triple Carbon Reduction Ofwat innovation project - which is developing evidence around MABR and nitrous oxide emissions as well as green hydrogen potential, the N recovery and net zero Ofwat innovation projects which we are partners in.

Unconstrained options

All options available to reduce emissions where assessed against the criteria outlined in the table below. More detail on the criteria can be found in section 7.3 of our business plan.

Table 7 Options available to reduce emissions

No.	Option	Required outcome	Technical feasibility	Wider environmental outcomes	Risk	Environmental
1	Gas-to-grid					
2	Switching HGV fleet to liquid natural gas fuel					
3	Hydrogen generation and the provision of refuelling centres					
4	Switching HGV fleet to electricity					
5	Fleet (car and van) replacement					
6	Nitrous oxide monitoring and real time control					
7	Aeration changes to reduce nitrous oxide					
8	Membrane Aerated Biofilm Reactor (MABR)					
9	Ammonia recovery or treatment from digested sludge					
10	Methane emission reductions					
11	Renewable energy PV					
12	Renewable energy Wind					
13	Renewable energy Hydro					
14	Utilisation of 'waste' heat					

2.2.2 Constrained options

Options that pass the initial test where assessed against another round of criteria (more detail on the criteria can be found in section 7.3 of our main business plan).

Table 8 Constrained options

		Feasibility and risk		Performance	Engineering	Cost and benefit	
1	Gas-to-grid	CHP at end of life, Renewable Obligation Certificate (ROC) coming to an end. Viability of connection to gas grid	Possible supply chain risks if high demand across the sector	Large carbon savings through the displacement of natural gas in the gas grid	Medium complexity	Large capital outlay but large carbon savings over long period. Contributes to difficult area for UK plc to decarbonise	
2	Switching HGV fleet to electricity	Relevant vehicles available	Availability of charging infrastructure	Large carbon savings through reduced diesel use	Low complexity	Initial larger capital outlay of vehicles but reduced operational costs	
3	Fleet (car and van) replacement	Relevant vehicles available but some supply delays	As vehicle range and charging infrastructure improves, increased scope for use throughout the region	Large carbon savings through reduced petrol and diesel use	Low complexity	Initial larger capital outlay of vehicles but reduced operational costs THIS INVESTMENT IS BASE	
4	Nitrous oxide monitoring and real time control	Equipment available, low complexity of installation		Carbon savings and knowledge building	Low complexity	Nitrous oxide reductions and possible energy consumption reduction	
5	Aeration changes to reduce nitrous oxide	Equipment available, low complexity of installation		Carbon savings and knowledge building	Low complexity	Nitrous oxide reductions and possible energy consumption reduction	
6	Membrane Aerated Biofilm Reactor (MABR)	Equipment available as modules	Proven technology but complexity in operation	Carbon savings and knowledge building	High complexity	Nitrous oxide reductions and possible energy consumption reduction	
7	Ammonia recovery or treatment from digested sludge	Relatively complex installation	Tank covering needs careful monitoring	Carbon savings and knowledge building	Medium complexity	Nitrous oxide reductions	

		Feasibility and risk		Performance	Engineering	Cost and benefit	
8	Methane emission reductions	Installations at a number of different points in the biogas generation process, dependent on site context	Tank covering needs careful monitoring.	Carbon savings, maximising methane capture and thus biogas generation	High complexity	Maximising value of biogas	
9	Renewable energy PV	Low complexity, technology well known and widely adopted	Grid electricity prices/renewable electricity prices drop below those associated with the installation.	Carbon savings	Low complexity	Carbon savings and opportunity for storage during excess production THIS INVESTMENT IS 'FEASIBLE' AND NOT 'SELECTED'	

2.2.3 Feasible options assessment

All options that progressed to the constrained optioneering stage were deemed as feasible in order to meet our required need -- we set out the reasoning for this below:

Table 9 Feasible options assessment

No.	Option	Feasible solution	Justification
1	Gas-to-grid	Y	We have considered all of our ten sludge treatment centres (STC) where we currently use our biogas to generate heat and power via CHP engines for conversion to biomethane and gas injection to grid. The options assessment included a review of the asset condition and remaining life on the existing engine fleet, date at which existing renewable obligations schemes close and viability of obtaining a gas grid connection for export of biomethane into the grid. Through this exercise we have identified three of our sites - Cottonvalley, Great Billing and Whitlingham for transition in AMP8. The enhancement expenditure is net of base capital maintenance that would have been required to replace those engines on the selected sites that would reach end of life. The solution therefore offers value in delivering in AMP8 and delivers large carbon savings in an area (heat provision in the wider economy) which is difficult to decarbonise.
2	Switching HGV fleet to electricity	Y	We have modelled our routes across vehicle types with each of the above technologies and found the best £ invested per T/CO2 saved benefit to exist on an electric drivetrain, this includes benefits on maintenance, servicing and parts.
3	Fleet (car and van) replacement	Y	Whilst electric cars and vans require higher capital outlay, they have reduced operational costs over their lifetime. Coupled with the carbon reduction afforded, this approach will be taken forward in base expenditure
4	Nitrous oxide monitoring and real time control	Y	Our existing monitoring programme and knowledge from other studies has shown that accurate, continuous nitrous oxide monitoring of treatment processes will allow insight and understanding into patterns of production and enable identification of operational changes to mitigate. Combined with monitoring other operational parameters (Dissolved Oxygen, flow, load etc), an optimised operating regime can be developed and implemented using an advanced process control system.

No.	Option	Feasible solution	Justification
5	Aeration changes to reduce nitrous oxide	Y	Investment in this category is targeted to modify or fortify existing treatment process to provide further emissions reduction. This includes provision of less air in some processes and extending anoxic zones or conversely, provision of more air at some sites with aeration process redesign. Our analysis from our own monitoring and from other studies has demonstrated that existing process design and engineering of aeration design for treatment compliance and energy efficiency may not always be optimum for process emission minimisation.
6	Membrane Aerated Biofilm Reactor (MABR)	Y	Membrane Aerated Biofilm Reactors (MABR) is one of the most promising technologies that may offer a significant and transformational reduction in nitrous oxide emissions from wastewater treatment, with the drastically lower emissions than conventional activated sludge process, some reporting 80-90% reduction, and other studies approximately 50% reduction. MABR could also offer further potential for emissions reduction, by treating the lower residual nitrous oxide contained in the aeration exhaust air flow, eliminating the need for expensive and cumbersome process covers and presenting a more effective option with multiple benefits.
7	Ammonia recovery or treatment from digested sludge	Y	In contrast municipal wastewater treatment, digested sludge centrate is characterised by significantly higher ammonia concentration (40 to 50 times higher than domestic wastewater) and much lower volume to treat. A high specific emission of nitrous oxide per mass of nitrogen in the wastewater has been reported from the literature and our seen in own monitoring, has led to emissions from centrate treatment becoming an emission hotspot and a priority.
8	Methane emission reductions	Y	Our eight STCs where advanced anaerobic digestion (AAD) (thermal hydrolysis, and biological hydrolysis (Monsal EEH, and Helea HpH)) is practised offered the most efficient potential for reducing methane losses were Great Billing, Cotton Valley, Whitlingham, Cliff Quay, Pyewipe, Colchester, Basildon, and King's Lynn. Solutions specific to particular sites were developed in the context of existing full scale or demonstration plants across the UK or Europe to ensure viability and deliverability.
9	Renewable energy PV	Y - as a 'feasible' not a 'selected' investment in the data tables	PV presents a cost effective way of delivering renewable electricity. However, the relationship between capital costs and the value of the electricity produced can change and therefore in some cases a Power Purchase Agreement (PPA) is the most cost effective mechanism for delivery. However, due to scale a PPA is not viable and therefore we have included some PV investment as 'feasible'

2.2.4 Environmental and social value

Our Value Framework covers a wide range of categories and incorporates environmental and social measures (such as Biodiversity net gain, carbon, traffic disruption and noise) alongside traditional measures such as flooding, interruptions to supply and pollution. This enables us to consider a broader range of benefits and disbenefits of our investments and their alternatives, leading to investment decisions that more holistically consider value and the impacts our actions may have on the environment, customers, and communities.

With the exception of HGV investments, all our enhancement investments are based upon existing sites and involve additions to or modifications to existing plant and equipment with low impact upon the wider society of the environment. Therefore, for net zero enhancement investments particular consideration was given to the carbon savings achieved as a consequence of the operation of the investments and the capital (embedded) carbon emitted as a consequence their construction.

The operational carbon savings associated with the various enhancement investments have been calculated using the emissions factors and method in Carbon Accounting Workbook (CAW) v17 as per Ofwat methodology.

Capital carbon (embedded carbon emissions) has been calculated for the various investments using our in-house tools from cradle to as built.

We have a well established process for calculating capital (embedded) carbon where we have a host of capital carbon models relating to the various assets we design and construct. These models are back to back with financial models within Copperleaf C55, our system for calculating asset costs. Using this process we therefore arrive at both an asset cost and a capital carbon value for each investment.

The process we employ to measure and manage capital carbon is certified annually to PAS2080 (Carbon Management in Infrastructure) and has been the basis for a bespoke capital carbon reduction ODI in AMPs 6 and 7. Further, the models we employ have been used in the development of a proposed low carbon concrete bespoke ODI in AMP8. We believe that using our process we arrive at a robust outcome.

2.2.5 Investment benefits

Each option is assessed from a benefits perspective using Anglian Water's Value Framework. A baseline position is established that captures any current or expected impacts to service, customers, the environment, safety etc (and their respected likelihoods).

Each alternative (i.e. option) is appraised to establish a residual position, with updated impacts and likelihoods. This residual position also considers any additional benefits and disbenefits that may apply as a result of the intervention. These could be permanent (e.g. visual impact) or temporary (traffic disruption during construction) and consider a range of environmental and social measures including both capital and operational carbon.

For each enhancement investment the annual carbon savings have been calculated. These annual savings are presented as cumulative emission savings for each year in table CWW22. These savings have been applied to our performance commitment level (PCL) for our operational greenhouse gas emissions (water recycling) performance commitment (PC).

The net zero enhancement investments proposed within this business plan will both deliver reductions in emissions and provide further insight into different technologies and capital interventions to ensure we can make optimal investments in future AMPs

Process emissions

There are 28 investments delivering the process emissions portfolio across 16 of our largest sites. The investments are categorised as either nitrous oxide or methane mitigation. Whilst these are investments targeting carbon reductions they also promote either capacity or compliance improvements.

As discussed earlier, the production, reduction and removal of nitrous oxide is not well understood within the water sector. These investments will bring additional benefits of increasing knowledge and understanding for Anglian Water and the rest of the water sector such that further optimal investments can be made at PR29.

Fleet decarbonisation

The investment will reflect the replacement of 12 rigid bodied HGVs and 26 articulated tractor units, 4 hook-lifts and 4 tippers with electric equivalents. Costs assume 100,000 miles per year per vehicle at 1.6kWh/mile. This will increase our demand for grid electricity, but that will be purchased as green electricity.

Gas-to-grid

Gas to grid provides the optimal investment in term of cost per tonne of carbon saved using a capex measure.

2.2.6 Managing uncertainty

Process emissions

The main uncertainty associated with the net zero specific enhancement relates to the costs and benefits associated with activities to reduce process emissions. The science in this area is uncertain and is a constantly developing area for which there is currently limited understanding around techniques for emissions mitigation.

To manage this uncertainty a significant part of our investment in process emissions will be to improve monitoring of emissions - a low regret investment that will significantly improve our understanding of the issue over the long-term. The purpose of this investment is to improve certainty and take early action on process emissions, and the certainty of deliverability of these investments is reasonably high as they are existing technologies. We are mitigating supply chain risk by phasing investments over the AMP.

Fleet decarbonisation

The main uncertainty relating to fleet decarbonisation relates to the final solution that we will put in place during AMP8. There are a number of potential solutions which will help to decarbonise the fleet including LNG, electric battery and hydrogen fuel. LNG and batteries are proven technologies in the transport sector more broadly, but are new to us in their application to HGVs, and hydrogen fuel is an emerging solution that currently has high uncertainty.

Gas to grid

The key uncertainty we face in relation to our gas-to-grid investments is the deliverability risk should other companies take a similar approach as thereby pressure is placed on national supply chain resources. Beyond this risk, we consider there is a good degree of certainty in the solution we are proposing, having used technology which is proven and has been used by other water companies.

To mitigate the supply chain risks we issued a Prior Information Notice (PIN) via Find a Tender in spring 2023 setting out our intentions from transition from CHP to biomethane upgrading and grid injection. We have received thirteen expressions of interests from the supply chain and all have recently returned pre-qualification questionnaire, these are under evaluation. Our intent is to progress a procurement strategy for these projects in advance of AMP8 to ensure we are in a strong position to secure capacity to deliver the proposed projects.

2.2.7 External funding

Gas to Grid

The production of biogas and upgrading to biomethane produces a gas of value. This biomethane after our site use is netted off is injected into the national gas grid infrastructure and sold at a commercial rate generating a revenue income stream. The value of the biomethane at the point of sale is directly linked to volatile wholesale gas market prices therefore forecasting of this revenue stream is challenging. There is potential to obtain additional income from green incentive schemes, however at this time it is not clear what incentives will be available for gas to grid schemes as at the current time existing anaerobic digestion facilities that transition from CHP electricity generation to biomethane upgrading and grid injection do not qualify under the current green gas support scheme (GGSS), however we are of the understanding this position may change with future support schemes.

The op ex benefit of the gas to grid schemes has been calculated using estimates for the future value of gas exported and the savings associated with the maintenance of the CHP equipment which will no longer be required. The loss of income from Renewable Obligation Certificates (ROCs) (previously earned from renewable electricity generated by the CHP units) and the additional costs of electricity usage required for the gas to grid schemes have been accounted for in the calculations

Fleet

We forecast an opex saving on fleet as a result of the transition to electric vehicles. This is based on the unit cost of electricity compared with diesel and petrol traditional fossil fuels. As commonly reported the initial purchase capital investment of alternate fuelled vehicles is high that traditional combustion engines but maintenance and operating costs are typically lower.

2.2.8 Direct procurement

We have considered the suitability for our net zero investment for DPC. Considering each investment in the context Ofwat's guidance on DPC we have determined that our net zero investments are not suitable for delivery through DPC. The table below sets out the position of each of our enhancement investments against the DPC criteria.

Table 10 Consideration of investment against Ofwat's DPC criteria

	Process emissions	HGVs	Gas to grid
Size test	No - Less than £200m whole life cost	No - Less than £200m whole life cost	No - Less than £200m whole life cost
Discreteness test	No - Investments are heavily integrated with existing assets	No - Individual investments are less than £5m	No - Individual investments are less than £5m

2.2.9 Customer view

Our engagement on net zero has focussed on the scale and timing of investment in net zero. As identified in our Customer Synthesis Report, customers are supportive of these activities to reduce our carbon footprint but see this as a long-term rather than short-term ambition. We have reflected this within the selection of our options, selecting and developing a multi-AMP strategy which phases improvements across AMPs whilst putting us on the right path to meet our long-term targets. Customers are particularly supportive of efforts to switch to more sustainable sources of energy, which has been reflected where possible in our selected options. Our engagement with customers as part of our value framework has supported our option consideration, but we have not undertaken engaging with customers on the technical solutions we put in place to achieve the overall net zero ambition.

2.3 Cost efficiency

2.3.1 Cost breakdown

The development of the greenhouse gas reduction costs in our plan follows our cost efficiency 'double lock' approach set out in chapter 7of our business plan. Through this approach we have ensured that are costs are efficient in their bottom-up build up, and this is cross-checked through external benchmark approaches. This section sets out how we have ensured cost efficiency of our greenhouse gas reduction investments through step one of our double lock approach. Step 2 is explored in the Benchmarking section below.

We have taken a robust approach to developing our greenhouse gas reduction costs, building on our experience from delivering similar schemes into the bottom-up development of costs (before external cost benchmarking challenges are applied in step 2 of our 'double-lock' approach). The detail of the cost development approach is set out below, along with a breakdown of costs we provide in table CWW3.

Cost estimation methodology

We follow a common cost development methodology across our enhancement investments in a three phase process:

1. Establish cost and carbon models
2. Input the cost drivers into the model (including location specific factors)
3. Data validation, internal challenge and assurance

In phase 2, we derived our total cost estimation for each scheme by gathering location based data which influences the cost estimates for each scheme.

For the three ‘Gas to Grid’ investments we have used supplier quotes to obtain outturn costs for this plant as we have not installed this previously. The cost models have been used to cost additional items required outside of the those covered by supplier quotes.

For the Methane (CH_4) investments we are proposing to capture additional methane post digestion to reduce our greenhouse gas emissions at 8 of our sites.

We derived our scope for each scheme through technical review with Mott MacDonald. The key cost assumptions and estimations have been built using both the cost models applicable to each asset and the on-site design information to inform our cost estimation for PR24. The estimations have been built using the design information available at each site alongside the cost models applicable to each asset. The vacuum degassing system is new to Anglian Water so quotes were obtained and costed accordingly.

For the nitrous oxide investments we are proposing two different approaches. One for Sludge Treatment Centres (STCs) and on for Water Recycling Centres (WRCs).

For our STCs with existing liquor treatment plants, we are proposing to cover, capture and treat the off gasses to remove nitrous oxides, this was scoped using parametric models. We are also proposing to install new liquor treatment/recovery plants on two of our largest STCs, this reduction in load returned to the WwTW will result in a significant reduction in the generation of nitrous oxides, the liquor treatment is a known technology and has been scoped ground up using existing cost models, liquor recovery has been developed using budget quotes for the package plant and cost models for the remaining infrastructure.

Nitrous oxide optimisation on our WRC’s comprises of 4 different stages, the options were developed by Jacobs and presented as a matrix approach of layered investment options. These include the following

- Real time control seeks to optimise the conditions within an aeration ditch to minimise the production of nitrous oxides, two companies have provided budget quotes for varying sizes of install, as well as a recommendation for additional sensors required to operate.
- The extension of anoxic zones
- The upgrading of current aerators
- MABR plants are a new and novel technology, a budget quote was provided for the MABR cells and P&IDs for three sites, Jacobs also received similar for other water companies and used this to generate a basic cost curve. We have used the P&IDs for our sites to validate this curve.

Where project construction elements can be broken down into major work elements such as Membrane Aerated Biofilm Reactor (MABR), monitors assessing Nitrates, dissolved Oxygen and Ammonia and odour control units, these costs are estimated individually by using the parametric cost models and the on-site design information and then aggregated to inform our cost estimation for PR24.

Table 11 Investment cost breakdown

Investment ID	Investment name	Scope	Capital Cost £m AMP8	OPEX cost £m (25-30)
I019824	Cotton Valley STC - Centrate quality	* Liquor Treatment Plant *Feed PS *Return PS *Building *Telemetry *Ancillaries (Landscaping, Roads, Fencing	14,376	191

Investment ID	Investment name	Scope	Capital Cost £m AMP8	OPEX cost £m (25-30)
I039067	Cotton Valley STC gas to grid	Site specific *Biomethane package plant *Pipework *Site CCTV, lighting and telemetry	7,513	1,796
I039073	Great Billing STC gas to grid		5,403	1,620
I040415	Whitlingham STC Gas to Grid (AMP8)		9,433	1,437
I040368	Cotton Valley STC Fugitive emissions CH_4	*Aeration M&E in digestion tank *Chamber *Odour Control *Vacuum Degassing System *Post digestor tank cover	5,083	-14
I040722	Great Billing STC Fugitive emissions CH_4		3,656	-741
I040725	Whitlingham STC Fugitive emissions CH_4		2,426	-348
I040727	Cliff Quay STC Fugitive Emissions CH_4		4,048	-168
I040729	Pyewipe STC Fugitive emissions CH_4		4,063	-250
I040731	Colchester STC Fugitive emissions CH_4		3,689	-166
I040732	Basildon STC Fugitive emissions CH_4		4,101	-54
I040742	Kings Lynn STC Fugitive emissions CH_4		4,098	-218
I040745	Cotton Valley WRC Fugitive emissions CH_4	*Tank Cover	154	-
I040748	Basildon STC Fugitive emissions N_2O	*Odour Control *Tank Cover	1,548	14
I040750	Colchester STC Fugitive emissions N_2O		1,433	68
I040751	Cliff Quay STC Fugitive emissions N_2O		1,592	14
I040769	Whitlingham STC Fugitive Emissions N_2O	*Odour Control	692	12
I040863	Cotton Valley WRC Fugitive emissions N_2O	*RAS Pumping Station *Anoxic Mixer *Monitors *Scada	5,647	224
I040883	Great Billing WRC Fugitive Emissions N_2O	*Aeration M&E *Monitors *Scada	10,546	-

Investment ID	Investment name	Scope	Capital Cost £m AMP8	OPEX cost £m (25-30)
I040920	Bedford WRC Fugitive Emissions N_2O	*Aeration Diffusion Pipework *Monitors *Scada	1,133	-
I041295	Huntingdon WRC Fugitive Emissions N_2O		2,791	-
I040974	Broadholme WRC Fugitive Emissions N_2O		727	-
I040937	Kings Lynn WRC Fugitive Emissions N_2O	*Monitors *Scada	952	-
I040943	Newton Marsh WRC Fugitive Emissions N_2O		447	-
I041099	Letchworth WRC Fugitive emissions N_2O	*RAS Pumping Station *Aeration Diffusion Pipework *Anoxic Mixer *Monitors *Scada	11,341	14
I041106	Hitchin WRC Fugitive emissions N_2O		1,331	71
I040918	Basildon WRC Fugitive Emissions N_2O	*Anoxic Mixer *Monitors *Scada	2,773	5
I041105	Newmarket WRC Fugitive Emissions N_2O		4,597	11
I041114	Dunstable WRC Fugitive Emissions N_2O	*Aeration M&E *RAS Pumping Station *Anoxic Mixer *Monitors *Scada	12,244	57
I041200	Flitwick WRC Fugitive Emissions N_2O		6,270	183
I041224	Great Billing STC Liquor Ammonia		6,946	433
		Total 31 sites	141,053	4,189

Table 12 Investment cost breakdown -- HGV and Gas to Grid

	Units	Capital Cost £m AMP8	OPEX cost £m (25-30)
HGV	48	11,325	-3708
Gas to grid renewable incentive opportunity			-5,456
	Total	152,378	**482**

2.3.2 Benchmarking

In stage 2 of our cost efficiency 'double-lock' on greenhouse gas reduction, we used a variety of methods to assess, benchmark and challenge the costs in our plan.

To cross-check the costs we are including in our plan we have sought external cost benchmarks. Given the relatively sector specific nature of the activities included in this area of enhancement (e.g. reducing process emissions) and cost data has not historically been collected on an industry basis, data for cost benchmarking is limited.

We have sought alternative methods to understand the efficiency of our costs by assessing the available parametric models from WRCs TR61. However, no comparable data is available as our aeration plant requirements are Membrane Aerated Biofilm Reactor (MABR) which are much larger complex designs than the standard aeration plants.

In light of the absence of external cost benchmarking data, we have sought assurance of the robustness of our cost estimates through embedding market tested costs into our plan. The cost estimation methodology described above sets out how we have applied this approach across our greenhouse gas reduction investments. We therefore have confidence in the robustness of our cost estimates in this area.

2.3.3 Assurance

The costs estimates have been developed using our C55 cost estimation tool for which we have had third party assurance from Jacobs.

2.4 Customer protection

If our greenhouse gas reduction enhancement is cancelled, delayed or reduced in scope, customers are protected by the Net Zero Price Control Deliverable which we have included in our business plan. This PCD is based on the tonnes of CO_2e of greenhouse gas emissions reduced.

By setting the PCD at the level of CO2e reduction, this ensures that the full benefits of this investment (which are specifically to deliver greenhouse gas reductions which are not delivered from other parts of the plan) are covered by the PCD.

For more detail on our Net Zero PCD, please refer to our 'Price Control Deliverable' appendix. [17]

17 ANX ANH37

In addition to the PCD, our PCL for our operational greenhouse gas emissions (water recycling) PC has been set in line with the benefits of these investments. If they are not delivered we will also incur a penalty for this PC.

3 Sludge

Overview

- This investment is comprised of five elements:
  - New Sludge Treatment Centre capacity
  - Adaptive planning
  - WINEP investments related to the no deterioration driver
  - IED containment
  - Enhancements to open cake storage
- Sludge is a valuable output of our water recycling process which should be treated as a resource that can deliver environmental and economic benefits rather than waste.
  - Sludge enhancement is specified by the EA under the WINEP no-deterioration and improvement drivers. Further to this, additional resilience capacity is required within our STC network to mitigate against seasonal sludge production peaks, improve operational resilience, reduce environmental compliance risks associated with buffering and manage sludge stocks.
  - We will invest £199 million, including £60m to construct additional cake pads to store sludge and £37m on investment to expand sludge treatment and disposal to provide new capacity for growth
  - We have considered the potential for non-traditional and nature-based solutions for bioresources. At present there is no viable technical nature-based solution for the treatment and safe recycling of sewage sludge and associated bioresources products at the scale required at this current time, however we recognise non-traditional options may become available in the longer term.
- We partnered with the COCE Alliance to undertake bottom-up benchmarking of our bioresources costs.

Table 13 Investment Summary

PR24 costs (£m)	
Capex	169.8
Opex	29.6
Totex	199.4
Benchmarking	
Method	Scheme outturn costs. Asset level cost comparison with other companies.
Costs removed	Benchmarks showed our costs to be similar in line with the upper quartile benchmark.
Customer Protection	
Price Control Deliverable	Bioresources - sludge capacity
Ofwat data table	
CWW3.137-CWW3.139	Sludge storage - Cake pads / bays / other; (WINEP/NEP)
CWW3.143-CWW3.145	Sludge treatment - Thickening and/or dewatering; (WINEP/NEP)
CWW3.146-CWW3.148	Sludge treatment - Other; (WINEP/NEP)
CWW3.162-CWW3.164	Sludge enhancement (growth)
CWW3.185-CWW3.186	Bioresources Resilience
CWW3.187-CWW3.188	Bioresources - Non WINEP cake pads
CWW3.189-CWW3.190	Bioresources - IED and Reg changes

3.1 Delivering for the long term

3.1.1 Investment context

Investment is required to mitigate key risks in AMP8 including:

- Surface water nutrient pollution - by providing enhanced sludge storage with dutch barns to prevent re-wetting of treated sludge, enhanced dewatering at three STC sites and purchase of more accurate sludge spreading equipment

- Increased resilience - by investing in additional sludge treatment capacity to avoid storing of backlogs of untreated sludge during seasonal production peaks in winter and spring. This will improve out end to end operational resilience across the bioresources price control
- Increasing capacity - by investing additional capacity to cater for new housing growth in our region as well as the additional sludge that is produced by enhanced WRC treatment techniques such as nutrient removal schemes

These risks are driven by:

- population growth within the region, equating to an annual increase of 3.093TTDS per annum by 2030 compared with 24/25;
- the requirement for additional sludge production arising from the proposed WINEP programme; we forecast this to increase sludge production by 8.211TTDS by 2030
- tightening environmental regulations (such as potential revisions of Farming Rules for Water)
- and Operational resilience

Sludge enhancement is specified by the EA under the WINEP no-deterioration and improvement drivers. As these investments are statutory and are mandated by WINEP for AMP8, there is no option for this to be deferred until later AMPs.

Further to this, additional resilience capacity is required within our STC network to mitigate against seasonal sludge production peaks, improve operational resilience, reduce environmental compliance risks associated with buffering and manage sludge stocks. Insufficient capacity to receive and treat raw sludge will lead to sludge removal being inhibited at regional Water Recycling Centres (WRCs), risking failure to comply with environmental standards and permits and posing a risk to the environment,

Using our value framework we have assessed the risk if no additional capacity was provided, this equates to £6.7m per annum.

Table 14

Value Framework Category	Description	Rationale	Risk (£k)
Natural Capital	Permit compliance & effluent discharge quality	Permit compliance - raw cake storage Risk to final effluent quality due to inability to move sludge out for STC's during times of high sludge production	£748.10
Social Capital	Odour, noise nuisance, PR	Double handling of raw cake, storage, mobile lime treatment and recycling	£3342.77
Manufactured Capital	Additional costs / loss of revenue	Assumed surplus sludge is treated by mobile lime stabilisation resulting in increased opex costs £/tds	£2609.28

Without the additional capacity set out in this enhancement investment, we forecast a minimum of 7000 tonnes of dry solids (tds) would require storage and alternative treatment, equating to 28,000 tonnes per annum of raw cake by 2029/30 in a best case scenario (we expect this could be 20% greater under a central estimate.

Our only current options for this additional raw cake would be to either; utilise mobile liming and recycle to land, export to land reclamation or trade with a third party, such as a neighbouring water company. Mobile liming creates significant odours and is not a sustainable basis for the future. Land reclamation opportunities are sporadic and cannot be relied upon as a continuous outlet and our neighbouring water companies face similar seasonal trends in capacity versus production that we do, resulting in periods where no surplus capacity exists.

Sludge is a valuable output of our water recycling process which should be treated as a resource that can deliver environmental and economic benefits rather than waste. Currently the regime for bioresources is complex due to changing regulatory requirements, market challenges, and the role of sludge in meeting net zero targets. Our investment plan has been developed to meet these challenges and ensure operational resilience whilst enabling and permitting flexibility of approach in future AMPs.

As outlined in our SDS we are committed to our long-term ambition to be a carbon neutral business and to support sustainable growth in the East of England, one of the fastest growing regions in the UK. Essential to meeting these ambitions is an integrated, sustainable and innovative bioresources strategy, utilising and maximising the potential of emerging sludge markets where possible.

3.1.2 Scale and timing

Presently we have little headroom with our sludge treatment asset base as demonstrated within the Sludge Production vs Capacity Graph below. This shows expected sludge volumes produced in Network plus (red line) over the year and the capacity provided by Sludge Treatment Centres in Bioresources under different scenarios, the horizontal lines represent available capacity at out STC under the following scenarios;

a Blue solids line is with the proposed 23TTS additional capacity at an average STC uptime of 85%

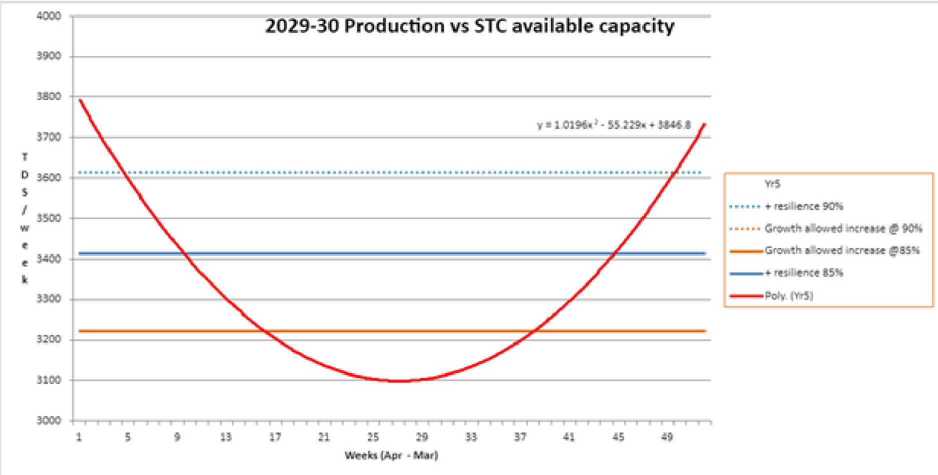
b Dotted blue line is as scenario A but at 90% average STC uptime

c Solids orange line is with no additional resilience capacity, therefore only includes the 11.304TTDS additional capacity to cater for growth and extra sludge production arising from WINEP

d Dotted orange line is as scenario A but at 90% average STC uptime

At times where the red production profile exceeds the horizontal capacity lines we have a forecast a capacity shortfall, this results in either balancing sludge stocks through storage, use of mobile lime stabilisation or finding alternative outlets. We consider it is not viable to balance and manage sludge stocks in scenarios C & D.

Figure 4 Production vs STC available capacity



This graph illustrates that presently for 20-30 weeks of the year we produce more sludge at our WRCs than we have capacity to treat. This risk has until now been managed through a combination of trading sludge, diverting raw sludge cake to land reclamation, buffer storage of cake to process later in the year, and mobile treatment via lime stabilisation and storage of lime treated biosolids cake. However, these options are not sustainable in the medium to long term: failure to sustain reliable, regular removal of sludge from Water Recycling Centres for treatment presents a risk to WRC compliance, odour nuisance and pollution risks from raw cake storage and temporary operations. Market and mobile temporary treatment cannot be guaranteed to provide sufficient capacity to mitigate these risks. Therefore these options do not provide resilient solutions to protect the bioresources supply chain.

The forecast graph also illustrates that if no new capacity was provided in AMP8, despite continuing to target 85-90% uptime across our bioresources asset base, our sludge production would outstrip our STC available capacity for over 33 weeks of the year by the end of the period. This would, in the worst-case scenario, require us to store 28-33,600 wet tonnes of untreated sludge cake for treatment later in the year or by alternative means such as mobile lime stabilisation, which we do not deem a resilient or reliable solution. We have worked with WaterUK via Atkins and through the innovation fund to understand whether smaller capacity increases (e.g. trading) could be sufficient to replace the need for additional new capacity. Through this, we found there was insufficient capacity across England and Wales to manage these peaks, and therefore we cannot plan for additional capacity to be provided by others. We have used our tactical bioresources network tactical modelling tool to support our assessment of options.

Available STC treatment capacity is a significant risk. Our plans for 2025-30 assume additional new treatment capacity of 23,000 TTDS per annum being made available by 2030. The graph in figures below shows the modelled risk profile with and without this capacity.

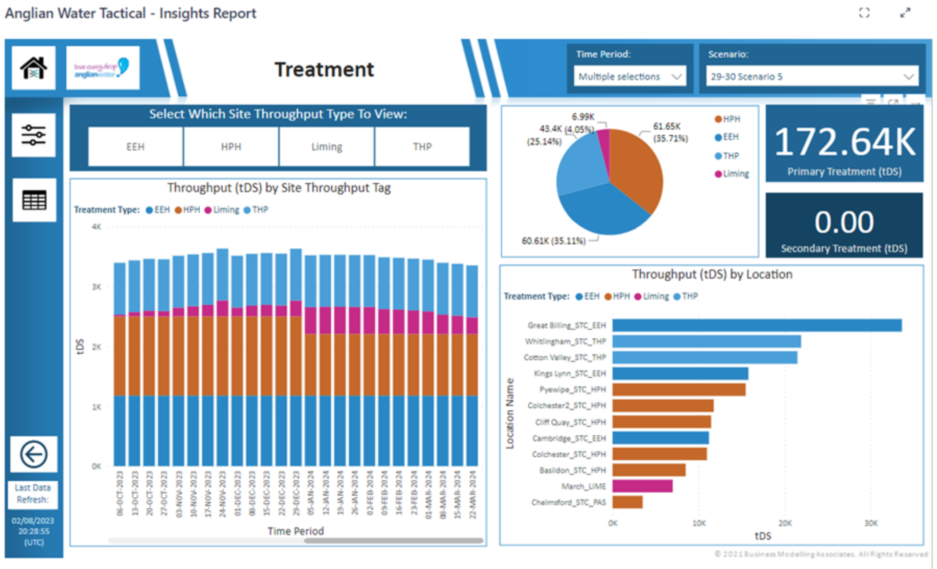
The two charts are output visuals taken from our Bioresources Tactical Planning Model. The model acts as a decision support tool where we can test and compare scenarios over up to a 60 week timeframe.

The first chart we have modelled a scenario with no new available sludge treatment capacity whereas the second chart is the output where the new proposed 23TTDS capacity is constructed and available. The first chart output shows we cannot treat all of the sludge produced and solve the model, in this instance the model assumes we would need to treat a proportion of the sludge using mobile lime stabilisation, this is represented by the pink bars on the throughput and location charts and the pink segment on the pie-chart. The second chart shows the model solves without the need for mobile lime treatment.

Mobile liming is the default selection in the model where we have insufficient available permanent capacity, however, in reality this option is not popular and we would rather consider a variety of available options such as trading with other

WaSC's/Third parties or other alternatives such as use of land reclamation. However, these outlets are not guaranteed to be available and would be assessed on a case by case basis versus lime stabilisation as and when the need arises.

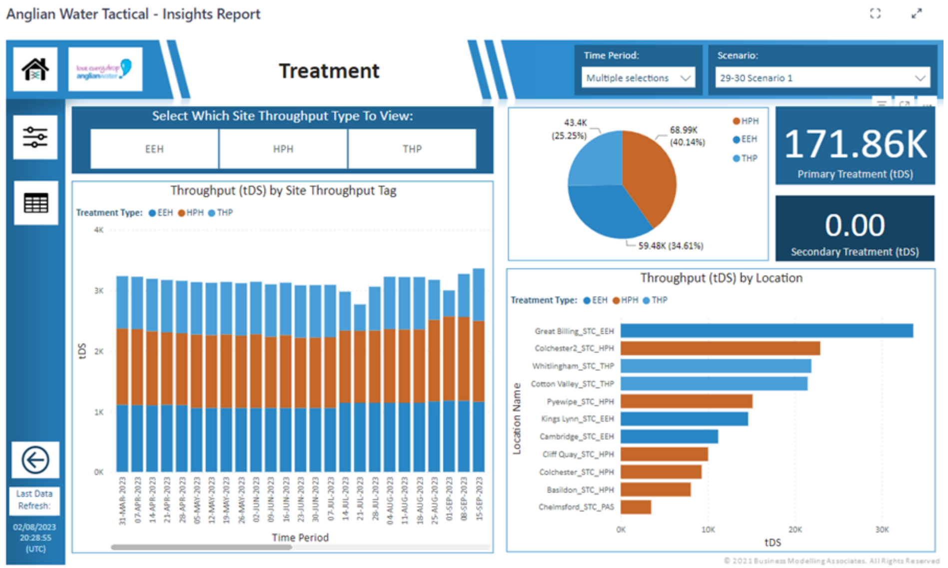
Figure 5 2029-30 modelled risk position (no new capacity provided)



This forecasts that at the most optimistic modelled case we would require to export 7TTDS to other treatment. Model assumes that this is mobile lime stabilisation but this could be to a third party or land reclamation. The risk is that there is no guarantee that these alternative outlets are available, therefore our enhancement plan assumes we require the additional 23,000TDS capacity to ensure we have a resilient asset base to manage the forecast sludge production.

Our base plan with the additional capacity is least risk. In this scenario all sludge is modelled to show all sludge produced in area can be recycled and treated throughout installed available capacity as demonstrated above.

Figure 6 Extract from BMA tactical model - breakdown of through put by STC with proposed 23TTDS additional STC capacity



This assessment of headroom and additional capacity requirements has been reaffirmed by CIWEM and Atkins, who were commissioned by WaterUK to compare capacity and headroom across the industry and co-create a long term national bioresources strategy for the safe, sustainable management of bioresources up to 2050 [18]. This report concludes that inter-company trading is insufficient in AMP8 and beyond as the industry does not have significant headroom to manage stocks through trading, and must look to increase capacity in the short to medium term. This assessment also reflects the shift to Environmental Permit Regulations under the EA Sludge Strategy and the subsequent lag time on spreading cake to land and the implications for cake storage.

In addition, **sludge enhancement is specified by the EA under the WINEP no-deterioration and improvement drivers. As these investments are statutory and are mandated by WINEP for AMP8, there is no option for this to be deferred until later AMPs.** This supports the recommendation of the Atkins industry-commissioned long-term strategy report for companies to have a minimum of 3 months storage for covered treated cake and to increase this to 6 months storage over time. The increase from 3 - 6 months covered storage is

18 https://www.water.org.uk/sites/default/files/2023-09/WaterUK_BioresourceStrategy_FullReport_V2_15.08.23.pdf

linked to the aim of the EA sludge strategy to move from Sludge Use in Agriculture Regulations over to EPR, Atkins advised that the average time to obtain permits for deployments to allow treated biosolids to be delivered to farmers is likely to significantly increase meaning more storage will be required on the water company sites.

The need to deliver additional capacity and resilience capacity in AMP8 is driven in part by the uncertainty surrounding the Farming Rules for Water (FRfW) Guidance Review scheduled for 2025. Currently, we are entirely reliant on agricultural recycling for our biosolids production, and have already faced pressures (i.e., extreme weather events preventing access to land, stricter limits on levels of phosphate in biosolids to be spread to land). The EA has confirmed that if the Defra statutory guidance in relation to enforcement of the FRfW is removed, application of biosolids cake in the autumn, ahead of crops with no immediate fertiliser nitrogen requirement, would not be permitted. Modelling by Grieve/ADAS indicates that a ban on autumn applications ahead of cereal crops would result in AWS having insufficient land to recycle its biosolids to agricultural land (Please refer to 'National Landbank Assessment Report' and 'Anglian Water Landbank Assessment Report', attached as appendices to our plan, for more detail). We have sought to mitigate this risk through a clear LTDS adaptive pathway trigger in this eventuality, in which we consider the additional capacity proposed within this AMP8 investment to mitigate this risk to be low risk.

One of the conclusions of the National Bioresources Strategy was that investment is required to accelerate the development of alternative technologies to address challenges posed by tighter environmental regulations and other emerging risks that impact on availability of agricultural land to sustainably recycle products from bioresources such as treated biosolids cake. At present the only viable and deployable technology that can be implemented at scale is incineration, however the strategy recognises the role that emerging alternative technologies can play in future scenarios and the added value circular economy benefits such technologies such as Advanced Thermal Conversion (ATC) offer.

Figure 7 Extract from the WaterUK Long Term Bioresources Strategy Report (section 7.3 Additional Research & Development Needs)

Thermal conversion

- Investigate the technological readiness and future potential of non-biochar forming ATC technologies.
- Research the different technical solutions for hydrogen production (methane cracking, syngas cleanup etc.) in preparation for the UK Govt. decision on the roles of methane vs hydrogen.
- Study to determine the regulatory framework of recovery of biochar in the agricultural market and other markets, and comparison with other countries to determine the best direction of travel for the UK.

At present with no clearly defined regulatory pathway for change and the absence of regulatory frameworks for the products these alternative technologies provide, such as BioChar there is limited inertia within the technology sector to accelerate technology development. Therefore, there is an acknowledged risk that without positive intervention to invest in exploration, understanding and scaling of these emerging technologies and close collaboration with our regulators, academic and scientific communities to build the regulatory frameworks incineration will likely remain the only viable and deployable option. Our investment of £10m over AMP8 is targeted at enabling this development and change with the aim of unlocking future opportunity that will both underpin our long term bioresources strategy out to 2050 and support our Net Zero and Circular Economy ambitions.

We have included investments at our STCs to ensure compliance with new Industrial Emissions Directive (IED) permits. We include only investments we consider to be new enhancement requirements and this is in alignment with our response to the Ofwat letter and data request issued to water companies on 1stAugust 2023.

Our enhancement investment is for secondary containment in accordance with BAT guidance and CIRIA 736 requirements[19]. The investment comprises of new containment walls, bunding, impermeable areas based on outcome and recommendations from spill modelling carried out as part of the permit application process. Final acceptance and detail design of the containment solution are subject to improvement conditions and require environment agency approval as part of the permitting process.

19 https://www.gov.uk/guidance/best-available-techniques-environmental-permits

Our enhancement case also reflects the increase in operating costs for additional monitoring, inspections and sampling in order to meet the required BAT conditions. We have only included items we consider to be enhancement over base expenditure as outlined in our response to the 1st August 2023 Ofwat data request. Items include, frequent routine return liquor sampling, bioaerosol risk assessments and enhanced monitoring of odour control systems, written scheme and regular inspection of tanks and associated assets by specialist qualified structural engineers.

3.1.3 Interaction with base expenditure

This expenditure enhances the capacity of our sludge treatment by 23TTDS to cater for increased sludge levels because of growth in the region and tightening environmental standards (11.304 TTDS included As Sludge enhancement (Growth) expenditure (CWW3.162 and 3.163))) and to provide enhanced operational resilience to cater for seasonal sludge production to improve resilience across the bioresources value chain is included in the table below (11.696TTDS included as Bioresources resilience expenditure (CWW3.185 and CWW3.186)).

The table below sets out the activities which we consider to be base and not included in this enhancement investment, related enhancement activities which are included in other parts of our plan and the activities which are included in our plan as sludge enhancement.

Table 15

Base	Enhancement included in other portfolios	Enhancement included in this area
Our base expenditure plans are modelled to maintain current levels of performance across the bioresources price control. This includes for the required refurbishment and/or renewal of assets when at end of life for example tanks, CHP engines, dewatering plant. Our base programme is also targeted to improve efficiency (end to end cost of sludge treatment) through optimisation programmes including energy efficiency, process optimisation to improve conversion efficiency (MWh/TDS) and dry solids efficiency reducing transport carbon and cost.	Net Zero - Gas-to-grid	WINEP - Covered cake storage Enhanced Dewatering Precision Spreading Equipment
-	Net Zero - Process Emissions Reductions CH4 (post digestion)	Resilience - Additional sludge treatment capacity (11.696TTDS of total 23TTDS proposed) Adaptive Planning Future Technology R&D
-	Net Zero - Process Emissions N2O reductions (Sludge Liquor Treatment	IED - Spill containment enhancements in accordance with new permitting requirements for BAT and CIRIA 736
-	-	Cake Storage - Enhancements to our open storage cake pads

Investment to make improvements to our cake storage facilities (as driven by WINEP no deterioration & sludge improvement drivers) constitutes enhancement and not as base expenditure because:

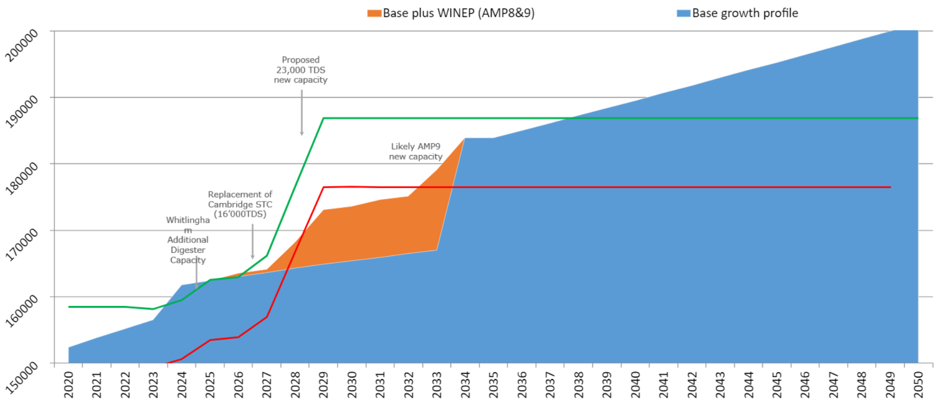
- It provides a significant enhancement in our storage capacity. The area of covered storage provided by the WINEP investments is 101,940 m2, providing capacity for over 122,328 m3 of treated cake and therefore against the WINEP drivers for increased resilience in the sludge supply chain to agriculture.
- It improves resilience in the agricultural supply chain.
- The provision of enhanced drainage and covering with dutch barns will prevent water logging allowing run off to be more effectively managed, whilst securing the integrity, storage characteristics and quality of the treated products to be delivered to our farmer customers.

3.1.4 Long term context (historic)

There is no investment overlap or duplication of activities or services levels with what has been delivered in previous AMPs. We have made investments during each price review period to ensure that we maintain sufficient capacity to treat all raw sludge produced because of our water recycling operations, though such investment is distinct from the proposed expansion of capacity in this instance.

In AMP7, we invested to increase capacity at our Whitlingham Sludge Treatment Centre by 6.4ttds to cater for growth and additional sludge due to tightening environmental standards. The delivery of this additional capacity at Whitlingham STC will be measured at the end of AMP7 through our end of period bespoke PC as a protection mechanism for customers.

Figure 8 Sludge production vs capacity over time



The figure above illustrates our forecast sludge production from 2020 to 2050 and overlays our available incumbent capacity at 85-90% uptime, these are typical uptime values used across manufacturing and production industries. The green line denotes that capacity is at 90% availability (TDS/y), and the red line that capacity is at 85% capacity. The graph includes our AMP7 investment at Whitlingham STC, providing an additional 6.4TTDS by 2025 together with a planned 4TTDS increase at Cambridge as part of our plans to relocate our WRC and STC, and finally our proposed 23TTDS AMP8 investment.

3.1.5 Long term context (future)

Our bioresources strategy is aligned to our long-term net zero ambitions captured within our LTDS. Our core pathways for bioresources and net zero sub strategies are aligned to maximise benefits in supporting our net zero ambitions. This includes continuation of our strategy to treat sewage sludge by advanced anaerobic digestion and recycling high quality biosolids products to agriculture. Biogas created through the sludge treatment process will continue to be used as a valuable resources to generate renewable heat and electricity at our STC sites, however we will transition three sites to biomethane upgrading and grid injection as existing renewable incentive schemes end and engines reach end of life. We also include investments to support de-carbonisation of our bioresources logistics fleet by investing in electric trucks and investments to reduce process emissions across our bioresources operations, this includes covering, capture and beneficial use of biogas from tanks downstream of the digestion process and recovery of ammonia from return liquors that will reduce nitrous oxide emissions from our processing of this waste water stream.

Loss of agricultural land bank would have a significant negative impact because incineration is the only currently viable alternative technology. Incineration of sludge would mean that we would not generate the biogas currently used to generate renewable heat and electricity. Furthermore, it would required additional fossil fuels to ensure stable incineration of the sludge cake, thus having a doubly negative impact on our overall emissions.

To mitigate this risk we have included within our core pathway a significant investment to accelerate the development to full commercial scale of more sustainable advanced thermal conversion (ATC) technologies such as Pyrolysis. The investment is aligned to the research & development needs identified in the WaterUK Developing a long-term strategy for bioresources in England report [20]. This includes investigating the technological readiness and future potential of non-biochar forming ATC technologies, research the different technical solutions for hydrogen production (methane cracking, syngas cleanup etc.) in preparation for the UK Govt. decision on the roles of methane vs hydrogen and studies to determine the regulatory framework of recovery of biochar in the agricultural market and other markets, and comparison with other countries to determine the best direction of travel for the UK.[21]

We have updated our 25 year strategy for Bioresources. The strategy is closely aligned to the conclusions and findings from the WaterUK Report - Developing a long-term strategy for bioresources in England published in 2023.

Our updated strategy sets out the following key ambitions for bioresources over the period to 2050, these are;

- Safe, efficient, sustainable treatment of sewage sludge meeting future demands, reflecting population growth and tightening environmental standards that lead to forecast increased sludge production of up to 173.1 TTDS by 2030.
- Production of high quality bioresources products for onward beneficial use. This will align with principles of the circular economy, zero waste and positively support our wider business goal on Net Zero.

20 https://www.water.org.uk/sites/default/files/2023-09/WaterUK_BioresourceStrategy_FullReport_V2_15.08.23.pdf
21 Please refer to section 2.2.6 'Bioresources' in our LTDS for more detail.

- Embrace innovation, enable diversification of product types to open new markets, strengthening operational resilience, exploiting opportunities and mitigating risks across the bioresources value chain.
- Ensure our bioresources activities are resilient and adaptable to change, this achieved through a systemic adaptive planning approach, embracing markets and pursuing low regret, best value investment strategies.
- Support enablement and growth of emerging bioresources markets, collaborating with the supply chain, water companies, wider waste sector and regulators to ensure robust, resilient market solutions can be offered and contracted meeting the current and future needs of the sector.

We support the finding of the recent report by CIWEM and Water UK 'Developing a long-term strategy for bioresources in England' which identified the need for greater certainty of approach for managing bioresources to "support the delivery of national policies, improved environmental outcomes, better planning and investment decisions for WaSCs, as well as the development of a productive bioresources market". As the industry route map demonstrates, there are several potential pathways to deliver these goals which will require flexibility of strategy. Therefore, in addition to the creation of additional capacity within this investment, we stress the importance of further research and development in AMP8 to improve confidence in alternative strategies due to the lead time to deploy in future AMPs.

We note that currently the options companies can explore are significantly limited by regulatory uncertainty, which will require collaboration between regulators and companies to overcome and would support companies in developing strategies and pursuing innovative technologies. Examples of this include biochar, which currently due to lack of regulatory support cannot be spread to land bank. While initially investment in new technologies may make companies appear inefficient when comparing spend, over the long term this will most likely improve the efficiency of the asset base and reduce the likelihood of being 'locked' into less efficient and beneficial options.

Discussion with the EA has resulted in incineration being removed from AMP8 investment into an adaptive pathway and phased into AMP9. The EA has stated it cannot support transition to incineration or alternative technology in AMP8 under a WINEP driver. In addition, we have removed investment in incineration strategies from AMP8 as immediate investment would close off other strategies or make them more difficult to justify in the future due to high assets value of installation, missing opportunities to embrace new technologies which generate greater environmental and social benefit (I.e. bio polymers).

3.1.6 Customer support

The need for investment is driven primarily by statutory requirements or the need to create capacity to ensure we can continue to run our operations rather than customer support for discretionary spend.

Nonetheless, we have sought to ensure our proposed investment is consistent with customer support for our ambition in other areas. As identified in our Customer Synthesis Report, customers are supportive of our efforts to reduce our carbon footprint and utilise alternative forms of renewable energy. Our package of investments for bioresources (such as the removal of incineration from the plan) coupled with our net zero investments such as Gas to Grid and addressing process emissions all support meeting this customer ambition. We also note that improving river water quality and reducing pollution is a customer priority for PR24, for which our proposed investment into storage has been designed to significantly reduce the risk of this occurring.

3.1.7 Cost control

The investment is driven by factors outside of management control. As the data on forecast production vs STC capacity in an earlier section illustrates, the ultimate driver of population growth is the primary need for additional capacity, which is outside of company control. Additionally, tighter environmental regulations (i.e., associated with the P-programme) have subsequent consequences on the avenue of sludge recycling to land bank, which also drives the requirement for additional capacity.

We have also taken steps to ensure the efficiency of the relevant costs. We have engaged with and driven forward developments in the sludge markets during AMP7. An example of this is successfully leading an Ofwat Innovation Catalyst Fund project on 'Unlocking Bioresources Markets' with a specialist SME - Business Modelling Applications and four neighbouring WaSC's, Northumbrian Water, Yorkshire Water, Thames Water and Southern Water.

We have followed this up by issuing a PIN (Prior Interest Notice) to the market for our proposed AMP8 new 23 TTDS capacity investment. 20 companies have responded to the notice but only 8 of those companies have gone on to respond to the pre-qualification questionnaire and we are currently evaluating responses and planning the next steps. However, it should be noted no neighbouring WaSC responded and since we issued the PIN two suppliers who we consider would have the capability to design, build and operate a facility have withdrawn interest stating at present due to regulatory uncertainties and unproven nature of alternative treatment technologies they feel unable to offer a long term solution.

"We haven't been able to find a consortium lead to partner with to provide design or other professional services, and our conversations with contractors have shown that they have relatively low interest in entering the Bioresources market in this way".

"We have discussed internally and at this stage we will unfortunately have to withdraw from the process. This is due to the amount of live project work and available solutions at present"

Nonetheless, at this time given the high levels of environmental and economic uncertainty outlined above, we require investment to increase headroom at our STCs by a sufficient level to mitigate the risk of limited headroom across the industry limiting possibilities for inter-company trading (as outlined by the National Bioresources Strategy). We are hopeful this will aid in opening up sludge markets in future AMPs.

We have also considered the possibility of utilising other avenues for funding for R&D of innovative technologies and will continue to engage with the Ofwat Innovation Fund for the development and scaling of solutions where appropriate. However, given the scale of the challenge to enable alternative thermal conversion technologies, criticality of timing to ensure these technologies are market ready and a viable alternative to incineration as the land bank declines, together with having in place appropriate regulatory frameworks for beneficial recycling of products such as BioChar our assessment is the total cost would be in excess of £100m over the next 5 years. £10m represents our reasonable share of the total cost.

In our assessment of costs for the future technology investment we have assessed the size and share of investment. Our fair share is based on the proportion of sludge treated and produced as biosolids. In our view it is critical that the investment across the sector is of significant scale to generate sufficient inertia for the supply chain to develop advanced thermal technologies together with appropriate data and evidence to facilitate creation of regulatory frameworks to allow beneficial use of products such as BioChar within a wide range of markets.

3.2 Unlocking greater value for customers, communities and the environment

3.2.1 Option consideration

For each of the investment areas, we have considered a wide range of potential options before selecting our preferred option to meet the required need. We have considered the potential for non-traditional and nature based solutions for bioresources, but found no unconstrained options available for bioresources. This is because at present there is no viable technical nature based solution for the treatment and safe recycling of sewage sludge and associated bioresources products at the scale required at this current time, however we recognise non-traditional options may become available in the longer term (10-15 years) as the biorefinery/bio-organic engineering solutions and markets sufficiently develop to a point these solutions are commercially viable.

Bioresources capacity improvements

As outlined in our Options Assessment Reports (OAR) and Options Development Reports (ODR) submissions to the Environment Agency, three options were considered to address the capacity challenge and provide resilience to meet seasonal production peaks.

Table 16 Options considered throughout the optioneering process (bioresources capacity improvements)

Option	Description	Unconstrained	Constrained	Feasible	Outcomes/ Comments
New sludge treatment capacity at Colchester for 23 TTDS per annum.	Preferred option is for a new advanced anaerobic digestion facility with liquid and raw cake reception, biogas handling with biomethane upgrading for grid injection, enhanced dewatering for final treated cake to achieve a target of 40%DS in final product and a 3 month capacity final product store (dutch barn).	Yes	Yes	Yes	Additional Line 3 (CWW3) for resilience capacity & growth (CWW3.162/3)

Option	Description	Unconstrained	Constrained	Feasible	Outcomes/ Comments
Increased treatment capacity at Cotton Valley STC and upgrade of our Pyewipe STC facility to provide 6.9 TTDS of additional capacity	Alternative also includes 12,000m2 of strategic raw cake storage in a fully enclosed facility fitted with ventilation and abatement technology to manage emissions to meet permitting requirements.	Yes	Yes	Yes	-
No Build - Use of markets and trading.	This is an option that we continue to explore and in March 2023 we issued a Prior Information Notice (PIN) to the market through Find a Tender to seek interested parties. We have also led on an Ofwat Innovation Fund Catalyst project 'Unlocking Bioresources Markets' with Business Modelling Applications, Northumbrian Water, Yorkshire Water, Thames Water and Southern Water. This project demonstrated whilst there is some opportunity the sector does require new capacity to meet demand and provide resilience across the bioresources value chain, to unlock the opportunities these are often dependent on the strategy, plans and determination of these plans across multiple WASC's. The companies need certainty that the required capacity will be available when needed and that certainty cannot realistically be provided by sludge trading markets until plans are assessed and in the public domain. Therefore, whilst we continue to explore opportunities is parallel with business planning any opportunity would only materialise during the delivery planning phase, post determination._	Yes	-	-	-

WINEP sludge no-deterioration & sludge improvement drivers

The WINEP lists site specific outputs to be delivered within AMP8 to meet sludge no deterioration drivers. Outputs include new sludge storage for non-stackable sludge, new storage barns for stackable sludge, and the development of alternative treatment measures and increased range of agricultural outputs for sludge under relevant environmental permits including reducing transport costs and reducing environmental risk.

Table 17 Options considered throughout the optioneering process (WINEP sludge no-deterioration and improvement drivers))

	Unconstrained	Constrained	Feasible	Outcome/ Comment
Sludge storage				
Do nothing	Yes	-	-	-
Refurbishment of impermeable base & walls and improved drainage	Yes	Yes	Yes	Enhancement - additional line 4 (CWW3.187/8)
Option 2 plus roll on/off Gortex covers	Yes	Yes	-	-
Open sided dutch barn	Yes	Yes	Yes	WINEP - (CWW3.137/8)

Fully enclosed building with Odour Control	Yes	Yes	Yes	-
Discontinue storage and provide storage elsewhere	Yes	Yes	-	-
Resilient Outlet				
Drying & Advanced Thermal Conversion/ Incineration (all sludge)	Yes	Yes	-	-
Drying & Advanced Thermal Conversion/Incineration (proportion of sludge)	Yes	Yes	Yes	Long term planning (AMP9) although have included £10m for R&D for ATC in Additional Line 3 (CWW3.186)
Drying only (all sludge)	Yes	-	-	-
Drying only (proportion of sludge)	Yes	-	-	-
Enhanced dewatering in combination with other options above	Yes	Yes	Yes	WINEP (CWW3.146/7)
New and increased cake storage (increase to 6 months)	Yes	Yes	-	-
Recycling				
Cease spreading and transition to 'sell from the gate strategy'	Yes	-	-	-
Distribute to field boundary and contact out spreading operation	Yes	Yes	-	-
Increase fleet to 11 spreaders operating lower hours per day	Yes	Yes	Yes	WINEP (CWW3.146/7)
Retain existing spreading fleet & provide farmer support, additional tractor & incorporation equipment to incorporate within 12 hour window	Yes	Yes	Yes	-

We also considered the use of advanced thermal conversion (ATC) technology (drying and pyrolysis) to produce a BioChar product from sludge at eight sites (Basildon, Cliff Quay, Colchester, Cotton Valley, Gt Billing, Kings Lynn, Pyewipe & Whitlingham). Whilst recognising this is an emerging technology at therefore cost information limited, we assess the costs of this solution would be broadly similar to that of implementing Incineration. We recognise that ATC technologies such as Gasification or Pyrolysis have potential to provide greater environmental benefit. However, the technology is still unproven at the required scale and there is no clear regulatory framework for recycling and beneficial use of the output products such as BioChar, and so we discounted this option until development of a solution at an appropriate scale can be undertaken. We recognise that ATC technology has potential to offer greater environmental benefit and will likely be more acceptable to stakeholders at some point in the future, so we are committed to working with the wider industry under the WINEP investigations driver and through other means such as the Ofwat Innovation fund to accelerate understanding and develop ATC technology such that it becomes a viable alternative to incineration for full scale commercial deployment in AMP9.

Adaptive planning

At present, ATC technologies are not feasible solutions for the reasons noted above. As outlined with the WaterUk (CIWEM/Atkins) report, cross-industry cooperation and research is required to enable these technologies to be considered feasible for commercial-scale roll-out in future AMPs. As such, we have included £10m within this portfolio for Bioresources Future Technology Investment to align with this recommendation from the National Bioresources Strategy to ensure sustainable technologies can be scaled from R&D to deployable solutions within AMP9 or when an adaptive planning trigger is activated. Solutions to be researched and developed include BioChar and hydrolysis, which we recognise have potential to offer greater environmental benefit than incineration and will likely be more acceptable to stakeholders at some point in the future.This investment will include extensive collaboration with other water companies, institutions and universities to consider novel processes.

We envisage R&D work being aligned to phase 2 on the National Bioresources Strategy and our proposed £10m would form part of a wider portfolio of cross industry work. We expect that the core activities will be assessment of alternative Advanced Thermal Technologies in terms of the suitability to treat sludge, understanding barriers to scaling technologies, understanding the composition of products produced by these technologies and the fate of contaminants and the pathways to solids, liquid or gas phase for example PFAS/PHOS and micro plastics. The work will also include working with environmental regulators and academia to develop regulatory frameworks for the beneficial use of the new products produced to support circular economy principles.

Industrial Emissions Directive (IED)

Our ten STC sites where we treat sewage sludge by Anaerobic Digestion all require IED permits from August 2022. Applications for all ten of our facilities have been made to the Environment Agency, to date we have received one permit for our Chelmsford site, the remaining nine are still with the Environment Agency for assessment and determination.

IED permits require sites have an asset infrastructure and operate in accordance with relevant BAT/BREF guidance. Whilst the compliance date to address any improvements is December 2024 there is recognition that elements of this work will be delivered in AMP8 due to delays in the permit evaluation process and complexity of the engineering solutions required.

We welcome the letter and data request from Ofwat received on 1st August 2023 and as requested responded with our data on IED expenditure requirements together with commentary on 22nd August. We look forward to ongoing engagement with Ofwat, EA and Defra on IED matters.

Within our PR24 bioresources enhancement case we have included only those investments we consider to be enhancement rather than base expenditure and complex in nature and therefore likely to be constructed in the AMP8 period. In our case this is investment on each of the ten sites for secondary containment solution to mitigate against the risk of catastrophic asset failure leading to pollution. The investment is based on the output of spill containment modelling and a recommended containment solution, the model results and recommended solution form part of our permit application for each site. The Environment Agency are still to comment on any containment solution and are putting in place improvement conditions on permits as they issue them requiring detailed designs to be submitted to the for approval for any containment work, therefore given only three IED permits have been issued to WaSCs at present with only Chelmsford being issued for AWS we anticipate that it is unlikely approvals will be granted to allow delivery of containment solutions within the current AMP period.

There are also a number of new monitoring, sampling and other regulatory requirements that once permits are issued impact on operating costs for the sites over and above what we consider to be included within base. We outline these in our response to the August 2023 data request. These include additional requirements for written scheme of examination for tanks, liquor sampling and analysis, frequent bioaerosol and odour surveys. We also include new additional costs associated with implementation of Farming Rules for Water that are not included within our historic bioresources base costs.

3.2.2 Cost-benefit appraisal

We set out the cost-benefit appraisal process for the options highlighted above. In our assessment we have considered which solutions represent best value to customers and the environment over the long-term.

Bioresources capacity improvements

Table 18

	Option 1-- New sludge treatment capacity at Colchester (23 TTDS p.a.)	Option 2 -- Increased treatment capacity at Cotton Valley STC and upgrade of Pyewipe STC (6.9 TTDS p.d.)	Option 3 -- No build
Is it a feasible option?	Yes - provides greatest level of operational resilience of the three options. This would negate the need to storage large quantities of raw cake for long periods when seasonal sludge production is high and outstrips capacity, reducing the risk of pollution to air and land from storage.	Yes - however does not create the full additional capacity required to treat additional sludge. As this would require more storage at seasonal peaks, it is less robust and reliable in contrast to the preferred option.	No - this option has been rejected for WINEP as the markets are yet to be established and water companies producing sludge require certainty of capacity.

	Also the lowest carbon impact of options - alternatives would require additional transport to transfer sludge in/out of storage and would require energy to manage airflow through cake storage barns.		Lack of capacity across the industry during seasonal sludge production peaks requires installing capacity to enable markets, as supported by the CIWEM/Atkins National Bioresources Strategy.
Is the solution cost effective?	Best value and least cost option.	Not as cost effective as preferred option - driven by transport and storage-related energy costs.	Not costed due to lack of feasibility.
Whole Life Cost (WLC)	£122.88m	£426.73m	-
Equivalent Annualised Benefit (EAB)	£2.381m	£1.557m	-
Key risks	-	-	N/A

Our preferred solution therefore is to construct 23.000 TTDS of new sludge treatment capacity in preference to additional enclosed odour-controlled storage. This is not only the lower WLC (Whole Life Cost) and better Equivalent Annualised Benefit (EAB) solution; it is also more sustainable in that it provides capacity to treat the sludge via Advanced Anaerobic Digestion to enhanced treated standards.

The alternative is to provide new additional storage for raw cake and/or lime treated biosolids cake. We have assumed that this additional storage would be contained with fully ventilated and odour-controlled buildings. In contrast, providing additional storage would lead to continued use of mobile lime stabilisation to manage the peaks producing a higher volume, lower quality product that is less acceptable to agricultural stakeholders. This is not a sustainable or appropriate solution, it is of high whole life cost, leads to reliance on continued use of less sustainable treatment solutions for peak lopping and would lead to future stranded assets as the industry moves towards alternative treatment methods such as advanced thermal technologies in AMP9 and beyond.

The production vs STC graph illustrates that the proposed additional capacity (23TTDS) is the realistic minimum requirement, and we are not requesting to build excessive amounts of additional headroom.

Industrial Emissions Directive (IED)

IED investments for secondary containment are a regulatory requirement to comply with new Industrial Emissions Directive (IED) permits. The option proposed aligns to the recommended solution from Spill Containment Modelling undertaken by specialist consultants and included within our permit applications. Due to the nature of the BAT and Ciria 736 requirements options are very limited and therefore only a single option was available for each site. Under the permits a full detailed design in accordance or equivalence to Ciria 736 must be approved by the EA. To date only three IED permits have been issued across England for sludge treatment sites, one of which is our Chelmsford site and so far no detailed design has been approved by the EA as a suitable compliant containment solution.

3.2.3 Environmental and social value

As part of our options consideration and appraisal process we have considered the environmental and social value of different solutions (utilising the value framework highlighted in chapter 7.3.3.3 of our business plan). This process has recognised the benefits of recycling biosolids to land (in contrast to alternatives such as incineration) in terms of their carbon and nutrient benefits from by-products of our sludge treatment processes. The use of biosolids can replace artificial fertilisers and build soil organic matter to restore soil health. In addition, recycling biosolids to land can provide carbon sequestration to provide carbon benefit from our sludge activities.

3.2.4 Investments benefit

Creation of additional STC capacity has a benefit for performance against the Discharge Permit Compliance performance commitment to offset deterioration. We do not anticipate this investment will create a benefit for performance above current levels. We set our PCL for Discharge Permit Compliance at full compliance. More detail is available in the Discharge Permit Compliance PC narrative in our OUT table commentary. The quantified benefits of this investment can be found in table CWW15.

Improvements in overall discharge compliance is brought about by providing a robust and sustainable outlet for sludge produced at our WRC's for treatment and onward recycling, this allows sludge stocks to be efficiently and effectively be managed on sites, mitigating risks associated with carrying high sludge levels in process tanks and high mixed liquor in aeration processes for example.

A robust and sustainable bioresources strategy also significantly contributes to our targets for energy demand by maximising energy that we can recover and use beneficially from our sludge treatment processes, such as generating green heat and electricity from our CHP engines or transitioning to biomethane upgrading and grid injection. This in turn supports our net zero, operational carbon and process emission targets.

3.2.5 Managing uncertainty

For more detail on our Uncertainty Mechanisms, please refer to chapter 10 of our main business plan narrative.

The scale of the programme is in part driven by the uncertainty surrounding the large-scale usage of agricultural outlet for biosolids application being considered as the best practicable environmental option for the future by all stakeholders. Due to the scheduled review of Farming Rules for Water Guidance in 2025, the EA and Defra are unable to specify with certainty in guidance if there will be any changes in spreading to land bank in AMP8. The proposed change from SUiAR to environmental permitting (EPR) via the implementation of the pending EA sludge strategy may also have a similar impact.

Discussion with the EA has resulted in incineration being removed from AMP8 investment into an adaptive pathway and phased into AMP9. The EA has stated it cannot support transition to incineration or alternative technology in AMP8 under a WINEP driver. With no AMP8 WINEP funding and no firm commitment on regulation/guidance impacting land bank we must mitigate risk through an uncertainty mechanism and clearly agreed adaptive pathway triggers.

An uncertainty mechanism on its own does not completely mitigate these risks, as sufficient time is required to plan, implement and deploy solutions, especially as alternative options have a long lead time of c.6-10 years. ATC technologies offer greater benefits but are currently not sufficiently developed to be offered at a commercial scale and there remains no regulatory framework for the products (BioChar etc) to allow for beneficial use. To address this remaining uncertainty and reduce risk relating to land bank, we have included within this investment portfolio £10m totex to investigate and develop alternatives to incineration with other water companies in AMP8 so options are available when required.

The proposed investment assumes there are no further investment requirements introduced by the EA following the confirmation of WINEP24.

3.2.6 External funding

Please refer to Cost Control for more detail.

3.2.7 Direct procurement

We recognise that bioresources projects are currently excluded from DPC under Ofwat's methodology, however given the size and scale of the investment portfolio we have considered the potential to deliver the required enhancement under a similar structure via a similar DBFOM-type (Design, Build, Finance, Operate & Maintain) model, this was included as an option in the PIN notice issued for the proposed 23TTDS of additional capacity. We intend to deliver our programme for AMP8 in-house, but remain open to considering DPC and similar models in future AMPs for the delivery of improvements dependent on greater certainty of environmental regulations.

3.2.8 Customer view

Our customer engagement has highlighted support for projects and initiatives for the management and recycling of sludge through our bioresources operations. This includes support for generation and use of renewable and low carbon energy. Our proposed investments are guided by these principles, our new capacity investments target use of advanced anaerobic digestion technology and includes state of the art digestion systems that maximise organic matter conversion, resulting on more biogas production than conventional technologies, this biogas will be used as a renewable heat source for the process but also upgrading to biomethane for grid injection, this support decarbonisation of heat and transport networks by displacing use of fossil gas.

Our long term strategy preferences transition to low carbon solutions that support a circular economy and we identify the need to accelerate research and development together with appropriate regulatory frameworks into alternative technology such as advanced thermal conversion that offer greater benefits that incineration in the event sufficient access to land bank is unavailable.

3.3 Cost efficiency

3.3.1 Developing costs

The development of the sludge costs in our plan follows our cost efficiency 'double lock' approach set out in chapter 7 of our business plan. Through this approach we have ensured that are costs are efficient in their bottom-up build up, and this is cross-checked through external benchmark approaches. This section sets out how we have ensured cost efficiency of our sludge investments through step one of our double lock approach. Step 2 is explored in the Benchmarking section below.

We have taken a robust approach to developing our sludge costs, building on our experience from delivering similar schemes into the bottom-up development of costs (before external cost benchmarking challenges are applied in step 2 of our 'double-lock' approach). The detail of the cost development approach is set out below, along with a breakdown of costs we provide in table CWW3.

Cost estimation methodology

We follow a common cost development methodology across our enhancement investments in a three phase process:

1. Establish cost and carbon models
2. Input the cost drivers into the model (including location specific factors)
3. Data validation, internal challenge and assurance.

In phase 2, we derived our total cost estimation for each scheme by gathering a data from specific needs to each investment requirements.

STC capacity improvements

The additional STC capacity proposed is 23.000 TTDS per annum, with approximately 11.304 TDS required to cater for population growth and additional sludge production arising from the proposed WINEP programme and approximately 11.696 TTDS to provide additional resilience capacity within our STC network to mitigate against seasonal sludge production peaks improving operational resilience reducing environmental compliance risks associated with buffering and managing sludge stocks.

We derived our costs for each scheme through the following process:

- Assessing the 25 years model for additional capacity at multiples sites
- Determined capacity by using the peak weekly production estimated 2030
- Process units sizes to specific process requirements, process train selected based on our 4 existing best performing STCs
- site specific requirements and
- assessment of construction constraints such as SSSI areas.

The table below provides a breakdown of our sludge treatment capacity costs.

Table 19

Investment ID	Investment Name	Scope	Capital Cost (£m)	OPEX Cost (£m) AMP8
I033831	Regional sludge treatment capacity	New 23'000TDS HpH STC, *Separate liquid sludge reception for indigenous and imported liquid sludges *Liquid sludge screening *Imported cake reception *Helea pre-treatment *Anaerobic digestion *Sludge dewatering and storage *Gas collection and upgrading for grid injection *Liquor treatment	74,685	1,218
		Total	74,685	1,218

IED Containment

The scope at each site is taken from the spill model completed by Mott MacDonald as part of the IED permit application to generated the secondary containment required. The table below sets out a breakdown of our IED containment costs.

Table 20

Investment ID	Investment Name	Scope	Wall length (m)	Impervious Liner (m2)	Capital Cost (£m)	OPEX Cost (£m) AMP8
I040671	Chelmsford STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	366.4	45,000	4,732	-
I040682	Cambridge STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	-	13,000	551	-
I040687	Basildon STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	287.1	18,000	1,704	-
I040689	Colchester STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	732.8	1,000	2,729	-
I040690	Cotton Valley STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	358	1,000	2,729	-
I040691	Great Billing STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	468.5	30,000	2,043	-
I040692	Cliff Quay STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	206.5	5,000	561	-
I040694	Kings Lynn STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	104.4	1,000	2,179	-
I040695	Pyewipe STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	48.35	-	737	-
I040696	Whitlingham STC IED Loss of containment	Bund walls (earth where possible concrete elsewhere) with impervious liner Flood gates	718.2	10,000	3,331	-

Investment ID	Investment Name	Scope	Wall length (m)	Impervious Liner (m2)	Capital Cost (£m)	OPEX Cost (£m) AMP8
		TOTAL	-	-	19,459	-

IED

The number of samples required was based on Chelmsford IED permit and extrapolated to the other 9 sites required.

The distance of haulage was determined by taking input from the national study completed by the specialist consultant Grieve Strategic Ltd commissioned by Water UK.

The table below provides a breakdown of our IED costs.

Table 21

Investment ID	Investment Name	Scope	Capital cost (£m)	OPEX cost (£m) AMP8
I041358	Bioresources Regulatory changes	Cost associated to *10 IED permits; tanks inspections and specialised sampling for Odour & Bio-aerosol Testing, Stack emissions and Liquor Returns *Farming Rules for Water - additional haulage Sludge distance	-	18,237
		TOTAL	-	18,237

WINEP Enhancements to open cake storage (Covered storage)

The existing footprint area of specific pad used to cover the 60% of total AW cake storage capacity to allow to stack more tonnes. THe table below provides a breakdown of our cake storage costs.

Table 22

Investment ID	Investment Name	Scope	Cake area (m2)	Capital cost (£m)	OPEX cost (£m) AMP8
Various	Cake pad extensions at 27 location for site specific type of Raw, Digested, Digested skips and non conforming cake. No Barn store	(2) Boston WRC, Popyhill WRC ,(2)Whilton WRC, Chalton WRC, Harwich and Dovercourt WRC, Spalding WRC , Sudbury WRC , Rayleigh West WRC , Pyewipe STC , (2) Kings Lynn STC , Cambridge STC, (2) Cotton Valley STC, Teversham WRC, Sawston WRC, Stamford WRC, Cliff Quay STC , Clare WRC, (2) Tetney Newton Marsh WRC,Over WRC, (2) Chelmsford STC	63,913	12,182	-
-		TOTAL		12,182	-

WINEP Biosolids Treated Cake Spreading Equipment

The table below provides a breakdown of our spreading and adaptive planning costs.

Table 23

Investment ID	Investment	Scope	Capital cost (£m)	OPEX cost (£m) AMP8
I036196	Regional Sludge Recycling resilience	Expand spreading fleet to 11 vehicles	4,144	-
I041217	Bioresources Future Technology Acceleration	AWS share of inter-WASC initiative to accelerate advanced thermal conversion technologies and the associated products from pilot R&D scale to point where tech can be fully deployed across sector at scale providing a viable sustainable alternative to incineration	-	10,000
		TOTAL	4,144	10,000

Table 24

	Capital cost (£m)	OPEX cost (£m) AMP8
Total	169,847	29,559

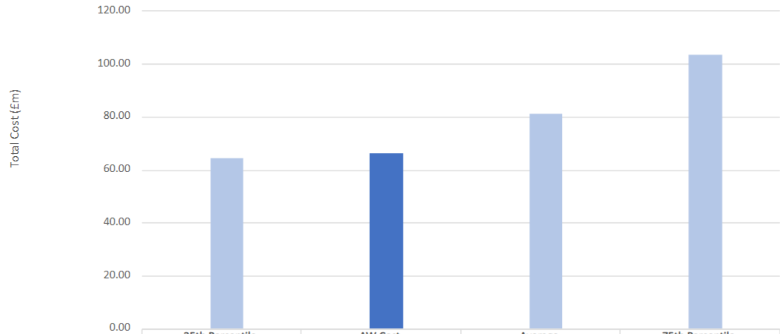
3.3.2 Benchmarking

Due to the scale of investment proposed within the sludge enhancement programme, we sought external support to benchmark costs proposed with the additional capacity and WINEP-driven elements of the programme, which makes up majority of the programme.

The use of historic scheme outturn data and the benchmarking of this give us high confidence that efficient cost estimations have informed the costs included in our plan. To further cross-check this, we have taken a sample of nine investments from each area of the programme representing 62% of the total sludge enhancement to be benchmarked (£105.91m). Benchmarking was carried out by The COCE alliance (comprising of Mott McDonald and AECOM) was commissioned to undertake bottom up detailed benchmarks of the individual components of the sample scheme (£66,022k)of our bioresources costs.

The graph below shows that overall our capital direct costs are in-line with the benchmarks:

Figure 9 Sludge enhancement - overall programme asset only costs benchmarked



	25th Percentile	AW Cost	Average	75th Percentile
New 23'000TDS HpH STC	43.99	50.39	56.17	71.67
Enhancements to open cake storage (Covered storage)	11.22	3.28	13.80	17.64
Enhancements to open cake storage (open storage)	1.51	0.94	1.72	2.01
Enhanced dewatering	7.45	11.41	9.31	12.08
Sludge Enhancement - Scheme Costs	64.17	66.02	81.01	103.40

In light of the evidence presented above and on account of all the schemes scope in these programme are the same nature, we have confidence that the costs we have estimated for our PR24 bioresources programme present an efficient rate.

3.3.3 Assurance

Jacobs have provided assurance on the cost build up of this investment through assurance of C55. Mott McDonald and Aecom have also provided assurance on the cost benchmarks.

3.4 Customer protection

Customers are protected against the non-delivery, delay or reduction in scope of this investment through the bioresources Price Control Deliverable. This will return allowance to customers on a ttDS/year capacity basis. More more detail, please refer to our 'Price Control Deliverable' appendix [22]

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THE QUEEN'S AWARDS FOR ENTERPRISE: SUSTAINABLE DEVELOPMENT 2020

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