03

Net Zero Investments

Transforming wastewater and sludge treatment to reduce greenhouse gas emissions

WONDERFUL ON TAP

SEVERN TRENT

Executive summary

This is our response to Ofwat's call for companies to submit competitive net zero proposals.

This proposal outlines our plan to reduce the greenhouse gases emitted from two of the most significant contributors to Severn Trent's footprint: wastewater and sludge treatment processes and heat and fuel. We are ambitious on net zero and we have included a range of investment options alongside our stretching base plan. This is to allow Ofwat to compare proposals across the sector, so that they can take the decisive action necessary in the next five years to align with our statutory UK net zero objectives.

Case for change

The water sector's greenhouse gas emissions make up almost one-third of the UK's industrial and waste-related emissions. To meet the UK's net zero commitments, the Climate Change Committee estimates that the water sector must reduce emissions by 34% by 2030 (2021 baseline). Our Science Based Target commits us to a 46% reduction in our direct operational Scope 1 and 2 emissions by 2031 (2020 baseline).

Our Scope 3 emissions are already a challenge and are forecast to increase over the next AMP, driven by expanded statutory obligations, including WINEP and water resources. While we are committed to working with our supply chain (and this is part of our Science Based Target) in order to meet the 2030 target, we must make significant reductions in two key categories of Scope 1 emissions:

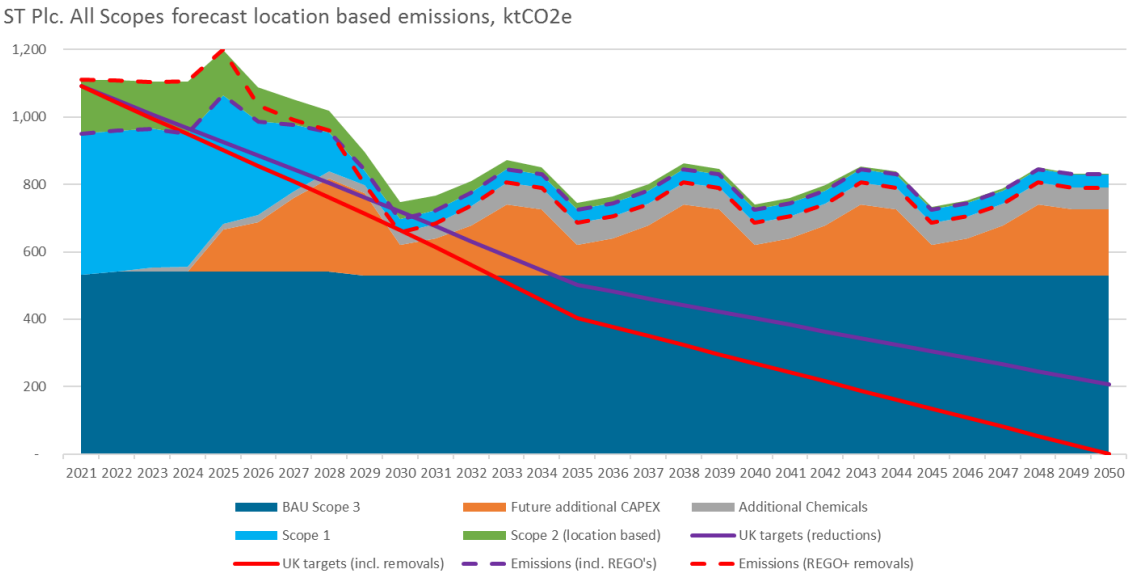
- **Process emissions.** Emissions from wastewater treatment processes – nitrous oxide (N_2O) and methane (CH_4) – account for 82% of Severn Trent's Scope 1 emissions. Reducing process emissions is the water industry's most urgent net zero challenge: since wastewater treatment processes are unique to our sector, we cannot rely on market-based solutions; and
- **Heat and fuel emissions.** Emissions from natural gas, diesel, and fuel oil account for 13% of our Scope 1 emissions. Our use of imported natural gas for heating is set to increase as we develop new processes to meet higher environmental standards for bioresources. Reducing emissions from other heat and fuel sources will therefore be critical to achieve our targets.

Long-term Solution

Severn Trent is committed to achieving net zero greenhouse gas emissions, in line with both our social responsibility as a FTSE 100 company and the UK's legally binding net zero commitments. The route to net zero is outlined in Figure 0.1, with Scope 1 emissions represented in light blue. The graph shows the residual estimated Scope 3 challenge including both our current baseline in dark blue and forecast upward pressures from future obligations in orange.

The key point to emphasise in the chart below – our PR24 plans put us on the right trajectory to delivering the 2050 statutory requirements. However, we still have a significant amount of work after 2030 to deliver on these.

Figure 0.1: Severn Trent's net zero challenge



AMP8 proposal

Our base expenditure includes a commitment to deliver a stretching greenhouse gas emissions reduction of 115ktCO_2e in AMP8 making a 30% contribution to our 2030 Scope 1 emissions reduction target. In addition, we propose enhancement investment of £430m to deliver a package of interventions in AMP8 to make decisive steps towards the long-term target. These are innovative proposals with a degree of uncertainty, and our estimated benefits are based on central estimates. Details of the uncertainty ranges are provided throughout the business case. Through this investment we are committing to deliver the following benefits:

- **Reduce Scope 1 emissions.** Deliver greenhouse gas emissions reductions of 223ktCO_2e during AMP8, making a further 58% contribution to our 2030 Scope 1 emissions reduction target on top of reductions from base, at an average cost of £125/tCO_2e abated[1]; and
- **Build the foundations for future emissions reduction.** Reduce the per-tonne cost of emissions reduction for the UK water sector, so enabling future affordability and intergenerational fairness. Confirm the emissions reductions for different solutions to inform future plans.

The proposed activities (summarised in Table 0.1) have been through our rigorous adaptive planning process to balance certainty with cost efficiency.

[1] This represents an efficient level of delivery compared to the 2030 low-range policy cost of carbon of £140/tCO_2e published by BEIS in September 2021.

Table 0.1: Proposed activities in AMP8

Activity	Details2	AMP8 Cost	Annual emissions reduction (ktCO2e)	Cost per unit (£/tCO2e)[3]
Elimination: Change processes to prevent greenhouse gas production	Heat and fuel projects	£16.3m	9.6-14.6	£123-185
	Cellulose recovery at three sites	£63.1m	2.5-15.3	£186-1,120
Reduction: Optimise processes to reduce greenhouse gas emissions	Process optimisation at 105 sites	£9.0m	27.2-40.8	£29-44
	Digital twin at 32 sites	£53.3m	20.2-30.4	£108-163
	ASP intensification at 13 sites	£104.1m	21.5-51.5	£189-454
	Active gas capture at 18 sites	£91.3m	32.1-48.1	£33-49
Treatment: Adapt assets to remove greenhouse gases once emitted	Cover and treat ASP lanes at 23 sites	£92.9m	4.5-66.7	£118-176
Total		£430.0m	117.6-267.4	Average: £125

This pace of investment is necessary because of the urgency of the net zero challenge and the need to deliver sufficient progress and enough solutions in the sector to allow delivery in AMP9, and to align with the UK's statutory targets.

Solutions must be deployed at scale to ensure we have the answers for PR29 so that the whole sector can efficiently and effectively tackle Scope 1 and 2 emissions. Our analysis also indicates that Scope 1 emissions reductions will become more expensive in the long term[4]. Delaying this investment beyond AMP8 is likely to result in larger bill increases for future customers, impacting affordability and intergenerational fairness. As the 2023 Committee on Climate Change report to Government notes, "pace should be prioritised over perfection"[5].

We have carefully considered the risks associated with the uncertainties. On balance, the need is urgent enough to act now and there are enough options in the pipeline that we can adapt our plan to deliver the outcome of rapid emissions reductions as we learn more from our ongoing programme.

We are confident that this proposal is deliverable, financeable and represents the best option for customers. This proposal creates the conditions for Ofwat's benign technology common reference scenario to be realised in the UK, so that others can benefit beyond AMP8.

[2] Please see Section 2 and Appendix C for full details of each activity

[3] This is calculated as the 30 year NPV in 2022/23 prices per tonnes carbon dioxide equivalent over the same period

[4] See section 5.2

[5] https://www.theccc.org.uk/publication/2023-progress-report-to-parliament/ page 14

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Note: Annexes referred to sit within separate PR24 documents whereas Appendices are contained within this document

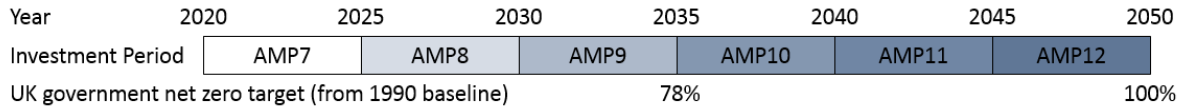
1. The need for investment

This section describes how our proposed investments are shaped around government net zero priorities. It introduces process emissions and heat and fuel and why they are areas for priority investment in AMP8. Finally, it summarises the research we have undertaken to understand what our customers' requirements are in this area.

1.1 Responding to government priorities

Climate change is among the most significant challenges facing the world, and the steps we take between now and 2030 will be critical if we are to limit global warming to 1.5°C, the long-term temperature ambition of the Paris Agreement. The UK is one of the few countries with a legally binding commitment in line with this global agreement: net zero greenhouse gas emissions by 2050, and a 78% reduction by 2035 (compared to 1990).

Figure 1: The UK government's legally binding net zero commitments – a timeline



The World Meteorological Organization now judges it is more likely than not we will temporarily exceed 1.5C in the next five years, which will impact on water systems, as well as the wider world, unless deep emissions cuts are made within the next five years.[6]

Although the UK's climate commitments have not yet been allocated to specific sectors, there are clear policy expectations that we align our climate-related activities with these commitments:

- The Intergovernmental Panel on Climate Change (IPCC) states that emissions reductions must be delivered across all sectors if we are to meet international climate commitments;[7]
- Defra's strategic priorities for Ofwat includes the expectation that water companies '*have regard for the policies and proposals set out in the Net Zero Strategy*' and that Ofwat '*will have an important role in scrutinising and challenging companies' business plans*' against these commitments[8];
- Ofwat states that "water companies have a key role to play in the overall context of the UK and Welsh governments' commitment to net zero emissions by 2050, and, proportionally, have a large role to play in decarbonising the activities of ''*Water Supply, Sewerage, Waste Management and Remediation' sector, which is the fifth largest emitter of greenhouse gas emissions*;'" and[9]
- As part of the 2023 Energy Bill, the Government plans to amend Ofgem's statutory principal objective to protect the interests of existing and future customers and add a specific duty to

[6] https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years
[7] https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/
[8] Defra Strategic Policy Statement for Ofwat
[9] https://www.ofwat.gov.uk/publication/net-zero-principles-position-paper/

support the Government to meet its legal obligation to get to net zero by 2050[10]. We might expect similar changes for other sectors in future.

Sector collaboration is essential as our sector's greenhouse gas emissions make up almost one-third of the UK's industrial and waste-related emissions.[11] Acknowledging the severity of the impact of climate change, the sector has identified a detailed routemap to support transition – Water UK's Net Zero 2030 Routemap, which lays out a path to the Government's statutory 2050 target.[12]

Severn Trent is committed to achieving net zero greenhouse gas emissions in line with both our social responsibility as a FTSE 100 company and in response to the Government's policy expectations for water companies of a 68% reduction below 1990 levels by 2030.

UK targets have been set by the Government based on a 1990 baseline of 887 megatonnes of CO_2e for the whole UK and have not yet been allocated to sectors. Table 1.1 below shows what 2030 and 2035 targets would look like if the sixth carbon budget was prorate-ed across the sector based on its reported emissions. The total reduction of 100% by 2050 includes an allowance for removals, but we have excluded this to focus on the required reduction of direct emissions. Our plan does not include any offsetting, so this remains consistent. The sector does now have a full set of 1990 data, so we have matched the trajectory of the Sixth Carbon Budget Balanced Net Zero pathway from 2021 to 2050 to meet the same objective. This is shown in table 1 below.

Table 1: Interpreting the government's GHG reduction targets for the water sector

6CB balanced net zero pathway	1990 baseline	2021 baseline	2030	2035	2050
Sixth Carbon Budget ($MtCO_2e$)	887	516	340	237	96
% reduction from 1990 baseline*	0%	44% (42%)	68% (62%)	78% (73%)	100% (89%)
% reduction from 2021 baseline*		0%	**39%** (34%)	**63%** (54%)	**100%** (81%)

** Excluding removals (bracketed values represent % reductions including allowance for removals)*

Our challenge for AMP8 is to deliver significant progress towards the Government's commitments, based on a 'no- and/or low-regrets' approach that is efficient, cost-effective, and guided by customer priorities.

In 2022-23 our reported location-based Scope 1 and 2 total GHG emissions were 567.3$ktCO_2e$ compared to a 2020 baseline of 583.5$ktCO_2e$[13]. A summary of the values reported in our 2023 annual report and accounts is given in table 2. This is forecast to rise to 641.8$ktCO_2e$ by 2030 as a result of upward pressures from growth and statutory drivers, if nothing is done.

Table 2: Our baseline and current year GHG emissions in $ktCO_2e$

	Severn Trent Plc 2019/20 baseline	Severn Trent Plc 2022/23
Scope 1 emissions – combustion of fossil fuel on site	18.2	51.2
Scope 1 emissions – process emissions	348.1	346.5

[10] https://www.ofgem.gov.uk/publications/ofgem-welcomes-proposed-legal-mandate-prioritise-uks-2050-net-zero-target#:~:text=Ofgem%20has%20welcomed%20the%20Government's,future%20gas%20and%20electricity%20consumers.
[11] https://www.ofwat.gov.uk/publication/net-zero-principles-position-paper/
[12] Water UK Net Zero 2030 Routemap
[13] https://www.severntrent.com/content/dam/stw-plc/shareholder-resources/2023-reports/ara-report-2023.pdf

Scope 1 emissions – transport fleet	17.6	19.7
Scope 1 total emissions	383.9	417.3
Scope 1 and 2 total emissions – location based	583.5	567.3
Total annual gross operational emissions – location based	605.2	584.4
Total scope 3 emissions	505.7	541.7
Total GHG emissions – all scopes	1,110.8	1,126.2

Calculated using the latest UK grid emissions factors

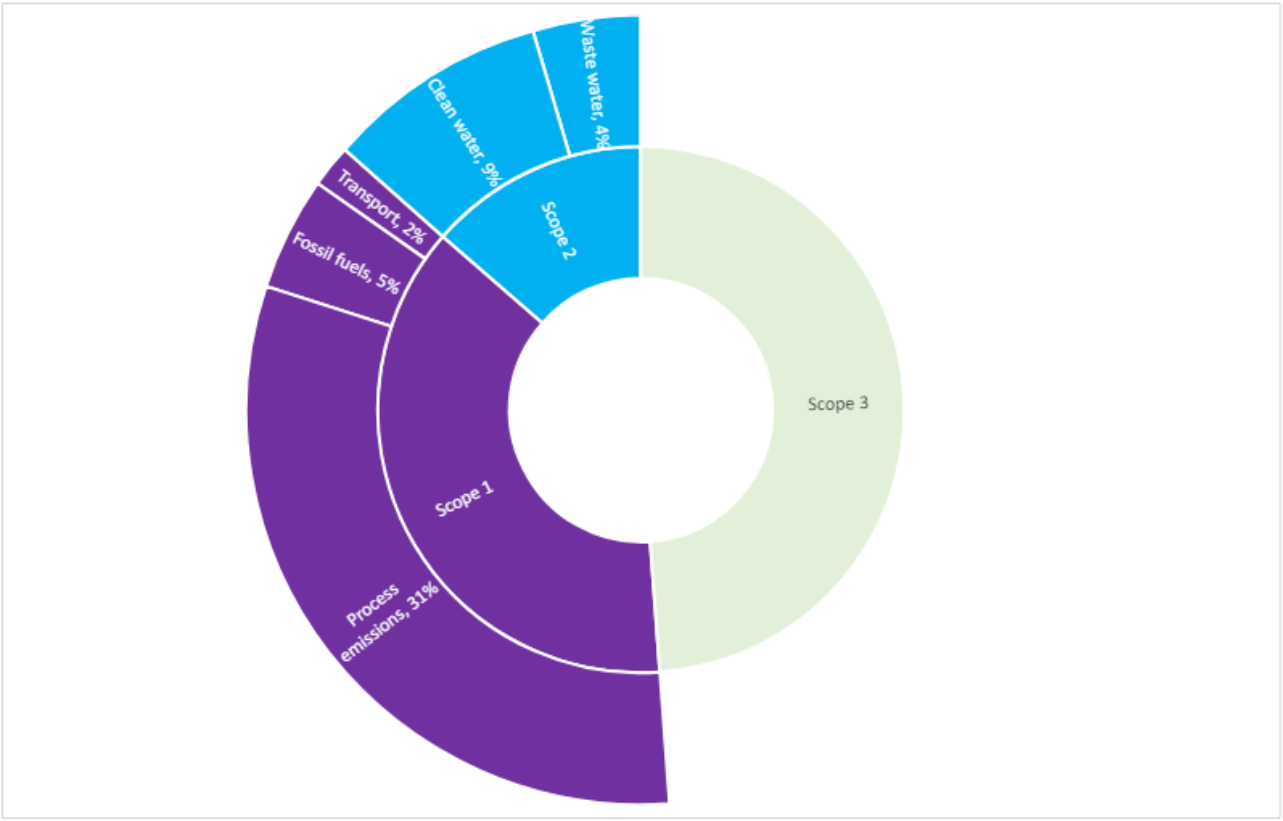
1.2 Why process emissions?

Process emissions – those resulting from our wastewater and sludge treatment processes – account for 82% of Severn Trent's direct greenhouse gas emissions (see Figure 2). Historically, the water sector has estimated process emissions based on population and volume of wastewater treated. Our work to monitor and measure process emissions (see Appendix A) is already demonstrating that they are substantially higher than estimated by the Carbon Accounting Workbook, strengthening the case for immediate investment in reduction technologies.

We have considered process emissions from our water assets but, given they represent 0.1% of our process emissions, we are not proposing to tackle these in AMP8. This is in line with industry efforts and best practice.

Unlike capital carbon emissions from construction that are likely to reduce with the actions taken in other sectors, process emissions will require water company action in all plausible scenarios. We have taken into account what base expenditure will deliver (see Section 3.4) and, even after allowing for this, significant additional investment is required in process emissions.

Figure 2: Severn Trent Scope 1&2 (operational) greenhouse gas emissions, 2022



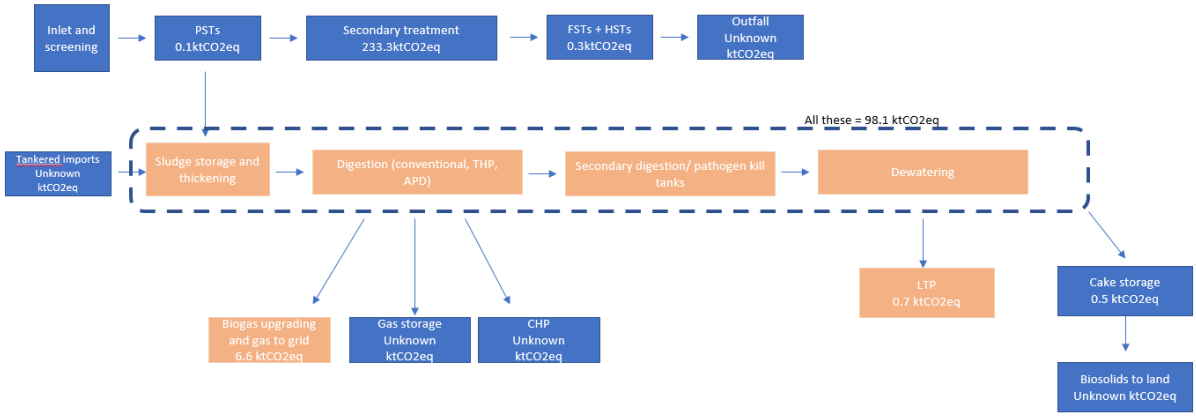
As part of our Science Based Targets, we have committed to 70% of our supply chain signing up to plans for decarbonisation of their own direct emissions. For further details on how we are reducing our operational greenhouse gas emissions from our supply chain, see our Sustainability Report[14]. In the same document, we also outline our approach to capital carbon emissions. Note that capital carbon emissions have been fully considered as an impact in this plan.

Process emissions occur in two main ways:

1. From biochemical reactions during secondary treatment of wastewater, resulting in the formation of nitrous oxide (N_2O). N_2O is a greenhouse gas with a global warming potential 273 times that of carbon dioxide (CO_2) over a 100-year timescale; and
2. From the escape and venting of gases from bioresources treatment processes, especially following anaerobic digestion (AD), resulting in the formation of methane (CH_4). CH_4 is a greenhouse gas with a global warming potential 27.9 times that of CO_2 over a 100-year timescale[15].

The processes that are the specific source of these emissions are shown on a schematic of the flowsheet of a typical wastewater recycling plant and sludge treatment centre in Figure 3. The values shown are Severn Trent's total process emissions for each part of the process. Totals in blue boxes are determined from emission factors based on measured data from our monitoring campaigns. Totals in orange boxes are determined from emissions factors based on literature as our own data is not yet available for these areas.

Figure 3: Overview of process stage and associated process emissions



The data in this figure relates to FY2022/23

The water industry in the UK currently uses the 'Carbon Accounting Workbook' (CAW) to estimate process emissions. However, studies have highlighted concerns about some of the assumptions built into the workbook which may have resulted in an under-estimation of emissions. In 2021 we embarked on an industry-leading monitoring programme that in time will provide a better understanding of our emissions, as well as aid in the development of UK specific emission factors.

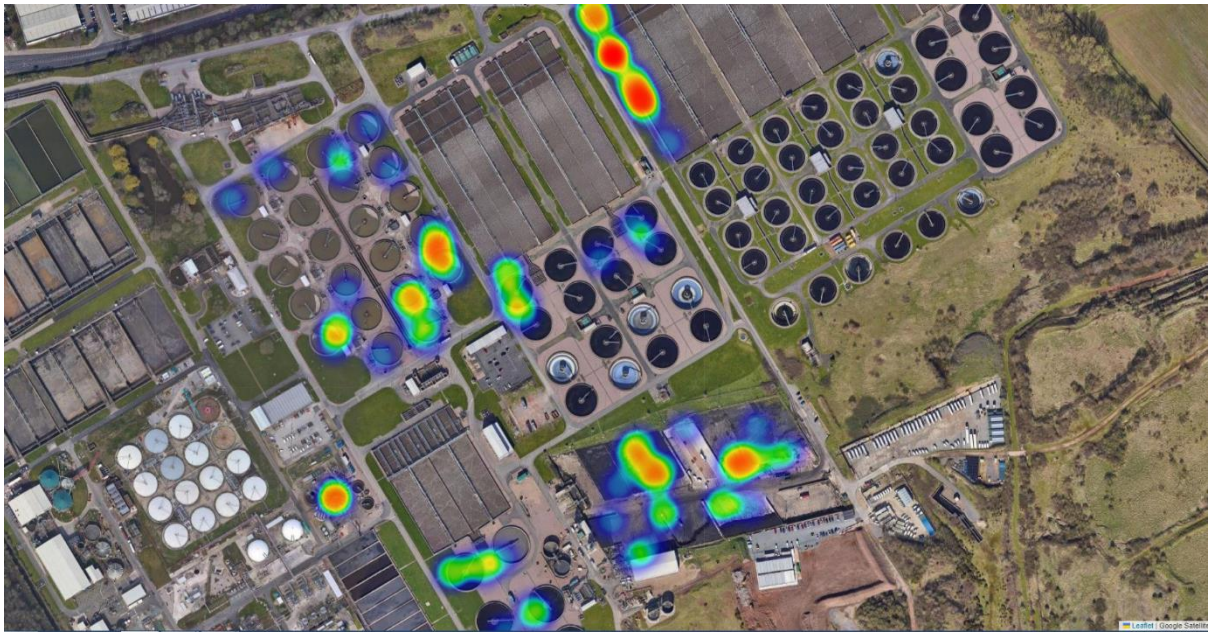
- Our monitoring consists of direct measurement of nitrous oxide emissions monitoring at nine wastewater treatment works. Our emission factor is determined by dividing measured emissions by measured load to ASP;

[14] https://www.severntrent.com/sustainability-strategy/reports-and-publications/
[15] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07_SM.pdf

- Direct N_2O measurement campaign using a flux monitor. This consists of placing a chamber with a fixed volume and surface area (flux hood) on top of the emission source. This hood is connected to a gas analyser which allows us to measure the amount of nitrous oxide accumulated inside of the chamber over time (e.g., kg of N_2O/m2 of asset/ hour);
- Drone mounted laser spectrometer to locate sources of methane emissions, enabling leak detection and repair (LDAR);
- We are also partnering with a small UK-based technology provider to roll out LIDAR-based camera systems across three sludge treatment sites to locate, track and quantify methane emissions; and
- In addition to this we have also partnered with Cranfield University to sponsor research aimed at creating a monitoring framework which combines the drone-based methane measurements and a mass balance type approach to quantify emissions. We believe this type of collaboration with academic and supply chain partners helps to accelerate improvements and eventually emissions mitigation.

To illustrate this with real data, figure 4 shows a heatmap that was produced during our monitoring studies indicating sources of N_2O emissions on a large wastewater and sludge treatment site. Red shows the highest sources of emissions, blue the areas with the lowest detectable levels. In this case emissions have been recorded using N_2O specific monitoring equipment and the locations of the readings tagged with GPS data to allow the production of an accurate heatmap.

Figure 4: N_2O emissions on a large treatment works



The water sector currently accounts for 3.1% of the UK's total methane emissions and 5.1% of its total nitrous oxide emissions.[16] Reducing emissions of these potent greenhouse gases will be critical to meeting the UK's net zero commitments. Methane is short-lived in the atmosphere compared to other greenhouse gases of concern, so there is a good reason to take steps to tackle its emissions in the near term. The importance of reducing methane emissions has been recognised as the best way to slow

[16] https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsatmosphericemissionsgreenhousegasemissionsbyeconomicsectorandgasunitedkingdom Of the six key Kyoto Protocol greenhouse gases, only N_2O and CH_4 are relevant to the water industry.

the rate of warming, with the Global Methane Pledge launched at COP26 to reduce global methane emissions by at least 30% from 2020 levels by 2030.[17]

In its Sixth Carbon Budget, the Climate Change Committee stated that, for the UK to meet its 2035 and 2050 commitments, the water sector needs to employ a combination of enhanced monitoring, operational measures, and continued rollout of advanced AD.[18] The Committee also predicts, in both its Widespread Innovation and Tailwinds scenarios, that there will be continued installation of more, novel technologies after 2030 to further reduce emissions in the water sector. Both scenarios focus on the development of new technologies and ambitious measures. This proposal fits with such an approach particularly in terms of the opportunity to reduce emissions and in our intention to share the learnings from our proposals with the wider sector in the UK, a globally.

Achieving this reduction is arguably our industry's most urgent net zero challenge, as:

- **Water companies have full responsibility for process emissions.** Wastewater treatment is fundamental to our core business of taking wastewater from our customers' homes and businesses safely. The emissions resulting from these processes fall squarely within our sole responsibility (as opposed to Scope 3 emissions, which are a joint responsibility between us and our supply chain), making them a priority for reduction;
- **The solutions will only come from the water sector.** Wastewater treatment processes are unique to the water sector, so we cannot rely on the development of market-based solutions (such as the operation of the national electricity grid or transport systems and zero emission vehicles). The technology we need will only be developed by specialist suppliers and sponsored and adopted by water companies themselves; and
- **The challenge cannot be delivered within base expenditure alone.** We have spent £164m to achieve a 24% reduction against our Science Based Target of 46% by 2031[19]. We are ready for the challenge to deliver an even more stretching reduction of 115ktCO_2e from AMP8 base expenditure, representing a further 20%, but we need to do more. See Section 3.4 for further details.

Table 3 – Our planned activities from AMP8 base expenditure

Activity	GHG reduction (ktCO_2e)
Stop natural gas combined heat and power (CHP) engines	23
Future reductions arising from bioresources growth	19
Methane leakage (find and fix)	38
Replacing fleet vehicles with low carbon alternatives	3.5
Cover secondary sludge tanks	31.5
Nature-based land solutions	0
Total	115

The work completed as part of our Long Term Delivery Strategy (LTDS) – including the development of several alternative adaptive pathways (see Section 3.6) – indicates that an ambitious approach to reducing process emissions is efficient, affordable, and consistent with a 'no- and/or low-regrets' approach.

[17] https://www.globalmethanepledge.org/
[18] https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Waste.pdf
[19] https://www.severntrent.com/content/dam/stw-plc/investors/fy-results-2023/full-year-results-presentation-2023.pdf

1.3 Why heat and fuel?

After process emissions, the next largest category of direct greenhouse gas emissions we can fully control is fuel use (see Figure 2). This is composed of the 13% that comes from burning fossil fuels on site, primarily to heat processes and buildings, and the 5% that comes from transport fuel.

Unlike process emissions, which are specific to our industry, these areas are much better understood and are part of much larger UK and global activities. Some activities to reduce greenhouse gas emissions from heat and fuel are already funded from base expenditure and we recognise the economics may change over coming decades. However, there is still a cost premium of adopting low-carbon technologies over and above traditional alternatives,[20] and this challenge, and these options, are therefore considered as part of this proposal.

The use of natural gas for heating is already a significant proportion of our heat and fuel emissions and is set to increase due to new thermal processes for bioresources treatment, including thermal hydrolysis and pelletisation. There are currently limited alternatives to this because the processes have a high heat demand which must come from a stable, safe, and affordable source. Reducing greenhouse gas emissions from other heat and fuel sources will therefore be important to allow us to drive down our Scope 1 emissions.

Unlike the electricity grid, which is predicted to decarbonise by 2035, decarbonisation of the UK gas grid is forecast to be much slower and therefore we need to make interventions and investments ourselves rather than waiting for this to happen.[21]

Heating offices and operational sites is more closely related to UK-wide discussion about how to decarbonise our gas-dominated domestic heating systems. Technologies such as heat pumps are still recommended by the Government[22] as the preferred way of decarbonising smaller scale heating.

We have already started our journey to decarbonising our vehicle fleet, tailoring our approach by type:

- For cars and light commercial vehicles, electrification has begun. We have committed to not buying another fossil fuel car in the future, we have built 352 charging points on our sites, and our van fleet is turning electric. To complete our transition in this area, we need to continue the rollout of electric vehicles and infrastructure. We recognise that our base allowance covers vehicles, so this proposal only considers the fundamentally new requirement for further charging infrastructure; and
- For larger vehicles, i.e. HGVs and plant, the future is still unclear but it is likely to be a combination of electrification and hydrogen use. Rather than picking an emerging technology, we will focus on medium-term transition options, including alternative fuel sources such as hydrotreated vegetable oil (HVO), that represent realistic 'no- and/or low-regrets' options.

We have derived options for each of these challenges and put them through the same adaptive pathway process as the more complex process emissions options.

[20] https://www.energy-uk.org.uk/wp-content/uploads/2023/03/Decarbonisation-of-heat-report-2018.pdf
[21] https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035
[22]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1148252/powering-up-britain-energy-security-plan.pdf

1.4 Responding to customer expectations

Climate change is one of the most significant challenges facing the world, and the steps we take between now and 2030 will be critical in limiting global warming. As we have developed our PR24 plan, we have spoken to our customers about the environment, climate change, and net zero. They have told us they are concerned about climate change and want us to take action to reduce greenhouse gas emissions.

This can be a challenging area for customers to understand and respond to with both a personal and community perspective, as well as balancing immediate and future-facing issues. We have taken care to ensure our research is meaningful to participants, and to distinguish between the causes and impacts of climate change, as well as probing multiple perspectives and intergenerational fairness. We have done this using a range of methods, including deliberative research to inform and probe in depth, alongside tracking key concerns over time.

Below is a summary of the key messages we heard from customers. For further details including how we address each specific item, see Appendix B.

We want full customer support for our proposals. Our solutions were scrutinised by Severn Trent's Expert Challenge Panel (ECP), our independent challenge group for PR24, to ensure we were incorporating customers' views on scope, pace, and affordability. The ECP challenged us to be clear on the choices we have made on pace (taking into account legal requirements and company ambition) and to consider the carbon impact of other investments, and how they align with this proposal. We made sure these challenges were added into our wider customer research.

Customers are worried about climate change and, in particular, the impacts of climate change on future generations. Combating climate change is seen as vital.

Throughout our research, and that undertaken by third parties, a consistent theme emerged in terms of the growing concern among customers about climate change. However, at the **wider societal level**, climate change is not the most pressing concern – that is *Poverty and the cost of living*, followed by *Health and social care*, *Crime*, and the *Economy/unemployment*[23]. Compared to other more personally pressing issues, *Carbon emissions/net zero* does not rank highly. Only 56% of customers in the Social Barometer[24] were concerned about *Carbon emissions/net zero*, compared to 84% concerned about *Poverty and the cost of living*.

In both our Social Barometer research and our strategic investment choices research, customers are more concerned about *the impacts of climate change* compared to the need to *reduce carbon emissions*.

Around 70% of customers believe climate change is already having an impact in the UK, and just under 60% say they are more concerned about climate change than they were two years ago[25]. Extreme weather, higher temperatures (and especially hotter summers), and increased levels of flooding are the key indicators for customers in their local area. Customers expect climate change to impact them personally in their lifetime and many do not think water companies are sufficiently prepared for the challenge.

[23] Social Barometer, Wave 5, Consumer Insight, March 2022
[24] ibid
[25] Social Barometer, Wave 1-5, Consumer Insight, Sept 2021 – March 2023

In our Affordability and Acceptability research, we found customers were becoming increasingly aware of issues relating to climate change, and combating climate change was seen as vital. They want to see environmental protection becoming central to Severn Trent's long-term plans.

Customers aren't well informed about net zero but support the need for action once informed. They expect Severn Trent to play its part in reducing greenhouse gas emissions and reaching net zero.

We found that customers have little spontaneous awareness of the carbon impact of water companies, with most focusing on the impacts of transport. Once more informed, customers are surprised about the scale of sector emissions[26].

Once informed of Severn Trent's net zero pledge however, 86% of customers are supportive, with support driven by our customers accepting it is something that needed to be done. Those who do not support it, while a minority, expressed cynicism both in terms of the impact on bills and whether the target is achievable.

In our deliberative research, participants agreed it is important for the **UK to play its part** in achieving net zero[27]. When it comes to **responsibility**, some question whose responsibility it is to address and fund it. Customers tend to think the Government, businesses and the general public all have a role, with more people feeling the Government should have the most responsibility for tackling climate change[28]. There is however uncertainty about how far individuals and business are willing to go.

> *"[The groups most responsible should be…] Homes with more than 1 car per adult, private jets, motor sport industry, people with more than 1 residential home."*
>
> HH customer, Net zero and carbon emissions deliberative research
>
> *"Neither businesses nor individuals will change voluntarily. Change will require enforceable legislation. Will government be willing to introduce and enforce necessary change? Personally, I doubt it. The cost in winning future elections will be too high."*
>
> HH customer, Net zero and carbon emissions deliberative research
>
> *"This is about governments, and I don't think I should be investing my money in something that is a corporate responsibility"*
>
> HH customer, Affordability and acceptability testing

When it comes to Severn Trent taking action, most participants in our deliberative research agree it is important that we play our part in helping bring the water sector to net zero. At the same time there is some concern about the impact this will have on bills. As seen across all our research on future investment, customers want to know that vulnerable customers will not be disadvantaged and there is a lack of understanding about the role of shareholders and profits.

We find some conflict across our research between prioritising future generations and protecting existing customers, and about whether current bill payers should pay for benefits that will be enjoyed by future generations. This occurs both specifically thinking about investment in reducing greenhouse gas emissions and at the broader context level.

In our Strategic Investment Choices research we asked to what extent customers agreed or disagreed that *Future generations should bear the costs of dealing with climate change*. We found that 29% of HH customers agree, compared to 43% of NHH customers and 15% of future customers.

[26] Strategic Priorities research, December 2021
[27] Net zero and carbon emissions deliberative research, DJS Research, June 2022
[28] Social Barometer, wave 1 (September 2021) and wave 2 (December 2021), Consumer Insight

In our Affordability and Acceptability research, we found there was an understanding that the investment proposed in reducing emissions may not have immediate benefits for bill payers, but it is deemed necessary. However, in our LTDS research customers are less supportive of paying a significantly increased bill for a worst-case scenario now (in terms of uncertainty for the future, and spreading costs more evenly over generations) due to both the lack of personal benefit and "now is not the time" (with current high inflation and interest rates). It is notable however that these views in the LTDS research are expressed at a broader concept level and considering long term bill profiles, rather than about tangible investment.

> *"I don't mind paying for things as long as I get them, but I only want to pay for things I do get"*
>
> HH customer, LTDS research

Compared to other investment areas, working towards net zero is a medium level priority

From our overall understanding of customer priorities, working towards net zero ranks as a medium level of priority when compared to some of the more tangible investment areas relating to protecting the environment and resilience to the impacts of climate change.

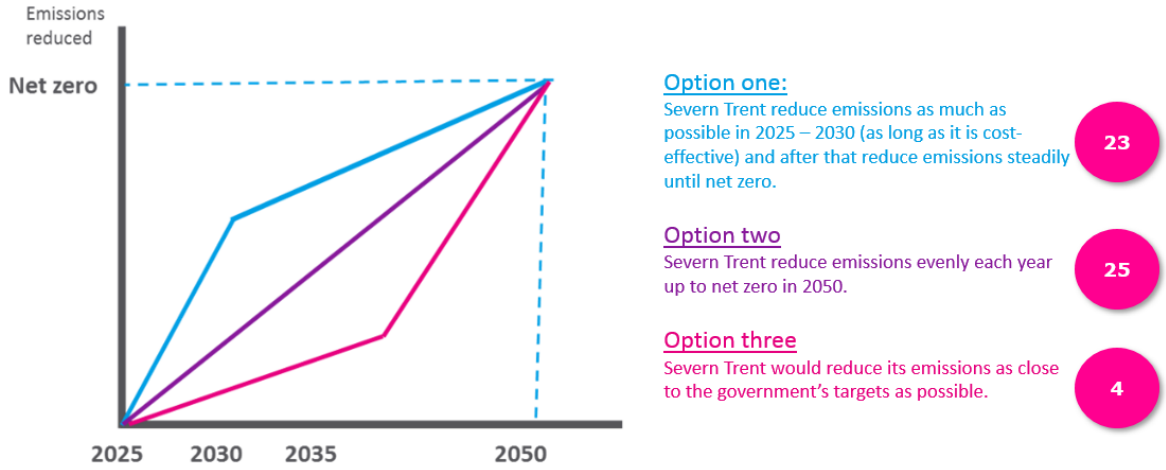
Customers are prepared to support some increase in their water bills to reduce process emissions. Some customers would like us to go further and faster on reducing greenhouse gas emissions but acknowledge that affordability is a concern.

This is an investment area in which we need to understand customer views on the **pace of investment**. We have discussed a range of options with customers and, across multiple research projects, have sought views on the preferred action, including presenting indicative bill impacts:

- Option one: Severn Trent reduces emissions as much as possible in 2025-2030 (as long as it is cost effective) and after that reduces emissions steadily to net zero;
- Option two: Severn Trent reduces emissions evenly each year up to net zero in 2050; and
- Option three: Severn Trent reduces its emissions as close to the Government's targets as possible.

In our deliberative research, participants showed roughly even support for a steady path to net zero and for acting more quickly, even when aware this would carry a greater bill impact. There is low support for delaying investment.

Figure 5: Levels of support for acting steadily, more quickly and more slowly



In our **Strategic Investment Choices** research customers were able to select their preferred level of investment (shown with indicative bill impacts), alongside options for other plan areas. Household and non-household customers selected similar levels of investment, while future customers are more likely to select a faster pace.

In our **Affordability and Acceptability testing** customers were very positive about our proposed approach, and the plan is seen as both acceptable and affordable. Many customers feel that going further represents good value for money and opt for this option, although there is some concern about this being overambitious and that a steadier pace is more achievable.

> *"I like the idea of being net zero by 2040, it's industry leading and will inspire others*"
>
> NHH customer, PR24 Affordability and acceptability testing
>
> *"Go for the alternative plan feels like a no brainer as it's not much extra*"
>
> HH customer, PR24 Affordability and acceptability testing

Our research on the **Long Term Delivery Strategy** reviewed this proposal with customers, in the context of longer-term planning uncertainties and intergenerational fairness. We found almost unanimous agreement among participants that Severn Trent should be **acting faster on its net zero strategy** – this is seen as a pressing and important issue that we need to take seriously. Customers also worry that organisations often fall behind these kinds of targets, and therefore going for the most stretching approach is the best way to ensure action is taken. Finally, customers feel they themselves are taking increasing action to limit their impact on climate change and it is only fair that organisations such as Severn Trent also do their fair share.

> *"It's absolutely massive, so they're right to get going with it"*
>
> HH customer, LTDS research
>
> *"At the end of the day, we're all doing our bit. Of course they should be thinking about it too"*
>
> HH customer, LTDS research

When it comes to solutions, customers want Severn Trent to focus on directly reducing process emissions and tend to trust Severn Trent to make the right technical decisions.

In our deliberative research, most participants tell us they trust Severn Trent to deliver the most effective solutions that benefit the environment and keep costs low (but there is a desire to be better informed) and most support Severn Trent's focus on reducing process emissions (and only using offsetting when direct reductions are too costly)[29].

Our plans continue to focus on lowering the sources of emissions and we do not intend to use offsetting. It is not part of our current plan and does not feature in our PR24 investment proposal.

When presenting our proposals in our PR24 Affordability and acceptability research, customers were very positive towards Severn Trent's planned approach and liked the innovation, showing that Severn Trent is a leading company, and that it would also help reduce future costs, thereby benefitting customers and society.

[29] Net zero and carbon emissions deliberative research, DJS Research, June 2022

Our overall plan is acceptable to customers, even though this investment area doesn't rank as highly as the others.

> *"The proposed plan sounds really good - having the world's first net zero sewage treatment works!"*
> HH customer, Affordability and acceptability research

In the quantitative research this doesn't rank as highly as the other investment options, however those between 18-24 rank it much higher than older age groups.

Our research on Long Term Delivery Strategy reviewed this proposal with customers in the context of the longer-term planning uncertainties and intergenerational fairness. We find almost unanimous agreement among participants that Severn Trent should be acting faster on its net zero strategy – this is seen as a pressing and an important issue that Severn Trent needs to be taking seriously. Customers also worry that organisations often fall behind these kinds of targets, and therefore going for the most stretching approach is the best way to ensure action is taken. Finally, customers feel that they themselves are taking increasing action to limit their impact on climate change and it is only fair that organisations like Severn Trent are also doing their fair share.

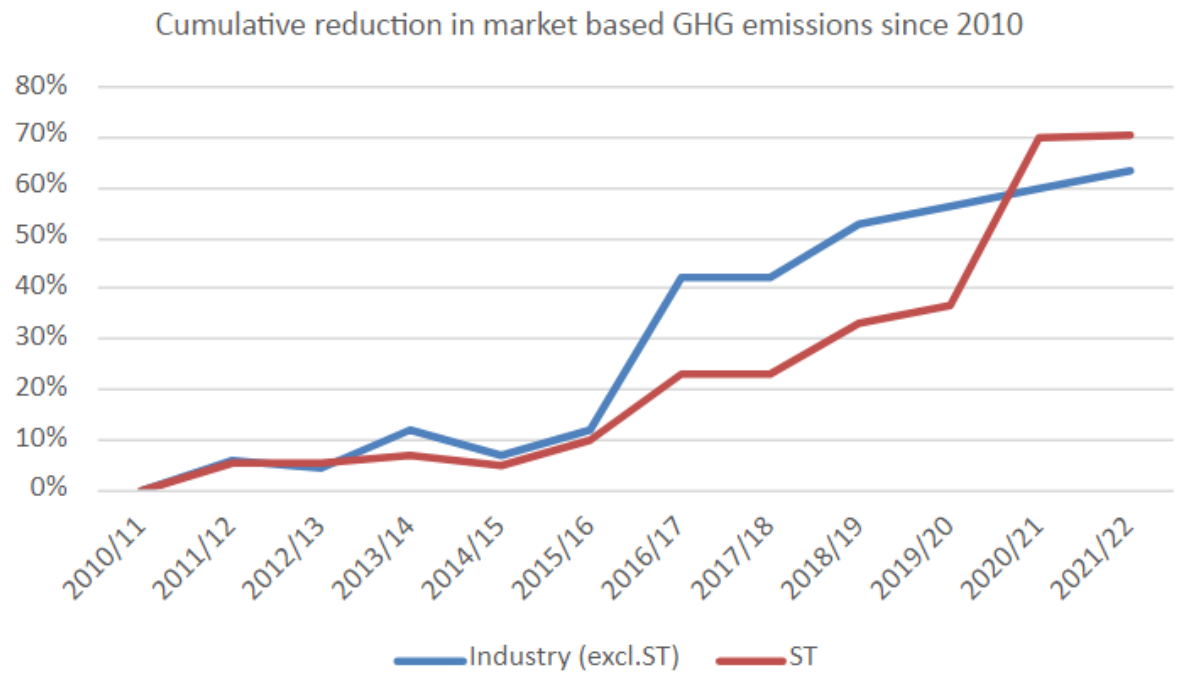
> *"It's absolutely massive, so they're right to get going with it"*
>
> HH customer, LTDS research
>
> *"At the end of the day, we're all doing our bit. Of course they should be thinking about it too"*
>
> HH customer, LTDS research

1.5 Management control

The need for investment outlined in this enhancement proposal is in response to the need to meet government net zero priorities (see Section 1.1) and is not driven by underinvestment to meet the challenges we are facing in AMP7 or have faced in previous periods. We have already invested in the economic carbon reduction options available to us on energy, renewables, and process optimisation, and we will continue to include those options as part of our base expenditure. Meeting the UK Government targets, however, requires further investment.

We have a strong track record of delivering emissions reductions in an efficient and cost-effective way: since 2010, we have reduced our operational emissions by more than 70%. Figure 6 below shows the reductions in operational greenhouse gas emissions we have achieved since 2010 compared to the average reported across the UK water sector.

Figure 6 Severn Trent and UK water sector greenhouse gas emissions reductions since 2010



Source discoverwater.co.uk

The path of our reductions shows our position is frontier, having achieved an above average reduction over this time. The investments we have made on reducing emissions in this period include[30]:

- £36m in energy efficiency capital investment since 2015;
- £400m in AMPs 5 and 6 across the Severn Trent group to reach our renewable energy targets;
- £5.2m in AMP7 from our new Carbon Tax Fund, both for new research and development innovations, process emissions monitoring, and optimisation trials, and in the people and skills needed to support the low carbon transition;
- £28m committed to the delivery of the Strongford net zero hub in AMP7[31]; and
- £1.5m in EV charge points in AMP7 to serve our growing electric fleet and the growing number of employees and visitors using electric vehicles.

On process emissions, we are already discovering where our existing assets are performing well. An example is an oxidation ditch site that is designed for total nitrogen removal which we have been monitoring to gain an insight into its impact on emissions. The results show consistently low levels of N_2O. Investigations of this type are increasing our understanding of what can be achieved through asset optimisation and could be replicated with investment. This shows that we are working hard to minimise the problem through our business-as-usual activities before proposing additional enhancement investment.

[30]https://www.severntrent.com/content/dam/stw-plc/shareholder-resources/2023-reports/ara-report-2023.pdf

[31] https://www.stwater.co.uk/news/news-releases/world-first--net-zero-hub--to-be-created-in-staffordshire--/

2. Identifying and assessing the best option for customers

This section describes how we have generated options and how we have prioritised solutions. It introduces the approach to valuation of greenhouse gas emissions and sets out the options that have made it through our assessment processes into this proposal. Finally, it compares our shortlisted options to the Jacobs review of net zero technologies commissioned by Ofwat in 2022.

2.1 Identifying the optimum scale and pace of investment

In Sections 3 and 4, we set out – including relevant evidence – the best value solutions needed in AMP8. But, as part of evidencing the best option for customers, it is important to understand the reasons to support the pace of action. In summary:

- **We have delivered cost-effective greenhouse gas emissions reduction through base expenditure in AMP7 and will deliver stretching reductions of 22% against a 2021 baseline in AMP8, also from base.** We have a strong track record of delivering emissions reductions in an efficient and cost-effective way: since 2010, we have reduced our operational emissions by over 70% for a total cost of £164m[32];
- **Elimination and reduction in greenhouse gas emissions are prioritised over the use of offsets.** Offsets are not included in our options. For further details, see Section 3.3;
- **The proposed investment makes sufficient progress with the reductions in greenhouse gas emissions in AMP8.** This means the remaining programme in AMP9 and beyond can reasonably deliver an emissions level consistent with net zero by 2050. It is clear across all scopes the target beyond 2030 will be harder to achieve. For further details, see Section 3.1;
- **We have deferred investment in several interventions where uncertainty is too great.** There are 10% of process emissions that we are not trying to tackle in AMP8 as the science behind their production and control is not well understood. We have also not decided to invest in areas where uncertainty is high, such as hydrogen, as we are not major drivers of the market. We continue to undertake self-funded trials such as the REWAISE project[33];
- **Our long-term net zero plan prioritises affordability and intergenerational fairness.** In line with our LTDS, we have taken an adaptive planning approach to support intergenerational fairness, stress testing our plans using future scenarios and defining our core pathway. This approach has allowed us to make evidence-based decisions about the pacing of our investment over 25 years. For further details, see Section 3.4;
- **Our analysis demonstrates that delaying investment will be more expensive in the long term.** For further details, see Section 3.5. Given that government net zero targets are driven by societal concerns and the costs of continued greenhouse gas emissions, packages of solutions that deliver significant reductions sooner and at low cost are also preferred and consistent with Ofwat's guidance on ambition. For further details, see Section 3;

[32]https://www.severntrent.com/content/dam/stw-plc/shareholder-resources/2023-reports/ara-report-2023.pdf

[33] https://cordis.europa.eu/project/id/869496

- **The incremental impact on bills in AMP8 is below estimates of customer willingness to pay.** This was tested in the costed choices research where customers were asked how they felt about a bill increase of £10. For further details, see Section 1.4;
- **We have assessed our capability and the capacity of our supply chains.** We are confident the programme we have identified can be delivered in AMP8. For further details, see Section 6.7;
- **Our investments in monitoring during AMP7 give us confidence in our data.** Severn Trent's work to monitor and measure process emissions has allowed us to calculate an accurate baseline for process emissions. It has also demonstrated they are significantly higher than previously estimated, strengthening the case for reduction. As well as this, we have benchmarked our data globally. For further details, see Appendix A;
- **We have trialled the technology needed to make process emissions reductions at scale.** We are investing during AMP7 into technology trials at our Spernal Resource Recovery and Innovation Centre and at our Strongford Net Zero Hub. This gives us greater confidence in the process changes that lead to the most cost-efficient emissions reductions and has given us an insight on their efficacy across the full range of assets we run, from lab to pilot to full scale. For further details, see Section 2.4; and
- **There are strong synergies with other drivers.** The chosen solutions are less likely to benefit from a significant economy of scope in the future associated with the necessary upgrade and replacement of existing equipment. This is low risk investment because the process emissions solutions are fitted to existing assets that will remain in service for the foreseeable future, including uplifts in process capacity for growth and due to the WINEP driver.

2.2 Approach to assessing options

We have applied a two-stage assessment: firstly, valuing and assessing costs and benefits of the options, and, secondly, stress testing the options against future uncertainties. Our approach to assessing costs to ensure they are robust and efficient is outlined in Section 5.

2.2.1 Valuing greenhouse gas benefits

There are three steps to valuing greenhouse gas benefits:

1. **Assessing the reduction in greenhouse gases likely to be achieved by each option (i.e. the primary benefit).** The baseline greenhouse gas emissions for each site are the values as reported in our statutory Annual Report and Accounts and our regulatory returns. These are the values which form the basis of our science-based targets and make up the totals given in Section 1. In the case of N_2O, each site's emissions have been determined using the reported site population and the same calculation used in our company-level reporting. In the case of CH_4 each site's emissions have been determined using the reported sludge throughput and the same calculation used in our company-level reporting. The likely success of each type of option has been assessed based on the best available knowledge from across the industry. This is built from the results of our trial work and the development of the Strongford net zero hub, as well as our consideration of similar schemes. These are reflected in the sensitivity ranges given for greenhouse gas reduction in Section 2.6;
2. **Calculating the carbon impact of the solution (i.e. a disbenefit of the construction of the solution).** Capital carbon values for construction have been calculated using the Severn Trent

Carbon Calculator tool developed by Jacobs using sector data. Where a new asset does not exist in the tool, the closest equivalent has been used, as outlined in Appendix E. It is not possible to include other scope 3 values such as reagents for monitoring equipment as such information is not available, however the value will be so low that this does not make a material impact; and

3. **Converting the total net operational and capital carbon into monetised values using the standard Benefit Assessment Tool.** In September 2021, the Government published a guide to the valuation of greenhouse gas emissions for policy appraisal and evaluation.[34] This includes a forward-looking guide to policy cost limits for carbon when assessing infrastructure projects. We are aware that the scope of the UK Emissions Trading Scheme is currently under consultation and that process emissions may become part of the scheme going forward, in which case we will be able to apply a real, market value to our options. In the meantime, we have used the 2030 guide prices per tonne of carbon dioxide equivalent (tCO_2e) to assess the options in this case, in common with all other carbon evaluations in our PR24 plan. Both the carbon values in tCO_2e and the monetised value as an annual operational carbon value are used in the assessment of options, as set out in the Service Measure Framework[35]. The latter is calculated by the Benefit Assessment Tool.

The calculation of £/tCO_2e has been undertaken over a 30-year basis, as this is the expected life of the assets. The cost represents the total NPV expenditure, i.e. the capital cost of installation plus the sum of the annual cost of operation and maintenance over the period. The tonnes of carbon abated is the total reduction over the period 2025-2055, less the capital carbon from construction.

Approach to Willingness to Pay

Using the policy cost of GHG emissions to value the benefit means this is not a Willingness to Pay value. However, we have used this value as an overall constraint on the proposed plan to ensure the proposal falls within customers' expectations. Recognising that our proposals will go into the net zero challenge fund process, we have disclosed the costs and benefits of our proposals. We believe the overall package represents good value for customers and for the UK as a whole in £/tCO_2e terms and falls within the bounds of what customers are willing to pay.

2.3 Seeking independent challenge and robust assurance

We have sought independent challenge at every stage of this process to test the rigour of our assessment and the prioritisation of our AMP8 activities.

Our Innovation teams have worked with stakeholders across the world to check our plans against global best practice and technology frontier. We share our thinking and seek challenge from other companies through Water UK technical networks, communities of practice, and the supply chain. We have also worked with European partners such as Aqualia in Spain as part of our Horizon 2020 funded project at Spernal.[36]

In 2022 we established a worldwide partnership with Melbourne Water and Aarhus Verband, which are recognised as leaders in carbon neutral thinking in the worldwide water industry. This partnership

[34] https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation
[35] See Annex 2 LTDS, section 4.3.4 for our approach to CBA
[36] https://cordis.europa.eu/project/id/869496

ensures we are looking as broadly as possible for opportunities in both continuing to understand our carbon baseline and in finding solutions to reduce it, while also using our partners to challenge our findings and thinking.

Our Strongford net zero hub proposals have been developed in conjunction with Atkins to ensure external rigour. The solutions have been market tested, and their contribution to process emissions reduction worked out. This knowledge has fed directly into this proposal and has actively challenged our assumptions on monitoring and the process emissions baseline. As the net zero hub is commissioned and put into operation we will continually review these contributions and update our plans.

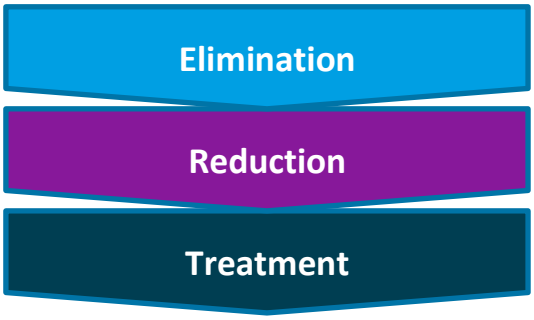
This enhancement proposal has been scrutinised by Jacobs and other external experts, as documented in our assurance process.

We sought challenge and feedback on the proposals from our ECP to ensure we were appropriately incorporating customers' views on scope, pace, and affordability. The ECP challenged us to be clear on the choices we have made on pace (taking into account legal requirements and company ambition) and to consider the carbon impact of other investments, and how it aligns with this proposal. For further details of the ECP's challenges, see Appendix B, Annex 2 LTDS and Annex 3a (Customer and stakeholder engagement, challenge and assurance).

2.4 Considering options across the hierarchy

We have identified three different categories of greenhouse gas emissions reduction, organised into a clear hierarchy:

Figure 7. Hierarchy of greenhouse gas reduction categories



- In the first instance, we have identified **elimination** options that prevent the greenhouse gas being created in the first place, either through the provision of a new type of treatment asset, by conversion of existing assets where economically feasible, or by the substitution of a fossil fuel source for a renewable one;
- Where we cannot eliminate greenhouse gas emissions, we have looked at **reduction** options. Typically, these rely on improved understanding of the mechanisms of greenhouse gas production from biological processes in both wastewater and bioresources treatment, or a trade-off for a lower-carbon alternative fuel; and
- Finally, we have looked at **treatment** options that deal with the greenhouse gas produced. Typically, these rely on covering tanks to capture greenhouse gases in the offgas from processes and treating it to destroy the gas, whether in-situ or elsewhere. These are less relevant for heat and fuel.

In line with Ofwat guidance for PR24[37] and on net zero,[38] we propose to address the root cause of process emissions rather than seeking to offset them. No funding is sought for any offsets.

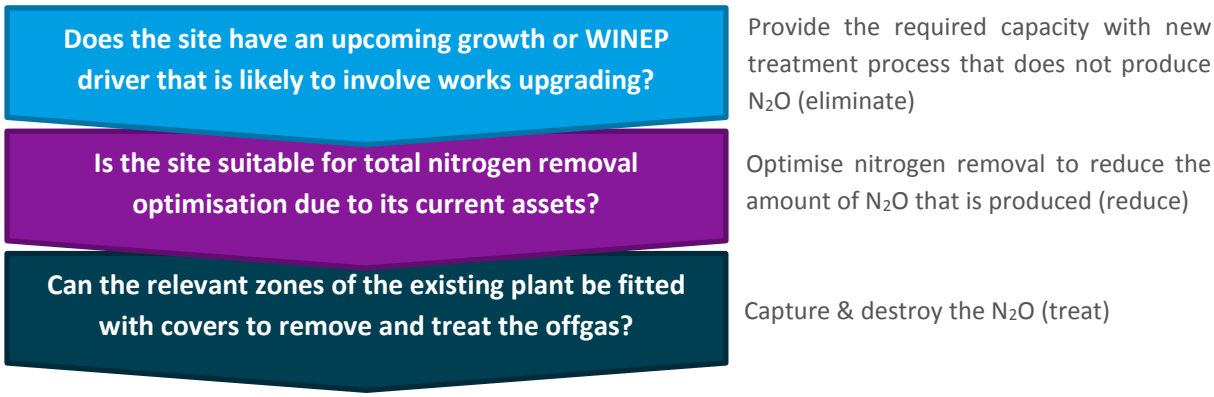
Principles for identifying process emissions options

Our most material source of nitrous oxide emissions is the activated sludge processes (ASP) which accounts for approximately three quarters of our wastewater treatment process emissions based on the population served by ASP sites. This is supported by the literature and by our own monitoring and detection work. In addition, the science around greenhouse gas emissions from biofilters is currently not well understood within the industry. This proposal therefore focuses on options for ASP sites. Research work is taking place to understand emissions from all processes, including biofilters, which are likely to form part of our plans beyond AMP8.

The principles we have adopted for identifying and sizing candidate schemes at ASP sites is shown in Figure 8. The options within each stage are outlined in Section 2.6. Where the primary driver is something other than process emissions, the costs are reflected in that enhancement proposal and the benefit has not been double counted.

For full details of how we developed the hierarchy for N_2O and CH_4, see Appendices B and C respectively. For the full list of options under investigation, see Appendices D and E.

Figure 8: Hierarchy of investment principles for N2O solutions at existing ASP sites

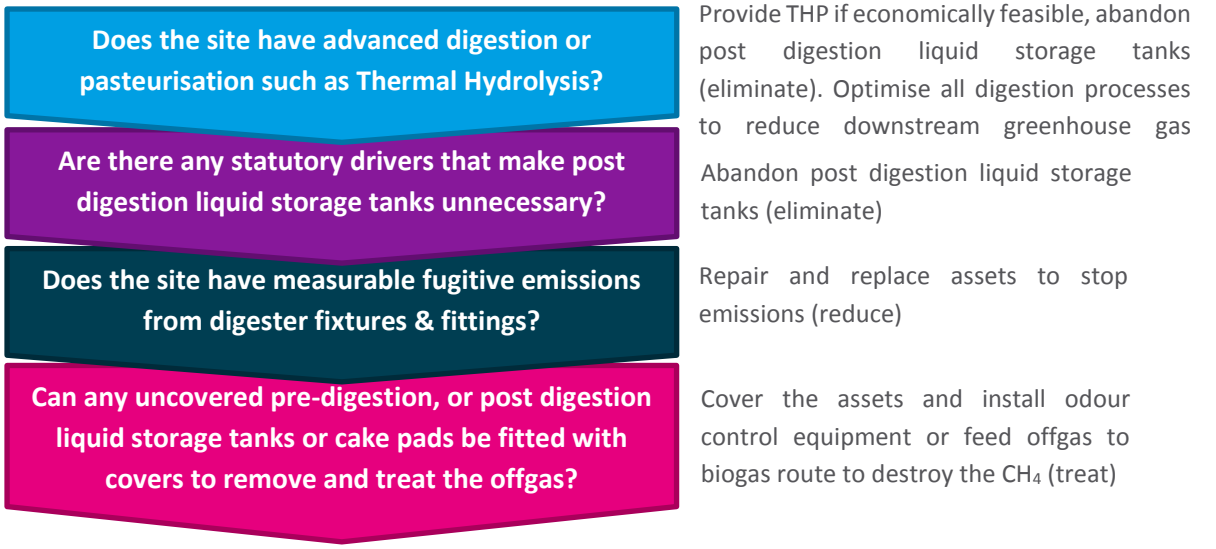


For bioresources digestion sites, there is a similar hierarchy of decisions. The options to replace processes are not as extensive in this area as advanced AD already provides a more futureproofed asset base compared with the iterative improvements in wastewater treatment driven by improvements in river quality. There is consequently a greater focus on identifying and removing the sources of greenhouse gas emissions from the bioresources digestion flowsheet.

The principles we have adopted for identifying and sizing candidate schemes at digestion sites is shown in Figure 9. The options within each stage are outlined in Section 2.6. Additionally, Section 2.6 covers N_2O production from bioresources liquors. Where the primary driver is something other than process emissions, the costs are reflected in that standard enhancement case and the benefit has not been double counted.

[37] PR24 and Beyond: Creating tomorrow together
[38] Net Zero Principles Position Paper

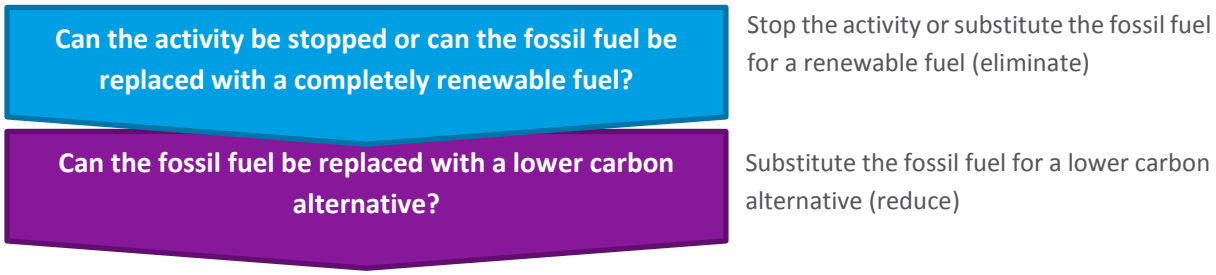
Figure 9: Hierarchy of investment principles for CH_4 solutions at existing bioresources digestion sites



Principles for identifying heat and fuel options

In most of our potential applications, this comes down to a choice between whether a completely renewable fuel source can be economically substituted, or whether a lower carbon alternative can be chosen. Note that all activities to reduce total heat waste and improve energy efficiency are part of our base activity. For example, we have already invested to reach 53% self-generated renewable energy whereas the industry total is 24%[39]. As well as reducing our Scope 2 emissions, this saves our customers an estimated £3 on their bill. We have therefore not included options to do this in this process. We will continue to find and deliver electricity and fuel saving schemes, for example finding lower heat input processes for digestion, as part of our base activity.

Figure 10: Hierarchy of investment principles for heat and fuel solutions



Where an option pays back, we would simply do it and such options are not included in this proposal.

2.5 Maximising innovation and learning

Achieving net zero and reducing process emissions is a global priority and we have sought to maximise the learning from this, specifically:

- We have gathered and shared monitoring data from sites, including Spernal, as outlined in Section 1.2 and Appendix A;

[39] % Renewable here calculated as total group renewable generation divided by total electricity consumption; compared using 21-22 data.

- We investigated innovative ways of reducing process emissions, such as spending six months in Scandinavia where a locally based technology scout evaluated emerging carbon solutions in the water and other sectors;
- We are investing during AMP7 in technology trials at our Strongford net zero hub and other sites, investigating which process changes drive the most cost-efficient emissions reductions and testing their efficacy across the full range of assets we run. We led the successful Ofwat Innovation Fund bid for Strongford, with buy-in from all other water and sewerage companies in the UK and Ireland, along with our international partners;
- As well as the projects we have led, we have engaged fully in all the innovation-funded projects and learned from those carried out by other companies in the sector, for example from Scottish Water's vacuum degassing trial;
- We have drawn lessons from the phase 1 and phase 2 UKWIR projects focused on understanding and reducing process emissions;[40]
- Reviewed and tested the ideas in the Jacobs review of net zero technologies (see Section 2.6); and[41]
- We are updating asset standards for the processes and equipment that contribute to greenhouse gas emissions, to reduced emissions from new equipment.

The nature of this proposal is to test, develop, and understand the best way to roll out net zero technologies at scale. The intelligence gained in delivering the investments outlined in later sections will be shared sector-wide through Water UK, UK Water Industry Research (UKWIR), and industry knowledge networks. This means other organisations which are not yet ready to take as large a step towards net zero in AMP8 will benefit from both the learning and the development of a mature UK supply chain, that our proposed investment would create.

It is essential at least one company takes these steps in AMP8 to help the sector reach net zero in the timescales required by government targets. By taking a lead, we benefit by directly reducing our GHG emissions, the sector benefits by having a tried and tested blueprint to follow and a capable supply chain to deliver it, and our customers and wider society benefit from the reduction in sector emissions and their contribution to reducing climate risk.

Stimulating innovation

Options such as anaerobic membrane bioreactor (AnMBR) and membrane aerated biofilm reactor (MABR) have been developed over several years, starting from laboratory scale, as part of our long-term plan to identify technologies for future deployment. They were both showcased in our PR19 plan. This approach underpins our development of options for the future, starting with support of academic research, through pilot plant studies, and on to full-scale demonstrators. We have used our Resource Recovery and Innovation Centre at Spernal to test and showcase these technologies. Some of the lower technology readiness level trials are still ongoing at Spernal but will not be ready for deployment until at least AMP9.

[40] UKWIR Report: 'QUANTIFYING AND REDUCING DIRECT GREENHOUSE GAS EMISSIONS FROM WASTEWATER TREATMENT PROCESSES' - Phase 1 2020 & Phase 2 2022

[41] https://www.ofwat.gov.uk/wp-content/uploads/2022/08/Net_Zero_Technology_Review.pdf

We collaborate widely with other water companies globally and domestically on such programmes of work, including our work with UKWIR and the submissions we have made and supported to the Ofwat Innovation Fund. The major innovation projects that relate to process emissions are shown in Table 4 below.

Table 4: Major innovation projects relating to process emissions

Innovation – inflight	Innovation – pipeline	Ofwat Innovation Fund
Hydrogen from waste ammonia Thermal treatment of ammonia PhD Biogas enhancements PhD Bioresources to fertiliser N_2O monitoring CH_4 monitoring and detection AnMBR Greenhouse gas emissions monitoring EngD MABR N_2O trial ASP cover and treat Digital twin for N_2O control	PhD wetlands as carbon sinks	Transforming the energy balance of wastewater treatment (WBC 1) Triple carbon reduction (WBC 2) Enabling whole-life carbon design (IWC 1) Industrial symbiosis (IWC 1) Organics ammonia recovery (IWC 1) Seagrass seeds of recovery (IWC 1) Strongford net zero hub

We have a PhD portfolio to create the necessary level of scientific rigour around process emissions monitoring, outlined in Appendix A. Some of the solutions outlined in Section 2.6 have been directly developed from the AD Fundamentals project[42], which has provided two consecutive EngD studies, and informed by earlier PhD studies.[43]

We have sought other thought leaders in net zero across the water industry in other countries, such as the Public Utilities Board (PUB) in Singapore. This approach led to the creation of our international Net Zero Partnership with Melbourne Water in Australia and Aarhus Vand in Denmark. We are collaborating on research and are producing a net zero white paper together.

A programme of trial work

Our Process Emissions optimisation team has conducted a number of hands-on trials since 2021 to put the learning from across the sector into practice and test it in real-world, full-scale conditions.

- We have installed Actilayer on a full-sized ASP lane at Spernal specifically to treat N_2O in the ASP offgas. This has been in service since 2022 and lessons learnt from this trial have been fed into the net zero hub deployment;
- We have installed MABRs from two different suppliers in the anoxic zones of two ASP lanes at Spernal. These have been in service since 2020 and were initially installed to test the technology's ability to treat increased load in the ASP. However, we observed during our trial monitoring that they were resulting in reductions in N_2O. This led us to research the literature and find other studies, referenced in the Jacobs technology review[44], that reported similar results;
- We have installed N_2O monitoring equipment at Itchen Bank. This is the only site in Severn Trent with a total nitrogen permit, so we were able to see the effect of a site operating with robust

[42] The AD Fundamentals project was an EPSRC funded PhD delivered with Imperial College https://spiral.imperial.ac.uk/handle/10044/1/59005
[43] https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/8494/Aboobakar_A_Thesis_2014.pdf
[44] https://www.ofwat.gov.uk/wp-content/uploads/2022/08/Net_Zero_Technology_Review.pdf

nitrification and denitrification. We have found such low levels of N_2O production at Itchen Bank that this has given us confidence in optimisation of nitrification and denitrification, whether through a digital twin or with more manual control; and

- We have trialled running lanes in very steady dissolved oxygen control at Strongford (prior to the net zero hub) to test the impact of steady operating conditions on N_2O production. This is another factor that feeds into the configuration of digital twins.

The Strongford net zero hub and global leadership

Our largest innovation project specifically focused on process emissions is the Strongford net zero hub, a full-size demonstration site that is deploying key items from our options list in AMP7 to evaluate their effectiveness, and capital and operational costs, together with the capital carbon associated with deployment. Because Strongford is one of our largest sites, a key objective is scaling the options to be trialled across the full range of site sizes at Severn Trent so they can be deployed with confidence in AMP8.

We have selected several technologies from the pilot scale trials at our Spernal Resource Recovery and Innovation Centre. The technologies impact processes across the end-to-end flowsheet and the net zero hub tests the benefits – and any potential disbenefits – of bringing them together as a blueprint at full scale. The site includes a combination of process emissions reduction and removal technologies, as well as solutions that recover resources from the treatment processes and recycles them back into the economy, resulting in the delivery of wider environmental and carbon benefits. These are brought together with a digital twin of the site to provide real-time, end-to-end process optimisation across projects. Based upon our monitoring programme (see Appendix A), we believe the combination of technologies will deliver net zero process emissions at the site. The technologies deployed at Strongford are shown in Figure 10 below.

All the technologies being deployed at the hub have been trialled and we are confident in their ability to both deliver reductions and to perform effectively, but no other organisation globally has achieved what we have at the hub. The supply chain is fully engaged and mobilised and we will have the site fully commissioned by Spring 2024. As previously stated, we will share the learning from the hub with the whole sector.

Figure 10: Strongford net zero hub technologies

2.6 Options under investigation

In 2021, as part of our wider carbon reduction programme, we established two technical expert groups from across the business, one focused on N_2O and the other on CH_4. Their remit was to explore and identify the reasons for production of both these greenhouse gases and to identify potential solutions for process emissions along the hierarchies set out in Section 2.4. Those solutions that are implementable in AMP8 are listed in the following tables, along with brief descriptions of what they are, their maturity, Technology Readiness Levels (TRL), and expected performance in terms of GHG reduction. TRLs range from 1 (conceptual) to 9 (commercially available). A more illustrative outline of each is given in Appendix C. Those that could not be considered for implementation in AMP8 are listed in Appendix D, together with the individual reasons why.

The anticipated GHG reduction from each option is given as a range and based upon our expectations as a result of analysing:

- Our own trials;
- Discussions with partners and other organisations;
- The net zero hub feasibility work; and
- Other published work.

Wastewater options that reduce N_2O

The options outlined in this section are all focused on the removal of N_2O from the ASP. We are continuing to monitor for CH_4 production from wastewater treatment but, so far, emissions have not been measured. These options are outlined in Table 5 below.[45]

Table 5: Wastewater options that reduce N_2O

Option	Type	Description	Maturity	TRL now	Anticipated TRL after trials	Likely GHG reduction
Cover and treat ASPs	Treatment	By covering ASP tanks, the N_2O produced during biological treatment and stripped from the liquid phase by airflow is prevented from escaping to the atmosphere	Photocatalytic covers to provide in situ treatment of N_2O are being trialled at Spernal and deployed at Strongford	7	9	50-80%

[45] Please note that, in our adaptive modelling, we have considered ASP intensification and the 'cover and treat' options to be mutually exclusive, whereas each potentially stacks with the digital twin and process optimisation options. This is for modelling reasons and gives the model choices rather than limiting it to the same flowsheet as the net zero hub. This means that for any given ASP site a set of solutions is identified that typically consists of:

- Installation of GHG monitoring and either manual process optimisation or digital twin; and
- Either cover & treat, **or** ASP intensification

The final solution for each site will be determined following detailed feasibility and design and will, of course, take into account what we learn from the net zero hub. This approach ensures that adequate but not excessive funding is included in this proposal to deliver the associated GHG reduction. A literal interpretation of the GHG reduction ranges suggests that any wastewater site would be expected to deliver between 40% and 130% GHG reduction, however the reality is far more nuanced, and we believe, based on our work to date, that the combination of options proposed across the sites will deal with the wastewater GHG emissions.

Digital twin	Reduction	By optimising ASP process parameters such as aeration, retention times and flow rates, it is possible to remove high levels of total nitrogen from the process. Research has shown an associated benefit is significantly reduced production of N_2O from the ASP. Different balances with other factors, such as energy use are required	Uses proven control methods and mechanistic modelling coupled with new N_2O monitoring technology and machine learning, and has been trialled at several sites in AMP7 and deployed at Strongford	8	9	20-50%
ASP intensification	Elimination	By using membrane aeration in anoxic or aerated zones, trials of MABR have shown extremely low levels of N_2O production. The addition of MABR cassettes to an existing ASP gives additional treatment capacity. We are also investigating other intensification options	Being trialled full-scale at Spernal and under consideration for AMP7 growth projects. MABR is identified in the 6th carbon budget[46] and the Jacobs net zero technology review[47]	7	9	20-50%
Process optimisation	Reduction	By employing monitoring technology, we can undertake operational actions to ensure that the best process conditions for low N_2O production are maintained and the impact is measured	Proven through our monitoring programme and tested across a range of trials	8	9	20-50%

Bioresources options that reduce N_2O

The option in this section, outlined in Table 6, is focused on the removal of N_2O from standalone liquor treatment plants (LTPs). This is only possible at the four sites where LTPs exist[48].

[46] https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Waste.pdf
[47] https://www.ofwat.gov.uk/wp-content/uploads/2022/08/Net_Zero_Technology_Review.pdf
[48] At the four sites where there is a discrete LTP, a split of greenhouse gas emissions between the LTP and secondary treatment was made based on the assessment of Strongford and benefits allocated in line with this. At these sites the benefit potential for all secondary treatment options, including digital twin and ASP intensification, was reduced to ensure no double counting of benefit could take place.

Table 6: Bioresources options that reduce N_2O

Option	Type	Description	Maturity	TRL now	Anticipated TRL after trials	Likely GHG reduction
Cover and treat LTPs	Treatment	By covering LTP tanks, the N_2O produced during biological treatment and stripped from the liquid phase by airflow is prevented from escaping to the atmosphere	Photocatalytic covers to provide in situ treatment of N_2O are being trialled at Spernal and deployed at Strongford	7	9	50-80%

Bioresources options that reduce CH_4

Table 7 below shows the option in this section, which is focused on the removal of CH_4 by encouraging the gas to form in primary digestion where it can be economically captured by existing equipment.

Covering secondary digestion tanks also captures CH_4 from digestate. However, due to the timing of clarifications of the application of the Industrial Emissions Directive (IED) not fitting with the AMP8 investment period, any such activity is carried out from base expenditure and is not included in this proposal. See Section 3.4 for more details.

Table 7: Bioresources options that reduce CH_4

Option	Type	Description	Maturity	TRL now	Ancitipated TRL after trials	Likely GHG reduction
Active gas capture from AD	Reduction	By resulting in more effective digestion and removal of CH_4 in the digester vessels, resulting in less carryover into downstream tanks. Digestate is then passed through a vacuum degassing process to remove any remaining traces	Sequential AD and vacuum degassing is being deployed downstream of the THP at Strongford	9	9	30-50%

Options that reduce heat and fuel use

The options in this section are cross-functional. The high heat demand from bioresources treatment means that cellulose recovery to provide an alternative fuel to natural gas is located at large wastewater recycling and sludge treatment centres. These options are outlined in Table 8 below.

Table 8: Options that reduce heat and fuel use

Option	Type	Description	Maturity	TRL now	Anticipated TRL after trials	Likely GHG reduction

Cellulose recovery	Elimination	By providing a substitute fuel source, we can eliminate natural gas and fuel oil for digester and thermal hydrolysis process heating	Trialled in AMP7	6	8	40-60% reduction in natural gas use
Heat pumps for buildings	Elimination	By eliminating natural gas and fuel oil as a fuel for space heating	Trialled in AMP7	9	9	Net benefit arising from fossil fuel reduction
Electric vehicle charging infrastructure	Elimination	By eliminating diesel as a fuel for light vans and cars	Deployed in AMP7	9	9	
HVO diesel replacement	Elimination	By eliminating diesel as a fuel for heavy goods vehicles and plant	Trialled in AMP7	9	9	

Comparison with Jacobs review of net zero technologies

In 2022, Ofwat commissioned Jacobs to review net zero technologies applicable to the water sector, including those that directly address process emissions. We have mapped our net zero options to those in the Jacobs review and found a very high degree of overlap: only one or two options under investigation do not appear in the Jacobs report, and while we agree that all options represent a reduction in GHG emissions, we do not agree that all would contribute towards our Scope 1 and 2 reductions. For example, co-digestion would not reduce direct company emissions but would contribute to offsetting national emissions. We recognise that a partnership approach may still be beneficial on a case-by-case basis.

Our approach to investigating each shortlisted option in the Jacobs report is summarised in Table 9.

Table 9 Options presented as shortlisted by the Jacobs review

Technology or solution	Considered in our 2030 Severn Trent plc Net Zero Strategy?	Included in this investment case?	Reason
Water efficiency across the urban water cycle	Yes	No	We agree that reduction in water consumption, including by metering, will reduce emissions and this is included in our long-term Water Resources Management Plan. However, net zero is not the primary driver for this activity, therefore our water efficiency proposals are covered by our water investment proposals and water base expenditure.
Pump efficiency	Yes	No	Pumps are our primary user of electricity, and we already have a proactive testing and refurbishment programme. We consider this to be business as usual activity and therefore funded from base expenditure.

Power purchase agreements	Yes	No	Power purchase agreements represent a way to procure green electricity and encourage renewable energy development, but we do not believe this meets the criteria for enhancement spend. In addition, they will not contribute to net zero under the location-based Scope 2 definition recommended for the Ofwat performance commitment. We continue to look for opportunities as a business as usual activity funded from base expenditure.
CH_4 monitoring & mitigation *(fixing leaks)*	Yes	No	We have begun CH_4 monitoring and control activity as part of our base maintenance activity this AMP and plan to continue this as it is part of responsible process management using base expenditure.
Membrane aerated biofilm reactor (MABR)	Yes	Yes	The basis for ASP Intensification options, see Table 2.6.1.
Conversion to nitrifying/denitrifying	No	No	Severn Trent ASPs are already designed to fully nitrify and some degree of denitrification is built in. New ASPs are built to design standards that allow for good nitrification and denitrification. Where it is possible to optimise denitrification within an existing works, for example where there is intermittent aeration with adjustable anoxic periods, this falls under process optimisation as another facet of N_2O setpoint optimisation. Building new unaerated zones and energy-intensive full flow recycles at large ASP works is considered likely to be a more expensive and higher Scope 2 and 3 carbon solution compared to cover and treat and ASP intensification.
N_2O setpoint optimisation	Yes	Yes	The basis for process optimisation options, see Table 2.6.1.
Real-time N_2O control	Yes	Yes	The basis for digital twin options, see Table 2.6.1.
AAD THP	Yes	No	We have been increasing our advanced digestion capacity as part of our bioresources strategy by installing more thermal hydrolysis plants in AMP7. We plan to continue this, but capacity and digestate quality are the primary drivers, rather than net zero, so are funded from bioresources base expenditure. We note also that while THPs produce more biogas and can reduce process emissions, they have a higher heat requirement, which increases Scope 1 emissions.
AAD EH or APD	No	No	As above, net zero is not the primary driver and this would be funded from bioresources base expenditure. There is some relationship to the proposed active gas capture options, especially sequential AD which is a conceptual extension of the principles of APD beyond separating methanogenesis from hydrolysis and acetogenesis.
ITHP	No	No	See comments for AAD THP.
Co-digestion	No	No	Net zero is not the primary driver and there are current fundamental legislative blockers. We do intend to grow digestion of biological waste other than sewage sludge, but only in our non-appointed Green Power business.
Gasification/pyrolysis	No	No	The primary driver for these technologies would be bioresources digestate improvement, rather than net zero and it involves new assets which, as Jacobs note, have not yet been deployed at scale in the UK due to practical, economic and technical reasons. Therefore, these options are not included in this net zero case.
Biodrying (sludge)	No	No	
Low-energy drying (sludge)	No	No	

N stripping (liquors)	Yes	No	We are investigating this option, but we believe it could be an economic spend to save opportunity in AMP8 from base expenditure, so have not included it in our enhancement case.
Tanker (biomethane)	Yes	No	Business as usual funded from base expenditure.
Heat recovery (onsite)	Yes	No	We are investigating this option but our AMP7 studies and trials conclude that opportunity is limited. If the economics of this technology improve, this would be an economic spend to save opportunity in AMP8 from base expenditure, so we have not included it in our enhancement case.
Biomethane to grid	Yes	No	We have continued to increase biomethane to grid exports over AMP7. This is economic, business as usual activity funded from bioresources base expenditure .
Stormwater separation & treatment with NBS	Yes	No	As with water efficiency, we agree that reduction in stormwater flow pumping can reduce operational emissions and this is included in our long-term sewerage plans. However, net zero is not the primary driver, and reducing storm flows only reduces electricity emissions marginally, with little to no impact on process emissions or fossil fuel use.

The elements of our options in our proposal that were not included in the Jacobs review are given in Table 10. Of these, some appear in the Jacobs longlist and others were not featured at all.

Table 10 Elements of our net zero proposals not presented as shortlisted by the Jacobs review

Technology or solution	In the Jacobs longlist?	Reason for inclusion in our proposal
Cover & treat	No	We have trialled the technology on one lane at Spernal and they will be included in the full-scale trial at the Strongford net zero hub. The technology has not been applied in the water sector to N_2O removal but is proven elsewhere, and we are working with suppliers to optimise in this application. Our trials at Spernal indicate successful N_2O removal and we are refining its deployment and operation at the net zero hub.
Active gas capture	No	Sequential digestion is an extension of the APD principles shortlisted in the review but takes them further and is proven in other countries in Europe – the effects of producing more gas in primary digestion are comparable with EEH, APD and THP. Vacuum degassing is a separate activity that has been trialled successfully in the UK.
Cellulose recovery	Yes	The use case in the longlist is for reduction in aeration demand due to removal of inert cellulose from the ASP reactor. Our use case is different and results in a Scope 1 fuel reduction from using recovered cellulose as a fuel in a biomass boiler, rather than a Scope 2 power reduction. As we will operate this at the net zero hub the full carbon balance will be closely monitored and evaluated to ensure there are no unintended negative effects on GHG reduction elsewhere in the wastewater treatment process.
Heat pumps	No	Heat pumps are a proven technology and a central strand of the UK government's strategy for decarbonising domestic space heating. There is reference to heat pumps in the Heat Recovery item, but it is assumed this is recovery of process or sewer heat rather than conventional ground or air source space heating.

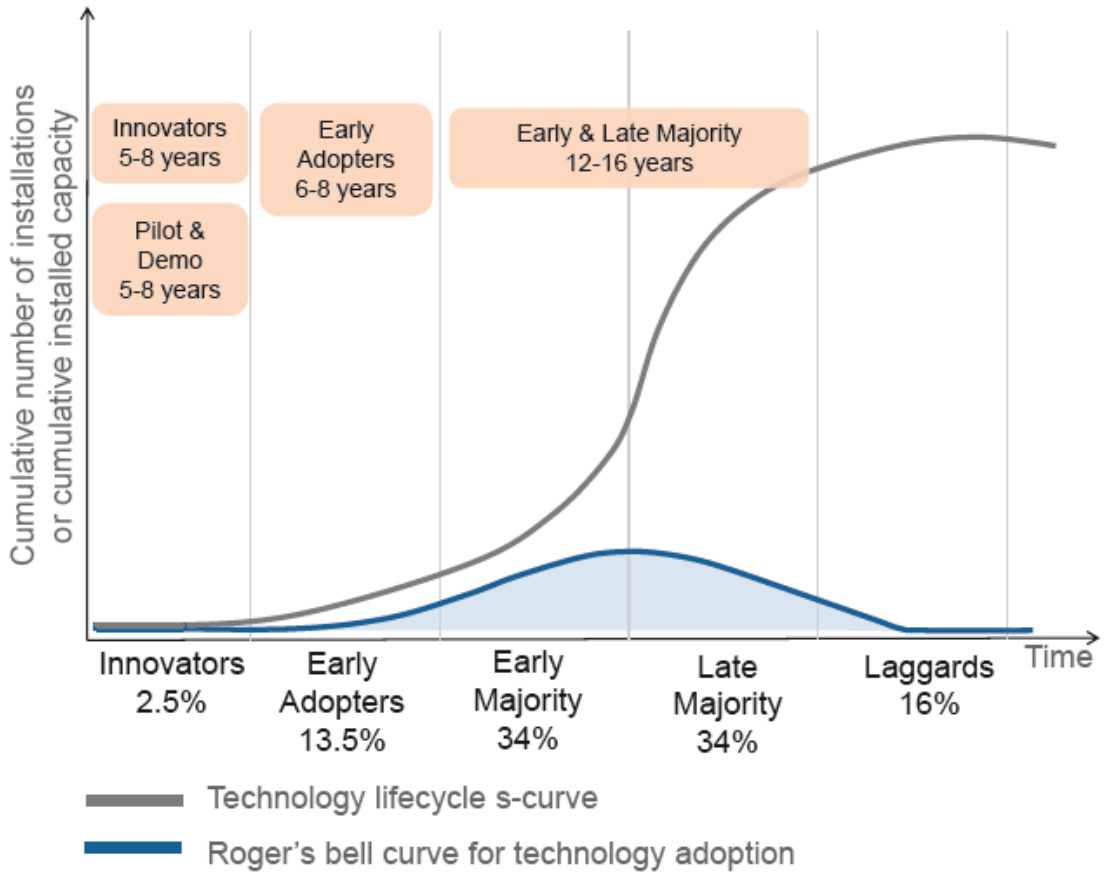
HVO diesel replacement	No	HVO is a transition measure until such time as hydrogen or electric heavy vehicles are the norm, and represents a low risk, low regrets activity that achieves substantial and real short-term GHG reductions.

We believe the reasons above for including these technologies in our proposal are robust and comprehensive and their non-inclusion in the Jacobs review is largely a factor of their current development state rather than not being suitable. In some cases, such as electric vehicles and heat pumps, the use cases are not water-specific which is why we believe they are not included in the Jacobs review. As part of our net zero hub commitments, we will share the findings of the rollout at scale of our new technologies with the rest of the sector to contribute to the wider knowledge base.

Learning curves and the development of technology solutions

A variety of research into the development of technology exists, with some studies looking specifically at technologies in the water sector. Such an example is Dynamics of Water Innovation: Insights into the rate of adoption, diffusion and success of emerging water technologies globally[49]. This study looks at examples of technology development in the water sector such as membrane treatment and ultraviolet disinfection and determines that this type of technology typically follows a learning curve of approximately 11 to 16 years before successful technologies begin being adopted at scale. This is shown in Figure 11.

Figure 11: The technology lifecycle s-curve for typical water technologies



[49] https://research.wur.nl/en/publications/dynamics-of-water-innovation-insights-into-the-rate-of-adoption-d

Source Paul O'Callaghan - Dynamics of Water Innovation: Insights into the rate of adoption, diffusion and success of emerging water technologies globally

Case studies – deep dives into the development of two technologies

Cover and treat and vacuum degassing are two of the key technologies in this proposal and provide a good case study to look at in more depth. They are a key part of our plans, are not specifically part of the Jacobs review and, as a result, their maturity is less well known and understood across the wider sector. SUEZ and Eliquo are the suppliers of ActiLayer and Elovac, the technologies that these options have been developed around, and they have shared their development timelines. We believe that the steps and stages outlined below show that the technologies are entirely consistent with the pace of development of other technologies, meaning that after approximately 10- to 20-years each of development they represent a stable and mature deployable solution rather than early-stage ideas.

Steps in the development of ActiLayer

- 2002/03: SUEZ, as international utility with wastewater and solid waste treatment operations contracts, identifies the topic of nuisance odour management as a key topic for research investment. The NOSE (No Odours for SUEZ Environment) R&D program is launched representing a five-year/€5m investment;
- 2009/10: Identification and preliminary pilot scale testing of photocatalytic covers (ActiLayer prototypes) for odour treatment applications;
- 2012: Execution of initial full-scale projects of photocatalytic covers (ActiLayer prototypes) for odour treatment applications;
- 2015: EU funding (Climate KIC) of SUEZ led team for Sewage Network Combined Emissions (Odours + GHG) Inventory & Monitoring proof of concept. Initial collaboration between SUEZ and Laboratoire des Sciences du Climat et de l'Environnement (LSCE ; Paris Saclay University research team led by climate science expert and Nobel laureate Dr. Philippe CIAIS);
- 2017-19: EU funding (Climate KIC) of SUEZ led team for Waste Miti^2 project focused on waste management solutions to address climate change impact with emphasis to accelerate evaluation and deployment of novel GHG mitigation solutions. Ongoing collaboration with Philippe CIAIS & LSCE. Resulted in development of our SCAN 360 methodology for *in situ* measurement of GHG emissions. Funding of coordinated scientific literature reviews to identify exhaustive list of GHG mitigation strategies – among the list was photocatalytic destruction of N_2O;
- 2018: ActiLayer solution technological advancements for odour management in response to client specifications via execution of full-scale projects;
- 2018: Launch TRACE (Tracking of Carbon Emissions) Industrial Chair funded by French National Research Agency (ANR) between SUEZ, TOTAL and LSCE with emphasis to develop low-cost sensors for continuous GHG monitoring, enhanced modeling techniques for GHG emissions – source contribution via reverse atmospheric dispersion modeling techniques, and real-time surveillance platforms for industrial GHG monitoring;
- 2021: Preliminary field tests on N_2O capture and treatment with ActiLayer covers within framework of ActiLayer Product Roadmap; and
- 2022 – Present: Launch of SUEZ-Severn Trent collaboration for testing and deployment of ActiLayer solution for N_2O capture and treatment at wastewater treatment facilities. SUEZ

launches dedicated program (R&D at lab and field-scale) to adapt and enhance design of ActiLayer solution for N_2O capture and treatment.

Steps in the development of Elovac

- 2014: The idea was born to use vacuum to remove methane and carbon dioxide from digested sludge to avoid methane emissions into the atmosphere and to increase the pH of the digested sludge to ease struvite precipitation in a subsequent reactor;
- 2016: First full-scale installation in Lingen. In the course of a funded project the installation was deeply evaluated, and some fundamental findings could be used for the further development of the process;
- 2019: Test and roll-out of the ELOVAC-P, a process combining vacuum degassing with simultaneous struvite precipitation. With this, the subsequent struvite precipitation and crystallisation reactor became obsolete;
- 2020: Design optimisation and first containerised demo unit for Europe built and first tests conducted. The capacity of the plant (20 m^3/h) allows for full-scale tests on site;
- 2021: First containerised demo unit (20 m^3/h) for the US built, shipped over and first tests carried out. Design of ELOVAC plants with a higher capacity (30 m^3/h and 40 m^3/h, respectively). First demo tests carried out in the UK. Orders received for ELOVAC units for Germany, South Korea and Denmark;
- 2022: Commissioning of new plants. Decision was taken to build a second demo unit for Europe since demo unit #1 was rented out for the whole year. Furthermore, first design works for an ELOVAC for water applications. Commissioning of new plants in Germany, South Korea and Denmark; and
- 2023: Design and manufacturing of an ELOVAC pilot plant for water applications.

We believe the other technologies contained in this proposal are similarly mature and the blueprint being developed through the Strongford net zero hub represents a sensible way of dealing with direct GHG emissions. The knowledge we are gaining and will share about their deployment only enhances this. This proposal therefore does not pose a risk of technology regret and given the scale of the challenge there is limited gain from waiting for new alternatives.

3. A ‘no- and/or low-regrets’ strategy for the long term

This section describes how we have applied the principles and processes outlined in our LTDS to the options identified in section 2. It covers the scenarios and constraints we have considered in our ‘no-and/or low-regrets’ modelling and the sensitivities each option has been tested against for every case of deployment considered. We outline how this proposal sits alongside the activities we will undertake in AMP8 from our base expenditure allowance. Finally, we consider future pathways.

See Annex 2, LTDS for a full description of our Long Term Delivery Strategy.

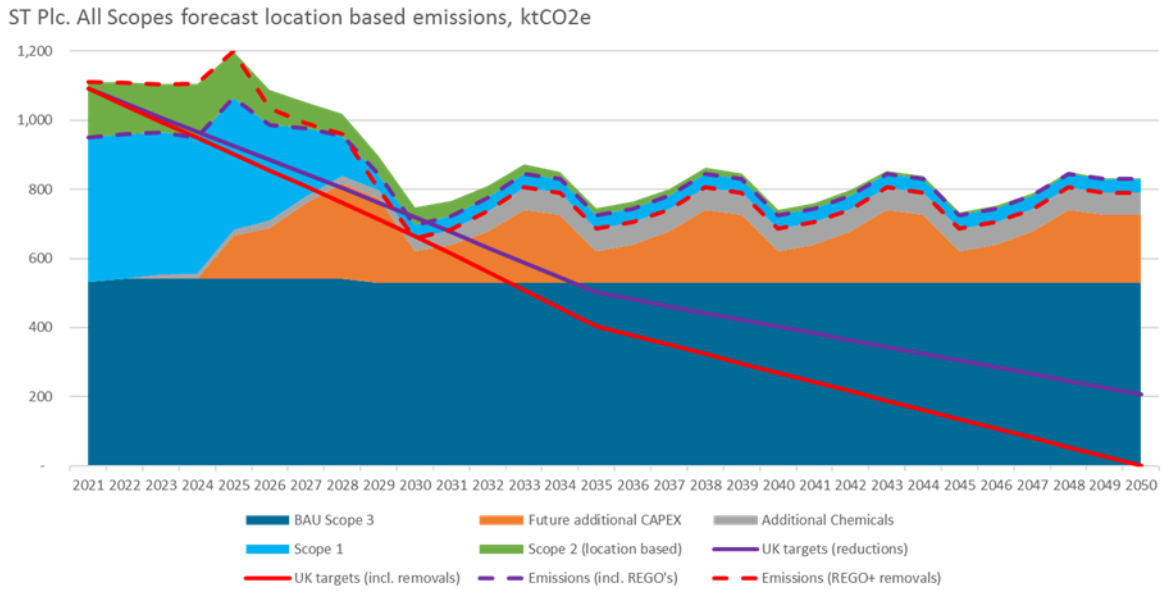
3.1 Our long-term strategy for greenhouse gas emissions

Severn Trent is committed to achieving net zero greenhouse gas emissions in line with the Government’s policy expectations for water companies. Our net zero commitment forms part of our 2050 strategic priority to ‘support a thriving environment’, outlined in our LTDS, and our approach is fully integrated with the adaptive pathways identified within this.

The scale of the Scope 3 challenge is shown in Figure 12. This chart shows our current baseline emissions levels across all scopes and how they are forecast to change. Scope 2 emissions are increased by other drivers, but the effect of UK electricity grid decarbonisation means they will reduce to zero as the grid decarbonises by 2035. The impacts of forecast asset investment in AMP8 and AMP9, together with the effects of programmes such as WINEP on chemical consumption, can be seen in the grey and orange Scope 3 segments of the chart. These upward pressures create a significant challenge when the required path to zero is overlaid as show in the dotted line.

Addressing the sources of greenhouse gases in this proposal is necessary for us to avoid going further off track with government targets due to the upward pressure on Scope 3 emissions forecast by other statutory activities over AMP8 and beyond. The impact of this proposal is shown by the reduction in the blue scope 1 segment.

Figure 12: Severn Trent’s net zero challenge



This chart clearly shows that there will be significant future challenges from Scope 3 emissions, namely additional chemical use as a result of WINEP, and existing Scope 3 supply chain GHG emissions

including construction after 2030. The reduction trajectories of other sectors that make up our Scope 3 emissions are not included in this graph, as we are trying to show the scale of the challenge yet to come, that we will have to work on with our supply chain post 2030 in order to reach the UK's 2050 targets.

For more information on our pathway to net zero, see our Sustainability Report.[50]

Delivering net zero in line with the Government target will mean significant greenhouse gas emissions reductions across our operational (i.e. Scope 1 and 2) footprint. Our vision is for a wastewater treatment system that is centred around low carbon, best value wastewater and bioresources treatment, delivering reductions in emissions from both energy use and treatment processes, without compromising on water quality. We have developed a three-stage plan to reduce greenhouse gas emissions over the next 25 years:

1. **AMP7 (2020-2025): Establish baseline and highest impact interventions.** We have established monitoring processes, restated accurate baseline emissions, and deployed innovation trials to understand the best reduction methods for process emissions. We are reducing process emissions by an estimated 34 $ktCO_2e$ by deploying technologies at the Strongford net zero hub through base expenditure in AMP7. We have also started to decarbonise our transport fleet;
2. **AMP8 (2025-2030): Deliver significant reductions in process emissions and reach net zero in heat and fuel.** We will target investment in our treatment processes with the highest emissions, deploying the best technology to make deep cuts in emissions at an efficient cost. We will reach net zero greenhouse gas emissions from heat and fuel use; and
3. **2030-2050: Roll out process emissions reduction across all operations.** We will systematically replace the remaining high emission treatment processes with safe, effective and efficient alternatives, adapting our strategy for maximum cost efficiency as the context evolves. We will deliver zero Scope 3 emissions by working in partnership with our supply chain to make sure their own decarbonisation plans are implemented.

What base buys in AMP8

If we did nothing, our projected Scope 1 and 2 greenhouse gas emissions in 2030 would be 641.8$ktCO_2e$. This takes account of future growth drivers and other upward pressures. In our wider net zero plans, the following activities will be undertaken from base expenditure in AMP8. This gives a 20% reduction against our Scope 1 and 2 baseline from base expenditure, which we believe represents a stretching level of reduction.

Table 11: Anticipated greenhouse gas emissions reductions through base expenditure in AMP8

Activity	GHG reduction ($ktCO_2e$)	Reason to fund from base
Stop natural gas combined heat and power (CHP) engines	23	No enhancement driver
Future reductions arising from bioresources growth	19	No enhancement driver – existing asset base will deliver greenhouse gas capture proportionate to current level from increased load due to growth
Methane leakage (find and fix)	38	Existing activity

[50] [insert link to 2023 Sustainability Report]

Replacing fleet vehicles with low carbon alternatives	3.5	The benefit of vehicle decarbonisation has been split 50/50 between vehicle costs (included in base expenditure as it is replacement of existing vehicles) and charging infrastructure (in this enhancement proposal). Charging infrastructure is additional to normal activity and required to enable a low carbon fleet
Cover secondary sludge tanks, and capture and destroy methane	31.5	Due to the relationship of this activity to potential IED actions, this has not been included as a proposal in this case (see Section 2)
Nature-based land solutions	0	Responsible companies will preserve and enhance nature on the land they own as part of core activity. This means preventing loss and slowly growing natural carbon sinks and represents an 'inset'. We have not included expenditure for inset proposals in any enhancement cases

There will be a further 160ktCO_2e reduction in annual Scope 2 emissions from continued use of renewable-backed electricity imports, which we have not counted in this proposal or the above reductions. This will not contribute to Ofwat's greenhouse gas reduction performance commitments to reflect the definition of location-based emissions for Scope 2. If we were to count this, it would be an approximately 27% reduction in operational emissions. Note that this activity will be counted for the purposes of science-based targets and will be reported transparently alongside our location-based emissions each year.

3.2 Our approach

There are four key elements of delivering a 'no- and/or low-regrets' strategy for reducing process emissions:

1. Robust assessment of need and timing (see Section 1);
2. Comprehensive range of options considered (see Section 2);
3. Careful modelling of the options, including major risks and scenarios (see Sections 2 and 3.2); and
4. Relevant third-party assurance (see Section 2.4).

In this proposal, we focus on the outputs of this process: see the Severn Trent LTDS for full details of the approach itself. To summarise the approach we have taken:

- Greenhouse gas reductions are valued as outlined in Section 2.2, consistent with the BEIS policy cost of carbon;
- This is used as a benchmark to assess whether various options for intervention are cost-effective (see Section 4.3 for the output);
- The options generated are selected as 'no- and/or low-regrets' by an optimisation process that picks the solution with the best NPV across the risk and sensitivity ranges considered; and
- We have ensured the resulting programme is affordable by seeking our customers' views as summarised in Section 1.4.

Reaching net zero is a semi-statutory type of investment. There are no direct statutory requirements for us as an organisation however we need to play our part in meeting the UK's targets as outlined earlier in this case. There is a degree of discretion about when to invest and when compared to other

investments, a high degree of uncertainty when it comes to identifying what represents low regrets investment. Therefore, in our programme-wide optimisation process, a Decision Making under Uncertainty (DMU) type decision support tool has been used.

3.3 Future scenarios

In order to develop the best value long-term plan, we have considered a number of plausible futures, developing different scenarios and considering the best way of meeting our long-term commitment to achieve net zero greenhouse gas emissions in all of those possible future worlds. This provides a systematic way of establishing how robust our investment choices are to future uncertainties.

We have considered how Ofwat's eight common reference scenarios[51] (CRS) change either the size of the problem we are trying to solve, or the costs and/or benefits of the solutions. In doing this, we concluded that none of the climate change, growth or abstraction Drivers of Uncertainty are relevant to the investment decisions for net zero as the deployment of the options under consideration would not be affected by these factors. We asked the Met Office to review this decision as climate change was the area we most wanted third party assurance on this decision for, and they endorsed it.[52] The high and low technology drivers have been mapped to scenarios in the model and are represented by faster and slower paces of technology respectively.

We have considered seven additional sensitivity tests, outlined in Table 12 below, that also represent variations of the plausible futures in the specific context of the net zero challenge. In addition, two sets of constraints were identified that were best explored as cost sensitivities, rather than greenhouse gas emission reduction trajectories to 2050.

Table 12: Model sensitivity tests and constraints

Sensitivity test	Title	Description
1	39% by 2030, 63% by 2035	This represents our core scenario and consists of a requirement to meet the UK targets of 39% reduction by 2030, 63% by 2035, and then no further constraints until the 100% target by 2050.
2	Other sectors do not meet their share of UK-wide reduction	If other sectors do not meet their share of carbon reductions, we may need to accelerate our progress. We have modelled this with a path to 2035 as test 1 then a requirement for the water sector to bring forward 100% reduction from 2050 to 2040.

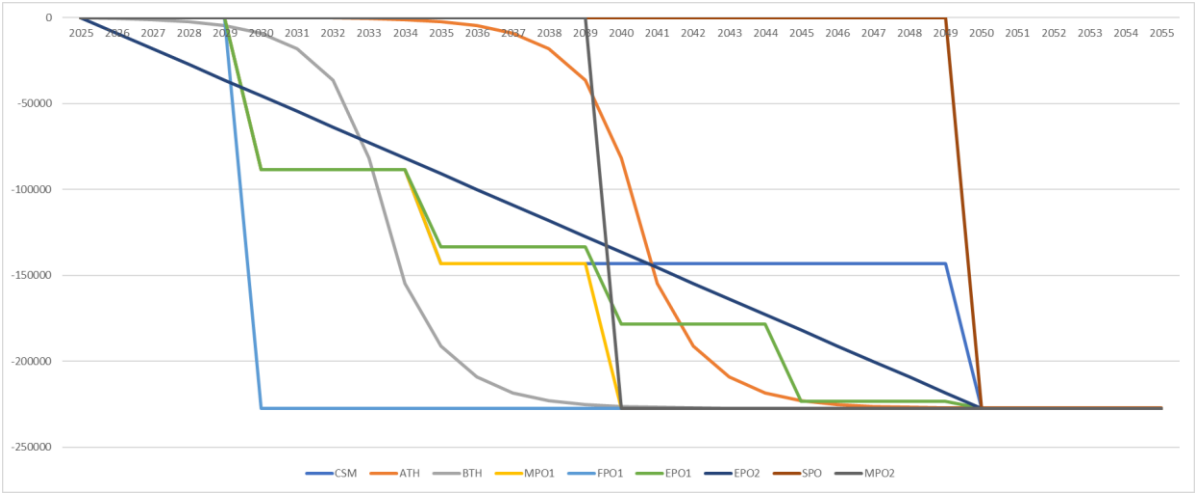
[51] Ofwat LTDS final guidance, pages 34-45: https://www.ofwat.gov.uk/wp-content/uploads/2022/04/PR24-and-beyond-Final-guidance-on-long-term-delivery-strategies_Pr24.pdf

[52] SevernTrent_ClimateInsight_Report_final.pdf

3	Fast pace	To reflect our triple carbon pledge and science-based targets, a reduction of 100% by 2030. This test maps to the most likely plan in portfolio.
4	Steady progress	This test forces the modelling to consider which options would be picked in a future where a linear profile of annual greenhouse gas reductions to 2050 is imposed.
5	Steady progress optimised by AMP	This test is like ref 4 but optimises against five-yearly rather than annual targets.
6	All by 2050 unconstrained	This test removes interim reductions from Scenario 1.
7	All by 2040 unconstrained	This test removes interim reductions from Scenario 2.
8	Benign technology	An S-shaped emissions profile delivering full reductions by 2035.
9	Adverse technology	An S-shaped emissions profile delivering full reductions by 2045.

These scenarios and constraints are shown graphically in figure 12 below.

Figure 12: The target GHG reduction profiles across all our modelled scenarios



We believe this approach gives a balance of adverse and benign futures. This has enabled us to avoid bias in our 'low- and/or no-regrets' selections, and extremely low-probability futures that can be created by combining too many low or high variables.

Defining costs and benefits

Table 13 below shows the uncertainty ranges of the costs and benefits used in our investment optimisation model. Uncertainty ranges are informed by the technology readiness level and the risks presented in feasibility studies.

Table 13: Uncertainty ranges of costs and benefits

Option	Cost uncertainty		Benefit uncertainty		Comment
Cover and treat (ASPs and LTPs)	-20%	+20% +50% +100%	-20%	+20%	Cost max uncertainty is site-specific based on a risk rating reflecting site access to ASP area
Digital twin	-20%	+20%	-20%	+20%	
ASP intensification	-20%	+20%	-50%	+20%	Benefit range reflects lower TRL
Active gas capture from AD	-20%	+20%	-20%	+20%	
Cellulose recovery	-20%	+100%	-80%	+20%	Cost and benefit ranges reflect lower TRL
Heat pumps	-20%	+20%	-20%	+20%	
EV charging infrastructure	-20%	+20%	-20%	+20%	
HVO diesel replacement	-20%	+20%	-20%	+20%	

3.4 Creating our 'no- and/or low-regrets' pathway

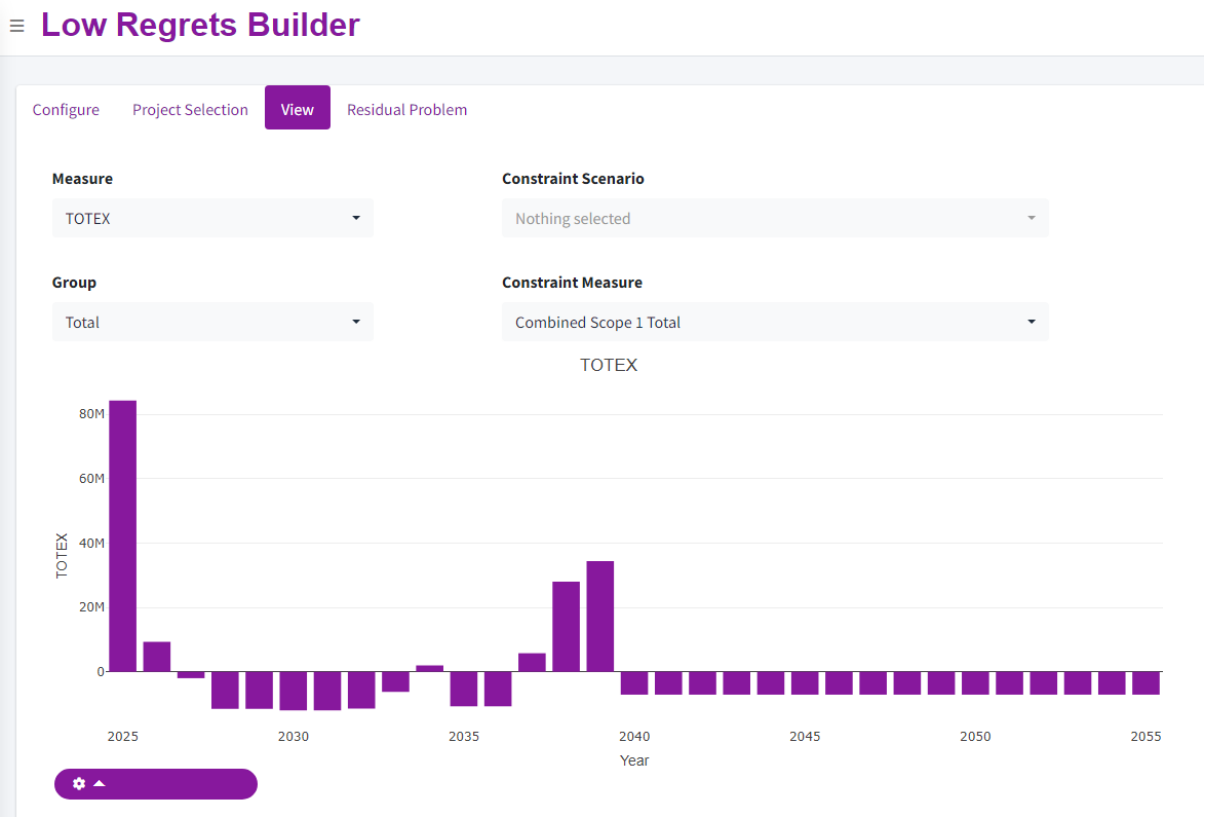
In line with our LTDS, we have applied a common method for optimising investment across the plausible futures. We have applied this approach in the following way:

- **Specifying the problem.** In all scenarios, the problem we are solving is to achieve net zero by, at the latest, 2050; and
- **Identifying options.** For effective optimisation, it is important we include a variety of options – more options that we need to solve the problem – or the only optimisation available is in sequencing. We also need to set up those options at the right level of granularity, which is at site level for process emissions reduction options and programme level for the lower value programmes such as EV charging infrastructure or HVO diesel replacement. In total, we have created options and given the model choices that together would tackle 125% of the emissions required. This is a set of modelled options that give us confidence that we have provided sufficient choices to be considered within the optimisation process.

In order to set the threshold for no regrets choices in optimisation, we explored different thresholds to see which modelled schemes would get picked different percentages of the time. Once a set of no regrets schemes had been identified, these progressed into portfolio-wide optimisation as selected no regrets choices, with other schemes entering into portfolio optimisation.

These candidate schemes would be available to be selected in portfolio to top-up the selections to meet the required level of GHG reduction. Any mutually exclusive schemes whose counterpart had been identified as no regrets would not be available for selection as candidates, nor would any schemes that had not been picked at all during the DMU modelling runs.

Figure 13: Using the low regrets application to identify a set of no regrets selections



Please note this view represents an illustrative example of our no regrets process from during programme development and the values in it are not intended to match the final proposal values

Despite being able to set the level for defining a no regrets scheme anywhere schemes that were selected between 0% of the time and 99% of the time, we set the bar high for low regrets by always starting at the top of the scale and seeing the impact of lowering the threshold. Typically, we saw that across the range of scenarios, the schemes that were picked as low regrets in AMP8 would remain constant with the main difference being those that could be picked in future AMPs, bearing in mind the scenarios we tested considered a wide range of carbon reduction trajectories.

As our most likely plan is aligned to our Science-Based Targets it was significant that the choices identified for AMP8 did not vary. This gives us confidence that the investment identified across a wide range of futures in optimisation is truly low regrets for AMP8 investment. Therefore, we used a 99% low regrets threshold to identify our no regrets choices shown in Section 4 – only schemes selected at least 99% of the time across the range of scenarios were picked as no regrets.

No schemes were mandated at any stage in the process; optimisation had the full set of schemes to pick from in both low regrets and portfolio stages.

The top-up selections made in portfolio optimisation are the least cost scheme options to hit the required GHG reduction, so the overall selection represents both the least cost and best value plans.

The options that have been considered in this case are limited by what is technically feasible, given that the majority of GHG considered are those arising from the treatment of wastewater, for which no technically feasible alternatives currently exist. In the case of heat and fuel projects, the most promising alternatives to fossil fuel use have been considered and the options are shaped based upon reasonable expectations of societal change. For example, from speaking to the fuel industry we know that provision of non-fossil diesel fuels for general purchase will not be complete across the UK in the

next few years, hence our HVO proposal considers the storage of fuel on our own sites in the absence of market provision.

In the case of process emissions, customer behaviour change is largely focused on water use and there are no foreseeable customer behaviour or partnership working programmes that will significantly reduce the organic and nitrogen loads that are the fundamental sources of CH_4 and N_2O. Nature-based solutions are not suitable for significant replacement of large treatment works, although we do expect they will play a key role in AMP9 as we focus on the remaining direct emissions at smaller works and catchments – development of the understanding around their effectiveness will be essential during AMP8. The solutions proposed are largely additive in nature. Although we have tried to limit the combination of too many different technologies in this proposal to pick the lowest cost options, if there are future new drivers the options under consideration could be stacked further. For example, ASP intensification could be added to meet a future growth driver at a site that is already covered, and there are likely to be synergistic benefits with the ASP treating more load and producing a lower level of GHG emissions that result in longer media life and lower operational costs for the media in the active cover.

We have considered a range of customer, stakeholder, and regulatory insights in this plan. Table 14 provides an indication of how we have weighted opinion from the various groups in determining the approaches outlined above such as setting scenario constraints in our optimisation. The groups are:

- Majority customer preference and specific customer segments – this insight is drawn from our customer research projects and other sources such as Ofwat and CCW;
- Stakeholder / expert view – such as our ECP and technical auditors Jacobs; and
- Government guidance – such as government net zero targets, the Climate Change Committee's carbon budgets, Defra's environmental principles policy statement and Ofwat's net zero principles position paper and PR24 guidance.

Table 14: How we have balanced customer, stakeholder and regulatory insights

Reducing greenhouse gas emissions		
	Relative weighting	Summary of view
Majority customer preference	High	Customers expect us to play our part in reducing greenhouse gas emissions and reaching net zero. While it is a medium priority compared to other investment areas, customers support our proposal and some feel we could go further.
Specific customer segments	Medium	Future customers are more likely to select a faster pace of investment.
Stakeholder/ expert view	Medium	We have balanced two differing views across stakeholders and experts. The first is from climate experts who urge us to take prompt and decisive action in response to the overwhelming climate evidence. The second is a more mixed picture of innovation and technology experts who agree with a faster pace and consider the technology is ready for full scale application compared with some more traditional engineering consultancies who consider a slower pace would be more appropriate while we gather more data and test new technologies is more appropriate. We have also sought views form the supply chain supporting our net zero wastewater hub when deciding on the optimum pace.
Regulatory requirement	High	Government has set national targets to achieve net zero by 2050 and deliver a 34% reduction by 2030 to hot its interim targets. Ofwat plans to consider this as a sector wide target, funding the required reduction at the most efficient unit cost.

How this has shaped our plan	There is consensus across all groups that we should be making progress towards net zero. To address concerns about bill impacts, we have included an ambitious reduction through base spend (in addition to a significant reduction already being delivered in AMP7) and we have ensured that the majority (around 80%) of the technologies we are proposing are already established and costs are not likely to significantly change. We have also listened to customers who want us to focus on the most harmful emissions. We have listened to stakeholders who consider that all companies should focus on Scope 1 and 2 emissions and then Scope 3 emissions will be reduced by default. This is why the majority of our investment is focused on reducing process emissions. We have assessed costs and efficiency, but we are not cited on other companies' submissions. Ofwat's methodology will ensure only efficient costs are funded through prices. Our plan is to cut over 220 $ktCO_2e$ GHG emissions, through addressing process emissions at our wastewater treatment works, in our sludge treatment processes and by reducing fossil fuel use.

3.5 Results and selection of the core pathway

Our optimisation tools allow us to look at the effects of individual scenarios as well as which schemes are low and/or no regrets across multiple combinations. Using this tool, we were able to see that isolating the common reference scenario that is relevant to this case, did not affect the no regrets choices made 99% of the time.

The following sections outline how the three company-wide adaptive pathways in our LTDS affect this proposal. Due to the nature of net zero and climate targets, it should be noted that none of them contain a future world that would trigger lower investment or indicate that any of the investment in this proposal would not be required.

Adverse climate triggered change

This pathway has the least impact of the three adaptive pathways. Any triggers and decision points resulting from this pathway would effectively be too late to significantly affect the investments in this proposal, however in such a future world we would be glad to have already taken action. Crucially our proposed investments are clearly all no regrets in the context of this pathway as although their impact on a global scale is small, this pathway results from wider inaction on net zero. In a pathway where climate targets continue to become more significant, there is likely to be increased scrutiny of other sectors which will help our remaining Scope 3 GHG emissions as outlined below.

Societal shifts

This pathway means that, by 2040, customers expect faster progress on net zero. We plan to be focusing on our remaining Scope 3 GHG emissions by this stage so this pathway supports these efforts, and this future world supports the actions we would have already taken as a result of this proposal. By 2040 we are likely to have tackled the remaining direct emissions from sources that are not technically feasible such as smaller works and fixed film processes. It is anticipated that our AMP9 plan will focus on our remaining direct emissions, as innovative solutions are found and trialled during AMP8 in the same way that we have trialled technology in AMP7, culminating in the net zero hub proof of concept at the largest scale.

Government Led Legislative Future

This pathway is similar to Societal Shifts, but with an earlier expectation of progress on net zero and driven by legislation that is likely to result in clear and specific drivers to deal with our remaining direct emissions in AMP9, similar to the legislation put in place in the energy sector. As with Societal Shifts, this future world helps our supply chain focus on our remaining Scope 3 GHG emissions as no sectors would be able to avoid taking action on their own direct emissions. Again, the pathway supports the actions we would have already taken in AMP8.

4. Summary of the 'no- and/or low-regrets' investment for AMP8

This section describes the outputs of our 'no- and/or low-regrets' proposals that have been shaped by the LTDS. It shows which of the options introduced in Section 2 have been selected and the associated costs and benefits. Finally, it presents a greenhouse gas abatement curve showing how each part of the proposal contributes to the overall reduction.

As the LTDS optimiser is a decision support tool, the outputs have been checked to assess whether they appear reasonable, in particular:

- Does the output programme meet the GHG reduction requirements?
- Do the individual programme elements and the overall proposed programme of work look like good value when compared to benchmark carbon abatement costs?
- Have the most cost beneficial options been selected as priorities, i.e. as low regrets picks?
- Do the top-up selections look sensible and represent good value?
- Is the programme balanced in terms of delivery, and does it contribute to an overall balanced package when considered as part of the whole PR24 plan?

The first four of these tests were found to be met, as evidenced in the rest of this section. We also considered whether the solutions met the carbon hierarchies outlined in Section 2 and feel that there is a good mix of mitigation types. Balanced against the size of our legacy asset base, there is a good mix, and we are not dependent upon options at the foot of the hierarchies.

At a PR24 programme level, some post-optimiser adjustments were made to balance deliverability over the five years of AMP8 which resulted in a minor adjustment of optimum year of delivery within the AMP period for a small number of elements in this proposal. This had no effect on overall totex values and all data table values reflect the outputs of the post-optimiser profiling.

4.1 Low regrets selections

Table 15 shows the options that were selected for this proposal using the process above. The AMP8 totex for each low regrets option is given along with the annual GHG reductions. The £/tCO_2e is given calculated on an NPV basis as outlined in section 2.2, along with the Social Benefit Cost Ratio (BCR) as calculated using our benefits assessment tool.

Table 15: Overview of low regrets selections

Activity	AMP8 totex cost (£m)	GHG emissions reduction ($ktCO_2e$)	Capital carbon ($ktCO_2e$)	£/tCO_2e[a]	Social BCR
Digital twin at 32 sites	53.341	25.3 (range: 20.2-30.4)	0.02	130 (range: 104-156)	1.22 (range: 0.98-1.46)
Cover and treat at 17 sites	55.986	41.7 (range: 33.4-50.0)	1.5	107 (range: 86-128)	1.61 (range: 1.29-1.93)
ASP intensification at seven sites	17.956	13.2 (range: 6.6-15.8)	1.6	124 (range: 103-248)	1.39 (range: 0.70-1.67)
Active gas capture at 18 sites	91.278	40.1 (range: 32.1-48.1)	1.0	39 (range: 33-49)	2.23 (range: 1.78-2.68)

Cellulose recovery at one site	39.200	7.6 (range: 1.5-9.1)	0.03	234 (range: 195-1,170)	0.77 (range: 0.15-0.92)
EV charging infrastructure	1.600	3.5 (range: 2.8-4.2)	0.04	50 (range: 42-63)	3.48 (range: 2.78-4.18)
Heat pumps for buildings	14.129	2.3 (range: 1.8-2.8)	0.2	257 (range: 214-321)	0.74 (range: 0.59-0.89)
Process optimisation	8.967	34.0 (range: 27.2-40.8)	0.04	35 (range: 29-44)	5.05 (range: 4.04-6.06)
Total	**282.097**	**167 (range: 125.6-201.2)**	**4.4**	**Average 88**	**n/a**

a: This is calculated as the 30-year NPV in 2022/23 prices per tonnes carbon dioxide equivalent over the same period.
b: The benefit shown for EV charging infrastructure & heat pumps is net of new scope 2 emissions incurred

4.2 Top-up selections

Table 16 shows the additional options that were selected for this proposal using the process above. These options were selected by the optimiser because the no regrets options in section 4.1 do not by themselves reach the GHG reduction target set for the optimiser to achieve under the most likely plan, which is profile 3 in Table 11. These options did not get picked as AMP8 no regrets choices under scenarios that had a carbon reduction profile with reductions occurring beyond 2030.

The AMP8 totex for each top-up option is given along with the annual GHG reductions. The £/tCO_2e is given calculated on an NPV basis as outlined in section 2.2, along with the Social Benefit Cost Ratio (BCR) as calculated using our benefits assessment tool.

Table 16: Overview of top-up selections

Activity	AMP8 Totex cost (£m)	GHG emissions reduction ($ktCO_2e$)	Capital carbon ($ktCO_2e$)	£/tCO_2e[a]	Social BCR
Cover and treat at six sites	36,907	13.9 (range: 11.1-16.7)	1.0	245 (range: 204-306)	0.71 (range: 0.57-0.85)
ASP intensification at six sites	86.515	29.7 (range: 14.8-35.6)	4.1	273 (range: 227-546)	0.64 (range: 0.32-0.77)
HVO diesel replacement	0.602	6.3 (range: 5.0-7.6)	3.0	157 (range: 131-196)	1.09 (range: 0.78-1.31)
Cellulose recovery at two sites	23,874	5.2 (range: 1.0-6.2)	0.02	209 (range: 174-1,045)	0.85 (range: 0.17-1.02)
Total	**147,899**	**55.1 (range: 31.9-66.1)**	**8.1**	**Average 246**	**n/a**

a This is calculated as the 30-year NPV in 2022/23 prices per tonnes carbon dioxide equivalent over the same period

4.3 Benefits of the combined solution

Tables 15 and 16 show the social benefit cost ratio calculated using our Benefit Assessment Tool. Typically, the social BCR is higher for the low regrets investments, as these are selected as low regrets on the basis of being the least cost for the given benefit. The exception to this is the cellulose schemes which is a function of the candidate cellulose schemes being picked as lower cost ways of reaching the overall GHG reduction target in optimisation compared with other portfolio schemes, whereas the low regrets cellulose scheme is selected on account of its significant individual contribution towards

the GHG reduction target. Many of the groups of schemes have a social BCR greater than one which indicates they would be cost beneficial regardless of net zero commitments.

Benefits in AMP8:

- Primary benefit: Emissions reduction of 223ktCO_2e during AMP8. This represents a 57% contribution to Severn Trent's process emissions reduction, a 69% reduction in emissions from heat and fuel, a 58% contribution to Scope 1 greenhouse gas reduction and a 20% contribution to Severn Trent's total greenhouse gas reduction including Scope 3, all from a 2020 baseline.
- Secondary benefits:
  - Reduction in the per tonne cost of emissions reduction for the UK water sector by sharing knowledge on the most cost-effective interventions;
  - Make the UK the first country in the world to materially reduce process emissions from sewage treatment; and
  - A better understanding and control of gaseous emissions is likely to yield health and safety benefits although this is not a primary driver for this proposal.

Most of the benefit from these investments will start to be delivered in 2030, as such data tables CW21 and CWW22 do not reflect the true, full year effect benefit which would fall in financial year 2030-31.

5. Robust and efficient costs

This section describes how we have built cost models for our proposals in order to understand they are both robust and efficient. It outlines the two-stage approach we have taken to market testing, first at our Strongford net zero hub and then by inviting members of our supply chain to test our initial view of unit costs at a range of sites.

5.1 Cost robustness

To ensure robust cost estimates we have taken three approaches:

1. Outturn cost learning from AMP7 projects;
2. Market-tested high value and most uncertain aspects; and
3. Considered learning curves to understand how costs may change over time as innovative solutions become commonplace.

Developing cost estimates and learning from the net zero hub

We have assessed the cost robustness of our data at key steps throughout the development of this proposal using our Cost Robustness and Maturity (CRAM) assessment. The first assessments reflected relatively low confidence in cost data as it had been built and scaled from small-scale trial data or early AMP7 capital scheme costings.

The second milestone in cost development was the Strongford net zero hub feasibility assessment carried out by Atkins. This involved Severn Trent and the Atkins team directly negotiating with suppliers of the technologies to be deployed, alongside a clear analysis of the benefit to be delivered.

The next step for process emissions options was to go to market with supply chain organisations so we could fully market test the cost models made to this point, across a range of representative real sites for all technology options. We engaged Mott MacDonald Bentley (MMB) to review six sites, representative across a range of sizes, and bottom-up cost the installation of technologies.

This allowed further refinement leading to a final set of unit costs. These are given in each section below. All costs are inclusive of 15% optimism bias and 6.25% burden. See Annex 4a Costs, efficiency and stretch for an overview of our approach which includes more explanation about optimism bias and burden rates. Once unit costs had been developed, the sizing of process emission assets was undertaken by the internal Treatment Process Engineering (TPE) team as part of the same exercise they undertook to support the development of solutions for the WINEP programme. This was done to ensure consistency in sizing assumptions.

The unit costings, applied to these asset sizings, form the basis of our costed site-by-site schemes that the LTDS-based cost modelling outlined in Section 3 has been based on.

For heat and fuel options, prices were developed based upon supplier quotes across a range of sites. We had experience of deploying over 350 EV charging points to operational sites in AMP7 and so have been able to anticipate real-world costs and issues such as grid supply capacity on smaller sites.

Table 17: Breakdown of costs

Basis of estimate	Total as %

Severn Trent unit cost database (STUCA)	0%
PR19 final determination/cost models	0%
Market-tested/independently benchmarked	100%
Non-standard, bottom-up build	0%
Total	100%

5.1.1 Cost derivation

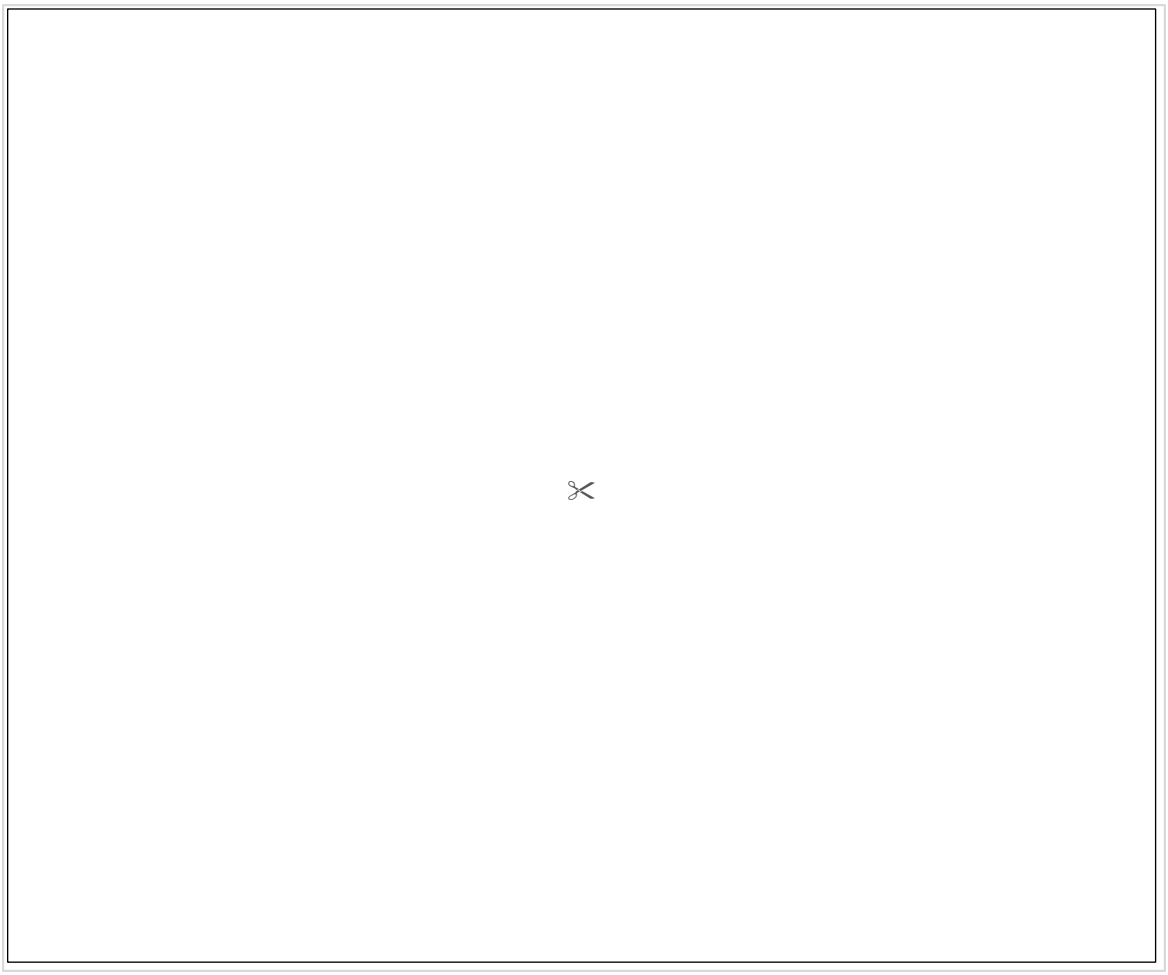
Cover and treat (ASPs and LTPs)

Costs for both secondary treatment (ASP) and liquor treatment (LTP) covers have been derived based on the area to be covered in m^2. Our full estate of ASPs was assessed by the TPE team along with an updated assessment of population, load and future treatment permit standards, resulting in an area to cover in m^2.

Our existing LTPs were assessed by the Bioresources team and the size of the aerated tanks was identified in m^2.

Costs were derived from the curve shown below. The points represent the costs for each site assessed by MMB which shows a wide range of sites were assessed.

Figure 14 cost curve for cover and treat



Digital twin

Costs for a digital twin have been determined based upon the principle that the combination of machine learning and mechanistic models developed at Strongford can be packaged to be deployed elsewhere regardless of size. Following discussion with the supply chain working on the net zero hub solution, a 60% reuse has been seen elsewhere with a roll-out cost of 50-75% of the original solution, when rolled out at other sites. We have taken a mid-range value of 60%.

The operational cost saving from digital twin results from energy savings, so this is scales to the size of site based upon the percentage reduction at Strongford.

Table 18: costs for digital twin

Cost element	£
Capex per site	[✂]
Opex per ASP lane/unit per year	[✂]

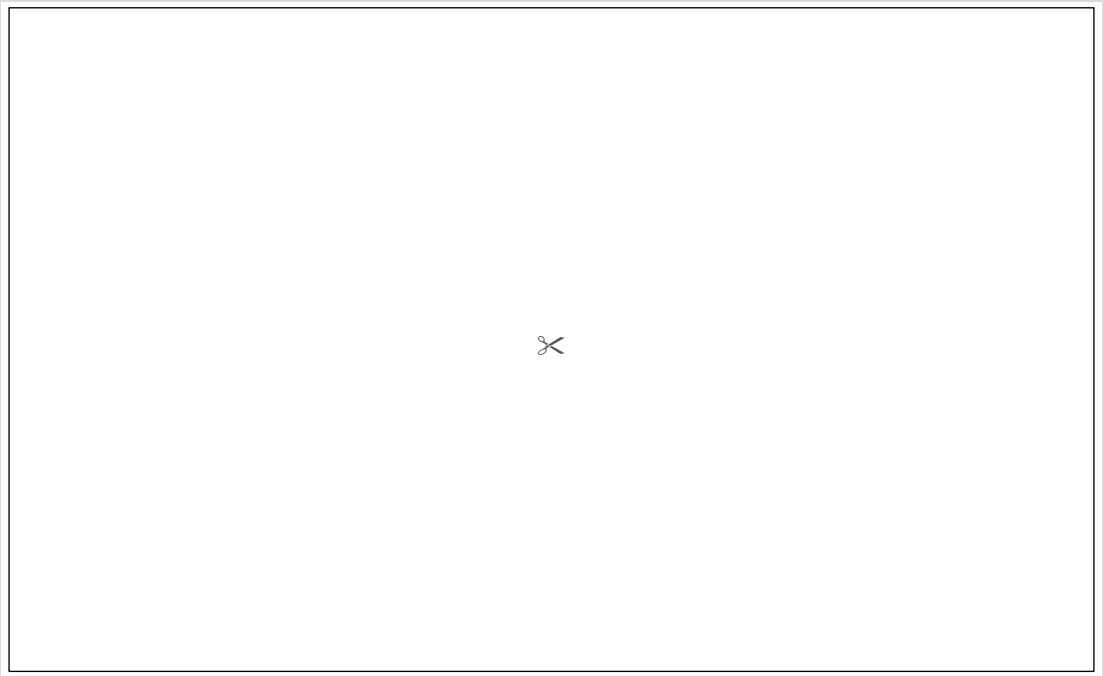
ASP intensification

Costs for ASP intensification have been based upon MABR. Costs have been derived on a per-cassette basis.

Our full estate of ASPs was assessed by the TPE team and the sites where ASP intensification would work were sized in terms of the number of cassettes, resulting in a final number of cassettes to install. Benefit was scaled based on the residential population, ammonia load, and emission factor.

Costs were derived from the curve shown below. The points represent the costs for each site assessed by MMB to illustrate a wide range of sites were assessed.

Figure 15 cost curve for ASP intensification



Active gas capture from AD

The net zero hub feasibility assessed vacuum degassing and series digestion as separate technologies, but our Innovation team concluded they should be delivered together as the benefits were synergistic. Costs for each technology were derived based upon digester volume as m^3.

Our costing exercises identified that these technologies are currently considered to need situating in a building, and that some sites (such as Strongford) have suitable buildings, and some (such as Finham) do not. As this is not known yet, we have picked a unit cost that reflects the impact of 50% of sites requiring such a building.

Our Bioresources team assessed our digester fleet and provided the sizes for all digesters that would be operational at the end of AMP8.

Table 19: costs for active gas capture

Cost element	£
Installation capex per m^3 digester volume	[✂]
Technology capex per rig	[✂]
Monitoring capex per site	[✂]
Monitoring opex per site per year	[✂]
Solution opex per m^3 digester volume per year	[✂]

Cellulose recovery

As the heat benefit from cellulose recovery in our use case is only relevant for the high levels of natural gas used at THP sites, our four operational THP sites, other than Strongford, were assessed. These are:

- Finham;

- Stoke Bardolph;
- Netheridge (to be constructed in AMP8); and
- Southern hub (to be constructed in AMP8, Roundhill was used as the basis of modelling).

The size of cellulose reactors has been scaled based on wastewater population equivalent, as it is determined by the incoming flow. The capex has therefore been calculated on the same basis.

The benefit from this use case of cellulose recovery is to reduce the amount of natural gas burned by 50% (see section 2.6). The cost of actual gas use for each site, adjusted for any future THP installation, was used to calculate opex benefits. Cellulose recovery requires some energy input and may drive other impacts on process emissions. Projects will only be net beneficial overall if reductions are higher than rises. Assessing this balance is a key part of the projects already underway and will be fully considered in design and delivery. If the balance does not work out, other options to reduce Scope 1 fossil fuel use will need to be considered to drive the same benefit.

Table 20: costs for cellulose recovery

Cost element	£
Capex per population equivalent	[✂]

Heat pumps for buildings

A separate feasibility project was undertaken to assess the potential for heat pumps at offices and smaller operational sites. JRP Solutions was commissioned to survey a representative range of sites to determine the cost and benefit, and the results of this study feed directly into this proposal.

Table 21: costs for heat pumps

Cost element	£
Air source heat pump cost per kW	[✂]
Ground source heat pump cost per kW	[✂]

EV charging infrastructure

Based on our knowledge from having installed over 350 EV charge points in AMP7, we have been able to estimate the cost of deploying a further rollout of charge points using supplier quotes.

Table 22: costs for EV charging infrastructure

Cost element	£
EV chargepoint cost including hardware, installation, software and system costs (depot installation)	[✂]
EV chargepoint cost including hardware, installation, software and system costs (home installation)	[✂]

HVO diesel replacement

Based on supplier quotes, we have identified costs to provide fuel storage to store and supply HVO to heavy good vehicles.

Table 23: costs for HVO diesel replacement

Cost element	£
HVO fuel storage cost per 10m^3 bunker	[✂]
HVO fuel storage cost per 20m^3 bunker	[✂]

5.1.2 Assurance and independent challenge

We have sought challenge and reviewed the costs throughout the development of the solutions along with more formal assurance. The key inputs include:

- MMB cost benchmarking exercise following net zero hub feasibility, as outlined above;
- Our PR24 assurance partners, Jacobs as part of our formal three lines of assurance; and
- Internal review and challenge – senior management and director level review of the business case, the Cost Reliability and Maturity (CRAM) process, managed centrally by quantity surveyors, technical governance through our Waste Service Area Board, and site visits involving personnel from across our operational and engineering functions to get a broader view.

Figure 16 illustrates how our cost reliability maturity increased as we developed the solution and estimates. In addition to the steps outlined above, we held workshops at three large sites – Finham, Netheridge and Coleshill – which drew together over 30 personnel from across our operational and engineering teams to discuss scope certainty by:

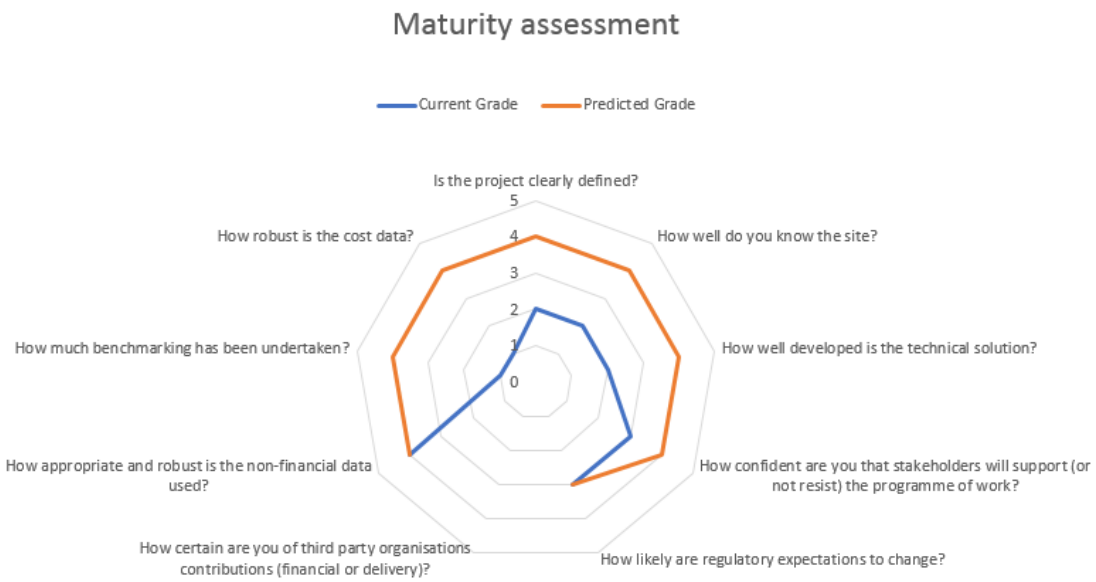
- Validating indicative scheme and asset sizing and future operating parameters;
- Reviewing base investment needs per site versus enhancements; and
- Considering the practicalities of implementing the identified solutions taking into account real-world conditions.

The learning from these sessions directly shaped the scope and requirements of the MMB cost benchmarking exercise. It was a key input into our decision to reduce our assumption about risk and contingency from 66% – which was taken from Green Book guidance for large and uncertain infrastructure projects – down to the 15% that we have included in this case.

The criterion in figure 16 about third-party organisations and delivery has not been scored but this is not being considered as a partnership scheme. We would not expect to be able to get third-party contributions. However, given the importance of this work and the level of innovation involved we are working with many organisations through our innovation network which does have a value, but we did not see the merit in valuing or assessing this.

The chart shows that we have made considerable improvement in both the maturity of the costs and the scope during the development of the case. In many cases exceeding the IPA guidance of a typical project at this stage in its development.

Figure 16: Improvement in Cost Reliability and Maturity (CRAM) assessments – from iteration 1, November 2022 (blue line) to final proposal (brown line)



5.1.3 Data table mapping

The costs for this proposal are located in tables CW21 and CWW22.

The Opex forecasts include a combination of both costs and savings depending upon the solution.

Table 24: Data Table Mapping

Line Title	CW3/CWW3 Reference	Capex/Opex	AMP8 £m
Greenhouse gas reduction (net zero)	CW3.127	Capex	8.73
	CWW3.177	Capex	429.93
	CWW3.178	Opex	-8.67

5.2 Demonstrably efficient costs

There is strong evidence that the cost of getting to net zero in the timescales required to avoid dangerous climate change will be significant and that much of this must be 'front-loaded'[53]. This is strongly supported by economic evidence. However, no wastewater treatment company in the world has implemented the scale of greenhouse gas emissions reductions from waste treatment which we are proposing. This means the proposal is, by its nature, innovative and so carries risk. However, the technologies we plan to deploy have the following advantages:

- They are being deployed at scale at our Strongford net zero hub, supported by the Ofwat Innovation Fund. The findings from these projects will be shared across the sector and the supply chain which will greatly improve understanding on how to deploy these and how to improve efficiency;

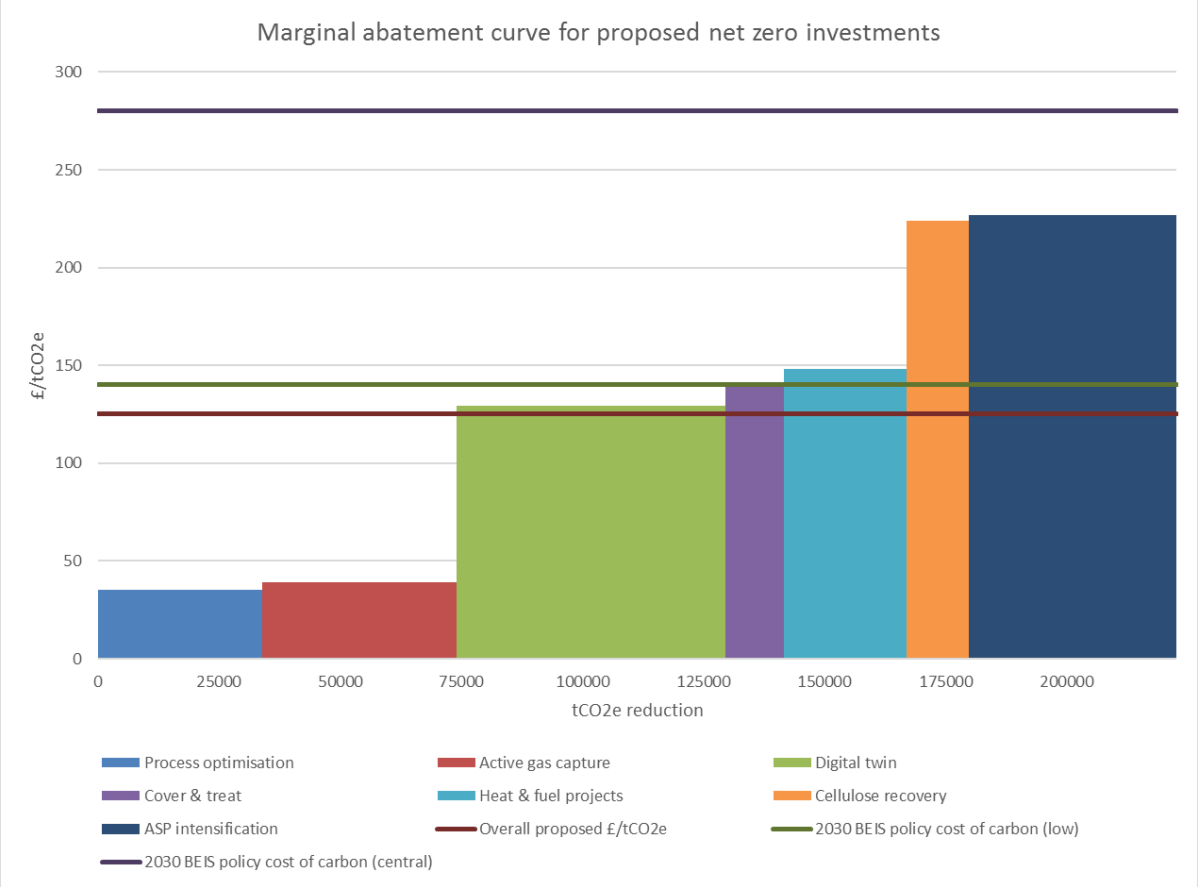
[53] https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring

- The types of technology deployed elsewhere are not wholly innovative – for example the construction of covers, operation of gas capture devices and deployment of monitors for collection of data and development of a digital twin are all tried and tested technologies in our own sector and in other sectors – albeit the precise application is different;
- The proposals are retrofittable to existing processes and can be planned to be delivered in line with WINEP and growth investment timescales. This means major rework will not be required; and
- The proposals we are making have small capital carbon emissions impacts as a result, and this means, in carbon terms, they quickly reduce more carbon than they cause and vastly more over their asset lives. In all cases this happens within the first year of operation.

For all the reasons set out above, this is an extremely difficult area to benchmark costs. To understand relative efficiency, we have examined the overall abatement cost for these activities. As net zero is a statutory requirement by 2050, there are likely to be projects that would not be cost beneficial in their own right as is common with other statutory activities. However, even this subset of projects compares well to the BEIS policy cost of carbon, as all are below the 2030 central value of £280/tCO_2e abated.

The proposed programme of investment is shown graphically in figure 17 which is a marginal abatement curve for the most likely GHG emissions in the ranges indicated. For clarity, the low regrets and candidate schemes have been combined where relevant to show overall activity abatement costs. The curve also shows the average programme cost and the 2030 BEIS policy cost of carbon low and central values.

Figure 17: Cost of abatement for proposed plan



- The 2030 BEIS policy cost of carbon low series value of £140/tCO_2e is shown on the chart and it can be seen that the overall programme value is lower than this at £125 /tCO_2e; and
- The 2030 BEIS policy cost of carbon central series value of £280/tCO_2e is shown on the chart and it can be seen that every activity taken individually is lower than this. During net zero investment evaluation, if a programme of work falls under the low series value, it is often considered appropriate to test individual activities against the BEIS high value of £420/tCO_2e. For example, Natural Resource Wales' Net Zero GHG Emissions PR24 driver for their National Environmental Plan follows such an approach[54]. We believe that comparing to the lower value demonstrates a harder test and demonstrates that our proposals represent good value.

Another aspect of efficiency to consider is the extent to which this programme will help drive efficiency beyond AMP8. One of the aims of the net zero competition is to gather information and drive efficiency to enable fuller, more efficient roll out across the sector in AMP9 and beyond. The range of solutions and applications we are proposing are representative of the work needed and the asset groups likely to be seen across the sector. The evidence presented in "Dynamics of Water Innovation"[55], Thesis by Paul O'Callaghan shows:

- There is good evidence that implementation of known technologies to slightly different applications controls costs; and
- There is good evidence that having deployed the technology at scale at one major works will reduce implementation costs elsewhere.

[54] Net Zero Driver FINAL Dec 22.doc

[55] Dynamics of Water Innovation Dec 2020, https://edepot.wur.nl/536755

6. Customer protection

This section outlines how we will hold ourselves to account for the delivery of this proposal and the benefits within it. It demonstrates how the proposal will contribute towards the common performance commitments for greenhouse gas emissions. Finally, it considers the capacity of our supply chain to deliver the proposals.

Severn Trent has a strong track record of securing third-party funding to support the development of both energy- and process-related innovation. We will continue to explore all sources of external funding for greenhouse gas reductions, including government funds and competitions, to encourage and support efforts to decarbonise the UK across all industry sectors. This proposal, however, is based on options that have high technology readiness and cannot usually be funded through innovation schemes for rollout at scale. We recognise many such funding schemes are already supported indirectly by our customers through general taxation.

We will continue to seek opportunities in solution development that incorporate partnership working and attract third-party contributions. To the extent we can attract third-party funding, we will use this to offset costs.

6.1 Holding ourselves to account for delivery

There are currently no common performance commitments (PCs) or outcome delivery incentives (ODIs) for process emissions. However, we welcome the inclusion of process emissions and fuel use in the proposed Operational Greenhouse Gas Emissions common PCs for AMP8. These PCs are how we propose to hold ourselves to account for the delivery of the investment in this proposal.

Any performance commitment for Natural Capital is likely to be of limited relevance to Process Emissions, due to the limited applicability of nature-based solutions to the major sources of greenhouse gas emissions. Given the likely common performance commitments, we do not expect there will be a case for bespoke ODIs in this area.

Severn Trent is also held to account on greenhouse gas emissions reduction through several other routes. We have strong reputational commitments to customers and investors in the form of our science-based targets, our membership of schemes such as the UNFCCC Race to Zero[56] and the EV100[57]. In addition, we have reporting responsibilities under SECR[58] and TCFD[59]. Our Science Based Targets mean we have signed up to robust reporting of our performance and on updating our future path to net zero. All variations of our net zero targets require substantial progress on process emissions reduction as outlined in Section 1.2.

6.2 Proposed Price Control Deliverable

We have developed a Price Control Deliverable which sets out the outcomes customers can expect as a result of this enhancement expenditure, and we have taken into account outcome delivery incentives where appropriate.

[56] UNFCCC Race to Zero
[57] EV100, The Climate Group
[58] Streamlined Energy & Carbon Reporting
[59] Task Force on Climate-related Financial Disclosures

Our aim is to ensure customers are protected from under or late delivery through easy to measure, track and verify deliverables.

We have taken account of existing regulatory reporting mechanisms and have aligned our deliverables with these mechanisms where appropriate.

We will continue to develop the detailed measurement methodology which will include third line assurance review to ensure there is sufficient specificity in the definition to meet the repeatability and reporting accuracy required as part of the APR requirements.

Our proposed PCD for this enhancement will have an impact on performance in relation to the common performance commitments related to operational greenhouse gas emissions. ***Table 25: Proposed PCD 1***

PCD 1	Operational GHG emissions (waste and bio)
Description	Our plan is to reduce the greenhouse gases emitted from waste and bioresources operational processes through a range of elimination, reduction, and treatment interventions.
	Measure Reduction in greenhouse gases emitted from our operational activities in $ktCO_2e$ from a March 2025 baseline. Measurement $ktCO_2e$ reductions will be measured in line with guidance in the operational greenhouse gas emissions (wastewater) performance commitment and will be reported and monitored through the existing APR process.
Conditions on scheme	The allowance is conditional on the company reducing the emission of greenhouse gases by $ktCO_2e$ by 25 March 2030 compared to a baseline assessment set at 31 March 2025. All assessments of greenhouse gas emissions will be completed using the relevant guidance from the common performance commitment.
Assurance	Assurance will be carried out in line with the requirements of the operational greenhouse gas emissions (wastewater) common performance commitment requirements (Section 4).
Cost sharing incentive payments	Cost sharing incentive rates will be calculated using the Ofwat PCD payments model when the ODI rate and the cost sharing approach for price control cross-cutting programmes has been confirmed by Ofwat.
Impacts on performance in relation to performance commitments	Cumulative Impact on operational greenhouse gas emissions (wastewater) will be $207.9ktCO_2e$ in AMP8 and $1,080.5ktCO_2e$ in AMP9.

Table 26: Proposed PCD 2

PCD 2	Operational GHG emission water
Description	Our plan is to reduce the greenhouse gases emitted from water operational processes through a range of elimination, reduction, and treatment interventions.
	Measure Reduction in greenhouse gases emitted from our operational activities in $ktCO_2e$ from a March 2025 baseline. Measurement $ktCO_2e$ reductions will be measured in line with guidance in the operational greenhouse gas emissions (water) performance commitment and will be reported and monitored through the existing APR process.
Conditions on scheme	The allowance is conditional on the company reducing the emission of greenhouse gases by $ktCO_2e$ by 25 March 2030 compared to a baseline assessment set at 31 March 2025. All assessments of greenhouse gas emissions will be completed using the relevant guidance from the common performance commitment.
Assurance	Assurance will be carried out in line with the requirements of the operational greenhouse gas emissions (water) common performance commitment requirements (section 4).

Cost sharing incentive payments	Cost sharing incentive rates will be calculated using the Ofwat PCD payments model when the ODI rate and the cost sharing approach for price control cross-cutting programmes has been confirmed by Ofwat.
Impacts on performance in relation to performance commitments	Cumulative Impact on operational greenhouse gas emissions (water) will be 3.4ktCO_2e in AMP8 and 33.2ktCO_2e in AMP9.

Table 27: Proposed Deliverability Profile

Deliverable	Unit	2025/6	2026/7	2027/8	2028/9	2029/30	2030/31
Waste and Bio	ktCO_2e		0.3	24.7	70.2	112.6	216.1
Water	ktCO_2e		0.4	0.9	1.3	1.3	6.6

We note that the current Ofwat performance commitment guidance for greenhouse gas emissions differs from other greenhouse gas accounting methodologies by focusing on isolating performance measures from methodology changes. Ofwat have therefore specified the use of Carbon Accounting Workbook v17 for reporting performance throughout AMP8. The industry, via UKWIR, is currently working on developing a specific version of this Carbon Accounting Workbook, in consultation with Ofwat, aimed to meet the requirements of the performance commitment through AMP8.

We note that any changes in methane emissions due to investment or operational change (both up and down) cannot currently be calculated through Carbon Accounting Workbook v17 because this relies only on a limited set of standard one-size-fits-all emissions factors applied to sludge volumes, which are not representative of site performance. The performance commitment must allow reporting of site-specific methane emissions, measured through assured processes, in order for the standard performance commitment to hold us to account for methane emissions reductions. We appreciate that not all companies want to do this, particularly where they plan to make no improvements to methane emissions over AMP8. In the event that the performance commitment measure does not allow for site-specific methane reporting, we are open to having more specific performance commitment measures associated with this investment proposal to ensure that customers are fully protected.

6.3 Overlap with other statutory instruments

There are no statutory instruments that cover greenhouse gas emissions other than the net zero commitments set by the Government, the impacts of net zero energy policies on our energy costs and our statutory emissions reporting commitments.

6.4 Managing uncertainty

We recognise while there is an element of uncertainty inherent in our proposed programme, not least because while we are within months of commissioning our first full site deployment of these technologies, there will be more insights to be gained over continuous periods of operation.

Some of the proposals also require changes in our operating model, with new skills, ways of working and management processes needed. We have planned that into our existing projects and all investments to reduce emissions will have pre and post monitoring as essential components. Our proposal is to take on the outcome target of emissions reduction at our risk.

6.5 Deliverability

With initial investment at our net zero hub made and a blueprint in place, the key factor in delivering the carbon reductions required to keep pace with the Government 'all scopes' trajectory (Scopes 1, 2 and 3) to 2030, and subsequently 2050, will be the ability to access funding through the price review to deploy at scale. This business case is a direct follow-on from the work we have done to date, and we believe it is at a more mature stage of deliverability than any other solution in the sector.

Creating the Net Zero Hub and securing the supply chain partnerships required that guarantee delivery has been a critical component to building confidence that we can deploy solutions at scale in the next five years. Our partners, such as SUEZ, are global organisations which have been with us since the start of the journey and are fully cognisant of what will be required over the coming years to deliver our ambitions. Likewise, our capital construction partners have been secured into the next five-year cycle to ensure resource constraints do not impact the pace of delivery. More broadly, in the context of our overall investment plan for AMP8, we have been mindful to ensure the supply chain required for our Net Zero Programme does not conflict with other areas of our investment proposals so that in effect the Net Zero Programme has 'ring-fenced' capacity for delivery.

We have engaged our supply chain and gained expressions of interest for early contractor involvement in AMP8 pricing and design to bring the experience of these organisations into the cost models, and to start the process of securing capacity to deliver the key integration and installation works.

We have always assumed that, due to the integrated nature of the options for process emissions reduction, Direct Procurement for Customers (DPC) would not be suitable for delivery of this proposal. We are pleased to see Ofwat's clarification on technical discreteness[60] and consider the case studies given in that document to be directly comparable with the technical separability of the investments proposed for process emissions. The options in this proposal would not pass the construction risk or operations and maintenance risk tests on any site.

The solutions considered for heat and fuel are considerably lower than the £200m threshold set for such a programme of work and so DPC is also considered to be unsuitable for delivery of these elements. The other options in this proposal would not pass the programme scalability test.

[60] https://www.ofwat.gov.uk/wp-content/uploads/2023/04/DPC-Technical-discreteness-guidance.pdf

7. Appendices

Appendix A: Quantifying the baseline for process emissions

Quantifying the size of the problem

The baseline for process emissions across the UK water industry has historically been calculated using the Carbon Accounting Workbook[61]. This is a resource that is used by all water companies and represents the definitive calculation of emissions from wastewater and bioresources processes. While it is updated annually, the emission rates in the workbook that calculate N_2O are based on work from 2006 and recently work has been undertaken in Europe that has revealed the actual emissions rates from secondary treatment processes are likely to be higher than hitherto thought.

The industry-first monitoring trials that we have undertaken are:

- Direct and continuous monitoring of N_2O emissions from secondary wastewater treatment;
- Campaign of flux monitoring to target and quantify N_2O emissions from previously unknown sources;
- Fixed CH_4 sensors to understand and track fugitive emissions from bioresources sludge treatment assets; and
- Airborne CH_4 sensors carried by drones combined with ground-based surveys to find and fix methane leaks.

Our new baseline number of 340ktCO_2e for operational emissions in Severn Trent is substantially higher than previously thought as a result of the insight from this work. Although this means we must deliver a larger reduction, quantifying the real value is an essential and positive step as we have reduced the uncertainty from previous estimates and theoretical models. Through our new direct monitoring and validation, we now have more confidence about what reductions are needed to ensure Severn Trent makes a meaningful contribution to the UK's net zero commitments.

Sizing the problem

Process emissions have been under-researched over the past decade because they are complex to measure and understand, and it has been difficult to predict likely emissions reduction solutions. Historically, the water sector has estimated process emissions based on emission factors applied to population and volume of wastewater and sludge treated, and it has not been incentivised to monitor, report on, or reduce them.

During AMP7, Severn Trent has made investments, through base expenditure and Green Recovery projects,[62] to measure and understand our process emissions.

Activity	Expenditure
N_2O monitoring to date (2023)	£418,298
CH_4 monitoring with drone & Cranfield project	£119,188
Committed spend on fixed methane monitoring	£331,000
Total	£868,486

[61] Carbon Accounting in the UK Water Industry: Methodology for estimating operational emissions, Version 15
[62] [name project]

This has allowed us to calculate an accurate baseline for process emissions, which has been developed using the longest running UK specific measurement campaign. Our monitoring campaign has the highest ratio of measured data to estimates (40:60) of all UK water companies. It has also enabled us to understand the most efficient and cost-effective ways to reduce process emissions in practice, and to evidence the improvements made.

Our investments include:

- **Direct N_2O monitoring at eight wastewater treatment works** estimated to be responsible for 42% of our N_2O emissions. These sensors monitor the levels of N_2O in the wastewater as we treat it, helping us understand the mechanisms of N_2O production and to explore options for reduction. We are also undertaking spot sampling with a flux monitor to identify and quantify emissions from sources not currently included in the Carbon Accounting Workbook[63]. In addition, we are developing a new methodology to measure ASP emissions using the mobile flux monitor as a way of spot sampling sites as well as validating the fixed monitors; and
- **Direct CH_4 monitoring in three bioresources treatment facilities** using a LIDAR and laser spectroscopy-based camera system capable of the detection and quantification of fugitive methane emissions. These monitoring technologies are still early in their development, which means we are taking some risks in trialling them, but we believe this is the best way of driving innovation and improve their applicability to our sector. We are also exploring campaign-based monitoring to provide additional coverage as well as to validate the fixed systems we are trialling. In addition to these, we have implemented a 'find and fix' workstream, using a drone based CH_4 monitor and an optical gas imaging camera, allowing us to pinpoint, isolate, and fix leaks. In addition to this we also partnered with Cranfield University to sponsor an MSc by research project aimed at developing an innovative monitoring framework for methane emissions from sludge treatment centres. This project also developed and tested an early mass balance-based approach to enable emissions quantification using drone-based measurements. The findings were shared in the European Biosolids conference in 2022 and published in Remote Sensing journal by MDPI in 2023.[64]

This work is already demonstrating that process emissions are significantly higher than estimated, strengthening the case for prioritising process emissions reduction. As well as helping us to size the problem, this data has enabled us to bring certainty to our 'no- and/or low-regrets' plan for AMP8 and identify the interventions we should defer to future AMPs.

[63] Carbon Accounting in the UK Water Industry: Methodology for estimating operational emissions, Version 15

[64] Abeywickrama, H.G.K.; Bajón-Fernández, Y.; Srinamasivayam, B.; Turner, D.; Rivas Casado, M. Development of a UAV Based Framework for CH_4 Monitoring in Sludge Treatment Centres. *Remote Sens.* **2023**, *15*, 3704. https://doi.org/10.3390/rs15153704 - https://www.mdpi.com/2072-4292/15/15/3704

Appendix B: Line of sight – Reducing greenhouse gas emissions

Climate change is among one of the most significant challenges facing the world, and the steps we take between now and 2030 will be critical in limiting global warming. As we have developed our PR24 plan, we have spoken to our customers about the environment, climate change, and net zero. Customers have told us that they are concerned about climate change and want us to take action to reduce greenhouse gas emissions.

This can be a challenging area for customers to understand and respond to with both a personal and community perspective, as well as balancing immediate and future facing issues. We have taken care to ensure our research is meaningful to participants, and to distinguish between the causes and impacts of climate change, and to probe multiple perspectives and intergenerational fairness. We have done this using a range of methods, including deliberative research to inform and probe in depth, alongside tracking key concerns over time.

The investment proposed to reduce greenhouse gas emissions is driven by statutory requirements and is informed by a comprehensive understanding of customer support on both pace and solution type. This is an area where we find consensus in the need for action, but some mixed views in terms of whose responsibility it is and on the pace of delivery.

In this Appendix we summarise the key insight we have drawn from our triangulation of customer research, the research sources we have drawn the insight from, and we provide more detail on each of the themes coming from our research. For this area of the plan, we have consulted customers on both the need for investment as well as the desired pace and solution type.

Key insight

- Customers are worried about climate change, and in particular the impacts of climate change and the impact on future generations. Combating climate change is seen as vital.
- Customers aren't well informed about net zero but support it once informed. They expect Severn Trent to play its part in reducing greenhouse gas emissions and reaching net zero.
- Compared to other investment areas, working towards net zero is a medium level priority.
- Customers are prepared to support some increase in their water bills to reduce process emissions. Some customers would like us to go further and faster on reducing greenhouse gas emissions but acknowledge that affordability is a concern.
- When it comes to solutions, customers want Severn Trent to focus on directly reducing process emissions and tend to trust us to make the right technical decisions.
- When presenting our proposals in our PR24 Affordability and acceptability research, customers were very positive towards Severn Trent's planned approach and liked the innovation, showing that Severn Trent is a leading company, and that it would also help reduce future costs, thereby benefitting customers and society.

How this has shaped our plan

The Table shows how we have weighted the inputs from customers, stakeholders and taken into account the external context, including any relevant regulatory requirements.

We then summarise how the key insight in this area has shaped our plan.

Reducing greenhouse gas emissions

	Relative weighting	Summary of view
Majority customer preference	High	Customers expect us to play our part in reducing greenhouse gas emissions and reaching net zero. Whilst it's a medium priority compared to other investment areas, customers support our proposal, and some feel we could go further.
Specific customer segments	Medium	Future customers are more likely to select a faster pace of investment.
Stakeholder / expert view	Medium	We have balanced two differing views across stakeholders and experts. The first is from climate experts who urge us to take prompt and decisive action in response to the overwhelming climate evidence. The second is a more mixed picture of innovation and technology experts who agree with a faster pace and consider the technology is ready for full scale application compared with some more traditional engineering consultancies who consider a slower pace would be more appropriate while we gather more data and test new technologies is more appropriate. We have also sought views form the supply chain supporting our net zero wastewater hub when deciding on the optimum pace.
Regulatory requirement	High	Government have set national targets to achieve net zero by 2050 and deliver a 34% reduction by 2030 to hot its interim targets. Ofwat plans to consider this as a sector wide target, funding the required reduction at the most efficient unit cost.
How this has shaped our plan	There is consensus across all groups that we should be making progress towards net zero. To address concerns about bill impacts we have included an ambitious reduction through base spend (in addition to a significant reduction already being delivered in AMP7) and we have ensured that the majority (around 80%) of the technologies we are proposing are already established and costs are not likely to significantly change. We have also listened to customers who want us to focus on the most harmful emissions. We have listened to stakeholders who consider that all companies should focus on scope 1 and 2 emissions and then scope 3 emissions will be reduced by default. This is why the majority of our investment is focused on reducing process emissions. We have assessed costs and efficiency, but we are not cited on other companies' submissions. Ofwat's methodology will ensure only efficient costs are funded through prices. Our plan is to cut over 220,000 tonnes of CO2 emissions, largely through addressing process emissions at our wastewater treatment works.	

Independent assurance

On this area of the plan Sia Partners have stated that this document clearly meets the requirements for demonstrating line of sight.

1. Synthesis of engagement		2. Demonstrating use	3. Evidence views on strategic investment	
Engagement sources used to inform plan	Evidence of link between narrative & engagement source	Customer views' influence on the PR24 plan	Evidence of engagement on Need	Evidence of engagement on Solutions
A wide range of sources across all phases of engagement have been used to inform this view: • **Social barometer tracker (wave 1 - 5)** • **Strategic priorities research** • Tap Chat - Climate change adaptation discussion • **Net zero and carbon emissions deliberative research** • **Strategic investment choices research** • **Long term delivery strategy research** • **PR24 Affordability and acceptability testing**	In addition to the review of Severn Trent's Annex 3a: Customer and stakeholder engagement, Sia Partners has reviewed the original engagement source documents. The narrative provided surrounding customer views on reducing greenhouse gas emissions clearly originates from the engagement sources given. This narrative is aided by the provision of direct quotes from customers and the use of data and graphics from the research.	Engagement findings show that customers held concerns over bill impacts, and there is mixed support for scale of investment due to concerns around affordability. As a result, Severn Trent are proposing the majority is delivered through base spend. Additionally, the majority of the plans are surrounding reducing process emissions, as preferred by customers.	There is clear evidence of engagement on reducing greenhouse gas emissions Several sources have identified that customers feel that combating climate change is vital and would like Severn Trent to directly reduce process emissions.	Customers have been engaged on their preferred pace of investment to test future solutions. Specific solutions have been tested with customers, reducing direct emissions have been found to be the most preferred solution.

Detailed insight sources

For this area we have gathered insight through different approaches including our BAU research, and specific PR24 research activities. Each activity is summarised in the following Table including the scope of the research, the objectives and methodology and number of customers involve. All main sources have been assured by Sia Partners as robust and meeting Ofwat's high quality research standards. For more information on our customer engagement assurance please see Section **Error! R eference source not found.** of Annex 3a.

Phase	Date	Research activity (agency)	Objectives	Methodology	Number of customers engaged	Sia Partners assurance
Understanding needs and priorities	September 2021 – April 2023	Social barometer tracker (wave 1 – 5) (Ci)	Tracking survey on a range of topics including wider customer priorities, the environment, climate change and investment priorities.	Online tracking survey Panel: Made In Surveys	Representative sample of HH customers (500 per wave)	Yes
Understanding needs and priorities	Dec-21	Strategic priorities research (Community Research)	Explore a multitude of future priorities, drought resilience and the environment.	Online community and depth interviews	30 Bill payers (HH), 10 future customers, 10 small businesses (NHH) and 5 vulnerable customer depths	Yes
Understanding needs and priorities	Nov-21	Tap Chat – Climate change adaptation discussion	To understand: whether COP26 has made customers think any more about climate change; what challenges, threats and opportunities Severn Trent faces from climate change; whether customers have noticed any impacts of climate change and whether disruption to their water and wastewater service due to climate change is acceptable or whether it's something Severn Trent should invest in to avoid at all costs.	Tap Chat discussion	163 Tap Chat members	No
Exploring opportunities for investment	Jun-22	Net zero and carbon emissions deliberative research (DJS)	1. Understand levels of customer support for Severn Trent reducing its process emissions so that it can meet the Government's net zero targets. 2. Explore customer preferences for the pace at which Severn Trent should reduce its process emissions. 3. Understand willingness to pay to reduce process emission and explore any concerns customers have about the impact this could have on their, and others' bills	Online community, IDIs and 2 reconvened focus groups	55 HH customers, including 3 digitally disenfranchised, and 6 NHH customers	Yes
Refining the plan	Nov-22	Strategic investment choices research (Explain)	Robust quantitative research to understand customer preferences when presented with strategic investments, exploring priorities with, and without, a view of the bill impact that investment will have.	Online panel Dynata and face to face survey	1954 HH customers, 79 future customers and 436 NHH customers	Yes

Phase	Date	Research activity (agency)	Objectives	Methodology	Number of customers engaged	Sia Partners assurance
Is the plan acceptable and affordable?	Jun-23	Long term delivery strategy research (Thinks Insight & Strategy)	1. Test the 2050 vision with customers and the PR24 plan as the first stage in achieving longer term ambitions 2. Understand whether future targets are acceptable, stretching enough or too stretching 3. Explore views on future uncertainties 4. Understand whether customers support the proposed approach to adaptive planning 5. Explore responses to potential future bill options including views on intergenerational fairness	Face- to- face deliberative workshops and IDIs	33 HH customers, 12 future customers and 12 NHH customers	Yes
Is the plan acceptable and affordable?	May - August 2023	PR24 Acceptability and Affordability testing (Thinks Insight & Strategy and Explain)	Understand whether the PR24 plan is acceptable and affordable to customers.	Deliberative workshops, IDIs and survey	Qual: 96 customers (72 HH and 24 NHH) Quant: 3969 HH and 200 NHH	Yes

Customers are worried about climate change, and in particular the impacts of climate change and the impact on future generations. Combating climate change is seen as vital.

Throughout all our research, and that undertaken by third parties, a consistent theme emerges in terms of the growing concern amongst customers about climate change. However, at the **wider societal level** climate change is not the most pressing concern - the top concerns are *Poverty and the cost of living*, *Health and social care*, *Crime* and the *Economy/ unemployment*[65]. Compared to other more personally pressing issues, *Carbon emissions / net zero* doesn't rank highly. Only 56% of customers in the Social Barometer[66] were concerned about *Carbon emissions / net zero*, compared to 84% concerned about *Poverty and the cost of living*. We've seen the effect of the media and COP26, with concern peaking at 66% in wave 2 which was conducted following the COP26 event.

In both our Social Barometer research and our Strategic investment choices research customers are more concerned about *the impacts of climate change* compared to the need to *reduce carbon emissions*.

Around 70% of customers believe climate change is already having an impact in the UK, and just under 60% say they are more concerned about climate change than they were two years ago[67]. Extreme weather, higher temperatures (and especially hotter summers) and increased levels of flooding are the key indicators for customers in their local area. Customers expect climate change to impact them personally in their lifetime and many don't think that water companies are sufficiently prepared for the challenge.

The word cloud above visualises how participants in our deliberative research think climate change will impact the planet[68]. When thinking about who will be most impacted, research participants were most concerned about the impact of climate change on future generations.

In our discussion with Tap Chat members, some customers also identify some opportunities of climate change, including the chance to be a leader in sustainability – improving our operations, electrifying vehicles and harnessing water to create energy, alongside focusing the mind on water consumption.

Non-household customers, especially those at larger organisations, quote experience of supply chain issues as a result of climate change, and are more in tune with wider carbon emissions targets and the impact this might have on future business planning. These customers feel expectations as business owners to demonstrate sustainability and expect this from Severn Trent too.

[65] Social Barometer, Wave 5, Consumer Insight, March 2022
[66] ibid
[67] Social Barometer, Wave 1-5, Consumer Insight, September 2021 – March 2023
[68] Net zero and carbon emissions deliberative research, DJS Research, June 2022

Future customers are more likely to believe that climate change is having an impact, with 79% of future customers agreeing that "Climate change is already having an impact in the UK" compared to 68% of household customers[69].

When looking at concern for a range of societal issues, **higher socio-economic** groups are more concerned about most of the environmental issues compared to lower groups, and those who are more **environmentally engaged** are much more concerned about most things compared to those who are disengaged. The difference is less marked for future gas and electricity prices.

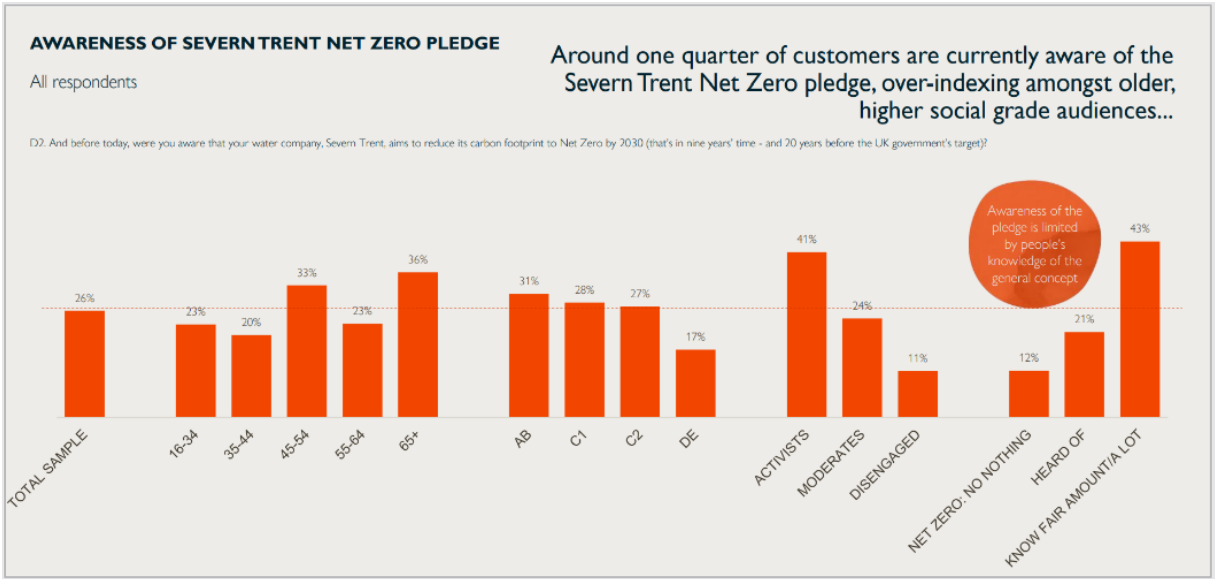
In our Acceptability and Affordability research we also find that customers are becoming increasingly aware of issues relating to climate change and combating climate change is seen as vital. They want to see environmental protection central to Severn Trent's long-term plans.

Customers aren't well informed about net zero but support the need for action once informed. They expect Severn Trent to play its part in reducing greenhouse gas emissions and reaching net zero.

We find that customers have little spontaneous awareness of the carbon impact of water companies, with most focusing on the impacts of transport. Once more informed, customers are surprised about the scale of emissions[70].

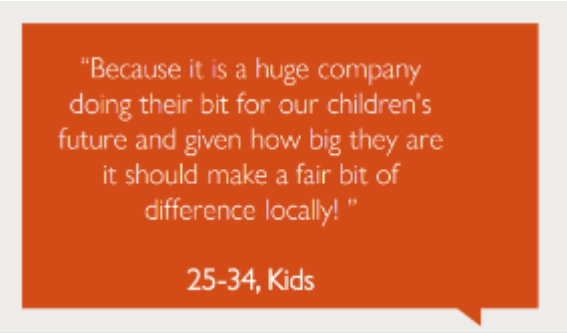
Around 50% of customers say they have heard of net zero policies (in general) but know very little about them - knowledge is greater amongst older customers and less amongst younger customers (16-34)[71].

In the Social Barometer, around one quarter of customers told us they were aware of Severn Trent's net zero pledge, with older customers, higher socio-economic grade, those who are more environmentally engaged and those who know more about net zero policies in general being more aware.

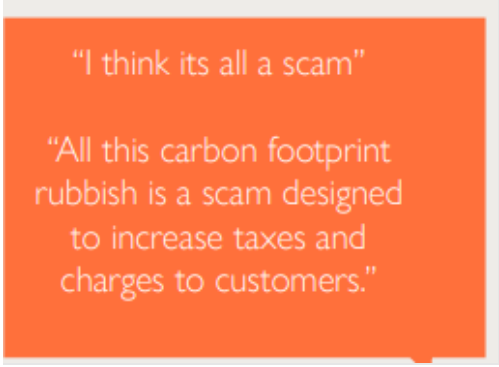


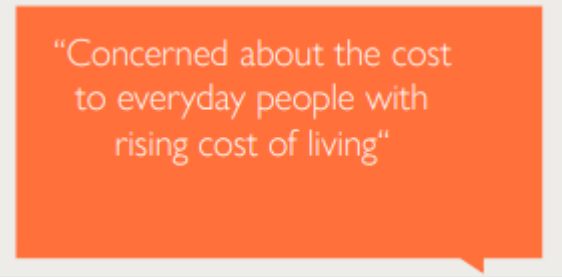
[69] Strategic Investment Choices research, Explain Research, November 2022
[70] Strategic Priorities research, Community Research, December 2021
[71] Social Barometer, wave 1 (September 2021) and 2 (December 2021), Consumer Insight

Once informed of Severn Trent's net zero pledge however, 86% of customers are supportive, with support driven by our customers accepting it's something that needs to be done.



Those who don't support it, whilst a minority, express cynicism both in terms of the impact on bills, and whether the target it achievable.





In our deliberative research participants agreed it is important for the **UK to play its part** in achieving net zero[72]. When it comes to **responsibility**, some question whose responsibility it is to address and fund it. Customers tend to think that the Government, businesses and the general public all have a role, with more people feeling the Government should have the most responsibility for tackling climate change[73]. There is however uncertainty about how far individuals and business are willing to go.

"[The groups most responsible should be…] Homes with more than 1 car per adult, private jets, motor sport industry, people with more than 1 residential home." HH customer, Net zero and carbon emissions deliberative research

"Neither businesses nor individuals will change voluntarily. Change will require enforceable legislation. Will government be willing to introduce and enforce necessary change? Personally, I

[72] Net zero and carbon emissions deliberative research, DJS Research, June 2022
[73] Social Barometer, wave 1 (September 2021) and wave 2 (December 2021), Consumer Insight

doubt it. The cost in winning future elections will be too high." HH customer, Net zero and carbon emissions deliberative research

"This is about governments, and I don't think I should be investing my money in something that is a corporate responsibility" HH customer, Acceptability and Affordability testing

Non-household customers think the Government has the primary responsibility for ensuring the UK achieves its targets, but some (especially larger businesses) feel they have some responsibility for enacting the change because they have the necessary knowledge, control and resources.

When it comes to **Severn Trent taking action**, most participants in our deliberative research agree it is important that Severn Trent plays its part in bringing the water sector to net zero. At the same time there is some concern about the impact this will have on bills. As seen across all our research on future investment, customers want to know that vulnerable customers won't be disadvantaged and there is lack of understanding about the role of shareholders and profits.

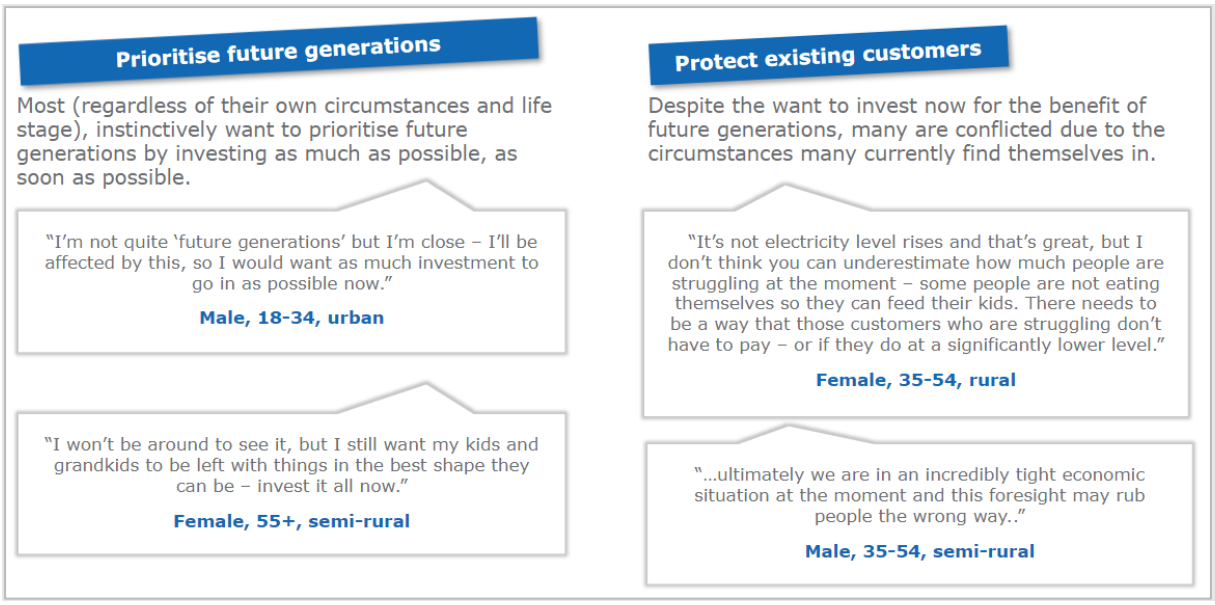
"I think it's important to achieve net zero, because this contributes to the wider issues like global warming and water shortages across the globe. If Severn Trent set a good example, then hopefully other water companies will follow suit, and other business sectors will look at ways to achieve the same goal" Future customer, Strategic priorities research

"I feel it is crucial for any water company to be working towards achieving net zero targets because if there is no plan of action to reduce greenhouse gas emissions then this will ultimately have an impact on climate change which will in turn have a detrimental effect on our water supply in the years to come" NHH customer, Strategic priorities research

Intergenerational fairness

We find some conflict across our research between prioritising future generations and protecting existing customers, and about whether current bill payers should pay for benefits that will be enjoyed by future generations. This occurs both specifically thinking of investment in reducing greenhouse gas emissions, but also at the broader context level.

In our deliberative research there are mixed views, with a fairly even split between those who agree and disagree that future generations should pay. The following Figure summarises some of the views expressed in the research.



In our Strategic Investment Choices research we asked to what extent customers agree or disagree that *Future generations should bear the costs of dealing with climate change*. We find that 29% of HH customers agree, compared to 43% NHH customers and 15% future customers.

In our Acceptability and Affordability research, we find there is an understanding that the investment proposed in reducing emissions may not have immediate benefits for bill payers, but it is deemed necessary, however in our LTDS research customers are less supportive of paying for a significantly increased bill for a worse case scenario now (in terms of uncertainty for the future, and spreading costs more evenly over generations) due to both the lack of personal benefit and "now is not the time" (with current high inflation and interest rates). It is notable however that these views in the LTDS research are expressed at a broader concept level and considering long term bill profiles, rather than about tangible investment.

"I don't mind paying for things as long as I get them, but I only want to pay for things I do get" HH customer, LTDS research

Compared to other investment areas, working towards net zero is a medium level priority

From our overall understanding of customer priorities, working towards net zero ranks as a medium level of priority, when compared to some of the more tangible investment areas relating to protecting the environment and resilience to the impacts of climate change.

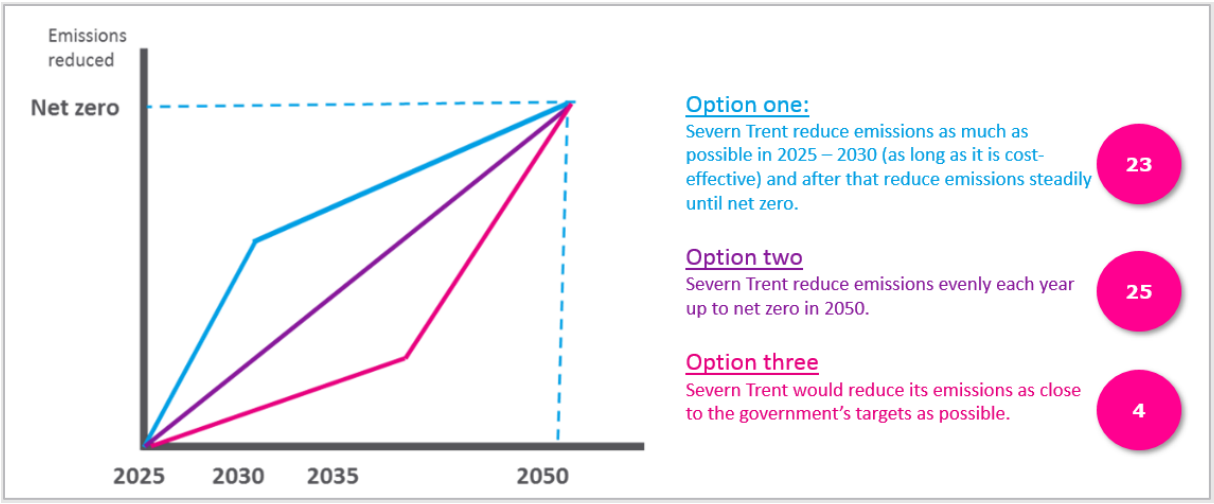
	Strategic Priorities research (2021)	Social Barometer (2021 - 2023)	Strategic investment choices (2022)	Deep dive research	Specific customer groups	PR24 Affordability and Acceptability Testing (2023)	Third party research - proposed ranking	Statutory expectation (in full or part)	Overall understanding of priority
Reducing process emissions	Medium	Medium	Level 3 investment selected (Future)	Customers are prepared to support some increase in their water bills to reduce process emissions, but there is concern about protecting vulnerable customers from bill increases.		Addressing climate change is seen as vital, although some question whose responsibility it is and resent having to pay for the investment. The proposed plan is seen as acceptable and affordable, and many see going further as representing good value.	Lowest importance (CCW Savanta)	Statutory	Medium

Customers are prepared to support some increase in their water bills to reduce process emissions. Some customers would like us to go further and faster on reducing greenhouse gas emissions, but acknowledge that affordability is a concern.

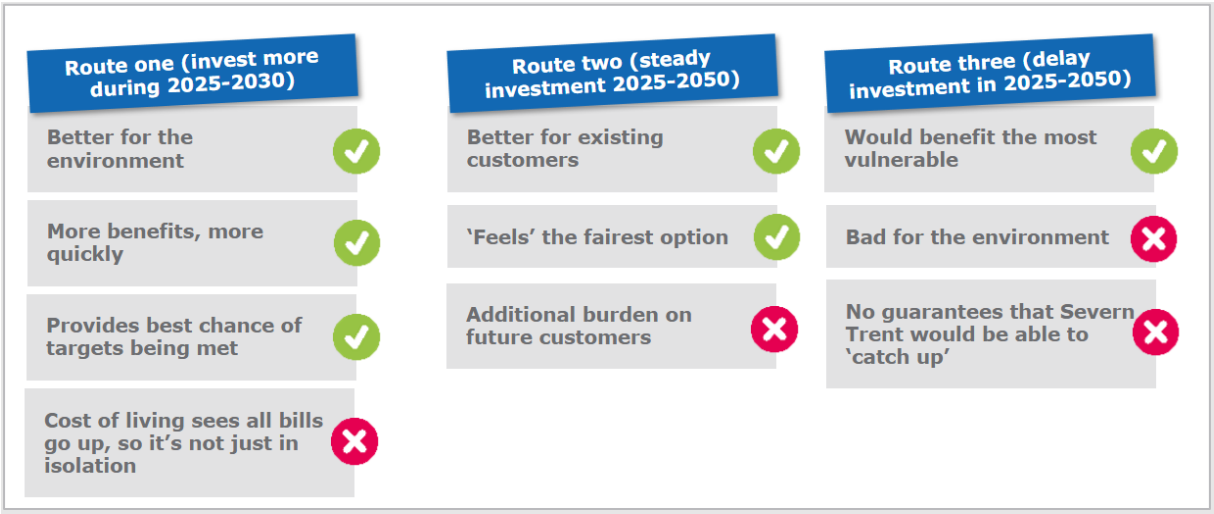
This is an investment area in which we need to understand customer views on the **pace of investment**. We have discussed a range of options with customers, and across multiple research projects sought views on the preferred action, including presenting indicative bill impacts.

- Option one: Severn Trent reduces emissions as much as possible in 2025-2030 (as long as it is cost effective) and after that reduce emissions steadily to net zero;
- Option two: Severn Trent reduces emissions evenly each year up to net zero in 2050; and
- Option three: Severn Trent reduces its emissions as close to the Government's targets as possible.

In our deliberative research, participants showed roughly even support for a steady path to net zero and for acting more quickly, even when aware this would carry a greater bill impact. There is low support for delaying investment.



The following figure shows some of the reasons why participants selected the option they did, although discussions do reveal some internal conflicts about the best option to take.

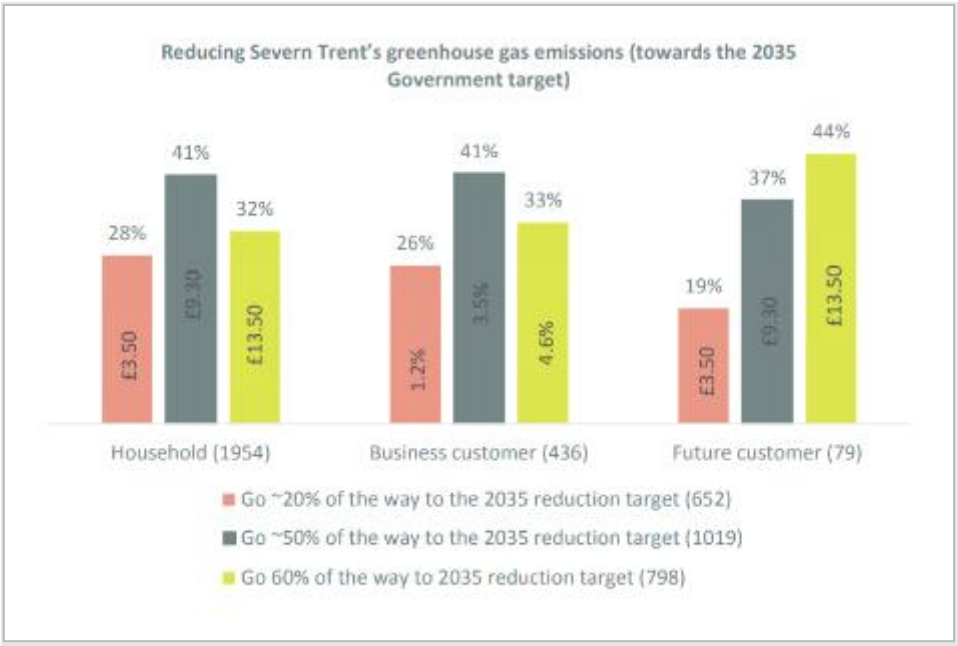


"You see how much people are struggling at the minute, but the issue isn't going away. They need to start now, but keep it in mind how much people are struggling." HH customer, HH customer, Net zero and carbon emissions deliberative research, (on selecting Route 2)

"There's energy bills, food banks, people are at breaking point already. Wait and see, and hopefully in a few years we're all much better off." HH customer, Net zero and carbon emissions deliberative research, (on selecting Route 3)

"We have to make progress on this, as quickly as possible. There's not really any time to waste, so going ahead and doing it now is the right thing to do, but there's so many other things happening… it makes it more difficult" HH customer, Net zero and carbon emissions deliberative research, (on selecting Route 1)

In our **Strategic Investment Choices** research customers were able to select their preferred level of investment (shown with indicative bill impacts), alongside options for other plan areas. Household and non-household customers select similar levels of investment, whilst **future customers** are more likely to select a faster pace.



When analysing different customer segments, we find that those on a higher income (>£80k), socio economic group A and those who say they have never struggled to pay their bills are more likely to choose the highest level of investment. Those who say they do struggle to pay their bills made choices in line with the overall results.

Those who say they make a great deal of effort to be environmentally sustainable are also more likely to select the highest level of investment, whilst views on climate change strongly correlate with investment choices, with 79% of those who did not feel climate change was happening selecting the lowest level.

When it comes to solutions, customers want Severn Trent to focus on directly reducing process emissions and tend to trust Severn Trent to make the right technical decisions.

In our deliberative research most participants tell us they trust Severn Trent to deliver the most effective solutions that benefit the environment and keep costs low (but there is a desire to be better

informed), and most support Severn Trent focusing on reducing process emissions (and only using offsetting when direct reductions are too costly)[74].

When presenting our proposals in our PR24 Acceptability and Affordability research, customers were very positive towards Severn Trent's planned approach and liked the innovation, showing that Severn Trent is a leading company, and that it would also help reduce future costs, thereby benefitting customers and society.

"The proposed plan sounds really good - having the world's first net zero sewage treatment works!" HH customer, Acceptability and Affordability research

Our plans continue to focus on lowering the sources of emissions and we do not intend to use offsetting. It is not part of current our plan and does not feature in our PR24 investment proposal.

When presenting our proposals in our PR24 Affordability and acceptability research, customers were very positive towards Severn Trent's planned approach and liked the innovation, showing that Severn Trent is a leading company, and that it would also help reduce future costs, thereby benefitting customers and society.

In our Acceptability and Affordability testing customers are very positive about our proposed approach, and the plan is seen as both acceptable and affordable. Many customers feel that going further represents good value for money and opt for this option, although there is some concern about this being over ambitious and that a steadier pace is more achievable.

"The proposed plan sounds really good – having the world's first net zero sewage treatment works!" HH customer, PR24 Acceptability and Affordability testing

"I like the idea of being net zero by 2040, it's industry leading and will inspire others" NHH customer, PR24 Acceptability and Affordability testing

"Go for the alternative plan feels like a no brainer as it's not much extra" HH customer, PR24 Acceptability and Affordability testing

In the quantitative research this doesn't rank as highly as the other investment options, however those between 18-24 rank it much higher than older age groups.

Our research on the **Long term delivery strategy** reviewed this proposal with customers, in the context of the longer term planning uncertainties and intergenerational fairness. We find almost unanimous agreement among participants that Severn Trent should be **acting faster on its net zero strategy** – this is seen as a pressing and important issue that Severn Trent needs to be taking seriously. Customers also worry that organisations often fall behind in these kinds of targets, and therefore going for the most stretching approach is the best way to ensure action is taken. Finally, customers feel that they themselves are taking increasing action to limit their impact on climate change and it is only fair that organisations like Severn Trent are also doing their fair share.

"It's absolutely massive, so they're right to get going with it" HH customer, LTDS research

"At the end of the day, we're all doing our bit. Of course they should be thinking about it too" HH customer, LTDS research

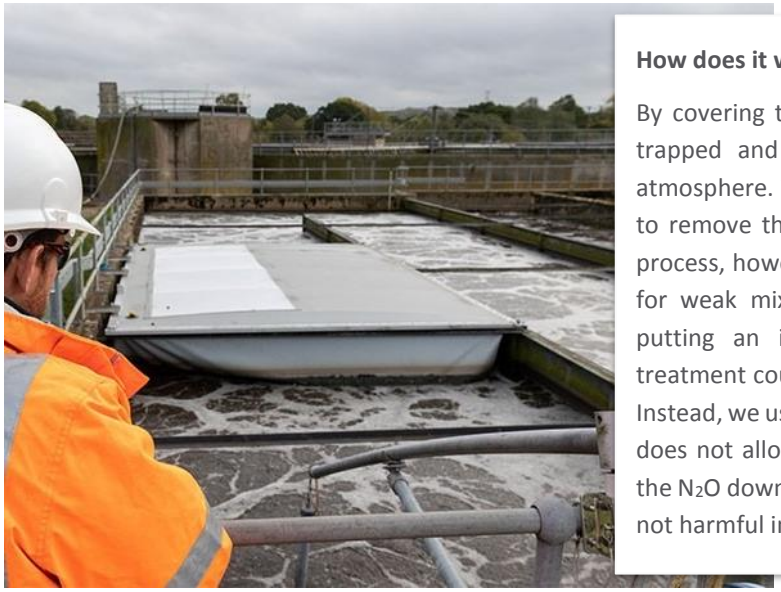
[74] Net zero and carbon emissions deliberative research, DJS Research, June 2022

Appendix C: Overview of options presented in this proposal

Cover and treat

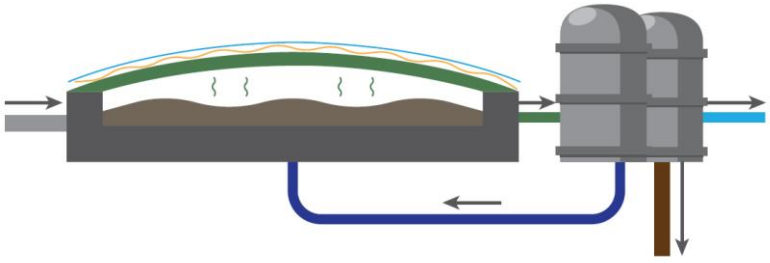
What sort of GHG emissions does it deal with?

Cover and treat deals with N_2O emissions from activated sludge plants. This type of process is typically found on our larger wastewater recycling works, but there are also smaller examples across the asset base. As the process treats ammonia in the wastewater, under certain conditions N_2O can be produced as an unwanted byproduct and released into the atmosphere.



How does it work?

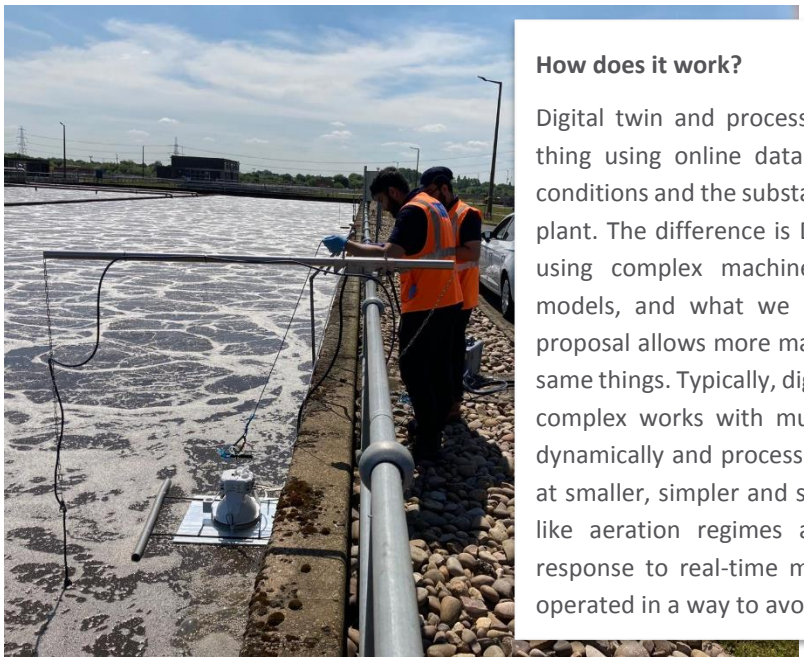
By covering the tanks, the air containing N_2O is trapped and prevented from escaping to the atmosphere. Traditionally we would have looked to remove this air and treat it using a chemical process, however this is not a proven technology for weak mixtures of N_2O. As well as this, by putting an impermeable cover over a large treatment could create a dangerous atmosphere. Instead, we use a photocatalytic membrane which does not allow the build-up of gases and breaks the N_2O down into nitrogen and oxygen which are not harmful in these forms.



Process optimisation & digital twin

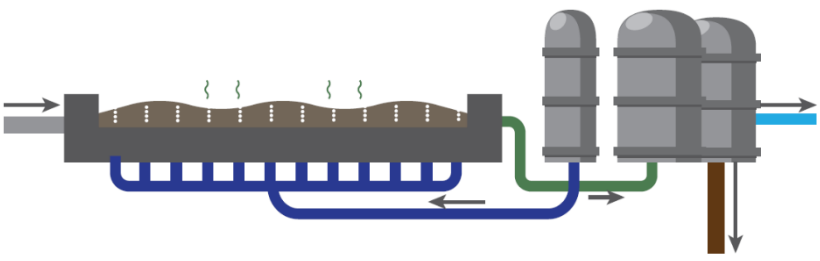
What sort of GHG emissions does it deal with?

Both these options deal with N_2O emissions from activated sludge plants. This type of process is typically found on our larger wastewater recycling works, but there are also smaller examples across the asset base. As the process treats ammonia in the wastewater, under certain conditions N_2O can be produced as an unwanted by-product and released into the atmosphere.



How does it work?

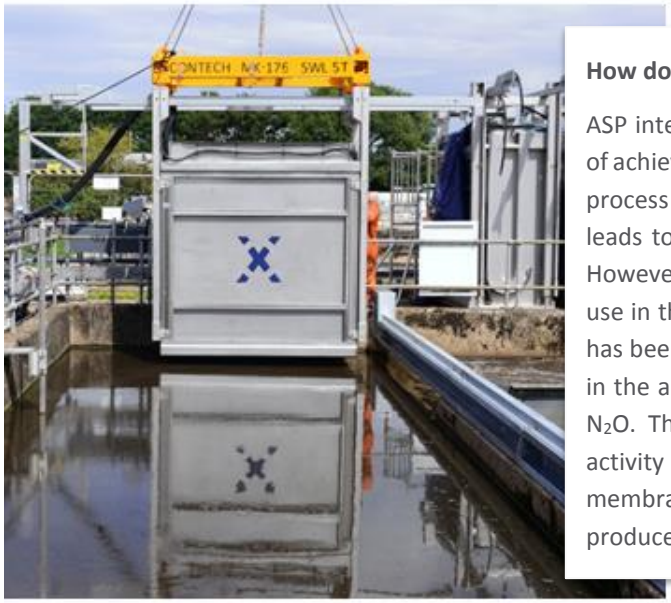
Digital twin and process optimisation both do the same thing using online data to give information on process conditions and the substances in and around the treatment plant. The difference is Digital Twin is done automatically using complex machine learning, AI and mechanistic models, and what we call process optimisation in this proposal allows more manual interventions to achieve the same things. Typically, digital twin would be found on large, complex works with multiple process streams that vary dynamically and process optimisation would be employed at smaller, simpler and stable works. By controlling things like aeration regimes and works and return flows in response to real-time measured data, the works can be operated in a way to avoid the conditions that create N_2O.



ASP intensification

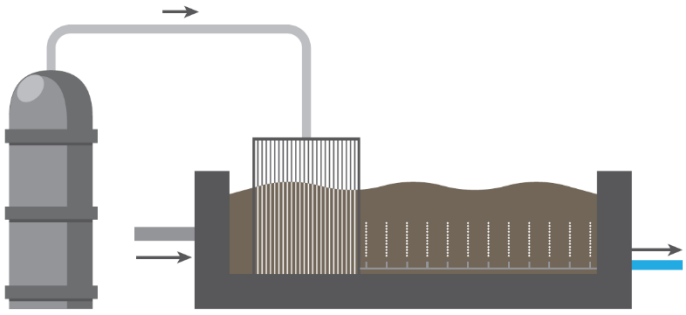
What sort of GHG emissions does it deal with?

ASP intensification deals with N_2O emissions from activated sludge plants as well as reducing Scope 2 emissions by using less energy. This type of process is typically found on our larger wastewater recycling works, but there are also smaller examples across the asset base. As the process treats ammonia in the wastewater, under certain conditions N_2O can be produced as an unwanted byproduct and released into the atmosphere.



How does it work?

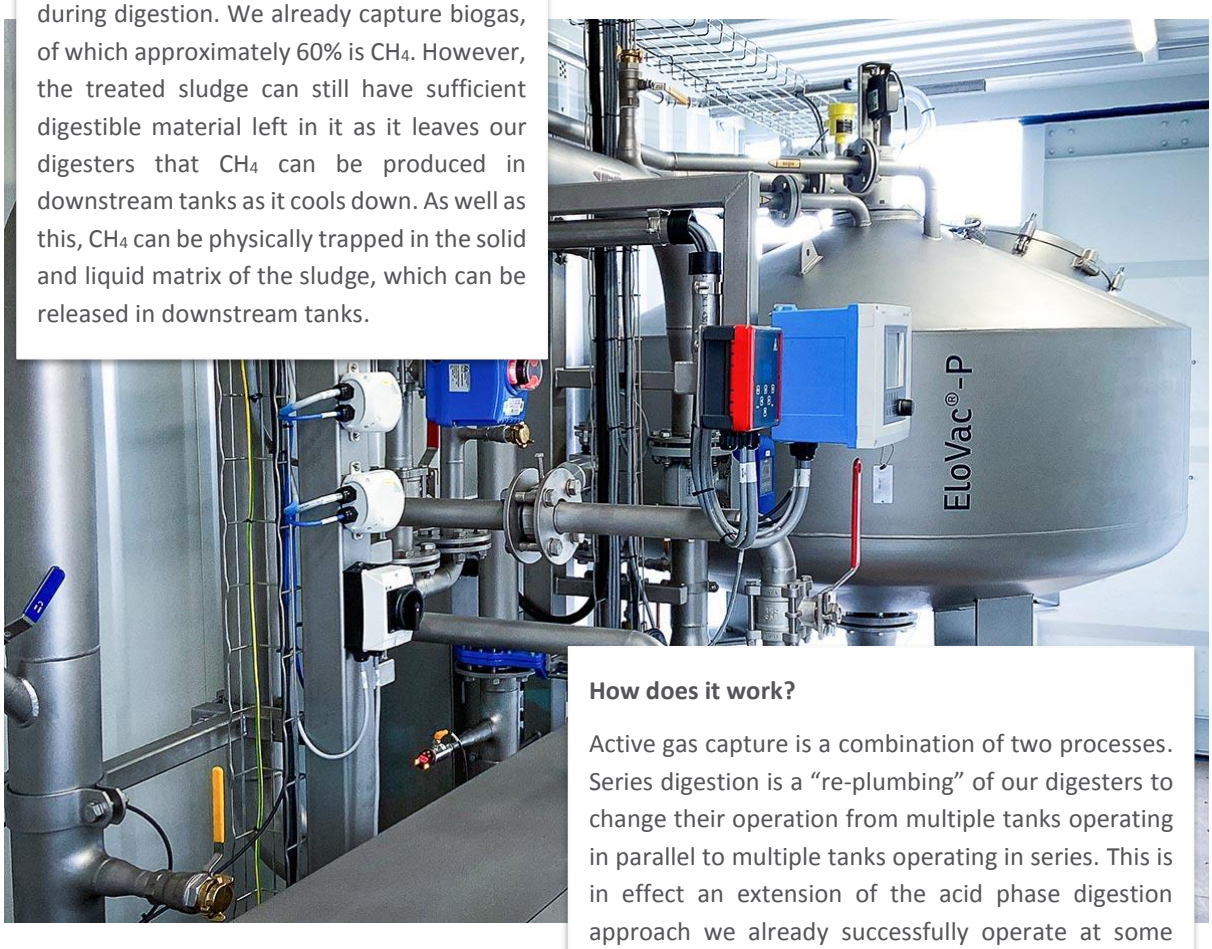
ASP intensification was originally developed as a way of achieving greater aeration efficiency by aerating the process using more energy efficient membranes. This leads to a GHG benefit from reduced electricity use. However, this is not the main benefit underpinning its use in this proposal. With processes such as MABR, it has been observed that placing the aeration cassettes in the anoxic zone results in a reduction in measured N_2O. This is thought to be due to the biochemical activity taking place in the biofilm that grows on the membranes, resulting in lower unwanted N_2O being produced and released into the atmosphere.



Active gas capture from AD

What sort of GHG emissions does it deal with?

Active gas capture targets the CH_4 produced during digestion. We already capture biogas, of which approximately 60% is CH_4. However, the treated sludge can still have sufficient digestible material left in it as it leaves our digesters that CH_4 can be produced in downstream tanks as it cools down. As well as this, CH_4 can be physically trapped in the solid and liquid matrix of the sludge, which can be released in downstream tanks.



How does it work?

Active gas capture is a combination of two processes. Series digestion is a “re-plumbing” of our digesters to change their operation from multiple tanks operating in parallel to multiple tanks operating in series. This is in effect an extension of the acid phase digestion approach we already successfully operate at some sites, but taken a stage further. The result is to increase the level of digestion achieved meaning lower levels of digestible material remain in the sludge. Coupled to this, vacuum degassing is a physical process that treats the sludge as it leaves digestion to remove any remaining gas from within the sludge matrix.

Cellulose recovery

What sort of GHG emissions does it deal with?

Cellulose is a valuable product that is present in wastewater, mainly from sources of paper. We can recover it and, ultimately, as a circular economy solution it may contribute to GHG reductions across a wide range of scopes. Recognising the relatively early stage of the technology and downstream markets we are using it to replace natural gas, so the GHG reduction is associated with a reduction in fossil fuel use.

How does it work?

Cellulose is recovered from the wastewater process through an enhanced level of primary treatment including specific cellulose recovery cyclones. It is washed to create a handleable product and this is used to feed biomass boilers at operational sites with high heat demand, typically due to thermal hydrolysis sludge treatment. We are monitoring for any changes in GHG emissions from the remainder of the wastewater recycling process as a result of removing the cellulose and changing the composition of the wastewater.

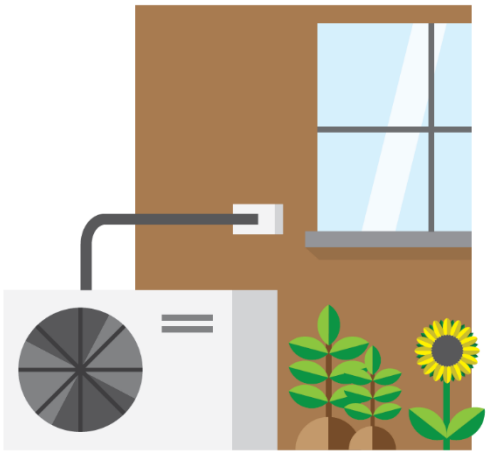
Heat pumps in buildings

What sort of GHG emissions does it deal with?

Heat pumps are used to replace natural gas, heating oil and, in some cases, diesel to heat office spaces and operational buildings. The GHG reduction comes from a reduction in fossil fuel use.

How does it work?

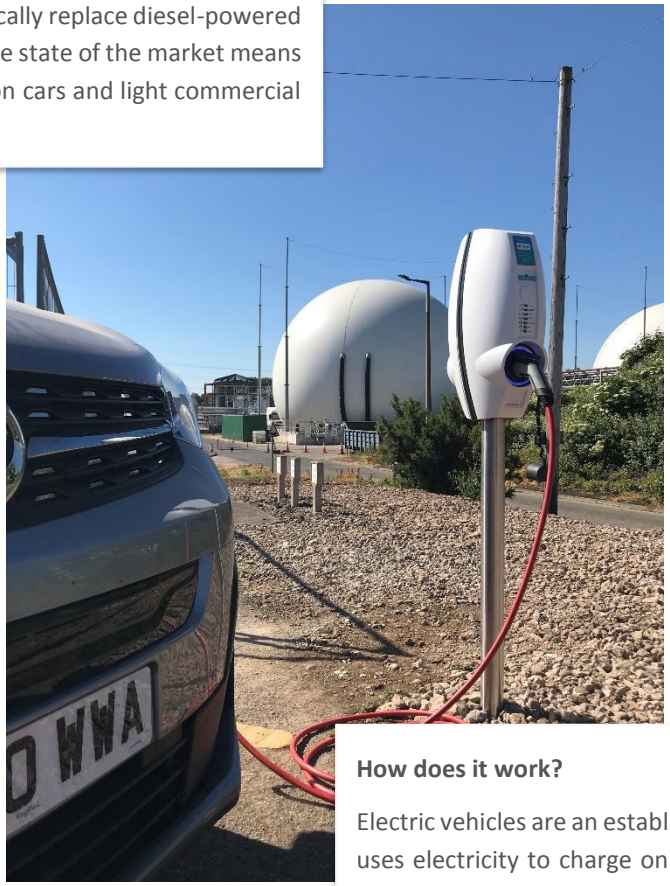
The way in which heat pumps are used in this proposal is the same as they would be to heat a domestic house or other space. It's an established technology that uses electricity to generate a heat differential from the ambient air temperature and feed a hot water or space heating system



EV charging infrastructure

What sort of GHG emissions does it deal with?

Electric vehicles prevent GHG emissions from fossil fuel as they typically replace diesel-powered vehicles. Currently, the state of the market means that we are focused on cars and light commercial vehicles.



How does it work?

Electric vehicles are an established technology that uses electricity to charge onboard batteries, with the vehicles being powered by electric motor. This proposal contains only the charging infrastructure as vehicle replacement is already part of our base plan.

HVO diesel replacement

What sort of GHG emissions does it deal with?

While electric vehicles are available for cars and light commercial applications, this is not the case for medium and heavy vehicles, such as tankers. For these vehicles we wait and see if the market develops heavier electric vehicles or moves to hydrogen fuel cells. In the meantime, we can reduce the impact by moving our existing fleet to renewable fuels such as HVO, resulting in a reduction in GHG emissions from fossil fuel use.

How does it work?

Our existing plant and vehicles are able to use HVO as s fuel. However, HVO is not readily available in sufficient quantities for our needs using public infrastructure, so we need to provide storage and fuelling facilities for our fleet. This means they can run using HVO as a low regrets choice giving a GHG reduction, until we are able to replace them with next-generation zero-emission heavy vehicles.

Appendix D: Overview of options not taken forward to optimisation

Table F.1: Wastewater options that reduce N_2O

Option	Description	Maturity	Included
Nature-based wastewater treatment solutions	By replacing processes that emit greenhouse gases with nature-based ones that do not	Such processes for wastewater are well-established and already widely deployed, particularly in the form of constructed wetlands, although their contribution to CH_4 emissions is not widely understood	No, because the scale of deployment does not match our priority emitters of greenhouse gases
Algae carbon capture	By growing algae in dedicated reactors in controlled conditions	This has been trialled for phosphorus removal. However, the greenhouse gas benefit derived from processing the algae for biofuel or other product has not been fully established	No, because it does not yet have a proven benefit
Complete chemical treatment	By replacing traditional biological treatment processes with chemical oxidation of pollutants the potential for biological production of greenhouse gas is removed	Not yet proven at scale	No, because it is not yet proven. The Scope 3 chemical footprint may be adverse
Remove primary treatment	By removing primary treatment and taking crude wastewater to biological treatment processes there is a larger amount of readily biodegradable matter to increase total nitrogen removal, with the associated N_2O reduction benefit	Fully	No, because the associated cost of upscaling biological treatment would be much less cost efficient than other options

Table F.2: Bioresources options that reduce CH_4

Option	Description	Maturity	Included
Pasteurisation /THP	By treating the sludge with a pasteurisation process (including thermal hydrolysis or pre- and post-pasteurisation) there is no need for secondary sludge storage to meet pathogen kill requirements. This stage can be designed out or abandoned removing a potential location for greenhouse gas emissions	Fully	Not in this case, as the primary driver is sludge compliance costs for THP are included in the bioresources plan

Optimise primary digestion	By optimising conditions for methanogenesis in the digestion process, all the CH_4 is released in the controlled digester environment and enters the biogas route in this ideal location. This means the potential for downstream tanks to emit greenhouse gases is reduced, or potentially the tanks are not required at all	Fully, trialled in AMP7	No, because there are other drivers which require downstream tanks to be covered, such as IED. Measurements will continue to be taken and there is potential for investment in future AMPs if other measures not sufficient
Oxidise CH_4 in secondary digestion	By employing a range of methods to encourage conditions for oxidation of CH_4 in secondary digestion tanks. Biological oxidation destroys the gas meaning it cannot be released to atmosphere	Not yet proven at scale	No, because it is not yet proven
Cover sludge cake storage	By collecting the CH_4 produced on the cake pad or in individual stockpiles following the primary digestion process and feeding it into the existing biogas route, greenhouse gases cannot escape into atmosphere	Fully	No, because our latest monitoring has shown considerably lower emissions than previously thought. We will continue to monitor the effects of active gas removal on post-digestion emissions in AMP8
Treat digestate to eliminate biological activity	By treating the digestate in a range of thermal and/or chemical ways, either the food source for the bacteria that produce CH_4 or the bacteria themselves are destroyed meaning no further greenhouse gas production can take place	Not yet proven at scale	No, because it is not yet proven
Control the post-digestion atmosphere	By physically controlling moisture content and gas entrainment, the conditions for production or release of greenhouse gases in cake storage are eliminated	Not yet proven at scale	No, because it is not yet proven
Treat cake to oxidise CH_4	By employing a range of measures, such as seeding old sludge cake with fresher materials or employing porous covers, the conditions can be created for the growth of CH_4 oxidising bacteria	Not yet proven at scale	No, because it is not yet proven

Replace floating digester roofs with fixed roofs	By replacing floating roofs with fixed roofs, the current methods of sealing (such as water seals) are no longer required, removing a source of physical fugitive emissions	Fully	No, because it is part of base expenditure
Identify and fix fugitive emissions	By using newly-developed monitoring technology such as drone-mounted sensors, it is now possible to identify specific sources of leaks and fugitive emissions	Fully	No, because it is part of base expenditure
Advanced thermal conversion	By treating digestate or raw sludge in high temperature and pressure thermal combustion and conversion processes, such as pyrolysis or gasification. This destroys all biological matter in the sludge, so no greenhouse gas-producing bacteria are left	Currently trialled at scale under Ofwat Innovation Fund projects	Not in this case, as the primary driver would be sludge compliance
Supercritical oxidation	By treating digestate or raw sludge in high temperature and pressure supercritical thermal oxidation processes. This destroys all biological matter in the sludge, so no greenhouse gas-producing bacteria are left	Not yet proven at scale	No, because it is not yet proven

Table F.3: Bioresources options that reduce N_2O

Option	Description	Maturity	Included
Ammonia and hydrogen recovery from liquors	By removing ammonia from high strength digested sludge liquors through electrolysis. This prevents downstream production of N_2O and allows production of pure nitrogen and hydrogen	It is being trialled at pilot scale at Spernal	No, because it would be implemented as part of a nutrient-augmented fertiliser flowsheet, which would not be funded in this way
Thermal treatment of ammonia	By removing ammonia from high strength digested sludge liquors through heating. This prevents downstream production of N_2O	Not yet proven at scale	No, because it is not yet proven
Alternative LTP design	By converting or adopting new designs of liquor treatment the nitrogen from ammonia is not converted into N_2O in either the LTP or downstream secondary treatment	Fully	No, because the options are too site-specific at this stage to meaningfully produce a cost. There will be six LTPs operating in AMP8

Appendix E: Capital carbon unit measures

Table G.1: Capital carbon unit measures

Option	Asset used in carbon calculator[75]	tCO_2e per unit	Unit measure
Cover and treat (ASPs and LTPs)	Tank cover – odour	0.026125	Per m^2
Digital twin	Instrument PLC	0.12 0.06	Assumed one set per ASP lane/module
ASP intensification	Aeration – diffused air filters (M&E)	0.042420	Per m^2 (assuming average 5m ASP depth)
Active gas removal from AD	Unthickened sludge pumping, Heat exchanger – sludge, 150mm diameter pipework	5.69	Per unit (1 unit per digester)
Cellulose recovery	Grit removal – detritor	0.45	Per unit
Heat pumps for buildings	Air Con Unit	0.57	Per 12kw unit
EV charging infrastructure	Instrument	0.06	Per unit
HVO diesel replacement	Fuel tank	76	Per $10m^3$ tank

[75] Source: Severn Trent Carbon Calculator.xls