NET ZERO 2030
Routemap

Contents

Foreword

When it was announced last year that the water industry was embarking on creating a strategy to achieve net-zero carbon emissions by 2030, I was excited to know that Ricardo would be playing a key role. Though this was going to be no small task, with the water sector ranking as the fourth most energy intensive industry in the UK, creating a realistic strategy was going to challenge everyone involved.

There is critical relationship between climate change and water resource management, and whatever sector you work in, water will play a significant role in what you do. It was essential that the sector took this proactive step that will have substantial positive impacts in helping the UK achieve it's 2050 target.

What has been achieved through the hard work, collaboration and innovative thinking, is an ambitious and critical strategy that identifies the pathways for UK water companies to build on their good work to date and bring their carbon emissions down to the net-zero target.

This is an important report, not just for the water industry, but for all sectors. The climate emergency that we are experiencing around the world, will not go away without strong leadership, innovative ideas and people who care enough to want to make a genuine difference. The work that has been done in developing this scientifically robust strategy is an indication to other organisations and industries of what is possible.

I have announced Ricardo's own ambitions for achieving net-zero ambitions by 2030. It is important to me that, like the water industry, we set an example, and lead from the front, encouraging others to follow.

An increasing amount of our business at Ricardo is focussed on addressing the challenges of climate change and I am delighted that our team has been at the forefront of this vital work with the water industry. We are proud to have worked alongside fellow consultants Mott MacDonald, pooling our technical knowledge and extensive experience to drive this valuable plan.

I look forward to seeing the water companies become pioneers through their own net-zero journey, helping other key industry sectors to understand what can be achieved.

Tackling the climate emergency is not the responsibility of one or two individual groups - it requires everyone to work together, and this plan is one further step to creating a healthier world for everyone.

Dave Shemmans
CEO, Ricardo PLC

Net-zero isn't something that any one water or wastewater company can achieve alone. Every single organisation will have to work with its peers, with the whole of its supply chain, with landowners and with its customers. Government and regulators have pivotal roles in setting the policy and legislative frameworks to enable and incentivise the transition. Net-zero by 2030 will be a huge team effort.

There will be many challenges but also opportunities and rewards.

The industry is a large energy consumer. An obvious way to cut emissions is to accelerate the switch to renewable energy. Many companies will be able to install solar, wind or hydro power capacity alongside their assets. Wastewater companies will also be able to produce biomethane and inject it into the gas grid or use it in transport.

Treatment and conveyance of water and wastewater requires attention to cut energy demand, resource consumption and construction of new infrastructure. That requires innovation in catchment management, working with farmers to reduce raw water contamination. It calls for the real time tailoring of treatment by tracking the weather and discharges. Rigorous attention to asset condition and technology upgrades are needed. Demand must be reduced by tackling leakage and encouraging customers to consume less – something the companies are already addressing. Fossil fuels must be phased out. Advances in water reuse and resource recovery are required.

Work is underway to fill some important gaps in the industry's knowledge, particularly regarding the emissions of methane and nitrous oxide from wastewater treatment. As research and monitoring produce new data, companies must share it freely, if the industry as a whole is to take timely action.

Net-zero recognises that some greenhouse gas emissions are inevitable, and these will have to be removed through carbon sequestration – principally by planting trees and restoring peatland. Geography and access to land will make it easier for some companies to do this: long-term partnerships, new carbon markets and transparent accounting will be essential.

All legs of the net-zero journey will be assisted by data. It is essential that the industry accelerates its embrace of the digital revolution to assist its understanding of carbon hot spots, the effects on emissions of operational changes, and potential trade-offs – between water companies, and across infrastructure systems. Digitalisation will be an enabler of net-zero.

Rapid innovation, upscaling and sharing are required. The industry's supply chain needs to be aligned, supported and rewarded to achieve this – consultants, contractors and manufacturers are mission-critical partners.

With this routemap, Water UK has blazed a trail – we're proud of our part with Ricardo in developing it. Others are eager to study it and learn. The next decade will be an exciting one as the industry pursues the goal. In September Mott MacDonald was externally certified carbon neutral – as part of the industry's supply chain we are playing our part. But our biggest contribution will be in helping our clients – in September we were reaccredited to PAS 2080, the international standard for managing infrastructure carbon by working together with others. We look forward to assisting the industry and in celebrating its achievement in 2030.

Mike Haigh
Executive Chair, Mott MacDonald Group

1 Introduction

1.1 Preparing the water sector to operate in a net zero economy

In 2019, the UK Government and the devolved administrations committed to the net zero national target as recommended by the Committee on Climate Change (CCC) and has amended the Climate Change Act such that the UK now has a target to become net zero by 2050. This is in response to the 2016 Paris Agreement's long-term temperature goal to keep the increase in global average temperature to well below 2°C above pre-industrial levels; and to pursue efforts to limit the increase to 1.5°C to avoid the worst effects of climate change.

With the importance of climate change in mind the water sector are working collaboratively to achieve decarbonisation that will have a lasting impact on UK emissions and make an important contribution to and play its part in the achievement of the UK Government target by 2050. This will also assist in protecting the water supply for customers against the risks posed by climate change over the longer term and in managing the risk of increased flooding resulting from climate change.

As part of their April 2019 Public Interest Commitment (PIC), English water companies made the commitment to achieve net zero carbon emissions for the sector by 2030. The water industry is the first sector in the UK to commit to net zero carbon emissions by 2030. The 2030 target will not simply demonstrate that the water sector is taking its role seriously. It will also serve to provide leadership in the delivery of a net zero UK economy.

The devolved administrations of Scotland, Wales and Northern Ireland are working to similar long-term targets for emissions reduction. Scottish Water has committed to becoming net zero by 2040 for operational and investment emissions and support the 2030 operational emissions goals in the PIC. Northern Ireland Water has the goal to fully exploit innovative approaches to energy and new technology to reduce its carbon footprint and ultimately become carbon neutral. Welsh Water has not yet declared a net zero commitment but is likely to align to the Welsh Government's net zero target by 2050.

The water sector has been calculating its greenhouse gas (GHG) emissions for over a decade and has achieved significant GHG reductions to date. However, it still accounts for almost a third of UK industrial and waste process emissions. Its contribution to the national emissions by 2050 is likely to increase, given the difficulty of decarbonising process emissions. Therefore, addressing the sector's emissions now can make an important contribution to the national net zero target by 2050, which is necessary to help stabilise the climate system to less than 1.5°C increase by the end of the century. Moreover, showing leadership by taking action will not only address the sector's carbon emissions, but also encourage others to do the same.

Net zero by 2030 means that the water sector will need to:

- Reduce current operational GHG emissions as much as possible through the use of efficiency interventions and alternative technologies,
- Use renewable energy generation and bioresources, exporting energy and fuels such as biomethane into the wider UK system
- Remove any residual emissions through contributing to the UK's natural sequestration efforts, especially through interventions such as peatland and grassland restoration and tree planting.
- To achieve net zero, any residual emissions will be addressed through offsets. The preferred route will be UK offsets, though global offsets may be required. Government policy to encourage the UK offsets market will assist water companies in being able to offset in the UK.

In addition, the water sector is considering how other sources of emissions that they have a degree of influence over may be targeted post-2030 and how to consider other emerging technologies and more transformational innovations still under development, such as hydrogen and large scale digital solutions applied at catchment level to optimise carbon emissions associated with wastewater, wholesome water energy consumptions and demand and process emissions[1], among others.

The water sector has already started working towards the UK carbon net zero goal with many programmes and initiatives in place. These include:

- A large investment in renewable energy generation has taken place over the last 30 years and has been maximising use of biogas and biomethane.
- Building on a reduction in leakage of a third since the 1990s, water companies in England have committed to triple the rate of leakage reduction to 2030 as part of the PIC and are

1. UK digital twin programme (https://www.cdbb.cam.ac.uk/what-we-do/national-digital-twin-programme)

delivering plans to reduce by a fifth the average amount of water used per person by 2050. This will significantly reduce the carbon and energy used by the sector and households.

- The water and wastewater industry in England agreed the PIC in April 2019, strengthening their ongoing commitment to work in the public interest and place wider good at the heart of everything they do. The companies agreed a series of pledges which complement their individual business plans by showing leadership at a national level.
- The sector will champion interventions through which water companies can integrate what it means to operate in the public interest within their business purpose, in line with best practice among leading socially responsible businesses. This could include steps such as amending licences or Articles of Association.
- The sector plan to plant 11 million trees across the country by 2030. The joint proposals will see trees planted on around 6,000ha of land across England together with work to restore original woodland and improve natural habitats that themselves provide natural sequestration through land use change.
- As bottled water is around 900 times more carbon intensive than tap water per litre, the sector has led on a national shift towards refilling water bottles through the Refill campaign. With partners City to Sea the industry has delivered an increase in the number of free refill stations from 1,500 in 2017 to around 26,000 today – and the number continues to grow. In addition, the sector has committed to preventing the equivalent of 4 billion plastic bottles ending up as waste by 2030 through the PIC.

1.2 Why the water sector has developed the routemap

The water sector has developed this net zero 2030 routemap to help support its transition to a lower emissions future, building on the work it is already doing, and enabling an acceleration and step change in decarbonisation. The routemap provides the direction for the sector on what its journey to net zero by 2030 may look like. This is done by illustrating a number of possible futures of decarbonisation for the sector through three pathways and a more likely sector pathway. Each pathway shows the main decarbonisation options and enablers the sector can consider. The sector envisage that this document will help water companies engage more strategically with the sector's regulators and supply chain, and with the UK Government to work together towards net zero. The routemap will also help water companies to create their own company action plans to align to the net zero sector target by 2030.

The routemap will also enable those involved in the sector (e.g. water companies, regulators, the wider supply chain and other relevant stakeholders) to understand the key opportunities and challenges in preparing the sector to become net zero by 2030 and working collaboratively to help with such a transition (e.g. through Asset Management Plan (AMP) 7, the 2024 price review (PR24) and beyond).

The net zero routemap has been developed to align with the following principles:

- Be credible in the eyes of government and other stakeholders.
- Be aligned with the principles of the Paris Agreement and the United Nations Convention on Climate Change (UNFCCC) 1.5°C pathway – (noting that Scope 3 emissions such as capital carbon and chemicals are being considered by the sector for including post 2030, whereas the Science Based Targets Initiative recommends the inclusion of these. This is discussed in section 2.3.
- Not involve retrograde steps from historical or current efforts or monitoring.
- Build on the existing arrangements in the water sector's Carbon Accounting Workbook (CAW).
- Address the issues that the water sector can control and directly influence. This means interventions that water companies (not individual companies, but the collection of water companies) can control are addressed first. Then interventions controlled by external stakeholders such as regulators and the supply chain that water companies can directly influence.

The UK and other countries will have to operate in a net zero environment by 2050. The water sector has committed to meet this challenge by 2030. This is a significant challenge for the sector since a net zero water sector will also need to maintain its current service, customer affordability and other challenges.

1.3 How to read the net zero routemap

In combination with the net zero routemap a net zero sector guidance document has been developed. The routemap provides options for the strategic direction to decarbonisation for the sector (water companies, regulators, supply chain), whereas the sector guidance document provides guidance and tools for individual water companies to develop their action plans and contains supplementary information on some sections of the routemap pertinent to action plan development. The structure of these documents is summarised in Appendix C.

The routemap has been developed by considering three possible futures for the sector in the form of pathways towards net zero emissions that involve different combinations of decarbonisation interventions. The pathways help the sector understand how changes in future market forces, supply chains, policies, incentives and the availability of funding, among other factors, may change gradually the course of action for the sector, and what could be the alternative paths to net zero for the sector as progress is being made over time. The approach has been common in different sectors, especially in the energy sector. The pathways are illustrative and are not a prescriptive route for the sector. In delivery, it is likely that elements will be drawn from each pathway to achieve net zero, and that these will vary between companies.

The pathways are challenging, demonstrating the leadership role the sector has adopted to achieve net zero by 2030, and require a range of enablers and true collaboration across the water sector value chain occurring. It is important to note that the scale of the net zero challenge is such that the water sector cannot do this on its own and a collaborative approach is required with the supply chain, government and regulators. Each pathway considers a number of actions under the control of the sector that would need to be taken as well as enablers required to be implemented by stakeholders external to the sector such as supply chain, regulators and government. These enablers are summarised in a table under each pathway to net zero.

It is recognised that the possible pathways to net zero involve decarbonisation interventions that can be outside the current price control funding cycle. During the development of this routemap, the sector has had significant engagement with different stakeholders to better understand available decarbonisation funding mechanisms that the sector may be able to access in the short and long-term through further engagement with bodies such as the Department for Business, Energy and Industrial Strategy (BEIS), Defra and Ofwat.

Finally, a combined pathway is also presented in section 4.5.1. This should not be considered the 'best' or 'correct' pathway for the sector, but a demonstration of how different elements of actions from the three different pathways could be brought together to give a balanced view of implementation costs and carbon reductions for the sector as a whole. The combined pathway will also help the sector lead the necessary discussions and collaborative effort with the supply chain, regulators and other stakeholders.

2
What does the 2030 net zero routemap cover?

This section sets out the approach the sector has taken to defining the boundary and scope for the net zero 2030 commitment and its routemap.

2.1 Organisational boundary

The water sector, as a regulated industry, has a robust and well-established boundary for financial reporting known as the 'appointed business'. The 'appointed business' boundary is well-defined for all companies by the sector's regulatory framework and using this definition to scope carbon emissions ensures the appointed business's activities are included in the analysis and the transition to net zero.

For the purposes of the net zero commitment, the organisational boundary for emissions (and the equivalent value to be netted off/offset to reach net zero) has been aligned to the appointed business as defined AMP6[2].

The boundary includes gross operational emissions associated with:

- Wholesome water (extraction, treatment, pumping and transport for maintenance).
- Wastewater services (pumping, treatment, discharge and transport for maintenance).
- Bioresources/sludge management (treatment and transportation. Sludge to land emissions not included).
- Administration activities and business travel.

Renewables export and offset activities are also included (so long as all associated emissions with such activities are accounted for and emissions reductions are not double counted).

The boundary also takes into account the following considerations:

- The water industry's CAW measures operational emissions from the appointed business as defined in AMP6.
- Any additional emissions data is being gathered at the discretion of the water company.
- Individual company financial reporting already uses the appointed business as it's boundary.

2.2 Scope of emissions

The minimum scope of gross emissions for the net zero commitment is the same as the mandatory scope used in the CAW. The CAW is the tool that was developed by the sector and has been used for over 10 years. It aligns with GHG reporting standards and regulatory requirements. This includes operational Scope 1 and 2 emissions, and Scope 3 where a core activity is outsourced.

Individual companies may decide through their own policies to include a broader scope of emissions. However, for consistency when reporting progress against net zero for the sector this will be done against the minimum scope of emissions.

2.3 The role of Scotland, Wales and Northern Ireland

As part of the work to develop this routemap it has been agreed that Scotland, Wales and Northern Ireland are included in the baseline and 2030 trajectory for the purposes of the routemap so as to provide a complete UK sector picture. However, in some cases it may be more appropriate to present the picture at a national level, and this should be given due consideration and decided upon dependent on the audience being presented to and aims of the presentation.

2.4 Other emissions — chemicals and capital carbon

There are emission areas that are not included in the 2030 net zero target as industry data for these is not widely available and/or consistent. Such emissions mainly belong to Scope 3 and include chemicals (except for where they are produced onsite), and capital carbon.

2. The appointed business boundary has been fixed to as it was defined in AMP6 to make clear the inclusion of bioresources activities within the boundary of the commitment. This was to mitigate against the opening of the bioresources market, which may lead to further separation of bioresources activities from appointed business activities.

In August 2020, the water sector committed to:

- Supporting a collaborative working group including the Water Services Regulation Authority (Ofwat) and other interested parties such as the Department for Environment Food and Rural Affairs (Defra), the Environment Agency, and the Climate Change Committee to explore ways replicate the approach taken on operational carbon from October 2020.
- enabling consistent capital carbon emissions reporting in individual water company APRs by 2025.
- enabling future capital carbon performance targets to be established individually by companies as part of their PR24 business plans.

It should be noted that the net zero 2030 commitment may not be align fully with all international standards (such as SBTi) until the actions above have progressed and more Scope 3 emissions are included in the target. However, this routemap aims to achieve net zero by 2030, well ahead of the government target of 2050, which allows two decades following this routemap for those emissions to be considered and potentially added to the target scope.

2.5 Synergies with the wider UK system

Achieving a net zero UK economy relies on maximising the synergies across all infrastructure sectors and the built environment. The water sector is a key part of the wider infrastructure system and has strong decarbonisation links with other sectors of the economy, particularly the Energy and Transport infrastructure sectors as well as the wider built and natural environment. The routemap highlights the opportunities for sectors to decarbonise faster by coordinating their approaches.

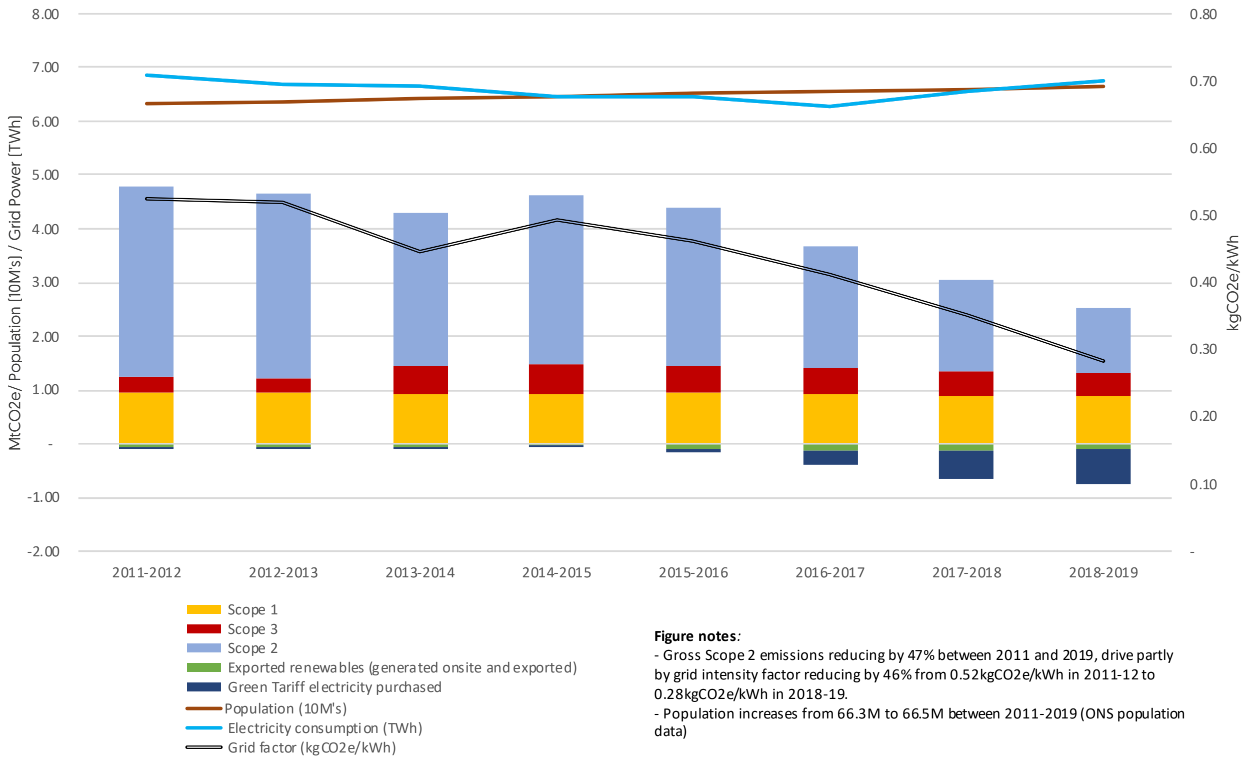
The routemap also highlights opportunities where the water sector can facilitate carbon reductions in the wider system that are outside its net zero 2030 boundary. The main inter-dependencies are discussed throughout the routemap and an overview is given in Appendix E.

3 Baseline and business as usual trajectory

3.1 Historic emissions

The water sector has achieved significant carbon reductions over the last 10 years, and the UK water sector is efficient in overall service performance[3] and energy consumption[4] when compared to other countries. Figure 3-1 gives a summary of their carbon reduction achievements to date that fall within the 2030 net zero scope of emissions and boundary.

Figure 3-1: UK water sector historic GHG emissions as reported in the CAW



Source: Data from CAW summary sheets from 2011-12 to 2018-19 where individual year data was not available this was filled based on the nearest year's data from each company

Figure notes:

- Gross Scope 2 emissions reducing by 47% between 2011 and 2019, driven partly by the grid intensity factor reducing by 46% from 0.52kg of carbon dioxide equivalent (CO_2e) per kWh in 2011-12 to 0.28kgCO_2e/kWh in 2018-19. Grid emissions factor intensity units are not labelled on either axis, but are presented to the correct scale in the Figure and actual values are included within the associated data labels.
- Population increases from 66.3 million to 66.5 million between 2011 and 2019 (ONS population data).

3. https://www.water.org.uk/wp-content/uploads/2018/12/GWI-International-sector-performance-comparisons.pdf
4. https://www.waterbenchmark.org/documents/Archive-IB2018-and-before (Sector and companies compare well against kWh/pe served by WWTP metric)

Figure 3-1 shows the different scope of emissions as included in the CAW and within the sector 2030 boundary. The CAW covers all UK water companies.

The sector has reduced its gross operational GHG emissions by almost 45% between 2011-12 and 2018-19 while upward pressures such as population growth, tighter regulatory standards and additional water resources and climate resilience interventions have occurred or been implemented during this period. In 2018-19 net operational emissions had fallen to 2.4MtCO_2e.

To achieve these reductions, the water sector has:

Water sector interventions to reduce emissions	Historical and current enablers
Invested in energy efficiency interventions in water and wastewater systems to reduce electricity emissions from pumping and treatment operations as well as in water efficiency and leakage reduction.	Company investment through Business Plans in efficiency programmes
Increased renewable energy generation by 43% since 2011-12 (333GWh increase, from 770 to 1,100GWh per year).	Company investment in renewables to keep customers bills low, in conjunction with energy tariffs that promoted on site renewables
Increased exports of renewable electricity to the national electricity grid - 45% increase in renewable electricity exports (~increase of 50GWh per year).	Company investment in renewables to keep bills low, in conjunction with energy tariffs that promoted renewables and available local grid capacity
Created additional biomethane (renewable gas) from sewerage wastes and injected this into the national gas network for use in homes and businesses. Over the past 4 years the industry has injected approximately 35,000m³ of biomethane into the grid mitigating 68,000 tonnes (CO_2e) of emissions.	Company investment in new technologies in conjunction with relative prices for energy, ROCs, RHI, and local grid capacity for connections
Purchased green electricity (with associated certificates) from wind farms and other renewable schemes (>2,000GWh – equivalent to powering all the households in the UK for around a week[5]).	Business decisions to invest in low-carbon energy

In past periods, there has been a strong link between deployment of decarbonisation interventions and the business planning process. Future periods should aim to build on the investment incentives that have enabled the sector's emissions reductions.

The decarbonisation of the UK electricity grid has also played a significant role in the sectors emissions reduction efforts. Without the significant decarbonisation of the grid, it is likely emissions would have remained stable. However, it is also important to recognise that without the energy efficiency interventions, renewable generation and demand reduction interventions introduced by the sector it is likely that the sectors emissions would have increased dramatically from their current levels.

It is important to note that there has been an upward trend in electricity consumption between 2015 and 2018-19, and this has been attributed to additional power requirements for pumping for water and wastewater services, an increase in water and wastewater treatment driven by environmental standards and climatic changes through having more intense rainfall and other extreme events.

5. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/826725/2019_Consumption_tables_2.xlsx (Note: 2018 Domestic Final consumption = 105,064 GWh)

3.2 Baseline — 2018-19

The 2018-19 reference baseline for the sector has been produced using the water companies CAW data for that year.

Figure 3-2 shows the sector's baseline GHG emissions.

- The total gross emissions are shown at the top of the graph. These are the emissions calculated using the Greenhouse Gas Protocol location-based methodology for Scope 2 emissions.
- The total net operational emissions are shown under this. These are the emissions calculated using the market-based approach[6] and with the emissions associated with water sector generated and exported renewables (such as biomethane to grid, renewable electricity from biogas, and others) where the sector holds the relevant REGO certificates[7] subtracted.
- More detailed gross emissions for each business (e.g. drinking water, wastewater or transport) and emissions category (e.g. grid electricity or process emissions) are shown in the middle of the graph.
- The emissions accounted for as market based and renewables export are shown at the bottom of the graph.

The main sector emissions are attributed to carbon dioxide (CO_2) primarily from grid electricity, and methane (CH_4) and nitrous oxide (N_2O) emissions from wastewater and sludge treatment processes.

Note: Process emissions are one of the emissions hotspots where the sector is investing significant effort to understand the scale of these emissions and appropriate mitigation interventions. The current data is based on the 2006 guidance from the IPCC, but work by UKWIR is under way to understand the impacts of the updated 2019 IPCC guidance and identify if a more UK water sector specific approach to process emissions estimation can be developed.

The baseline reflects the sector boundary and scope of emissions as defined in section 2.1. For example, where companies have contractual arrangements recycling treated sludge to land beyond the company boundary, these are excluded. Once the sludge is recycled, these emissions fall into the landowner's boundary and are outside the sector net zero boundary.

Process emissions uncertainty

The sector continually strives to align the quantification, estimation and reporting of its emissions through the CAW with international standards and best practice. Therefore, in parallel to the routemap development, UKWIR has commissioned a comprehensive review of the water sector's process emissions. This work has focussed on reviewing the status of the science and evidence behind wastewater process emissions factors and technologies used in the calculation of greenhouse gases by the sector and, in part, to inform future updates to the CAW.

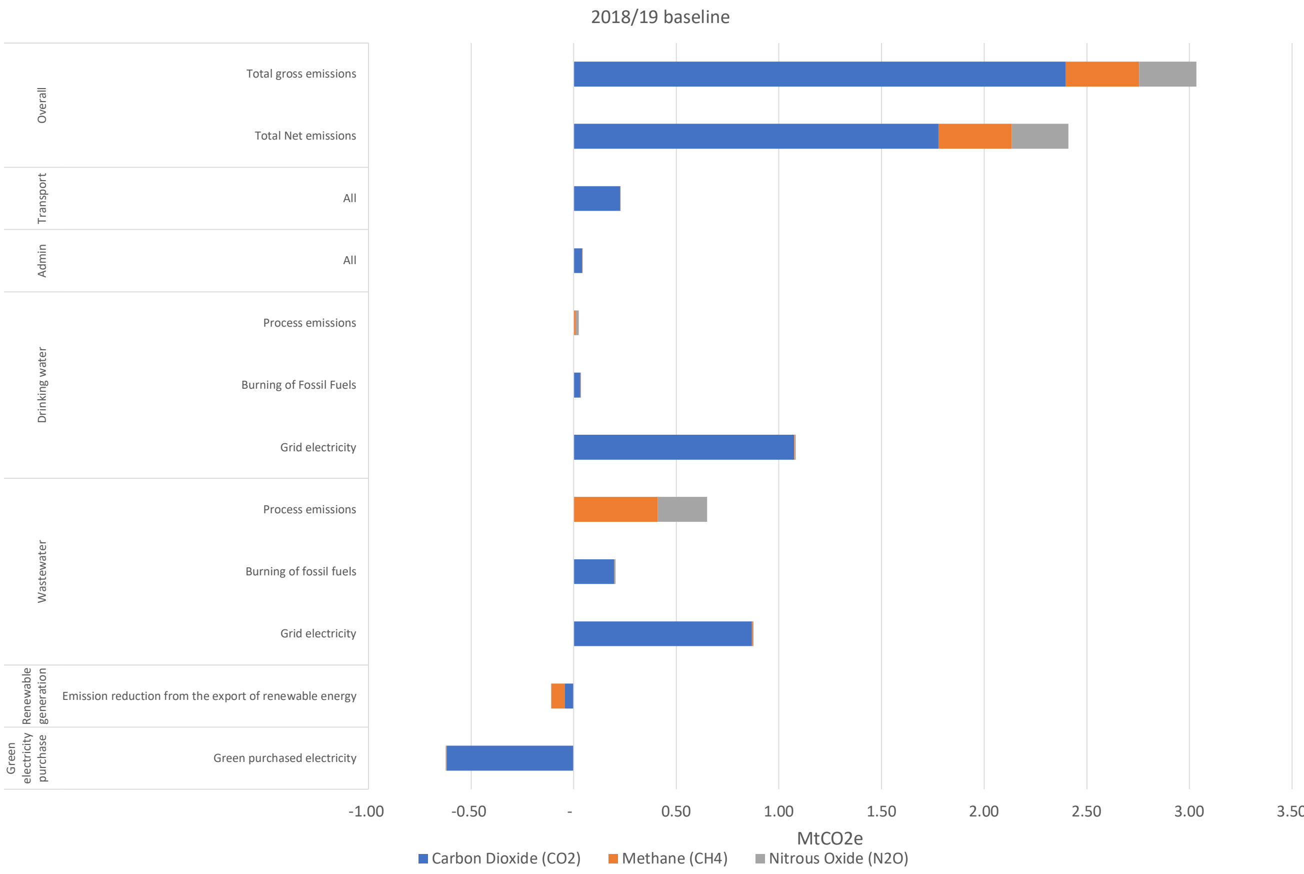
Through the UKWIR work, it has been found that an aspect of the underlying methodology for process emissions calculations within the CAW appears to be inconsistent with current greenhouse gas emissions accounting practice. Specifically, a methodology embedded in the CAW since it was established combines a Scope 1 emission and Scope 3 benefit to produce a lower emissions factor than IPCC data for Nitrous Oxide emissions from treatment processes. As a result, the sector is discussing future updates to the CAW that will bring the methodology in line with greenhouse gas accounting best practices.

Whilst this routemap has not been updated to reflect the initial findings of the process emissions review, nor any future changes to the CAW that the sector may make, analysis has been undertaken to understand the scale of the impact this may have. It has been estimated that the update could lead to an increase in gross and net emissions of 0,2$MtCO_2e$ per annum, equivalent to ~8% of the sector's net emissions. This means that the sector would have to accelerate even more the implementation of other decarbonisation interventions to close the residual emissions gap. Further references to the uncertainty around process emissions are made in the pathways section in chapter 4.

Beyond the methodology alignment recommendation, it should also be noted that the UKWIR process emissions project has highlighted that there is significant uncertainty in the true emissions arising from wastewater treatment processes, and that further research is required to establish a better scientific basis for the sector specific emissions factors. There are more phases of the project being planned, which will look to improve the uncertainty around the scale of these emissions through better measurement and field trials.

6. In Scotland the aim is for 100% onsite renewable generation rather than through green electricity purchases, which accounts for low carbon electricity under the gross calculation rather than the net.
7. Note: As required by the CAW, if the company keeps the REGO for self-generated electricity and consumes the power, a Scope 2 emission is not incurred. Alternatively, if the company sells the REGO for self-generated electricity and consumes the power, a Scope 2 emission is incurred.

Figure 3-2: UK water sector GHG emissions baseline 2018-19 as reported in the CAW



Source: Data from 2018-19 CAWs

Table 3-1 summarises the GHG emissions from electricity use and exports to provide more clarity on the baseline.

Table 3-1: Emissions by category

Emissions category	2018-19 ($MtCO_2e$)
Water grid emissions (gross)	0.88
Wastewater grid emissions (gross)	1.08
Total Grid emissions (water + wastewater) (gross)	1.96
Renewable energy exports	-0.11
Green tariff purchase	-0.62
Total emissions netted off	-0.73
Total net grid emissions	**1.23**

3.2.1 Business-as-usual trajectory to 2030

A key element of the routemap was to define the sector's 'business-as-usual' (BAU) trajectory towards 2030, taking account of the sectors current plans and commitments. Importantly, the 2030 trajectory is not a do-nothing projection as it assumes a degree of action is taken over the next decade. The 2030 trajectory also includes assumptions and forecasts for population growth, changes in demand, as well as incorporating anticipated external factors such as grid decarbonisation forecasts, market forces around electrification of transport among others. The 2030 trajectory takes into account relevant decarbonisation interventions the sector have committed to, some of which have been summarised in Section 3.1.

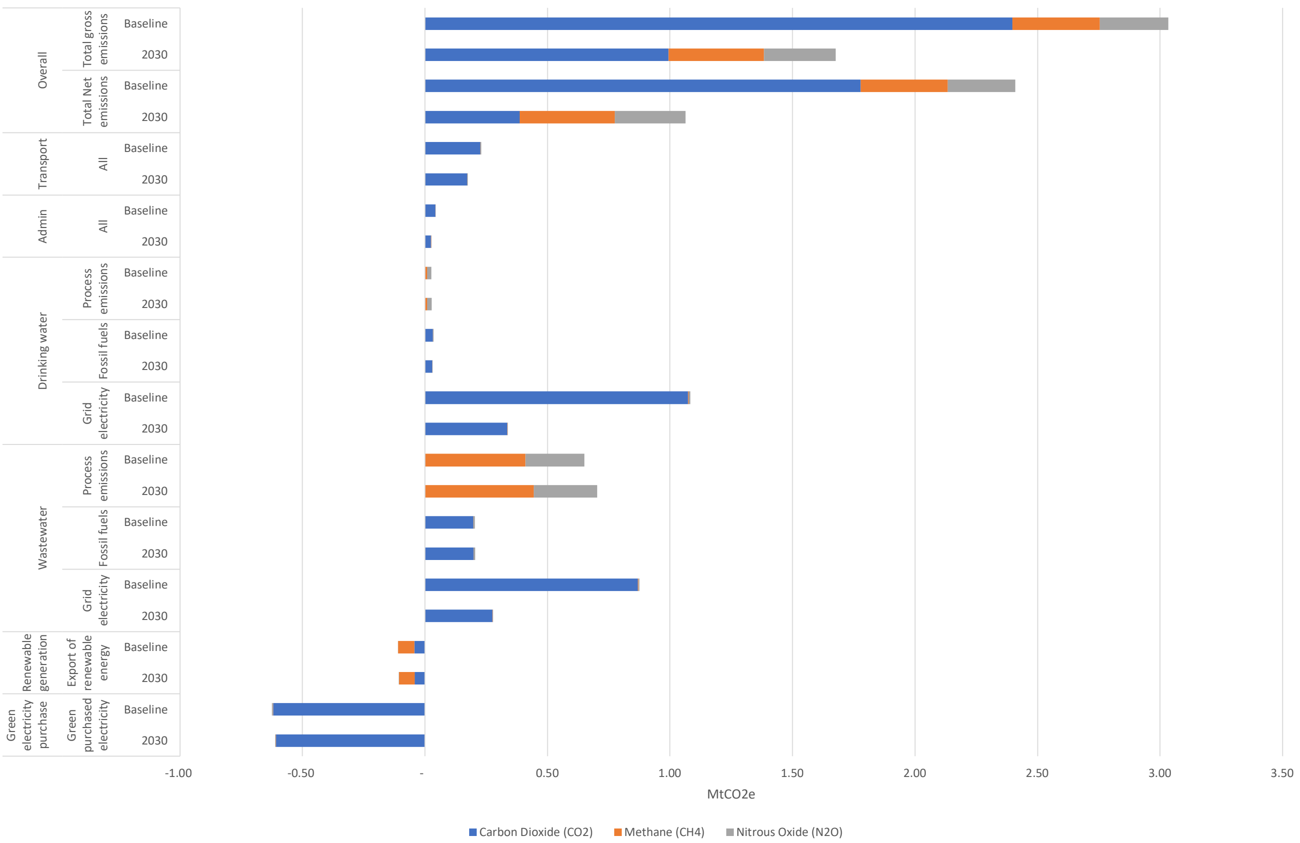
If operationally the sector remains on the BAU trajectory, meeting net zero by 2030 would mean all residual emissions would need to be removed through purchased offsets. However, such an approach would not be in line with the SBTi principles of reducing emissions as much as possible, before relying on renewables or offsets.

It is important to note that the BAU trajectory does not allow for increasing requirements in drinking water quality or other regulatory standards or other additional external pressures arising from climate change. These factors may introduce additional pressures to the sector, driving up future emissions trajectories and requiring additional interventions. Some national infrastructure programmes such as WINEP and RAPID have long planning cycles and decisions taken now can cause subsequent increases to emissions that will be hard to avoid after the infrastructure has been brought into operation.

The BAU trajectory confirms that the interventions deployed by the sector have mitigated some external factors such as population growth. It will be important that the sector, regulators and government are joined up on the impact of changes in regulation and other external factors, particularly in PR24, to help the sector balance the trade-offs between GHG emissions and other environmental or societal impacts.

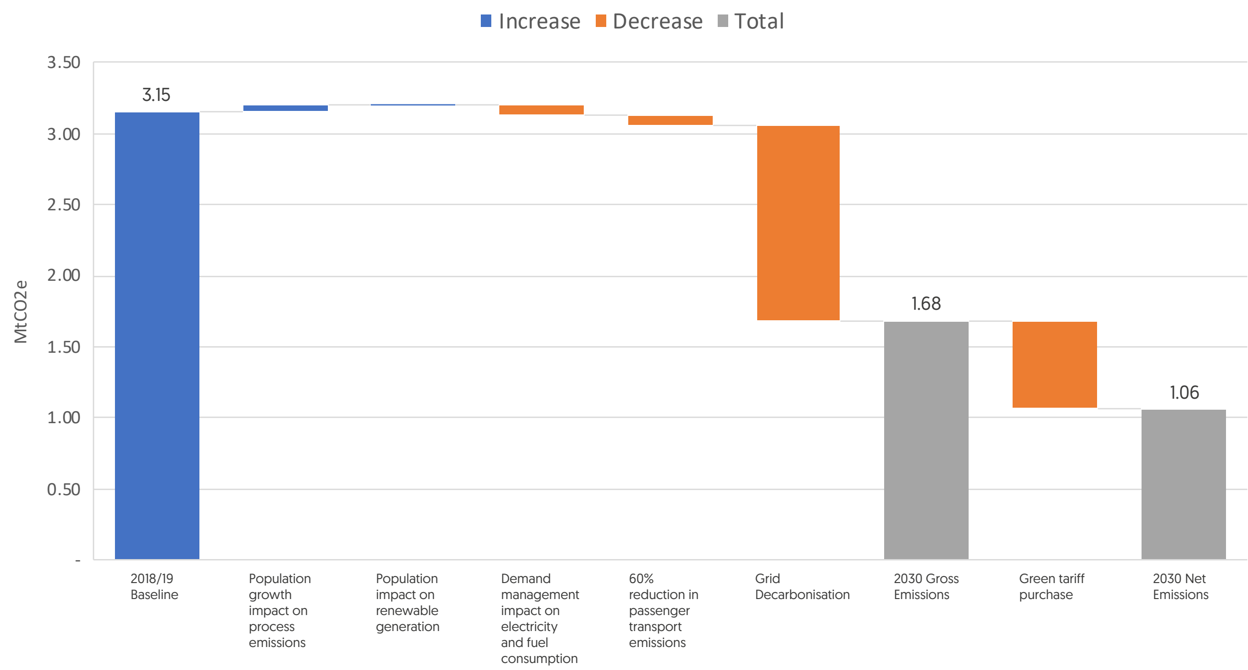
Figure 3-3 illustrates what the sector's GHG emissions may look like in 2030 compared to the baseline year. Without significant step change emissions in 2030 would still represent more than 60% of the baseline. To meet net zero without undue reliance on purchasing offsets, the sector will need to transition to low carbon infrastructure solutions that reduce those emissions or supply them by a low carbon source.

Figure 3-3: The BAU emissions breakdown and comparison to the baseline.



The key contributing factors to carbon reduction by 2030 and the residual emissions in the BAU trajectory are illustrated in Figure 3-4. The most significant interventions that the sector has direct control of include demand management, energy efficiency and purchasing green electricity, whereas the largest external factor is the gradual decarbonisation of the electricity grid. For external factors, such we have used suitable external sources to forecast the impact.

Figure 3-4: Visualisation of different factors impacting the BAU trajectory of emissions under business as usual operation.



4

Defining the pathways to net zero

4.1 The approach

The net zero 2030 routemap has been developed using the approach shown in Figure 4-1.

Figure 4-1: Routemap development flowchart

Defining the Routemap principles presented in Section 1

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Setting the emissions scope and boundary for the sector

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Defining the emissions reduction hierarchy aligned to the Science Based Targets initiative of reducing first, then investing in renewables and energy recovery and then removing any residual difficult to decarbonise emissions as a last resort

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Developing the baseline (2018/19) using sector data collected in the CAW

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Developing a Business As Usual trajectory for the Sector in 2030 building on historic efforts to reduce emissions and aligning with current company business plan activities to test if such trajectory will enable the sector to be Net Zero by 2030

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Assessing possible decarbonisation interventions for the sector and assessing high-level sector Marginal Abatement Costs and sector level carbon abatement potential

↓

Developing three pathways to net zero building on the possible decarbonisation interventions to present the possible routes the sector could follow to meet the 2030 target

↓

Comparing the three pathways and developing a combined pathway for the sector and the preferred routemap to Net Zero by 2030

Following the routemap water companies produce their own specific action plans for achieving Net Zero using the routemap and the sector net zero guidance document.

The routemap has been developed by considering three possible futures for the sector in the form of pathways to net zero that involve different combinations of decarbonisation options. The pathways help the sector understand how changes in future market forces, supply chains, policies, incentives, availability of funding, among other factors, may change gradually the course of action for the sector, and what could be the alternative paths to net zero for the sector as progress is being made over time. The approach has been common in different sectors, especially in the energy sector.

The pathways highlight a number of enabling actions that different stakeholders in the water sector would need to follow to be able to follow and implement each pathway to net zero. A number of actions and decarbonisation options that could be enabled more quickly have also been included in all three pathways. These are further discussed in Section 4.3.

4.2 Decarbonisation interventions

Through our review of the interventions the sector is already implementing, as well as additional interventions from the supply chain, water companies and other infrastructure sectors, a number of decarbonisation interventions have been identified, as shown in section 4.3 and Appendix A. The decarbonisation interventions follow the sector's net zero carbon reduction hierarchy.

The emissions reductions hierarchy is a means of prioritising decarbonisation interventions by encouraging credible reductions before offsets, in alignment with national and international net zero policies, and is shown in Figure 4-1. This also has the benefit of encouraging more cost negative/cost neutral efficiency interventions to reduce demand prior to implementing new technologies which involve additional investment. Cost negative/cost neutral interventions should always be considered before heavy investment in other technologies. Offsetting is included in the scope of net zero 2030, as a means of addressing residual emissions after opportunities for reduction and renewables have been taken.

The emissions reduction steps were divided into sub areas and aligned with the BAU emission areas to produce the categorisation of decarbonisation interventions as shown in Table 4-0.

The significant interventions (options with the greatest emissions reduction potential and/or applicability to the majority of water companies) in these areas were then identified, with some of the interventions with smaller impact being clustered together.

Figure 4-1: Emissions reduction hierarchy

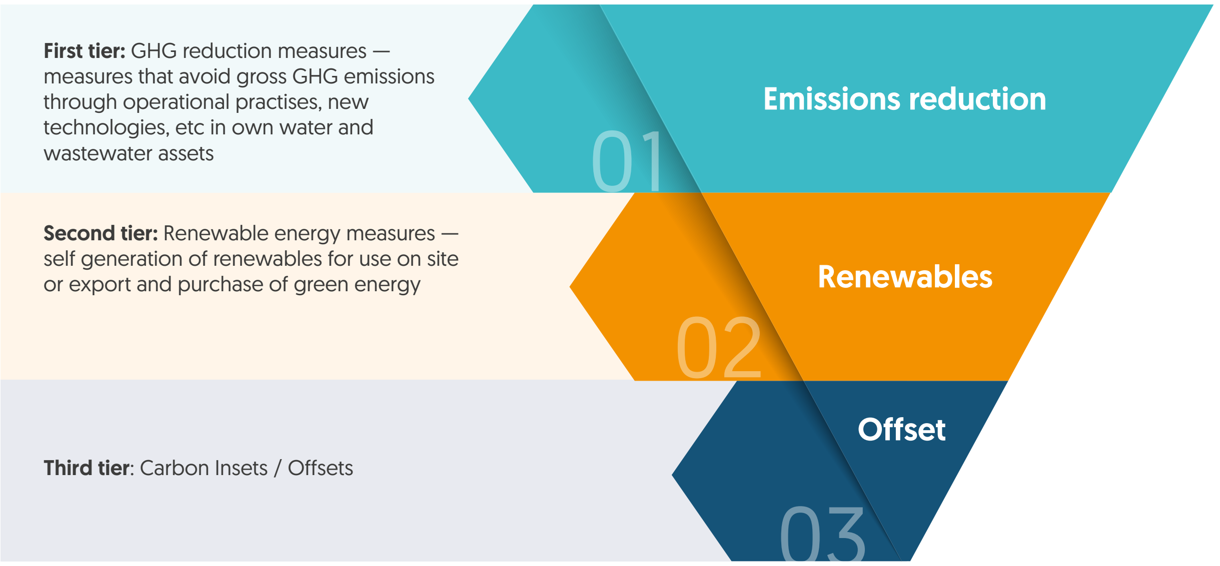


Table 4-0: Categorisation of interventions (actions taken to reduce carbon emissions)

1 Emissions reductions	**Efficiency interventions (those that reduce emissions by improving existing technologies and systems)**				**Alternative technologies (interventions that reduce emissions by moving from one technology to another)**			
	Water	Waste water	Transport	Admin	Water	Waste water	Transport	Admin
2 Renewables	**Self-generated renewables** (for use on site or exporting resources from within the scope boundary to outside it where the carbon benefit is retained)				**Procurement** (purchasing low carbon resources from outside the scope boundary)			
	Bioresources		Renewable electricity (potentially with storage)		Green procurement[8]			
3 Residual emissions	**Sequestration** (activities which remove emissions from the atmosphere and deployed in water sector land or within the UK territory)				**Purchased** (emission reduction activities that occur outside the water sector boundary for which credible carbon credits can be purchased – such as the UK and global carbon markets)			
	Carbon sequestration – insets				Carbon sequestration – offsets			

To guide the detailed analysis, the theoretical emission saving potential of the interventions were quantified using a top down approach and by making appropriate assumptions. This involved reviewing studies and pilots carried out by water companies, and other reputable data sources, to calculate the potential sector-level reductions.

As individual water companies develop their own action plans, these sector-wide estimates should be replaced with more detailed figures that suit individual company circumstances.

A number of non-cost criteria were also developed to assess the interventions. The non-cost criteria involved factors such as technical feasibility, co-benefits, customer acceptability, regulatory incentives among others. A full list of these criteria is included in Appendix D.

4.2.1 Costs for key interventions

To allow the interventions to be assessed, costs for each intervention were drawn from industry level data and supplemented by company specific data where similar interventions had been trialled or deployed at scale. There were significant ranges in the costs reviewed and there is an inherent uncertainty in the resulting sector level estimates. More detailed individual company costs that take into account any site-specific factors will ultimately be needed to inform individual company plans.

The main drivers of uncertainty in the costs and benefits in these costs are:

- **Scaling up of project/programme level costs to estimate sector level costs**. Costs vary significantly between companies due to variation in treatment type and size of works, geography and existing levels of performance.
- **Scaling up potential carbon reduction benefits of different options based on project level data, pilot trial results data**. These benefits are also affected by several factors, for example, the potential carbon reduction impact of an energy efficiency measure will be significantly impacted by the scale of energy efficiency measure companies have already implemented.

8. There is a difference to the approach for green tariffs between England and Scotland. In England green tariff purchase is acceptable whereas in Scotland there is an expectation of location based reporting for public bodies such as Scottish Water, hence purchasing green tariff with REGOs is not being actively pursued and they will not pursue market-based offsets/global offsets, instead looking for the nature based opportunities within their landholdings and within Scotland.

- **Uncertainty around process emissions is an important consideration for the sector**. As highlighted in section 3.2, there is uncertainty around the scale of process emissions from the sector. There are two issues that the sector is looking to resolve. Firstly, an update to the CAW methodology, which has been estimated to increase Scope 1 emissions by 0.2MtCO_2e/y. Secondly, there is the ongoing work by the sector, through UKWIR, to improve our understanding and reduce the uncertainty around emissions arising from wastewater treatment processes. When the science, and associated field trials data are robust enough, a future update to these emissions values can be expected.
- **The science behind the different removals and natural sequestration options is an area of ongoing work**. The current benefits for these decarbonisation options are based on the best available data that has been developed within the sector, and through engagement with external stakeholders such as the Woodland Trust, Defra and other industry engagement. Further work is being considered by the sector to better understand the sequestration potential for the sector and developing their calculation of the sequestration from their land holding as well as the way removal benefits can be accounted for during investment appraisal. External stakeholders are developing the science behind the sequestration potential of different interventions, which the companies are also supporting and engaging with.

The uncertainties above have been accounted for as best as possible and top down estimates have been made to provide indicative levels of costs and benefits of each intervention option at the sector level.

The costs for interventions have only taken into account the water company costs and impacts and do not consider wider social costs and benefits. These have been discussed in section 4.3 (the sector pathways). Companies developing their own action plans would likely consider these wider benefits and undertake a full economic analysis.

4.2.2 Marginal abatement costs of carbon for the sector

To understand the reduction potential and associated cost impacts of each decarbonisation intervention (or cluster of interventions), a marginal abatement cost of carbon (MACC) curve, in £ per tCO_2e abated, was developed (Figure 4-2).

The costs in the MACC are expressed as £/tCO_2e on the Y-axis and annualised tCO_2e abate figures on the X-axis. These are built based on the net present values (NPVs) for each option using a discount rate of 3.5% in line with the HM Treasury Greenbook guidance. The costs and NPVs were calculated based on indicative sector level costs from industry average costs and calibrated for the sector using selective water company data and water company information, where available, or estimates where data has not been available.

Creating the MACC also involved estimating:

- Capital cost requirements to implement options (£).
- Operational and maintenance costs required for each option (£).
- Operational savings or income (£).
- Allowance for capital replacements (£).
- Annual carbon reductions.

The above inputs were used to calculate a 10-year NPV for each cluster of options.

The MACC uses annualised NPV carbon abatement over 10 years to calculate an average abatement costs of each option considering the 2030 net zero horizon. NPVs were also estimated over a 30-year time horizon, accounting for capital replacements for assets and components with different asset lives, to demonstrate the impact on abatement costs when the longer time period to 2050 is considered. The carbon abatement potential of each option also accounts for estimates for grid decarbonisation using grid carbon intensity forecasts provided within the Treasury Greenbook supporting guidance[9]. This helps reflect the reducing carbon benefit of reducing grid power consumption over time as the carbon intensity of grid electricity reduces.

The MACC illustrates a snapshot of the range of decarbonisations options potentially available to the sector in year 2030. It shows the possible abatement potential of each option alongside the estimated annualised NPV cost per tCO_2e abated. The MACC does not take into account actual deployment rates or constraints that may affect the rate or scale of deployment of each option. These factors are considered in the Pathways presented in Section 4.3.

The key insights that can be drawn from the MACC include:

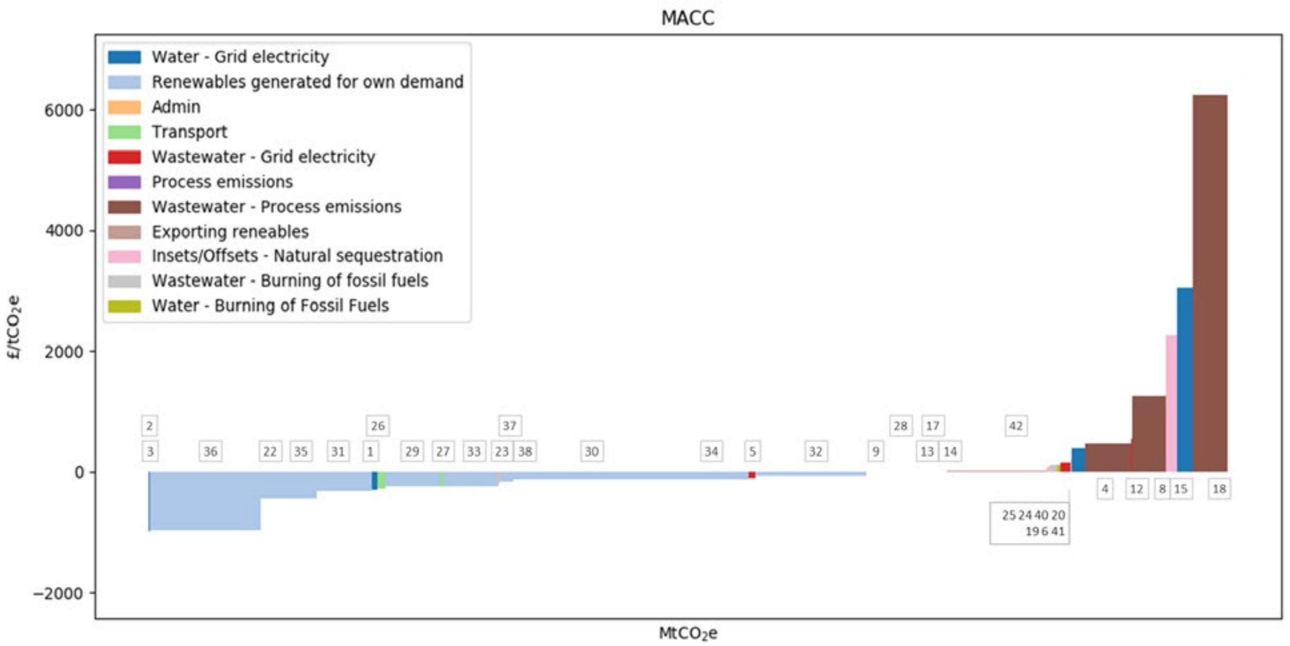
- Options to manage **wastewater process emissions** incur relatively high abatement costs but have significant reduction potential. There are also options looking to adapt operational procedures to manage and reduce process emissions, these also have significant reduction potential that could be cost-effective at sector level. However, as considered in section 4.3, the success of these operational adjustments is uncertain, as are the cost implications and rely on wide scale process emissions monitoring to inform what the best interventions could be.
- The ongoing UKWIR project to develop a better understanding of the scale of process emissions and mitigation interventions will help the sector reduce the uncertainties associated with carbon reduction potential from process emissions. This is one of the largest areas of uncertainty within the MACC and further guidance will be provided through the UKWIR process emissions project.
- Significant reduction potential from **solar and wind renewable generation** to meet the sector's own power demand. A number of different combinations of these options have been considered, including the difference between installing capacity to meet 20% of the sector's power demand and 40% of power demand, as well as on-balance sheet options or through power purchase agreements (PPAs). These options have been assessed as being cost negative, however, there are significant challenges to fully deploying these options at this scale and get the full benefit by 2030, which are discussed in section 4.3.
- A transition to **biomethane to grid** has substantial potential carbon abatement potential for the sector through significantly increasing renewables export potential and has a relatively low abatement cost. However, these abatement costs are uncertain, given incentive levels and qualifying criteria for the Green Gas Support Scheme have not been finalised. The costs have been based on assuming 70% of biogas production is utilised for biomethane upgrade and this achieves a per kWh incentive at a similar level to the current tier 1 Renewable Heat Incentive (RHI). It also includes for the remaining 30% of biogas being diverted to efficient boilers to provide the heat demand for sludge treatment process and reducing natural gas imports. Estimates of the likely capital investment costs required to deploy this at this scale have been included, see section 4.3.5. This option assumes that the sector would retain green gas certificates and retire these, so that the carbon benefit of the gas is allocated to the sector.
- **Energy efficiency interventions** can provide good value return on investment, however, they have a relatively small impact on the overall sector carbon reduction potential. This reflects the relatively high levels of energy efficiency already undertaken by the sector, as well as the gradually reducing benefit from energy efficiency interventions as the electricity grid decarbonises over time. This also includes for more transformative energy efficiency interventions that utilise catchment level monitoring interventions and digital twinning to unlock energy efficiencies at a system level by better understanding demands on water and wastewater services. The costs and benefits for these more transformational interventions are understandably more uncertain and are considered in section 4.3.4. There are many energy efficiency options that have been identified across the sector, including those through the Energy Saving Opportunities Scheme (ESOS), and the MACC enables comparison of the cost effectiveness of those interventions not already implemented to other emissions mitigation options.
- **Natural sequestration** interventions have limited mitigation potential in the first 10 years of implementation and tree planting incurs a relatively high abatement cost. However, when considered over the longer term their sequestration potential increases significantly (the benefits of increase with the age of the tree and is not substantial until the tree is 15 years old and older) with significantly reduced additional costs (to maintain the benefit). As such although the contribution to the 2030 target is limited, there will be increased carbon sequestration from the trees planted in subsequent years.
- The more **capital-intensive transformative** interventions clearly incur the highest abatement costs over 10 years, this reflects the large upfront investment required to implement these. When considered over the longer term, even when accounting for asset replacement costs, these abatement costs for these options could potentially drop significantly as they continue to abate over a number of years. These interventions include things such as deploying anaerobic treatment processes, or membrane aerated biofilm reactor (MABR) processes to reduce power consumption and process emissions. The widescale adoption of these interventions, is costly, extremely challenging, and unlikely to progress until the end of useful asset lives for the existing treatment assets.

The list of options includes mutual exclusivities (option numbers represent the options which cannot be applied additionally to each other). This primarily applies to the different renewable options which were modelled (e.g. solar meeting between 20% and 40% of total annual electricity consumption where the figures cannot be added, as this would result in solar meeting 60% of total annual electricity consumption).

9. Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal - Data tables 1 to 19: supporting the toolkit and the guidance

The MACC shows the average levelized costs and potential for emissions reduction from decarbonisation options reviewed, ranking these from the cheapest to most expensive to represent the costs of achieving incremental levels of emissions reductions. Each bar on the MACC shows the abatement cost (£/tCO_2e) as an NPV over 10 years and the annualised emissions reduction potential from a specific intervention.

Figure 4-2: Sector-level marginal abatement cost curve (MACC)



Intervention number	Hierarchy category	Intervention	Mutual exclusivities (option numbers represent the options which cannot be applied additionally to each other)	$MtCO_2e$ (annualised based on 10 years costs and benefits)	Cost band of abatement cost (£/tCO_2e) based on 10 year NPV and 10 year abatement potential
2	Water - Grid electricity	Water reducing power demand – 02 (replacing ageing equipment with modern equivalents)		0.00	<-500
3	Water - Grid electricity	Water reducing power demand – 03 (catchment management) Catchment approaches to reduce treatment power demand		0.003	<-500
36	Renewables generated for own demand	Wind – 40% total annual electricity consumption – on balance sheet	33,34,35	0.48	<-500
22	Admin	Admin – energy management		0.00	<-500
35	Renewables generated for own demand	Wind – 20% of total annual electricity consumption – on balance sheet	33,34,36	0.24	-100 to -500
31	Renewables generated for own demand	Solar – 20% of total annual electricity consumption – on balance sheet	29,30,32	0.24	-100 to -500
1	Water – grid electricity	Water reducing power demand – 01 (typical interventions)		0.02	-100 to -500
26	Transport	Transport – efficiency (journey reduction)		0.04	-100 to -500
29	Renewables generated for own demand	Solar – 20% of total annual electricity consumption – PPA		0.24	-100 to -500
27	Transport	Transport – efficiency		0.01	-100 to -500
33	Renewables generated for own demand	Wind – to meet 20% of sector total annual electricity consumption – PPA	34,35,36	0.24	-100 to -500
23	Admin	Admin - energy efficiency, alternative technology		0.00	-100 to -500
37	Renewables generated for own demand	Hydropower – dam head and run of river (mostly Archimedes' screw) – 5% total annual electricity consumption – PPA	38	0.06	-100 to -500
38	Renewables generated for own demand	Hydropower – dam head and run of river (mostly Archimedes' screw) – total annual electricity consumption – on balance sheet	37	0.06	-100 to -500
30	Renewables generated for own demand	Solar – to meet 40% of sector total annual electricity consumption	29,31,32	0.48	-100 to -500
34	Renewables generated for own demand	Wind – to meet 40% of sector total annual electricity consumption	33,35,36	0.48	-100 to -500
5	Wastewater – grid electricity	Wastewater reducing power demand – 01 (typical interventions)		0.03	-100 to -500
32	Renewables generated for own demand	Solar – to meet 40% of sector total annual electricity consumption – on balance sheet	29,30,31	0.5	10 to -100
9	Wastewater – grid electricity	Wastewater reducing power demand – 04 (site reorganisation to increase onsite combined heat and power (CHP) use) Site electrical rearrangement to allow additional CHP power to be used on site rather an exported		0.001	10 to -100
28	Transport	Transport – alternative technologies, biofuels, hydrogen and electric vehicles (EVs)		0.20	10 to -100
13	Reduce – alternative approaches	Minimising fugitive emissions Operational optimisations of current technology to minimise methane emissions from short-term storage of sludge, sludge transport, etc		0.01	10 to -100
17	Avoided emissions – alternative approaches	Water labelling EST Scenario 2: Mandatory Government-led labelling associated with Building Regulations and minimum standards. This includes minimum water efficiency standards for new buildings.		0.04	10 to -100
14	Reduce – alternative approaches	Operational optimisations of current technology to minimise N2O emissions from secondary treatment		0.10	10 to -100
42	Exporting renewables	Transition to biomethane production – injection to grid and other use.		0.43	>10
25	Reduce – renewables	Admin – onsite generation		0.00	>10
24	Reduce – alternative approaches	Admin – fossil fuel alternatives		0.01	>10
40	Insets/offsets	Peatland restoration (land) – within company territory		0.0	>10
20	Reduce – fuels onsite	Alternative to fossil fuels – wastewater (gas oil replaced by HVO)		0.0	>100
19	Reduce - fuels onsite	Alternative to fossil fuels – water (gas oil replaced by HVO)		0.02	>100
6	Reduce – alternative approaches	Wastewater reducing power demand – 02 (smart control/catchment level analytics)		0.05	>100
41	Insets/offsets	Grassland restoration (land) – within company territory		0.004	>100
4	Reduce – alternative approaches	Water reducing power demand – 04 (smart control/catchment level analytics)		0.06	>100
12	Reduce – alternative approaches	Conventionally digested sludge is upgraded to advanced digestion (THP)		0.20	>100
8	Reduce – energy efficiency	Wastewater reducing power demand – 03 (next-generation efficient products) High efficiency blowers and small pumps		0.01	>100
15	Reduce – alternative approaches	Alternative treatment processes – anaerobic treatment/MABR/alternative ammonia removal processes		0.14	>1,000
	Insets/offsets	Companies meet commitment to plant 11 million trees by 2030		0.05	>1,000
18	Avoided emissions – alternative approaches	Accelerated leakage reduction – million litres/day leakage reductions beyond current commitments		0.07	>1,000
16	Reduce – alternative approaches	Covering tanks, and capturing and treating emissions		0.15	>1,000

4.3 Sector pathways

To identify and test potential routes for the sector to reach net zero by 2030, pathway analysis has been used to consider three possible scenarios. Each of these scenarios reflects an alternative future where in which emphasis is placed on particular interventions or clusters of interventions. This approach provides strategic direction to the whole sector and illustrates how individual companies with particular opportunities might transition within a net zero water industry. Each pathway also quantifies the likely residual emissions that the sector would need to offset to reach net zero.

It is important to note that the scale of the net zero challenge is such that the water sector cannot do this on its own and a collaborative approach is required with the supply chain, government and regulators. Each pathway considers a number of actions under the control of the sector that would need to be taken as well as enablers required to be implemented by stakeholders external to the sector such as supply chain, regulators and government. These enablers are summarised in a table under each pathway to net zero.

It is recognised that the possible pathways to net zero involve decarbonisation options that can be outside the current price control funding cycle. During the development of the Routemap, the sector has had significant engagement with different stakeholders to better understand available decarbonisation funding mechanisms that the sector may be able to access in the short and long-term through further engagement with bodies such as the Department for Business, Energy and Industrial Strategy (BEIS), Defra, Ofwat.

Funding mechanisms and options could include:

- Access to Ofwat innovation fund where customer support is demonstrated.
- BEIS Industrial Sector Energy Efficiency Fund.
- Government's Woodland Carbon Guarantee (£50 million) and Government grants for peatland restoration.
- Defra forestry fund.
- Other central government funding could be made available for major projects that meet yet to be defined criteria for decarbonisation of the UK (e.g. £/tCO_2e abatement cost, scale of potential reductions).
- Access to green finance and appropriate commercial arrangements may be agreed that can fund much of this investment through private sources.

The three main pathways developed are defined as:

- **Demand led** – where water efficiency, leakage management, and energy self-sufficiency are prioritised.
- **Technology led** – where significant technology developments and investments take a bigger role.
- **Removals led** - where offsets through natural sequestration and nature-based solutions are prioritised.

A final **'combined'** pathway is also considered in section 4.5.1. This is not to be considered the 'best' or 'correct' pathway for the sector, but a demonstration of how different elements of approaches from the three different pathways could be brought together to give a more balanced view of implementation costs and carbon reductions for the sector as a whole. The combined pathway will also help the sector guide discussions and collaborative effort with the supply chain, regulators and other stakeholders.

Each pathway to net zero has been developed by:

- Providing a definition reflecting a plausible specific scenario.
- Selecting a number of decarbonisation interventions applicable to each.
- Assigning a maximum carbon reduction potential for the sector for each decarbonisation intervention.
- Assigning a deployment rate for each decarbonisation intervention for the sector by PR24 and 2030 (for some clusters, a post-2030 picture is shown).
- Developing a number of assumptions for enablers and actions for the sector and other stakeholders to implement all identified decarbonisation interventions.

4.3.1 Definitions

Table 4-1: Summary of pathway descriptions and main areas of focus

Pathway	Overall pathway description	Key focus for decarbonisation	Hierarchy focus areas (Figure 4-2)
Demand led	This pathway will assume that all possible energy efficiency and demand/per capita consumption (PCC) reduction potential is applied. Technologies for reducing emissions, renewables and then offset of emissions are applied at lower scale. Social influences for sustainable consumption will be key. Regulators assumed to be fully engaged and well prepared to understand trade-offs before PR24 – no increases in emissions due to regulatory influences in PR24.	Pathway focuses on managing demand for water and wastewater services by accelerating and going beyond existing 2030 commitments (e.g. leakage, PCC).	Reduce and renewables
Technology led	This pathway will assume that technological innovations are accelerated (costs rapidly reduced and policies in place) for investing more rapidly in renewables, sustainable transport systems and process technologies for capturing and managing more rapidly process emissions (pre and post 2030). This pathway will consider further acceleration from government via financial stimulus to accelerate and create new supply chains. In this option Ofwat is assumed to be proactively supporting the sector by supporting investment in decarbonisation technologies. The sector is also expected to take advantage of other government funding not passed through to customers.	Pathway focuses on accelerating technological innovations targeted at decarbonising largest emissions contribution areas.	Reduce and renewables
Removals led	This pathway will assume that there has been very slow progress in adopting additional reduction and renewables, in combination with increasing regulatory quality standards for the sector. Natural sequestration solutions (insets, offsets and purchased offsets) play a big part. This is very likely to result in higher cost post 2030.	Pathway focuses on accelerating activities which improve the natural sequestration capacity of the sector, within the companies own land and the wider UK territory.	Offset

4.3.2 Electricity procurement and accounting

Under all pathways the sector still utilises electrical energy supplied through the grid. This is the electrical energy demand not covered by "behind the meter" generation. This amount of grid delivered electrical energy is least in the technology pathway.

In each pathway, it is assumed that all grid delivered electrical energy purchased is zero emission, in line with the accounting method described below.

4.3.2.1 Green electricity accounting

The sector will quantify its emissions from grid supplied electricity in line with the Greenhouse Gas Protocol Scope 2 Guidance as interpreted by the UK Government. The accounting method will be updated in accordance with any revisions of the guidance.

Within the Guidance there are two distinct reporting methods for Scope 2 emissions, namely location-based and market-based methods.

A location-based method reflects the average emissions intensity of grids on which energy consumption occurs (using the grid-average emission factor).

A market-based method reflects emissions from an electricity supply that includes contractual instruments detailing specific generation source(s). The guidance establishes the Scope 2 Quality Criteria that these contractual instruments must meet. In the EU system, the Fuel Mix Disclosure regulations require all suppliers to disclose the emissions associated with the power that they supply. To do so, U.K. suppliers present Renewable Energy Guarantees of Origin (REGOs) and Generator Declarations to the industry regulator. The regulator is then able to calculate a 'residual' energy mix with an associated emissions factor for those supplies without an associated certificate. Suppliers are then able to issue a specific emissions factor for the energy supply to each customer.

The net zero commitment is to be measured using market-based reporting.

The sector will continue to report Scope 2 emissions using dual reporting (providing both location-based and market-based emissions in annual reports). Dual reporting is necessary to meet the Greenhouse Gas Protocol Scope 2 Guidance and the Companies (Directors' Report) and Limited Liability Partnerships (Energy and Carbon Report) Regulations 2018.

In practical terms, for market-based reporting, the rules associated with green electricity are as below. Companies should refer to the GHG Protocol Scope 2 Guidance for further detail.

- Where electricity imported through the grid includes a market-based emissions factor which meets the Greenhouse Gas Protocol Scope 2 Quality Criteria, the market-based emissions factor can be used. Where it does not meet such criteria the grid-average emission factor should be used.
- The market-based emissions factor can also be used for the Transmission & Distribution losses provided that the electricity supply covers the full amount of energy consumed including these losses and the supply satisfies the Quality Criteria.
- In the UK, Renewable Energy Guarantees of Origin (REGO) certificates can be used to satisfy the Quality Criteria provided that:
  - the REGOs are retired on behalf of the reporting company;
  - the REGOs are sourced in the same market as the reporting company's energy consuming operations;
  - the REGOs are the only instruments that carry the GHG emission rate attribute claim associated with that unit of electricity generation; and
  - the REGOs are issued for the same period as the accounting period.
- Where electricity generated at a REGO accredited installation is exported through the grid and the REGOs are retired by the generating company the export can be netted off gross emissions at the UK average grid emission factor.
- If the generating company retires the REGO for self-generated electricity and consumes the power, no emissions are incurred.
- If the generating company sells the REGO for self-generated electricity and consumes the power, a Scope 2 emission is reported at the UK average grid emission factor.

It is a decision for each water company as to whether they sell the REGO with the power.

4.3.2.2 Green gas accounting

Like electricity, gas may be transmitted and distributed through the transmission and distribution networks. The emissions released from gas consumption become the scope 1 emissions of the owner/operator of the equipment.

Historically, most of the gas consumed has been natural gas with a standard emission factor, but the water sector is leading on the production of biogas and biomethane from waste.

The Greenhouse Gas Protocol Scope 2 Guidance indicates that if a company has a contractual instrument specifying that its gas supply has a specific GHG emission rate associated with it, the company may report using the market-based method. The company should utilise the Scope 2 Quality Criteria to evaluate whether its gas use should be reported as scope 1 natural gas using a standard emission factor or using a specific emission factor with emissions reported separately from the scopes.

This evaluation requires some interpretation, since the Scope 2 Quality Criteria are specific to electricity and their guidance must be translated further for use with gas. This is an area for further work by the sector and other stakeholders.

4.3.2.3 Green electricity considerations

Reducing the sector's reliance upon grid electricity has benefits in addition to emissions reductions, such as increased resilience and cost savings.

Many in the sector already use a wide variety of commercial and physical power supply models to provide resilience and affordability. These include self-generation, private-wire, corporate Power Purchase Agreements and grid supply.

Although REGO backed green electricity purchased from a supplier has the same credentials as self-generated renewable electricity there are considerations associated with it:

- Purchasing green energy does not necessarily ensure deployment of additional renewable generation. However, long term PPAs may support new investment in generation assets by removing merchant risk.
- As more companies seek to attain net zero, more companies will be pursuing the green energy procurement route. As such there may be more competition for the available green tariffs and additional renewable capacity will be required to be brought online.
- There is a potential risk that REGO accounting changes to consider the timing of generation and demand, however as price volatility associated with renewables increasingly impacts wholesale markets the sector will need to maximise its flexibility for cost reasons as well as emissions.

4.3.3 Modelling of renewable electricity

The pathways include a range of renewable energy interventions with different technologies (solar, wind and hydro) being used to meet a proportion of the total annual sector electricity demand. The level of potential supply has been derived from the knowledge of our technical experts, including experience of water sector projects, and consultation with the water companies. A maximum of 80% of total annual electricity consumption in 2030 being met by these renewable generation interventions has been modelled in one of the pathways. The technical rationale for this is explained below. It should be noted that the modelled level of renewable supply applies at sector level, and some companies will not be able to achieve this, whereas other companies may be able to achieve a higher percentage. There are several market changes which are expected to occur during the timeframe of the routemap to assist with the deployment of renewables such as increased government / policy support as part of the UK net zero target and potentially higher grid electricity prices that may incentivise such shift to self-generation.

All scenarios have accounted for grid decarbonisation and as such renewable electricity options have reducing carbon benefits over time. However, they maintain the benefits of security/ resilience of supply and cost reduction.

For each renewable installation the individual water companies will complete a detailed feasibility study to establish the energy, cost and emissions benefits. It has been assumed that:

- Solar generation requires $14m^2$ of land or water per kW of PV (in line with a typical ground mounted solar farm).
- Solar PV typically operate with a capacity factor of <12% - they do not continually produce the rated capacity due to variations in light conditions during a day and over a year. Installing a 1MW solar array at a site with 1MW of consistent demand would rarely cause any export.
- This same site with 1MW of demand, but with a solar array larger than 1MW of solar installed would be able to supply more energy to the site over the year, but in the middle of the day on clear summer days supply may exceed demand. As an indicative example, for a 4MW array installed on a 1MW demand site, most of the energy generated (up to 80%) is still utilised by the site. The remaining 20% would be exported or be available to sleeve to another site. Such a site would self-supply 40% of the onsite demands. Sites can therefore be usefully sized to maximise onsite supply rather than avoid export.

- 125m² of land is required per kW for wind (based on a separation distance of 7 rotor diameters between towers, for a 90m rotor and a 2.5MW turbine)
- Wind turbines usually operate with a capacity factor of 25-35% depending on turbine and location. A site with a year-round 1MW of demand and 1MW of wind installed would also not see any export. In this case wind meets 25-35% of site demand (more in the winter than in the summer, only slightly more in the day but continues to generate at night), but there are some hours in the year where wind does not generate at all.
- This same site with a year-round 1MW of demand could increase installed capacity of wind significantly, and increase supply to site, but more would be available to export or sleeve.

Sites across a portfolio could have just wind, or just solar as above. Solar and wind generate at different times. Some sites with lots of space could have both wind and solar. In which case they could meet almost all power from onsite and could also make power available to export.

The net effect across a portfolio of sites is that up to 40% of power could be supplied from solar and up to 40% from wind.

The renewable power used onsite has the highest financial value as it displaces grid delivered power which usually costs 10-14p/kWh. Exported renewable power is typically sold at wholesale rates with small additional non-commodity payments so is of lower value. There are advanced commercial models, including sleeving of export and the use of unlicensed energy suppliers which may improve the business case for renewable generators in specific circumstances.

Development of a new renewable generation asset at, or near to a water company site with private wire supply to the site, is the most robust as there is demonstrable additionality and the power can be accounted for on a half hourly basis (noting that some renewable energy products supplied over the grid also have half hourly accounting).

A target of 40% solar and 40% wind (near 80% in total) of current power demands from renewables could take up to around 10% of the land (and surface water) holdings of the water companies. This is presented in the technology pathway. This is based on an informed estimate of UK water company holdings, derived from public sources[10] for England and Wales only. Scottish Water is owned by the Scottish Government, and the Government has access to much larger land portfolio through the agency Forestry and Land Scotland. Individual water companies will need to balance land use needs e.g. biodiversity, low impact solutions and renewables.

There are multiple third-party finance options for renewables and there are further opportunities to develop generation on land proximate to the water company sites. Utilising this third-party land can increase renewable capacity and improve project economics. Notably, schemes which include community ownership or partnership gain more support in planning and bring wider benefits to the water company which is seen to be progressive on a low carbon agenda. In addition, community companies are an opportunity to communicate with the community on water efficiency and other environmental issues.

A strategy for planning applications is needed. There is a presumption in favour of Sustainable Development in planning. Sustainable Development means development with an economic, social and environmental benefit. If power is renewable it has environmental benefits. If it is supplied on site (with the balance sleeved to another company site) there is an economic benefit. The water industry is recommended to develop a community energy strategy where there is a social benefit, because ownership and profits stay in the community that sees the impact. The planning system has recently changed for wind, to make sure communities have a particularly important role and community support for wind is critical. Therefore, a sector wide community energy plan could be particularly important in delivering new wind generation and thus meeting the net zero target.

In order to deliver the 80% renewables as in the technology led pathway, the following elements should be considered:

- Business planning should be done for portfolios of sites rather than for single sites – this increases the likelihood of decarbonising sites of varying sizes and for deploying the most appropriate generator type(s).
- The plan should allow for sizing schemes to export or sleeve energy, which may require investment in grid capacity.
- A business plan should consider evolving technologies including power storage and EV's to optimise the use of power onsite.
- Agreement of finance frameworks for off balance sheet projects from BEIS and Ofwat.

10. see https://whoownsengland.org/2016/08/29/liquid-assets-land-owned-by-the-water-utilities/

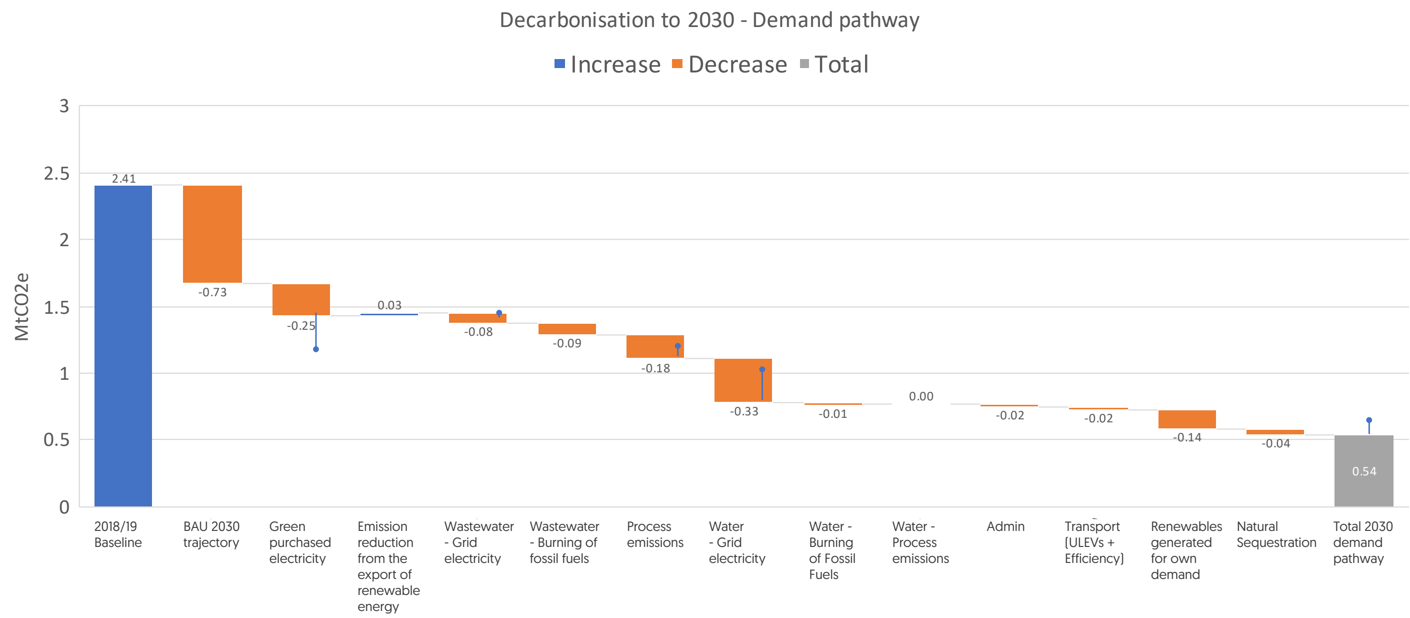
4.3.4 Demand-led pathway

The demand-led pathway focuses on managing demand for water and wastewater services, as well as maximising the efficiency of existing assets and technologies to minimise grid power and fossil fuel demand. Overall, the aim of this pathway is to demonstrate the impact of demand management and energy efficiency interventions on overall sector level emissions.

The demand-led pathway includes over 30 decarbonisation options that come together to deliver the reductions seen in Figure 4-5. The interventions which contribute the most reductions are summarised below:

- **Mandatory water labelling to reduce per capita consumption** (PCC): Government-led mandatory water labelling scheme covering building regulations, including standards for water efficiency for new builds. This is estimated to potentially reduce PCC by a further 6 litres/head/day and saving an additional 160,000 million litres over 10 years (-0.169MtCO_2e, equivalent to 7% of 2018-19 total sector emissions).
- **Deployment of renewables** (solar, wind and hydro): 40% of total annual electricity consumption met by a combination of solar and wind renewables generation (-0.148MtCO_2e, equivalent to 6% of 2018-19 total sector emissions).
- **Maximising self-sufficiency of power and heat generation**: Reducing natural gas imports and using biogas in combined heat and power (CHP) plant and boilers to reduce grid and fossil fuel imports (-0.080MtCO_2e, equivalent to 3% of 2018-19 total sector emissions).
- **Increasing monitoring and modelling of process emissions to inform operational adjustments to reduce these**: Optimising existing process operation to minimise NOx process emissions from secondary wastewater treatment processes (-0.078MtCO_2e, equivalent to 3% of 2018-19 total sector emissions).
- **Upgrade to advanced anaerobic digestion** (AAD): Upgrading 35% of conventionally digested sludge to advanced digested processes, reducing process emissions as well as increasing biogas to help meet power and heat demand on own sites (-0.071MtCO_2e, equivalent to 3% of 2018-19 total sector emissions).
- **Maximising self-sufficiency of power and heat generation**: Reducing natural gas imports and using biogas in CHP plant and boilers to reduce grid and fossil fuel imports (-0.080MtCO_2e, equivalent to 3% of 2018-19 total sector emissions).

Figure 4-5: Summary of demand pathway and level of reduction for each decarbonisation option cluster



The demand-led pathway reduces emissions to 0.54MtCO$_2$e per year, this is 1.14MtCO$_2$e less than the 2030 BAU trajectory (exc. green electricity purchase). To achieve net zero, the remaining 0.54MtCO$_2$e will need to be covered by identifying further options to reduce/net-off emissions, accelerating further options covered in other pathways or through offsets.

The demand pathway delivers a 77% reduction against the sector's baseline leaving some remaining emissions in 2030 to be mitigated through purchased offsets, or the inclusion of interventions from other pathways.

The demand pathway also significantly supports decarbonisation outside of the current water company boundary. The reductions in water demand driven in this pathway deliver up to 3.5 times[11] more carbon reduction benefits through a reduction household water heating demand than reduction driven through reduced water supply.

Because this pathway does not reduce gross power consumption or generate as much renewable power as the technology pathway it relies more significantly on green tariff purchases.

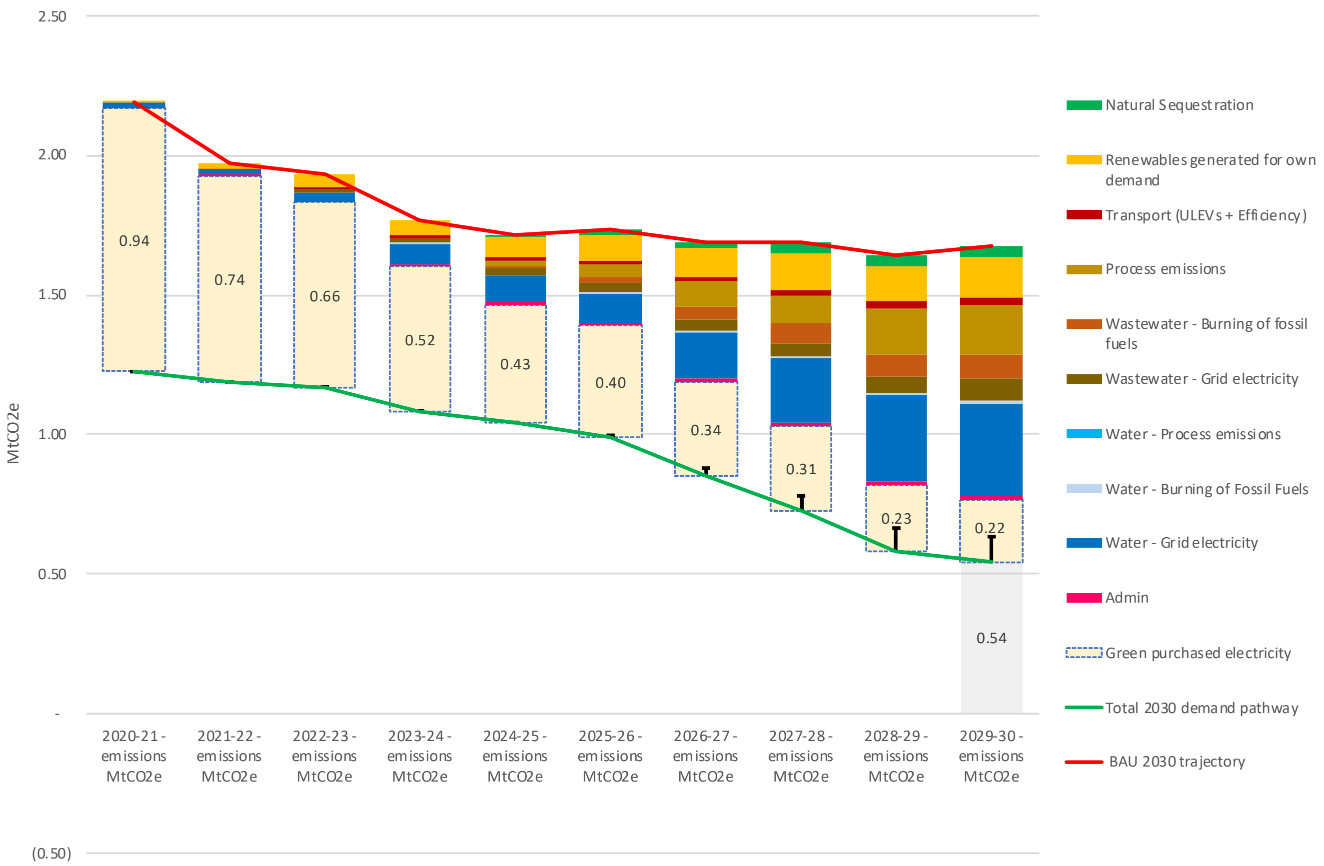
Figure 4-5 also shows error bars to reflect inherent uncertainties on the maximum reduction potential at sector level for each decarbonisation intervention. These are further discussed in this section.

The full list of options within the demand-led pathway are summarised in Appendix A, including the carbon reductions they achieve compared to the 2030 BAU trajectory.

Figure 4-6 shows the progress of decarbonisation within each of the emissions areas compared to the BAU trajectory up to 2030. Each bar represents an emissions area and how much it has been decarbonised from the decarbonisation interventions targeted at that cluster. The error bars (black vertical lines on pathway trajectory) on the green demand pathway line represent the uncertainty in the level of residual emission remaining for the pathway after all options are applied (see section 4.3.4.3).

The implementation of the demand-led pathway will require significant investment in accelerated demand management interventions, reducing wastewater and sludge treatment process emissions and the introduction of a mandatory water labelling scheme.

Figure 4-6: Timeline graph showing deployment of decarbonisation actions for demand pathway



11. Independent review of the costs and benefits of water labelling options in the UK, 2018 (link)

Table 4-2: Summary of main net zero interventions required in the demand pathway and enabling actions that would be required pre and post PR24 to meet the pathway

Net zero intervention	Pre-PR24	Pre-PR29 actions
Mandatory water labelling to reduce PCC	**Sector would need to:** • Demonstrate it is delivering on its own PR19 commitments on PCC and leakage reductions and driving innovation in this area to deliver the most ambitious reductions in PCC and leakage in AMP7 the sector has ever delivered (2023 and through APRs) • Engage with BEIS, suppliers (white goods manufacturers/ developers) and customers on the benefits of water labelling and how it supports the actions they are already taking to reduce PCC (2021) • Analyse the broader benefits of the significant PCC reduction this type of scheme is forecast to achieve on other areas (e.g. lower pressure in network resulting in reduced bursts, avoided costs of new supply schemes and associated energy consumption emissions) (2021-22) • Engage with BEIS and suppliers to develop a plan on how the scheme could be implemented and where investment could be shared between different stakeholders (2021) **Government and other relevant stakeholders would need to:** • Assess evidence[12,13] on the impacts of similar schemes globally and see if a similar UK scheme would align with the countries water resources needs and 2050 climate change commitments (2021) • Work with the sector, Ofwat and manufacturers to develop a scheme that splits costs equitably and does not disproportionately affect vulnerable customers through increased costs (2022) • Implement scheme by 2022 or 2023 Supply chain would need to be ready to respond with more water efficient products. Developers and contractors would need to be ready with capability to deliver water efficient homes, incorporating infrastructure such as rain and grey water recycling to significantly reduce wholesome water demand.	**Sector would need to:** • Continue to drive ambitious PCC and leakage reductions through AMP*, demonstrating innovation and ambition to be as efficient with its water resources as possible. • Engage and support customers to drive water efficiency through innovative means, utilising technology advancements and wider metering coverage. **Government and other relevant stakeholders would need to:** • Review progress of scheme and engage sector, white goods manufacturers and customers to assess impact and areas for improvement. • Continue to engage sector and customers to develop more progressive policies that help achieve water security and climate change commitments Suppliers demonstrate continued innovation to deliver more efficient products and homes
Deployment of renewables (solar, wind, hydro) at scale **By the end of AMP7 the technology pathway assumes that an additional 0.5GW of capacity solar and 0.1GW of wind is installed by 2024-25. This grows to 0.8GW of solar capacity and 0.3GW of wind capacity by 2030. This ambition will require significant effort from the companies, support from the supply chain and government.**	**Sector would need to:** • Identify and map suitable areas to expand on existing solar and wind generation (2022) • Engage the supply chain to test and develop suitable commercial arrangements that can be used to deploy these technologies at scale (2022) • Identify and explore appropriate financial frameworks for off balance sheet deployment of large scale solar and wind (2022) • Communicate ambition to meet majority of own demand through self-generated renewables to generate interest and engagement with supply chain (2021) Companies will need to actively identify barriers to implementation and engage National Grid and its supply chains to proactively remove these barriers. (2023) **Government and other relevant stakeholders would need to:** • Collaborate to develop appropriate accounting protocols, including for sleeved power, to allow companies to claim appropriate carbon benefits for offsite generation directly connected to sites (2023) • Develop clear planning policies that support development of community renewable schemes used to power critical infrastructure (2024) • BEIS and Ofwat need to agree finance frameworks for off balance sheet projects to help fund widescale renewables deployment (2023-24) • Provide supportive planning permission policy for renewables and DNO connections and potentially seek to support grid capacity improvements (2024) It is also worth noting future increases in purchased electricity costs and other policy instruments may incentivise further renewable self-generation.	**Sector would need to:** • Continue to review balance between land for renewable generation and land use changes which can help lower intensity of treatment required (2026) • Continue to engage the supply chain to review and revise commercial arrangements to help further deploy these technologies at scale (2027) • Communicate review and communicate ambition to meet majority of own demand through renewables to generate interest and engagement with supply chain Companies will need to actively identify barriers to implementation and engage National Grid and its supply chains to proactively remove these barriers. **Government and other relevant stakeholders would need to:** Review accounting protocols, including for sleeved power, to allow companies to claim appropriate carbon benefits for offsite generation directly connected to sites

12. Independent review of the costs and benefits of water labelling options in the UK, Energy Saving Trust, 2019
13. Independent review of the costs and benefits of water labelling options in the UK EXTENSION PROJECT Technical Report – FINAL, 2019

Net zero intervention	Pre-PR24	Pre-PR29 actions
Upgrade to AAD **While there has been a significant move towards advanced digestion processes in the last 10 years, a significant proportion of sludge is still treated through conventional anaerobic digestion (CAD) processes. Upgrading these CAD plants and the downstream infrastructure can have significant process emissions savings and an increase in biogas production. The demand pathway accounts for 35% of sludge currently being treated through CAD moving to advanced treatment processes including a mix of centralisation and upgrades of plants**	**Sector would need to:** • Identify optimal CAD sites for potential upgrade (2023) • Review opportunities to move more sludge through existing AAD plants (2023) • Engage with the market to identify and market-based opportunities for funding upgrades • Engage with BEIS and CCC on potential funding to reduce process emissions from industrial sector **Government and other relevant stakeholders would need to:** • Encourage Ofwat and water companies to agree how AAD upgrades to reduce process emissions will be funded (e.g. through price control, other government funding or markets). • Set up policies and funding mechanisms targeted at supporting difficult to reduce process emissions from the industrial sector to help achieve national 2050 net zero climate commitment	**Sector would need to have:** • Agreed funding sources of upgrades covering up to 35% of conventional digestion capacity • Engaged supply chain to deliver site upgrades before 2029-30 • Identified and agreed commercial contracts for any biomethane supply not through the grid network **Government and other relevant stakeholders will need to:** Encourage Ofwat and water companies to agree how AAD upgrades to reduce process emissions will be funded (e.g. through price control, other government funding or markets).
Moving from measuring to managing process emissions **The demand pathway accounts for widescale monitoring of process emissions being in place at all large wastewater treatment works by 2023. This upfront investment in monitoring is essential to improve understanding of process emissions pathways and identifying the most efficient interventions to mitigate these.**	**Sector would need to:** • Identify major sites and required monitoring (e.g. primary and secondary treatment, sludge tanks, sludge holding areas, sludge thickening areas and sludge treatment). • Engage supply chain to identify most appropriate process emissions monitoring methods and associated scale of costs • Engage as a sector with CCC and BEIS to put forward a proposal for sector level investment in process emissions monitoring investment, highlighting the potential reduction opportunity this unlocks through better understanding process emissions pathways. • Implement process emissions monitoring at all large WwTWs by 2022-23. • Use monitoring data produced from monitoring to identify suitable operational and capital interventions and use this to inform investment needs in PR24 business plan **Government and other relevant stakeholders will need to:** • Set up schemes and policies targeted at supporting difficult to reduce process emissions from the industrial sector to help achieve national 2050 net zero climate commitment • Set out requirements for funding for companies and sectors that enables reduction of these emissions	**Sector would need to:** Continue and expand Pre-PR24 actions **Government and other relevant stakeholders will need to:** Set up schemes and policies targeted at supporting remaining difficult to reduce process emissions from the industrial sector to help achieve national 2050 net zero climate commitment.
Maximising self-sufficiency of power and heat generation **The technology pathway accounts for the sector:** **a. Diverting 5% of biogas to efficient boilers to provide heat demand for treatment on top of recycled CHP heat** **b. Choosing to phase out power generation through natural gas CHP in favour of non-fossil fuel renewables sources**	**Sector would need to:** • Continue to improve efficiency of CHP heat recycled to sludge treatment processes • Identify sites where natural gas is being used to supplement treatment process heat demand and plan how biogas can be used to replace this demand • Make a choice to phase out natural gas CHP, even if initially grid power costs are higher. **Government and other relevant stakeholders will need to:** • Consider control measures on natural gas CHP generation to dis-incentivise this approach as the grid starts to decarbonise • Incentivise sectors to adopt alternative renewable sources of power and heat.	**Sector would need to:** • Make a choice whether to phase out natural gas CHP, even if initially grid power costs are higher with early retirement of existing CHP fleet • Continue to maintain and maximise CHP efficiency and optimising site layouts to utilise as much power and heat generated on site. **Government and other relevant stakeholders will need to :** Continue to develop and promote policies that align with a net zero future as different sectors decarbonise.

4.3.4.1 Key areas of uncertainty

The development of the demand-led pathway has considered a range of carbon reduction potential figures for the sector, for the different decarbonisation interventions. There are some inherent uncertainties associated with these ranges and how much reduction they will actually achieve at sector level. These uncertainties are illustrated by the error bars (shown as blue vertical lines) in Figure 4-5.

Carbon reduction potential associated with mandatory water labelling

The most significant area of uncertainty in this pathway lies within the carbon reduction potential associated with the water demand reductions associated with the mandatory water labelling scheme. Specifically, the 1.052gCO_2e[14] per litre carbon saving taken from Defra's annual emissions factors data releases. This factor has been used in a number of external studies to calculate the emissions savings within the water sector boundary from demand reduction interventions. However, it is from 2012. Therefore, there is a potential that this number is an overestimate given the expected efficiency gains since 2012 and the further decarbonisation to happen up to 2030. Estimates based on analysis of the latest 2018-19 data from company CAWs suggests that this value could have fallen to as low as 0.3gCO_2e/litre (~70% reduction) due to the considerable level of decarbonisation within the sector since 2012. Accounting for this reduced level of embodied carbon per unit of water saved would reduce the abatement achieved by the demand pathway by 0.14MtCO_2e by 2030. The other major uncertainty is the time taken for a scheme of this type to deliver water efficiency, and associated carbon savings.

Control over PCC reduction

Whilst water companies are able to influence PCC reduction, it is not all within their direct control. A mandatory water labelling scheme would support this aim and make it more likely to help influence further PCC reduction beyond current commitments. However, PCC can also be influenced by short and medium term unforeseen events, which are outside the control of the sector. For example, the ongoing impacts of the Covid-19 pandemic on water consumption are yet to be fully understood and how long these impacts will last are also uncertain. The modelling is based on an illustrative view of possible PCC reductions, and associated carbon benefits, in a scenario where policy and customer behaviours align favourably to make such reductions possible. Actual PCC reduction levels driven by ongoing interventions along with the mandatory water labelling scheme still remain uncertain.

Reducing process emissions

Additional uncertainty lies within the sector's ability to reduce process emissions from wastewater treatment processes and sludge treatment. The estimated uncertainty is 0.1MtCO_2e (~30% of the process emissions cluster in 2030), potentially more than doubling the level of residual emissions from the technology pathway. The uncertainty is relevant to:

- As highlighted in section 3.2, there is still uncertainty around the scale of process emissions from the sector. There are two issues that the sector is looking to resolve. Firstly, an update to the CAW methodology, which has been estimated to increase Scope 1 emissions by 0.2MtCO2e/y. The impact of this potential change is estimated to increase baseline process emissions by ~30% and the residual level of process emissions in 2029-30 by ~25%.
- Additionally, there is the ongoing uncertainty around the true level of emissions arising from wastewater treatment processes in the UK. There is ongoing work by the sector, through UKWIR, to improve the understanding of such emissions and reduce this uncertainty. The pathway reflects widescale monitoring of process emissions to be implemented at all large WwTWs by 2022-23 to support decision making and business plan development for PR24.
- Identifying feasible options to reduce process emissions, initially through operational adjustments to existing processes and then through gradual deployment of alternative treatment technologies. The technology pathway in its current state assumes that nitrous oxide (NOx) emissions could be reduced by 50%[15] from current estimates through adjusting operational processes, however, this remains to be a significant source of uncertainty. The sector will need significant support from the supply chain in understanding suitable operational adjustments while maintaining process performance and resilience to meet this challenge.

Energy efficiency interventions

Other less significant uncertainties relate to the carbon reduction potential achieved by energy efficiency interventions, including the more transformative smart monitoring interventions at catchment level (such as using digital enablers to predict and target infiltration or optimising pumping at large-scale catchment level through real time control). The relative contribution of existing energy efficiency interventions is relatively small as the sector has already targeted significant energy efficiency in the last 10 years. This means that the impact of the uncertainty around carbon reduction potential from energy efficiency interventions is relatively low.

14. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
15. Mitigating nitrous oxide emissions at a full-scale wastewater treatment plant [link]

4.3.4.2 Cost of implementing the demand-led pathway

This section provides indicative NPVs and upfront capital investment costs derived from top down industry figures and calibrated as much as possible from individual water company cost data, where provided. The NPV costs and capital investments are presented in indicative ranges to help the sector understand the order of magnitude of such costs when comparing the different pathways. There is a significant level of uncertainty in the development of sector level costs for the purposes of the routemap.

The costs only include the impacts on the water sector and not wider environmental and social impacts of each of the decarbonisation options. The NPVs and capital investment ranges should only be used as a guide by the sector and other stakeholders to identify major investment areas in each pathway. The sector, external stakeholders and individual companies will need to develop more robust costs, based on specific costs relevant to themselves. The costs in this report should not be used to make individual investment decisions.

The 10-year NPV estimates for the demand-led pathway range from -£250 million to -£650 million over 10 years. These were calculated based on the marginal abatement costs produced for each option (see section 4.2.1) and multiplied by the total tCO_2e abated by each option within the pathway. They are presented in Table 4-3 below.

Table 4-3: Summary of major decarbonisation intervention NPVs and key uncertainties

Decarbonisation intervention	10-year indicative NPV	Key cost uncertainties
Mandatory water labelling to reduce PCC	n/a	An NPV for this scheme has not been calculated as the costs of the scheme are not assumed to be incurred by the sector. The EST independent review[16] of implementation of the scheme was estimated at £60 million, with appliance manufacturers bearing the vast majority (£55 million) of these costs.
Accelerated leakage reduction to 7% greater than existing 2030 forecasts	-£300 million to £600 million	There is significant uncertainty to how this additional accelerated level of leakage above and beyond current commitments would be achieved. The NPV assumes that this additional leakage reduction would likely rely on targeted mains replacement beyond what is in company plans and therefore incur a higher unit cost than current mains replacement allowances. These are based on current estimates of a range of mains replacement costs. These have not allowed for future innovations that may reduce these costs significantly, or for alternative ways to achieve this additional leakage other than mains replacement. Key factors to consider are: Current levels of leakage, those companies with already low levels of leakage are likely to incur higher costs. Research has shown certain low levels of leakage, mains replacement may increase leakage. Therefore, it is important mains replacement is targeted to areas with greatest impact. Mains replacements costs do not increase in a linear pattern, initial interventions will be significantly cheaper and increase as more is implemented. The static unit rate used for this cost estimate does not allow for this.
Upgrading 35% of conventional digestion capacity to advanced digestion to reduce process emissions	-£80 million to -£160 million	Range of costs for £ per tonne of dry solids (tDS) capacity increase ranged significantly between £1,000 and £2,000 per tDS. Site-specific factors have a significant impact on costs. These costs only account for upgrade costs and benefits of reduced process emissions, not additional biogas and associated income, which would be picked up in individual company analysis. Other site specific cost impacts relate to existing asset condition, additional liquor treatment requirements or other site-specific constraints. Site specific case studies have shown that the range of costs could be between £3,200 and £5,000 per tDS to efficiently deliver all upgrades required.
Solar, wind and hydro generation	£130 million to £200 million	These costs assume private wired connections to treatment sites and sleeving arrangements which allow the transfer of excess power at one site to another within the same half hour period. The costs assumed that all 20% of demand generated by solar and wind respectively will be used onsite, and no sleeving arrangements to export to other sites will be required. The estimated NPV is based on a saving against the retail power tariff of between 2 and 3 pence. The costs do not allow for long term retail power price inflation that may increase the savings from private wired schemes in the longer term. They also do not account for any market reactions to a large-scale increase in demand for PPAs, this could increase the unit price of power through PPAs. There is also the potential that as the sector looks to achieve the higher levels of deployment of these technologies, that it will need to implement schemes that have higher capital costs and lower financial benefits. This has not been accounted for in the modelling and will need to be considered at a company level as deployment opportunities are appraised.
Process emissions monitoring	n/a	The cost of this monitoring has been included as an enabler to process emissions reductions and therefore, has not been linked to any single decarbonisation option.
Energy efficiency interventions	-£10 million to- £20 million	Although costs are well known for conventional energy efficiency interventions in the sector. This pathway also looks to bring in more transformative interventions to drive greater energy efficiency, such as wider scale monitoring within catchments and through company's treatment and distribution networks to maximise data analytics potential to identify further unknown energy efficiency potential. The costs and potential benefits of this wider monitoring remains uncertain.

16. Independent review of the costs and benefits of water labelling options in the UK, Energy Saving Trust, 2019

Overall, considering the total tCO_2e abated against the total estimated costs of the pathway the average abatement cost of the pathway over 10 years is between £70 and £180 per tCO_2e abated.

In addition to the NPV, upfront capex requirements have been provided for this pathway. These capital costs have been scaled up to sector level estimates from limited individual project level costs and are only provided as indicative figures to show the magnitude of capital likely to be required to implement this pathway at sector level. The major investment areas within the pathway are summarised below:

- Upgrading to 35% of CAD capacity to AAD is estimated to require between £200 million and £500 million of capital investment. This is assumed to cover the most significant elements of any upgrades but is unlikely to cover all site-specific costs, as covered in Table 4-3.
- Costs of accelerated leakage reduction is estimated to incur additional capital costs of between £1 billion and £2 billion. There are significant uncertainties related to these costs. These include the unit capex cost increase as more mains replacement is implemented, which does not follow a linear pattern. There is also uncertainty on the alternative approaches that could be deployed to achieve this additional 7% leakage reduction by 2030. This also highlights that leakage reduction is considered a very expensive decarbonisation option. The relative carbon savings per unit of water saved are low and are likely to continue to reduce as the water supply system is further decarbonised. Therefore, every £ spent on leakage reduction will continue to return less carbon reduction benefits over time. There are clearly multiple benefits to leakage reduction, however, the data suggests that from a carbon reduction perspective it is not the most efficient investment.
- Solar, wind and hydro renewables, the current assumption is that these would largely be deployed through PPAs. Therefore, they would largely avoid upfront capital investment costs for the sector. However, there may be costs associated with private wire infrastructure that companies would need to review on a site by site basis. If the sector were to invest in this scale of renewables itself, it is estimated these costs could be between £500 million and £800 million.

Table 4-4 provides a summary of what the potential cost implications of the major decarbonisation options within the demand-led pathway could be for different stakeholders.

Table 4-4: Summary of potential cost implications of largest contributing decarbonisation options for different stakeholders

Decarbonisation option	Water company cost (not recovered through price control)	Customer bill impact	Government/ regulator cost	Other
Water labelling EST Scenario 2: Mandatory Government-led labelling associated with Building Regulations ANS minimum standards	Limited costs beyond current expectation to engage manufacturers, local authorities, and customers about water efficient products. Potential to collaborate and fund product developments to accelerate routes to market.	Likely to result in a saving through reduced water use but more significantly through reduced water heating costs	Costs to develop and implement scheme Potential to collaborate and fund product developments to accelerate routes to market.	Costs to manufacturers of R&D to accelerate water efficient products to market and registration fees for products
40% of total annual electricity consumption met by a combination of solar and wind renewables generation	Potential cost saving on grid electricity price, as current assumption is renewables funded through PPAs. Alternatively, there would be a significant capital cost to develop this scale of renewables on the company balance sheets.	None	None	None
Export of renewable power to grid	Ongoing costs of maintenance and capital replacements. Likely to continue to generate income through export of power and heat.	Benefit from continued savings from renewable generation and export income.	None	Opportunity for third parties to offer services to increase generation potential if they have a commercial case that benefits companies and customers.
35% of Conventionally digested sludge is upgraded to advanced digestion (THP)	Companies may be able to save costs and increase generation through some incremental centralisation of treatment to existing AAD plants. However, this will be small scale.	Uncertain, as the funding mechanisms for such enhancements (AAD upgrades) would need to be agreed with regulators – funding being through customer bills or other mechanisms outside the price control. The way Net Zero is considered in the next price review by the regulators will be key in addressing this question.	Government funding could be used to target larger sites which can reduce process emissions and increase renewable generation. Commercial arrangements could be agreed with companies around how increased renewable generation income could help share or repay some of the government funded investment.	Potential for third party market entrants to fund upgrades or new AAD plants if they can make a commercial case for this investment. Likely that these entrants would want to take over existing plants and then make upgrades and operational efficiencies. Companies would need to agree arrangements that allow them to continue to access renewable generation from sludge treatment; or find alternative renewables sources to cover any loss in renewable generation transferred to third parties.
Operational optimisations of current technology to minimise N_2O emissions from secondary treatment	Uncertain. There could be increased or reduced power costs dependant on the operational modifications that are identified to have the most effective impact on process emissions and effluent quality	Uncertain, increased power costs could result in increased bills but could also be reduced if less aeration is needed.	Investment in widescale monitoring of process emissions across the water sector, particularly at large sites is essential to identify effective interventions. Company business plans have not accounted for this investment at PR19 and it needs to be in place before 2023 to inform PR24 business plans. Therefore, likely to need government funding to implement monitoring as an enabler to widescale process emissions reductions.	Opportunity for market entrants and innovations to provide commercial service arrangements, similar to energy efficiency arrangements, that could fund implementation of monitoring and identify process modifications to reduce these emissions.
Alternative to fossil fuels – sludge (divert 5% of biogas to boilers to provide heat demand for sludge treatment) and 85% to CHP plant.	Potential increase in costs as companies buy grid electricity rather than generate through natural gas-powered CHP.			

4.3.4.3 Risks and opportunities

The demand pathway represents an ambitious reduction potential from a number of decarbonisation interventions available to the sector in a single pathway and there are a number of risks in its deliverability. The key risks identified are summarised below:

- A mandatory water labelling scheme is not established or is significantly delayed. This would mean the sector would need to continue to drive PCC and leakage reduction as per its ambitious PR19 commitment, exceeding these where possible. However, it would mean that it is unlikely that significant reductions in PCC beyond current commitments are delivered by 2030.
- Government funding for decarbonisation projects is focused on other sectors and additional funding for early investment in important enablers such as process emissions monitoring is not made available.
- The sector is unable to implement enough process emissions monitoring on time to provide reliable data that will inform operational adjustments or relevant capital investments in the PR24 business plans. This would likely result in process emissions remaining at similar levels to the BAU trajectory and the uncertainty around the actual scale of these emissions would not be better understood.
- The sector does not secure additional funding for any conventional Anaerobic Digestion plant upgrades and a potential lack of market and policy incentives may mean that an appropriate business case may not be justifiable to cover the upfront capital costs of upgrades required. This would mean the sector would have to focus on covering the increased residual emissions through offsets rather than reduce them at source.
- The sector does not identify enough suitable land for renewables or significant site opportunities are lost or delayed due to planning barriers.
- Appropriate commercial models and accounting protocols cannot be agreed to encourage deployment of large-scale renewable generation. The sector would likely continue to the purchasing of green electricity in the short to medium term and then look to alternative power sources, such as production of hydrogen or others to meet power demand.

4.3.4.4 Consideration of company characteristics

This routemap has been written with a sector level net zero ambition in mind. However, it also acknowledges the significant variations in company types, size and geography between each of the companies. This section looks to highlight some of the company specific challenges and opportunities that may be faced by different company types.

Water only companies (WoCs) versus water and sewerage companies (WaSCs)

The demand-led pathway focuses on wholesome water demand interventions, which are applicable to WoCs and WaSCs. However, it also includes some options focused on reducing process emissions through upgrading of sludge treatment and operational adjustments to wastewater treatment processes. Process emissions form a much smaller component of WoCs emissions due to the much smaller amount of organic matter treated in water treatment processes and water sludge. Therefore, in this pathway WoCs would have a greater focus on the demand interventions and driving the introduction of a mandatory water labelling scheme. They would also focus more on the deployment of renewables to reduce emissions associated with grid power consumption.

Urban versus rural companies

A key difference between companies is the characteristics of the areas they cover. Many companies cover urban and rural catchments. However, some have significantly larger urban catchments and the associated land availability constraints associated with these. For the demand-led pathway, the major constraint may be on land availability on land adjacent to large power demand areas and thus the added complexity of private wiring renewables to these areas.

4.3.5 Technology-led pathway

The technology-led pathway focuses on minimising sector level emissions through the acceleration of trialling, testing and application of technologies that can help decarbonise the sector. Overall, the aim of this pathway is to demonstrate the impact of the accelerated application of technological interventions on overall sector level emissions.

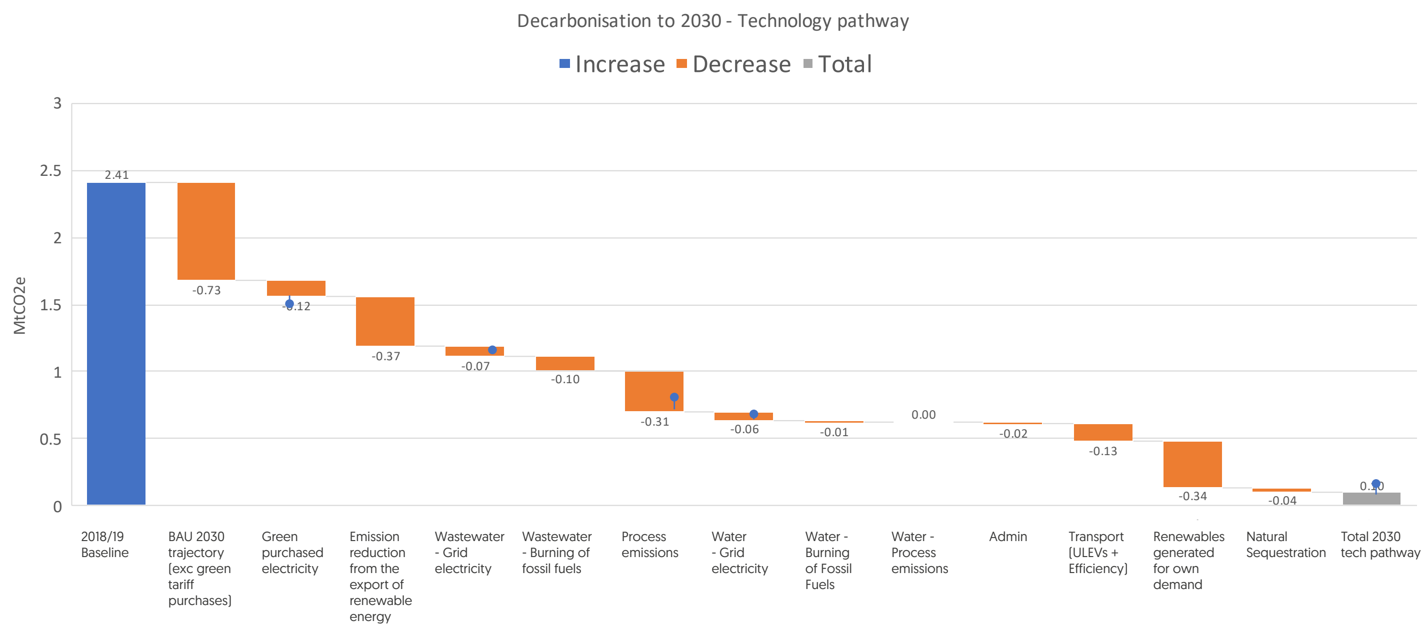
The technology-led pathway includes over 30 decarbonisation interventions that come together to deliver the reductions seen in Figure 4-7. The interventions which contribute the most reductions are summarised below:

- **Transition to biomethane**: Maximising renewable export potential of biogas by upgrading 70% of all biogas to biomethane and providing green gas into gas grid and/or utilised as a green fuel to decarbonise other areas such as heavy goods vehicle (HGV) transport. (-0.481MtCO$_2$e).
- **Deploy renewables** (solar, wind and hydro): 80% of total annual electricity consumption met by a combination of solar, wind and hydro renewables generation (-0.340MtCO$_2$e).
- **Upgrade to AAD**: Upgrading 90% of conventionally digested sludge to advanced digested processes, this significantly reduces process emissions and also increases biogas production. (-0.183MtCO$_2$e).
- **Increased monitoring and modelling of process emissions to inform operational adjustments to reduce these**: Implementing widescale process emissions monitoring at large WwTWs to understand direct and fugitive emissions from wastewater and sludge treatment processes.
- **Minimising use of natural gas imports by**: Diverting 30% of biogas to efficient boilers to provide heat demand for treatment and choosing to phase out power generation through natural gas CHP in favour of non-fossil-fuel renewables sources (-0.076MtCO$_2$e). Both these options align with the transition to biomethane and ensure moving away from CHP plant does not lead to an increase in natural gas imports.

This pathway achieves the greatest reduction potential, with approximately 0.10MtCO$_2$e of residual emissions remaining, but it also incurs the greatest upfront investment costs (estimated 10-year NPV of between -£250 million and -£500 million). The pathway also relies on a number of actions beyond the water sectors control to enable and incentivise the largescale changes in approach included within this pathway, in addition to interventions already within the control of companies.

The full list of options within the technology-led pathway are summarised in Appendix A-1, including the potential carbon reductions they achieve compared to the 2030 BAU trajectory.

Figure 4-7: Summary of technology-led pathway and level of reduction in each decarbonisation intervention



The technology pathway achieves the largest emissions reductions of all the pathways reducing emissions to 0.10MtCO$_2$e per year, the equivalent to 1.58MtCO$_2$e less than the 2030 BAU trajectory.

The technology-led pathway delivers a 96% reduction against baseline and the remaining emissions in 2030 are covered from purchased offsets in the UK or global carbon market, or the inclusion of interventions from other pathways.

Figure 4-8 shows the progress of decarbonisation within each of the emissions areas compared to the BAU trajectory up to 2030. Each bar represents an emissions area and how much it has been decarbonised from the decarbonisation interventions targeted at that cluster. The error bars on the green technology pathway line represent the uncertainty in the level of residual emission remaining for the pathway after all options are applied (see section 3.4.3.4).

The implementation of the technology-led pathway will require significant investment in innovation planning, technology acceleration and business case development before PR24 for technologies that show greatest promise for emissions reduction.

Figure 4-8: Timeline graph showing deployment of decarbonisation actions for technology pathway

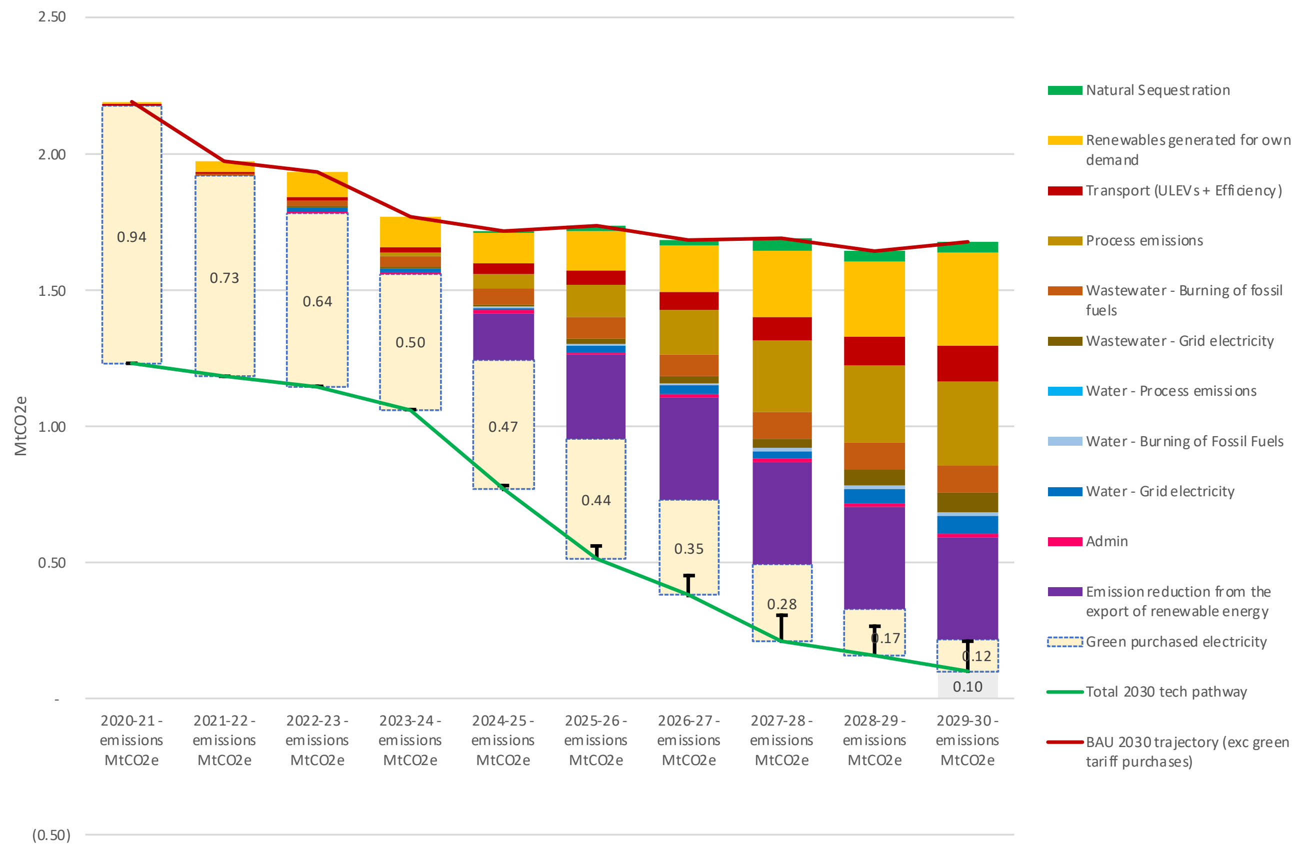


Table 4-5: Summary of main net zero interventions required in the technology pathway and enabling actions that would be required pre and post PR24 to meet the pathway

Net zero intervention	Pre-PR24	Post-PR24 actions
Transition to biomethane to grid **By the end of AMP7 the technology pathway assumes that up to 40% of biogas produced by the sector will be upgraded to biomethane and injected to the grid or compressed and supplied for use by other industries. This grows to a maximum of 70% of biogas upgraded to biomethane by 2026-27.**	**Sector would need to:** • Identify existing sludge treatment centres with feasible access to grid injection points [2022] • Engage with regional industries to identify alternative biomethane users willing to purchase compressed biomethane, this provides an alternative to grid injection where there are network constraints [2022] • Develop sector level view of overall green gas benefits the water sector can provide and engage BEIS to push for future Green Gas Support Scheme includes suitable allowances to incentivise water sector to support national UK decarbonisation through biomethane exports [2020] • Identify alternative infrastructure required (e.g. efficient boilers) to provide required process heat and power if biogas were to be diverted from CHP plant to biomethane upgrade plant [2022] • Agree capital funding sources for biomethane upgrade plants and associated ancillary infrastructure [2022] • Plan and implement biomethane upgrade plants at half of potential sites by 2024-25 **Government and other relevant stakeholders would need to:** Understand sectors significant potential to contribute to decarbonisation of gas, through biomethane production, and develop policy and support schemes that incentivise the sectors uptake. [2021 – scheme expected April 2021]	**Sector would need to:** • Implement biomethane upgrade at remaining sites by 2026, likely to be the approximate threshold for the Green Gas Support Scheme to apply. • Accept that there could be an increase in grid electricity consumption as the trade-off for reducing carbon by displacing natural gas with biogas **Government and other relevant stakeholders would need to:** • Consider future fuel transitions that can help the UK meet net zero challenges and develop policy and incentives accordingly (e.g. hydrogen power).
Deployment of renewables (solar, wind, hydro) at scale **By the end of AMP7 the technology pathway assumes that an additional 1GW of capacity solar and 0.2GW of wind is installed by 2024-25. This grows to 2.2GW of solar capacity and 0.8GW of wind capacity by 2030. This stretching ambition will require significant effort from the companies, support from the supply chain, regulators and government.**	**Sector would need to:** • Identify and map suitable areas to expand on existing solar, wind and hydro generation [2022] • Engage the supply chain to test and develop suitable commercial arrangements that can be used to deploy these technologies at scale [2022] • Identify and agree appropriate financial frameworks for off balance sheet deployment of large scale solar and wind [2022] • Communicate ambition to meet majority of own demand through renewables to generate interest and engagement with supply chain [2021] • Companies will need to actively identify barriers to implementation and engage National Grid and its supply chains to proactively remove these barriers, such as grid constraints. [2023] **Government and other relevant stakeholders would need to:** • Collaborate to develop appropriate accounting protocols, including for sleeved power, to allow companies to claim appropriate carbon benefits for offsite generation directly connected to sites [2023] • Develop clear planning policies that support development of community renewable schemes used to power critical infrastructure [2024] • BEIS and Ofwat need to agree finance frameworks for off balance sheet projects to help fund widescale renewables deployment • Work to reduce grid constraints to allow sites to install more capacity that is needed on site. • It is also worth noting future increases in purchased electricity costs and other policy instruments may incentivise further renewable self-generation.	**Sector would need to:** • Accelerate deployment of schemes, based on preferred commercial arrangements, to achieve up to 80% of own power demand. • Engage supply chain to understand developments in power storage technology to help maximise use of renewables generated onsite. **Government and other relevant stakeholders will need to:** • Continue to develop accounting protocols that drive the right behaviours to drive net zero policy
Upgrade to AAD **While there has been a significant move towards advanced digestion processes in the last 10 years, a significant proportion of sludge is still treated through conventional anaerobic digestion (CAD) plant. Upgrading these plants and the downstream infrastructure can have significant process emissions savings and an increase in biogas production. The technology pathway accounts for upgrading 90% of current CAD capacity to advanced processes by 2030, with most of these happening between 2025 and 2030.**	**Sector would need to:** • Identify CAD sites for potential upgrade [2021] • Engage with the market to identify and market-based opportunities for funding upgrades • Engage with BEIS and CCC on potential funding to reduce process emissions from industrial sector **Government and other relevant stakeholders will need to:** • Encourage Ofwat and water companies to agree how AAD upgrades to reduce process emissions will be funded (e.g. through price control, other government funding or markets). • Set up schemes and policies targeted at supporting difficult to reduce process emissions from the industrial sector (the water sector under the CCC sectors falls under Industry (majority of emissions, some fall into waste) to help achieve national 2050 net zero climate commitment • Set out requirements for funding for companies and sectors that enables reduction of these emissions	**Sector would need to:** • Have agreed funding sources of upgrades covering 90% of conventional digestion capacity • Engaged supply chain to deliver site upgrades before 2029-30 • Identified and agreed commercial contracts for biomethane supply not through the grid network **Government and other relevant stakeholders will need to:** • Encourage Ofwat and water companies to agree how AAD upgrades to reduce process emissions will be funded (e.g. through price control, other government funding or markets).

Net zero intervention	Pre-PR24	Post-PR24 actions
Moving from measuring to managing process emissions **The technology pathway accounts for widescale monitoring of process emissions being in place at all large wastewater treatment works by 2023. This upfront investment in monitoring is essential to improve understanding of process emissions pathways and identifying the most efficient interventions to mitigate these.**	**Sector would need to:** • Identify major sites and required monitoring (e.g. primary and secondary treatment, sludge tanks, sludge holding areas, sludge thickening areas and sludge treatment). • Engage supply chain to identify most appropriate process emissions monitoring methods and associated scale of costs. • Engage as a sector with CCC and BEIS to put forward a proposal for sector level investment in process emissions monitoring investment, highlighting the potential reduction opportunity this unlocks through better understanding process emissions pathways. • Implement process emissions monitoring at all large WwTWs by 2022-23. • Use monitoring data produced from monitoring to identify suitable operational and capital interventions and use this to inform investment needs in PR24 business plan. **Government and other relevant stakeholders would need to:** • Set up schemes and policies targeted at supporting difficult to reduce process emissions from the industrial sector to help achieve national 2050 net zero climate commitment. • Set out requirements for funding for companies and sectors that enables reduction of these emissions.	**Sector would need to:** • Identify major sites and required monitoring (e.g. primary and secondary treatment, sludge tanks, sludge holding areas, sludge thickening areas and sludge treatment). • Engage supply chain to identify most appropriate process emissions monitoring methods and associated scale of costs. • Engage as a sector with CCC and BEIS to put forward a proposal for sector level investment in process emissions monitoring investment, highlighting the potential reduction opportunity this unlocks. **Government and other relevant stakeholders would need to:** • Set up schemes and policies targeted at supporting remaining difficult to reduce process emissions from the industrial sector to help achieve national 2050 net zero climate commitment.
Minimising use of natural gas **The technology pathway accounts for the sector:** **a. Diverting 30% of biogas to efficient boilers to provide heat demand for treatment** **b. Choosing to phase out power generation through natural gas CHP in favour of non-fossil fuel renewables sources**	**Sector will need to:** • Ensure sufficient boiler capacity is available at sludge treatment centres as sectors phase out CHP and shift to biomethane to grid. • Make a choice to phase out natural gas CHP, even if initially grid power costs are higher. **Government and other relevant stakeholders would need to:** • Consider a tax on natural gas CHP generation to dis-incentivise this approach as the grid starts to decarbonise and incentivise sectors to adopt alternative renewable sources of power and heat.	**Sector will need to:** • Ensure sufficient boiler capacity is available at sludge treatment centres as sectors phase out CHP and shift to biomethane to grid. • Make a choice to phase out natural gas CHP, even if initially grid power costs are higher. **Government and other relevant stakeholders would need to:** • Continue to develop and promote policies that align with a net zero future as different sectors decarbonise
Decarbonisation of transport **Switch to ultra-low emission vehicles (ULEVs) for light goods vehicles (LGVs) and some HGVs. Other HGVs to move to hydrogen and biofuel.** • **100% passenger car mileage switch to electric (EVs)** • **80% freight-van mileage switch to EVs** • **80% freight-truck mileage switch – 30% hydrogen (H2), 40% biofuel, 10% EV**	**Sector would need to:** • Engage with the transport sector, provide specific vehicle performance requirements, and collaborate to trial and accelerate R&D of vehicles that meet these criteria • Communicate ambition to transition vehicle fleets by 2030 to engage supply chain and provide confidence for demand of vehicles • Develop internal policies which promotes ULEVs **Government and other relevant stakeholders will need to:** • Develop policy (e.g. scrappage schemes) that encourages an accelerated transition to ULEVs, including acceleration of charging infrastructure [2024] • Supply chain will need to engage with the water sector, and other sectors, requiring similar vehicle types to develop suitable performance vehicles at appropriate price points.	**Sector would need to:** • Develop own charging infrastructure at sites to continue to encourage greater transition to ULEVs and some HGVs • Develop hydrogen and/or biofuel fuelling for HGVs • Develop internal policies that influence the removal of barriers to ownership of ULEVs (e.g. home charging costs). • Identify alternative low/zero emissions fuel sources for HGVs and engage with transport sector to encourage the accelerated commercialisation of these

4.3.5.1 Key areas of uncertainty

As the pathway requires adoption of a number of technology options that have not been implemented at scale, there is a significant level uncertainty around the level of maximum reduction potential achieved by these options at sector level. The uncertainty in the reduction potential of these options is represented by the error bars in Figure 4-7.

Process emissions reduction potential

The most significant area of uncertainty is within the sector's ability to reduce process emissions from wastewater treatment processes and sludge treatment, the estimated uncertainty is 0.10MtCO_2e (~30% of the process emissions cluster in 2030), potentially more than doubling the level of residual emissions from the technology pathway. The uncertainty relates to:

- As highlighted in section 3.2, there is still uncertainty around the scale of process emissions from the sector. There are two issues that the sector is looking to resolve. Firstly, an update to the CAW methodology, which has been estimated to increase Scope 1 emissions by 0.2MtCO_2e/y. The impact of this potential change is estimated to increase baseline process emissions by 31% and the residual level of process emissions in 2029-30 by ~25%.
- Additionally, there is the ongoing uncertainty around the true level of emissions arising from wastewater treatment processes in the UK. There is ongoing work by the sector, through UKWIR, to improve the understanding and reduce this uncertainty. The pathway allows for widescale monitoring of process emissions to be implemented at all large WwTWs by 2022-23 to support decision making and business plan development for PR24.
- Identifying feasible options to reduce process emissions, initially through operational adjustments to existing processes and then through gradual deployment of alternative treatment technologies. The current pathway assumes that nitrous oxide (NOx) emissions could be reduced by 40% (based on slightly lower uptake than the demand pathway)[17] of current estimates through adjusting operational processes, however, this remains a significant source of uncertainty. There are limited UK specific studies to reflect the specific operating conditions. Therefore, the actual carbon reduction potential possible in the sector is very uncertain, and current levels of operational efficiency already achieved may mean further reductions at this scale are not feasible at many sites. The sector will need significant support from its supply chain in understanding suitable operational adjustments while maintaining process performance and resilience to meet this challenge.

Energy efficiency interventions reduction potential.

Other less significant uncertainties relate to the carbon reduction potential achieved by energy efficiency interventions, including the more transformative smart monitoring interventions at catchment level (such as using digital enablers to predict and target infiltration or optimising pumping at large-scale catchment level through real time control). The relative contribution of existing energy efficiency interventions is relatively small as the sector has already targeted significant energy efficiency in the last 10 years. This means that the impact of the uncertainty around carbon reduction potential from energy efficiency interventions is relatively low.

4.3.5.2 Cost of implementing the technology-led pathway

This section provides indicative NPVs and upfront capital investment costs derived from top down industry figures and calibrated as much as possible using individual water company cost data, where available. The NPV costs and capital investments are presented in indicative ranges to help the sector understand the order of magnitude of such costs when comparing the different pathways. There is a significant level of uncertainty in the development of sector level costs for the purposes of the routemap.

The costs only include the impacts on the water sector and not wider environmental and social impacts and benefits of each of the decarbonisation interventions. The NPVs and capital investment ranges should only be used as a guide by the sector and other stakeholders to identify major investment areas in each pathway. The sector, external stakeholders and individual companies will need to develop more robust costs, based on specific costs relevant to individually. The costs in this report should not be used to make individual investment decisions and they are indicative for the sector and not for individual water company investment planning purposes.

The NPV estimates for the technology pathway range from -£250 million to -£550 million over 10 years. The NPV shows that there is significant investment to be made and would therefore require alternative sources of funding (as described in Section 4.3). These were calculated based on the marginal abatement costs produced for each option (see section 4.2.1) and multiplied by the total tCO_2e abated by each option within the pathway.

The major option NPVs and key uncertainties are summarised in Table 4-6.

17. Mitigating nitrous oxide emissions at a full-scale wastewater treatment plant (link)

Table 4-6: Summary of major decarbonisation intervention NPVs and key uncertainties

Decarbonisation intervention	10-year indicative NPV	Key cost uncertainties
Upgrading 90% of conventional digestion capacity to advanced digestion to reduce process emissions	-£250 million to -£500 million	Range of costs for £ per tDS capacity increase ranged significantly between £1,000 and £2,000 tDS. Site-specific factors have a significant impact on costs. These costs only account for upgrade costs and benefits of reduced process emissions, not additional biogas and associated income. Other site specific cost impacts relate to existing asset condition, additional liquor treatment requirements or other site-specific constraints. Site specific case studies have shown that the range of costs could be between £3,200 and £5,000 per tDS to efficiently deliver all upgrades required.
Transitioning from biogas CHP to biomethane to grid and other uses	-£45 million to -£65 million	These costs include estimates of the capex investment for the sector in biomethane upgrade plants. These costs are highly uncertain and do not include for site-specific needs, or constraints to grid access points. Income has been based on an assumed wholesale grid price of 1p/kWh and assuming a financial incentive similar to the current RHI level. There are a number of site-specific factors that will impact the value proposition of this investment, such as: • Existing site infrastructure and age (e.g. CHP plant and boilers). • Existing renewable incentives income certifications. • Site-specific constraints (such as location, gas grid proximity, among others). The costs also do not take into account write-off costs of existing CHP infrastructure that the sector will be facing if decommissioning those early, the reduction in income from existing ROC levels that may still be in place until 2028, or specific excess costs for connecting to gas grid for difficult locations. It is likely therefore, that there may be additional costs companies will face if they choose to adopt biomethane to grid before their existing asset reach the end of their asset lives.
Solar, wind and hydro generation	£200 million to £300 million	These costs assume private wire connection to water supply or treatment sites which delivers an estimated 3p/kWh reduction compared to retail prices. Where more than 20% of site demand is generated, power is likely to need sleeving to another site which does not have renewable opportunity, (sleeving is the transfer of excess power at one site to another site, generated and used within the same half hour period, where both sites are contracted to the same electricity supplier). Sleeved power incurs the additional costs of retail power (network costs, balancing metering and contributions to public policy costs) so there is little cost saving for sleeved power but improved transparency of carbon savings compared to grid power. There is also the potential that as the sector looks to achieve the higher levels of deployment of these technologies, that it will need to implement schemes that have higher capital costs and lower financial benefits. This has not been accounted for in the modelling and will need to be considered at a company level as deployment opportunities are appraised. Key uncertainties include downside risks and upside opportunities and include: planning; regulatory issues, electricity price, and equipment price, all discussed above
Process emissions monitoring	The cost of this monitoring, which is expected to be relatively small has been included as an enabler to process emissions reductions and is assumed that could be part of a company's innovation funding programme.	The cost of operational adjustments that lead to N_2O emissions from secondary treatment processes has been assumed to be cost neutral. There is evidence that N_2O reductions can be achieved through managing aeration and reducing overall aeration costs[18]. However, there is significant variance between operational conditions at individual sites and there could be cost increases or savings depending on the requirements of each site. We have assumed the overall costs at the sector level would balance to be cost neutral. This is a significant uncertainty and assumption that the ongoing UKWIR project to develop a deeper understanding of process emissions and mitigation options will look to address.

18. Mitigating nitrous oxide emissions at a full-scale wastewater treatment plant (link)

Decarbonisation intervention	10-year indicative NPV	Key cost uncertainties
Decarbonisation of transport	£30 million to £40 million	The costs include an estimated current price premium for zero emission vehicles (ZEVs) and charging points, as the pathway assumes accelerated deployment rather than waiting for price parity to be reached between ZEVs and conventional vehicles. However, the calculation of total costs also considers the total cost of ownership of ZEVs (e.g. fuel and maintenance), which are typically lower than conventional vehicles. As a result, the measure is cost negative overall. The key uncertainties in the costs include: How availability, purchase and lease prices will evolve for ZEVs over the next 10 years. How the ongoing cost of ZEVs will evolve compared to conventional vehicle types – including fuel costs, tax, and parking and urban access charges/incentives.
Energy efficiency interventions	-£10 million to £20 million	This cost is impacted considerably by the uncertainty in the costs and benefits of enhanced smart control and analytics systems and next generation of efficient products. These interventions drive down the NPV of energy efficiency interventions whereas the other more conventional energy efficiency measure, which companies already exploit at a significant scale tend to be cost negative over 10 years.

Overall, considering the total tCO_2e abated against the total estimated costs of the pathway the average abatement cost of the pathway over 10 years is between £30 and £100 per tCO_2e abated.

In addition to the NPV one of the major considerations for investment is the considerable upfront capex requirement for this pathway. These capital costs have been scaled up to sector level estimates from limited individual project level costs and are only provided as an indicative guide to the magnitude of capital finance likely to be required deploy this pathway. The major investment areas within the pathway are summarised below:

- Upgrading to 90% of CAD capacity (currently 35% of all raw sludge is treated through CAD) to AAD is estimated to require between £0.5 billion and £1.2 billion of capital investment. This is assumed to cover the most significant elements of upgrades but is unlikely to cover all site-specific costs.
- Transition to biomethane to grid is estimated to require between £150 million and £300 million of capital investment. This is assumed to cover biomethane upgrade plant units but not significant site-specific infrastructure where there are constraints to grid injection points. These additional costs will need to be covered in company specific appraisals on a site by site basis.
- Solar, wind and hydro renewables, the current assumption is that these would largely be deployed through PPAs. Therefore, they would largely avoid upfront capital investment costs for the sector. However, there may be costs associated with private wire infrastructure that companies would need to review on a site by site basis. If the sector were to invest in this scale of renewables itself, it is estimated these costs could be between £1 billion and 1.5 billion.
- The accelerated investment in zero emission vehicles (ZEVs) is estimated to range in a premium capital cost compared to conventional vehicles of between £150 million to £200 million. There is evidence that the overall cheaper running costs could make this a cost neutral[19] or investment over the life of the investment, as demonstrated by its low marginal abatement cost, however this will be dependent on a number of factors including level of investment in charging infrastructure needed to meet the water companies operational needs, cost of the electricity used for charging and the cost of the EV compared to the current vehicle used. These will be influence by the development of the EV market and the national charging infrastructure.

Table 4-7 provides a summary of what the potential cost implications of the major decarbonisation options within the technology-led pathway could be for different stakeholders.

19. https://irena.org/publications/2013/Jul/Road-Transport-The-Cost-of-Renewable-Solutions

Table 4-7: Summary of potential cost implications of largest contributing decarbonisation options for different stakeholders

Decarbonisation option	Water company cost (not recovered through price control)	Customer bill impact	Government/ regulator cost	Other
80% of total annual electricity consumption met by a combination of solar and wind renewables generation	Potential cost saving on grid electricity price, as current assumption is renewables funded through PPAs. Alternatively, there would be a significant capital cost to develop this scale of renewables on the company balance sheets.	None	None	None
90% of Conventionally digested sludge is upgraded to advanced digestion (THP)	Companies may be able to save costs and increase generation through some incremental centralisation of treatment to existing AAD plants. However, this will be small scale.	Uncertain, as the funding mechanisms for such enhancements (AAD upgrades) would need to be agreed with regulators – funding being through customer bills or other mechanisms outside the price control. The way Net Zero is considered in the next price review by the regulators will be key in addressing this question.	Government funding could be used to target larger sites which can reduce process emissions and increase renewable generation. Commercial arrangements could be agreed with companies around how increased renewable generation income could help share or repay some of the government funded investment.	Potential for third party market entrants to fund upgrades or new AAD plants if they can make a commercial case for this investment. Likely that these entrants would want to take over existing plants and then make upgrades and operational efficiencies. However, it is likely that they would want to cover the costs of their investment through renewable exports and companies would need to agree arrangements that allow them to continue to access renewable generation from sludge treatment or find alternative renewables sources.
Operational optimisations of current technology to minimise N_2O emissions from secondary	Uncertain. There could be increased or reduced power costs dependant on the operational modifications that are identified to have the most effective impact on process emissions and effluent quality	Uncertain, increased power costs could result in increased bills but could also be reduced if less aeration is needed.	Investment in widescale monitoring of process emissions across the water sector, particularly at large sites is essential to identify effective interventions. Company business plans have not accounted for this investment at PR19 and it needs to be in place before 2023 to inform PR24 business plans. Therefore, likely to need government funding to implement monitoring as an enabler to widescale process emissions reductions.	Opportunity for market entrants and innovations to provide commercial service arrangements, similar to energy efficiency arrangements, that could fund implementation of monitoring and identify process modifications to reduce these emissions.
Large scale shift to utilising biogas generated for biomethane to grid exports	Upfront investment costs will need to be covered for biomethane upgrade units.	None. However, potential to reduce bills or fund other aspects of company investment plans if companies generate significant additional income through exports and associated incentives.	Will need to cover financial incentives associated with Green Gas Support Scheme (GGSS)	Potential for market entrants to provide finding for biomethane to grid upgrades, however, companies would need to ensure that their arrangements allowed them to continue to claim the export benefits of the green gas generated.

4.3.5.3 Risks and opportunities

The technology pathway presents amongst the most ambitious combination of decarbonisation interventions available to the sector in a single pathway. The key risks in delivering the options in the technology pathway include:

- Lack of availability of sufficient additional funding (outside the price control) stalls progress on early adoption and trialling of technologies which is critical to benefit realisation by 2030.
- Green Gas Support Scheme does not provide sufficient level of financial incentives, or excludes alternatives to grid injection, which disincentivises companies from investing in biomethane upgrade infrastructure and therefore there is not as large a shift to export biomethane. In this scenario, companies would continue to generate heat and power through CHP, and maximise their efficiency in doing so. This may also lead to further investigation of alternative uses for methane such as hydrogen production.
- Renewable energy risks: lack of appropriate land on site or near to site, or a planning risk especially to wind rather than solar (but there is an opportunity to work with local communities to develop wind projects off-balance sheet); regulatory issues particularly electricity market regulation (though, future Ofgem market regulation seems more likely to encourage local supply); electricity price including the risk of an over-supply of solar, with a consequent risk of reducing cost of power in the summer daytime (though there are also opportunities to move demand to periods of low price (e.g. for EV charging or hydrogen production); risk of grid constraint limiting the installation size and equipment price, where risk of adverse exchange rate movements and trade disputes persist (though the long term trajectory is still on the side of significant technology learning and falling equipment costs).
- The sector does not implement enough process emissions monitoring to provide reliable data to inform operational adjustments or capital investments in PR24 business plans. This would likely result in process emissions remaining at similar levels to the BAU trajectory and continued uncertainty around the actual scale of these emissions.
- For the transport there is a risk that the market availability of alternative vehicles and the national charging infrastructure will not develop at the rate to facilitate the assumed replacement of vehicles, however the decarbonisation of transport is a common challenge across sectors and a core focus of the national net zero policy.

  The sector can help make the necessary charging infrastructure happen by working with partners. Risks to the market for fleets include:

  – Financial – purchase cost, residual/resale value, battery replacement, total cost of ownership can be difficult to accurately predict.
  – Travel range limitations: dependent on charging network.
  – Charging times: limits flexibility.
  – Bureaucracy and organisation time investment.
  – Novelty of EV technology: lack of knowledge around technology and costs, limited choice of vehicle type.
  – Limited vehicle-body-classes available and that water sector has diverse fleet.

Additional opportunities for the sector to accelerate reductions further include:

- Adoption of anaerobic wastewater treatment processes as this technology matures and larger sites reach the end of their asset lives potentially justifying large scale refurbishments.
- Deploy engineering solutions to cover wastewater process units to capture and treat remaining process emissions. This is likely to be a costly activity and involve additional costs to deal with gas capture and processing as well as associated safety costs.
- Produce alternative fuel sources such as hydrogen and look to develop commercial arrangements that co-locate hydrogen production near wastewater treatment sites that can then use the oxygen by-product for aeration.
- Continue decarbonisation of transport focusing on HGVs, looking at hydrogen, biofuels, electric or other options.
- Further increase renewable generation through expanding wind capacity and looking at potential emerging alternative sources such as tidal generation (though it should be noted there has been limited progress in tidal to date due to its bespoke nature).
- Adopt large scale battery storage that can use less renewables capacity to meet its own demand and free up renewable capacity for wider UK consumption.

4.3.5.4 Consideration of company characteristics

This routemap has been written with a sector level net zero ambition in mind. However, it also acknowledges the significant variations in company types, size and geography between each of the companies. This section looks to highlight some of the company specific challenges and opportunities that may be faced by different company types.

Water-only companies (WoCs) versus water and sewerage companies (WaSCs)

The technology-led pathway focuses on accelerating the adoption of decarbonisation technologies and approaches to reduce emissions. However, the majority of options are focused on reducing process emissions through upgrading of sludge treatment and wastewater treatment processes. The other large area of focus is the transition to biomethane to grid, this relies on biogas production which is only suitable for WaSCs.

Therefore, in this pathway WoCs would have a greater focus on the on the deployment of renewables to reduce emissions associated with grid power consumption and decarbonisation of vehicle fleets. They would also continue to focus on energy efficiency interventions and switching to alternatives to fossil fuels used in generators.

Urban versus rural companies

A key difference between companies is the context of the areas they cover. Many companies cover urban and rural catchments. However, some have significantly larger urban catchments and the associated land availability constraints associated with these. For the technology-led pathway, the major constraint may be on land availability on land adjacent to sites with large power demand and thus the added complexity of private wiring renewables to these areas.

More rural catchments may also be constrained as to how quickly they can adopt EVs due to potentially larger ranges required by vehicles and more spread out charging infrastructure.

4.3.6 Removal-led pathway

The removal-led pathway focuses on accelerating the deployment of nature-based solutions to be able to remove CO_2 through natural sequestration within water sector land and the wider UK territory. The removal-led pathway also takes into consideration the interventions undertaken by the sector as planned in current company business plans as presented in the Business as Usual 2030 trajectory. The relevant decarbonisation interventions in this pathway are natural sequestration options ranging from afforestation/reforestation as well as peatland and grassland restoration.

This pathway has been developed to demonstrate the level of decarbonisation that natural sequestration could potentially achieve, although this is dependent on the level of policy support and the development of additional accounting mechanisms. However, it should be noted when water companies produce their action plans that in accordance with the emissions reduction hierarchy the interventions in this pathway should be considered after emissions reduction and renewables interventions have been made. It should also be noted that carbon sequestration in isolation cannot be used to achieve net zero. The decarbonisation hierarchy presented earlier in the routemap should be followed and carbon sequestration should be considered as a last resort.

The way CO_2 removals have been considered in this pathway is through taking the change in land emissions over a period of time from the baseline year to 2030. The model is based on the additionality of the interventions detailed in this pathway, and assumes other elements remain constant. The model does not include historical sequestration interventions as they were implemented outside the time period. Water companies may wish to include these when developing their individual company action plans, but if they do so should include all land-use change, both sequestration activities and emitters.

To date, work to assess the carbon potential of landholdings has been completed by only a few water companies. Some water companies (with peat based landholdings) have already started projects covering peatland restoration and woodland planting, however so far this has been limited in scale and largely focused on biodiversity and water quality improvements rather than targeting changes in the carbon flux. As part of the development of their action plans water companies will need to assess their land holdings and quantify the scale of natural sequestration interventions they can achieve.

The carbon reductions in the removal-led are shown in Figure 4-9. They are categorised as insets (interventions implemented within water sector land) and offsets (interventions implemented in wider UK territory). Residual emissions are addressed via purchasing of offsets in the global carbon market.

4.3.6.1 Insets

These are natural sequestration options and assumptions being considered to be implemented in water sector land:

1. The Sector meets its commitment to plant 11 million trees by 2023

In 2019, water companies in England announced plans to plant 11 million trees, part of a wider commitment to improve the natural environment and support their goal of achieving a carbon neutral water industry by 2030. This pathway assumed that the sector has planted 11 million trees by 2023 to maximise the sequestration potential by 2030. Although this timescale appears quite optimistic. The carbon removal potential by 2030 from this measure is 0.005MtCO_2e per year. By 2050 the natural sequestration potential from tree planting increases to 0.086MtCO_2e per year. This is understood to be additional and that the carbon savings will be accounted for by a credible carbon code such as the woodland carbon code.

This is primarily focused on water company land, however additional land will be provided by stakeholder partners such as local landowners and local authorities, The National Trust, The Wildlife Trusts and The RSPB .Statistics provided by water companies as part of this project shows tree planting has been limited so far, with uptake expected to increase over the next few years. The annual carbon sequestration rate of trees increases as they grow, peaking between 20 and 30 years. However, the annual sequestration rates are relatively similar for the first 10 years, meaning the annual sequestration rate at 2030 is only minimally impacted by later planting. Earlier planting is recommended to be able to assess the additional offsets that need to be conducted beyond this commitment and what is achievable in the water companies land.

2. The sector restores 10,000ha of degraded peatland within its land boundary by 2023

Assumption that the sector has 10,000ha of degraded peatland within its boundary that could be restored and that efforts to restore all such peatland are started by 2023. The carbon removal benefit can be much faster for peatland restoration than the gradual sequestration associated with tree planting[20] The carbon removal potential by 2030 from this measure is 0.048MtCO_2e. This is based upon the emissions difference between degraded peatland and restored peatland.

This is primarily focused on water company land, however additional land could be provided by stakeholder partners such as local landowners and local authorities, The National Trust, The Wildlife Trusts and The RSPB .Statistics provided by water companies as part of this project shows peatland restoration has so far been limited to key sites, with uptake expected to increase over the next few years. Earlier restoration is recommended to be able to assess the additional offsets that need to be conducted beyond this commitment and what is achievable in the water companies land.

It is important to note that a number of technical and science assumptions behind the carbon sequestration potential through peatland restoration still have a high degree of uncertainty. In addition the size of peatland at sector level that is suitable for restoration is uncertain and needs to be assessed in more detail.

3. The sector restores 10,000ha of grassland within its land boundary by 2023

Assumption that the sector has 10,000ha of degraded grassland within its boundary and has started efforts to restore all such grassland by 2023. The carbon removal benefit is much faster for grassland restoration than the gradual sequestration associated with tree planting. The carbon removal potential by 2030 from this measure is 0.022MtCO_2e.

Semi-natural grasslands cover a range of broad grassland types, such as upland and lowland acid, calcareous and neutral grasslands. They have significant habitat potential, with 247 out of the 1,150 UK BAP priority species being found in semi-natural grasslands and also have significant carbon sequestration potential, with grasslands possessing the highest carbon stock of any UK broad habitat[21]. Despite their importance, semi-natural grasslands have been in rapid decline, with 90% of lowland semi-natural grassland being lost in the UK since 1945, these losses mostly being driven by agriculture. Therefore, creating and/or restoring semi-natural grassland is highly beneficial from ecological and carbon sequestration points of view, and can be undertaken relatively easily (e.g. by spreading seeds of native wildflower and grass varieties).

Degraded grassland are assumed to be as follows: over grazed, enhanced nutrient input, reduced species diversity, habitat fragmentation, degraded soil structure. Degraded grasslands are assumed to be restored by reducing grazing impacts, reducing anthropogenic influences, enhancing species diversity and planting native wildflower species.

Carbon insets may not be required to be available in the form of carbon credits[22], however any calculations need to follow a credible approach. The Woodland Carbon Code is widely used by UK water companies and is the recommended tool when recording woodland planting. Uptake of the Peatland Carbon Code was limited by UK water companies and the code is considered to still be in its infancy, however this is still the recommended tool for assessing peatland restoration. The calculations of the carbon sequestration of these interventions have been calculated using a modelling approach, with model calculations and carbon flux coefficients used therein based on these codes, as well as data from relevant scientific literature. There is no tool or standard related to natural grassland planting or restoration, and these calculations have been conducted in line with reputable available scientific literature. It has been assumed that trees would be managed in accordance with good forestry practices and that peatland and grassland once restored would be maintained.

There may be additional smaller scale or water company specific interventions that can be included in individual water company action plans such as soil management, urban greening, promotion/protection of sea grass beds, or salt marsh restoration, but these are not included in the sector level pathway and will in some cases be geographically specific.

It is important to note that a number of technical and science assumptions behind the carbon sequestration potential through grassland restoration still have a high degree of uncertainty. In addition the size of grassland at sector level that is suitable for restoration is uncertain and needs to be assessed in more detail.

4.3.6.2 Offsets

These are natural sequestration options implemented within UK territory by the sector having an active contribution and through having a UK carbon market for the sector to be able to claim the removal benefit.

The removals pathway assumes the water sector places emphasis on investing in an ambitious level of natural sequestration activities within the UK territory. The following would be completed by 2028:

- 22 million trees planted which are forecast to remove 0.010MtCO_2e by 2030 and 0.172MtCO_2e. This would most likely require land not owned by the water companies.
- Restoration of 18,735ha of degraded peatland (1% of the estimated UK degraded Peatland)[23] which could potential remove up to 0.091MtCO_2e by 2030.
- Restoration of 5,375ha of degraded grassland (1% of the estimated UK degraded grassland)[24] which could potentially remove 0.013MtCO_2e by 2030.

These figures have been selected to give an indication of what could be achieved by offsets from this scale of natural sequestration interventions and indicate an ambitious level of offsets. Once water companies action plans have been completed and the actual level of offsets required has been established these may be revisited and the required scale and feasibility investigated further.

For the carbon removal benefit to be claimed by the sector, a sufficiently large UK carbon market would need to be in place so that the sector can obtain the relevant carbon credits to reflect the carbon removal benefit from these interventions.

As these interventions are outside the water companies' boundary they would be termed as carbon offsets. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project/measure that generates offsets. Offset calculations need to meet the requirements of PAS 2060 and/or UK Government or internationally recognised standards.

It is important to note that these interventions offer considerable additional benefits beyond carbon sequestration. These may include: biodiversity through habitat creation, water quality improvements, natural flood management, recreation creation and enhanced landscape aesthetics.

The sites which offer the most additional benefits may be located within the water companies' catchment area outside their ownership boundary, and so careful consideration should be given to siting the interventions and the variety of tree/grassland to be planted to offer the maximum additional benefits. These benefits should be balanced against the cost of using a third parties land, and the potential for having to share the carbon benefit. All carbon sequestration interventions would need to be implemented following any regulatory guidelines with planning considerations taken in to account.

20. The table in the IUCN report (page 21. http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/Review%20Peatland%20Restoration,%20June%202011%20Final.pdf) suggests that peatland stabilisation/carbon sequestration can occur within the first year of peatland restoration for different management techniques.

21. UK-habitat classification prepared by the UK Biodiversity Group that classifies all terrestrial and freshwater habitats in the UK into 37 broad habitat types.

22. Instead of carbon credits in the wider UK market, the sector could establish its own carbon scheme/market within its landholdings following a credible standard

23. Bain, C.G., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Gearey, B., Howat, M., Joosten, H., Keenleyside, C., Labadz, J., Lindsay, R., Littlewood, N., Lunt, P., Miller, C.J., Moxey, A., Orr, H., Reed, M., Smith, P., Swales, V., Thompson, D.B.A., Thompson, P.S., Van de Noort, R., Wilson, J.D. & Worrall, F. (2011) IUCN UK Commission of Inquiry on Peatlands. IUCN UK Peatland Programme, Edinburgh.

24. Natural grasslands (CORINE classes 321) = 14,407km2, assumed 25% degraded based upon available water company studies

Figure 4-9: Summary of removal-led pathway and level of reduction from each decarbonisation intervention

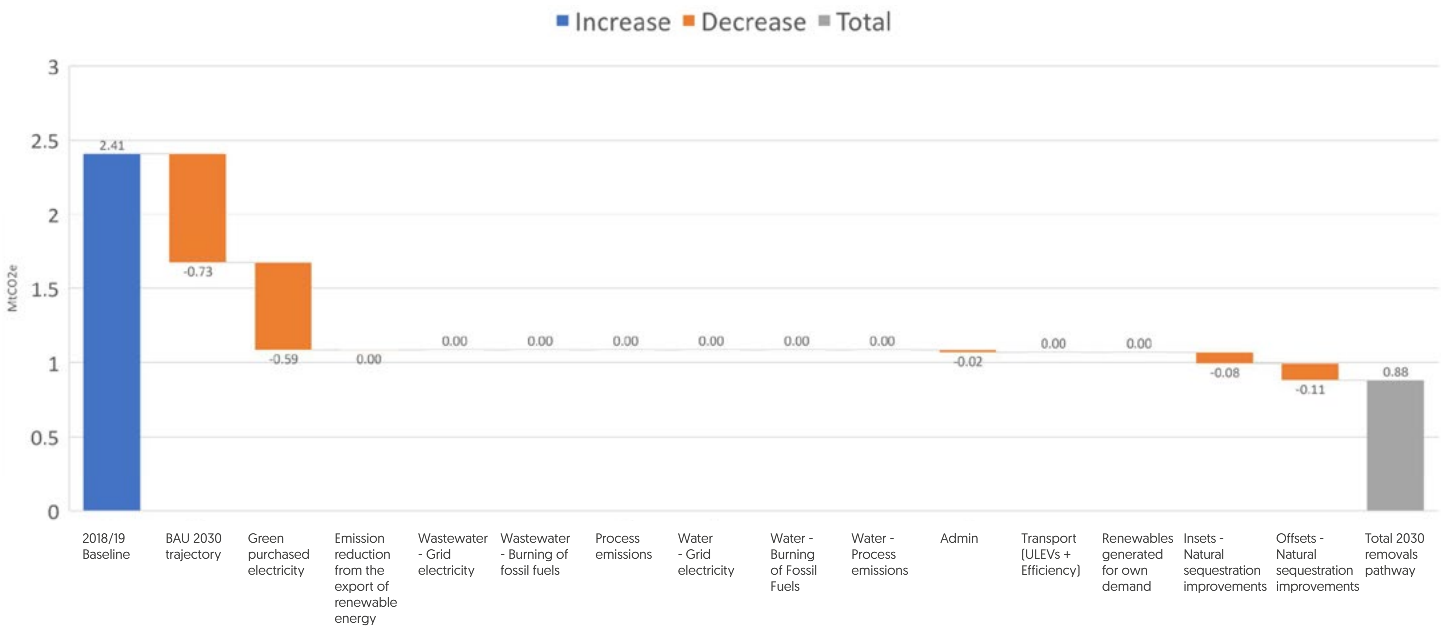


Figure 4-10 shows the progress of decarbonisation within each of the emissions areas compared to the BAU trajectory up to 2030 for the removal-led pathway. Each bar represents an emissions area and how much it has been decarbonised from the decarbonisation interventions targeted at that area.

The implementation of the removal-led pathway will require significant effort by the sector to accelerate natural sequestration solutions in sector land and in the UK territory before PR24.

Figure 4-10: Timeline graph showing deployment of decarbonisation actions for removal-led pathway

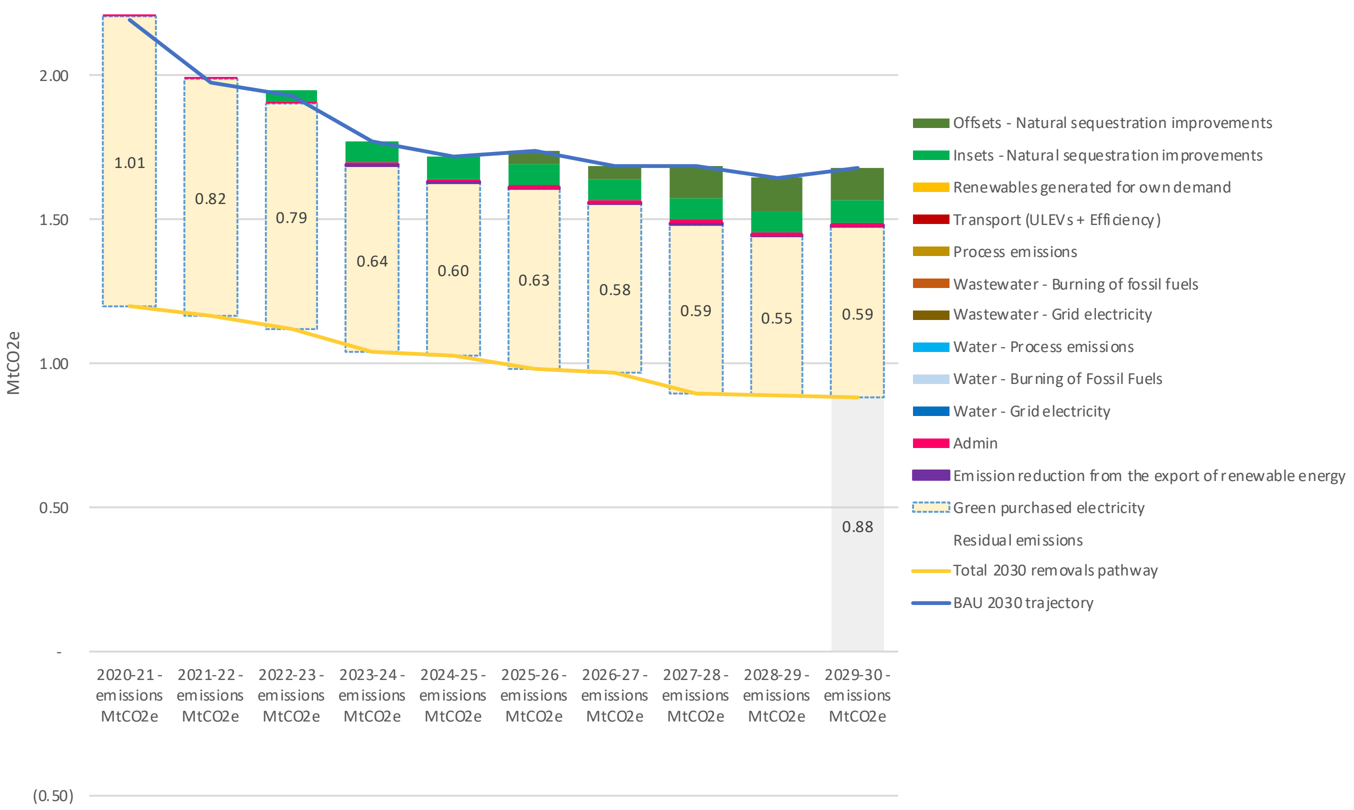
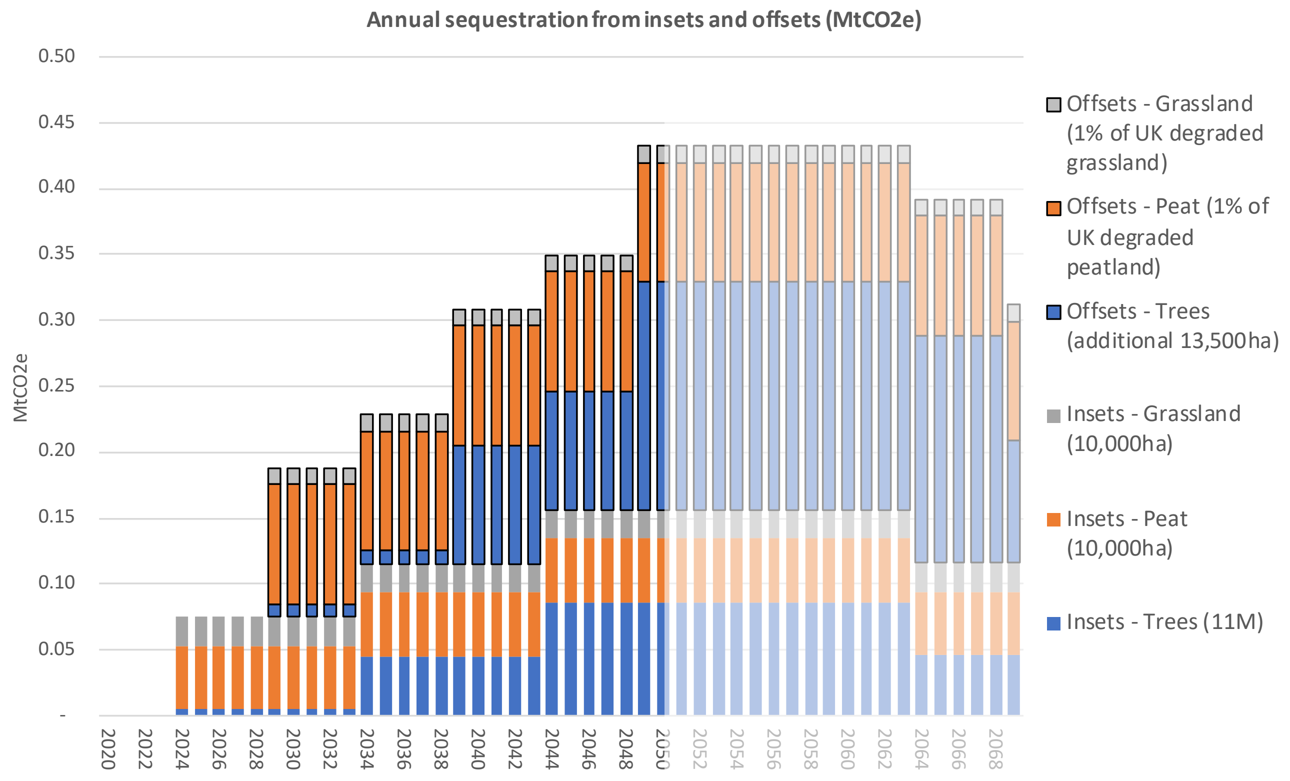


Figure 4-11 illustrates the carbon removal potential from the natural sequestration solutions in the removal-led pathway by 2050. The full carbon sequestration benefits of tree planting are not realised within the 2030 routemap timeframe. For tree planting the maximum annual sequestration rate is not reached until post 2030 (when trees are 20 to 40 years old), though this rate is governed by a range of factors such as tree species, yield class, management practices, etc. Coniferous woodland sequester slightly more carbon over their lifetime than broadleaved woodland, however additional benefits should be considered when planting trees, with a native mix of trees recommended for increased biodiversity benefits. It should be noted that the annual sequestration rates decrease after this period and so there needs to be continual tree planting to ensure the maximum annual sequestration rates are to be maintained.

The carbon savings from peatland restoration may not be guaranteed in the long term (post 2050) as climate change may impact their ability to sequester carbon. However, this should not detract from their significant savings in the short term.

Figure 4-11: Natural sequestration potential to 2050 from removal-led pathway



The removal-led pathway achieves the least emissions reductions of all the pathways reducing emissions to 0.88MtCO_2e per year.

Other options considered under this pathway are maximising the deployment of nature-based solutions such as catchment management and sustainable urban drainage systems (SUDS), as well as options around energy efficiency interventions in water and wastewater and administration buildings. Over the next 10 years, it is expected that there will be a continued drive for catchment-based thinking and solutions. The roll-out of the new Environmental Land Management (ELM) scheme should result in a shift from more traditional farming incentives to one where farmers are rewarded for providing public goods and services. This would include clean and plentiful water, clean air and also carbon sequestration potential through mitigation of and adaptation to climate change. Therefore, it is important that a standardised approach is established to accurately quantify avoided carbon (through reduced treatment/capital work) and carbon savings from catchment management.

Until a method is recognised and in place, opportunities for reducing carbon and maximising potential savings will be missed. Having the means to accurately quantify carbon savings should enable the selection of catchment mitigation interventions based not only on the water quality improvements they provide but also the carbon reductions. This has not been modelled at this stage due to the lack of a means to accurately quantify carbon savings.

The scenario behind the removals pathway, if followed in isolation without the sector considering decarbonisation options presented in the technology and demand-led pathways may not be the most credible when tested against the Sector 2030 routemap or Science Based Targets Initiative principles where the sector would need to demonstrate maximising reduction interventions first before any carbon removal options are considered.

The largest contributor to this sequestration benefit is the assumed 10,000ha of peatland restoration located in water sector owned land, and accounts for approx. 65% of the total sequestration potential by 2030. Given the potential significance of the peatland contribution to the total sequestration capacity it will be important to develop a better understanding of the science behind sequestration rates in different types of peatland, degradation rates, etc, noting that there is research being conducted in this area but that differing views between academics may cause challenges in deciding upon a common approach. The 2030 number also assumes that companies are maintaining any interventions implemented in peatland and grassland (as well as afforestation) and hence there is no reduction in the sequestration potential over time. This pathway assumes that there will be ongoing maintenance activities to preserve this benefit. An additional risk, which is not taken into account, is the potential future peatland and grassland degradation in the long term (i.e. 2050 and beyond) where gradual climatic changes may affect the ecosystem and remove the CO_2 sequestration benefit.

All carbon sequestration interventions are looked upon favourably in key government policies, including the UK governments, with support that has been announced including; the Peat Strategy included within Defra's 25 Year Environment Plan, as well as backing provided by the Welsh and Northern Irish governments for peatland restoration schemes, UK Government a publication by Defra[25] highlighted the important role the semi-natural grassland have as a habitat as well as carbon store, The UK Government announced support for woodland creation with a Woodland Carbon Guarantee scheme announced in 2019 to encourage farmers and landowners to plant more trees[26].

There are a number of enablers to allow the successful and credible implementation of the removal pathway. These are included in Table 4-8.

Table 4-8: Summary of main net zero interventions and enabling actions required pre and post PR24 for the successful implementation of the removal-led pathway in addition to BAU 2030 decarbonisation interventions being considered by the sector

Net zero intervention	Pre-PR24	Pre-PR29 actions
Insets **Plant 11 million trees within water sector land** **Restore 10,000ha of degraded peatland and 10,000ha of degraded grassland within water sector land**	**Sector would need to:** • Work across UK sectors to gain a better understanding on the science behind natural sequestration options such as peatland restoration and grassland restoration to be able to quantify the benefits and total potential that can be achieved within and outside sector land. • Undertake a land survey in sector land to be able to accurately quantify the types of land the sector has and assess the total natural sequestration potential for the sector using a bottom up approach. • Identify suitable locations and assess biodiversity considerations and plant 11 million trees in water sector land by 2023. Such afforestation schemes will have to follow credible national and international standards such as the Woodland Carbon Code, the Gold Standard, among others. • Identify suitable degraded peatland and grassland, assess the size of the carbon removal potential and implement interventions to restore 100% of the potential 10,000ha semi-natural peatland and 10,000ha semi-natural grassland assumed to be within the water sector boundary. This measure assumes that this activity will be largely undertaken by 2023. Therefore, 7 years of sequestration benefits are achieved by 2030. The peatland restoration interventions will need to follow national and international standards, such as the peatland carbon code, the gold standard and prove the right level of additionality. **Government and other relevant stakeholders would need to:** Collaborate with the sector and provide further guidance and support to help accelerate the deployment of such interventions by 2023	**Sector would need to:** • Maintain the natural sequestration interventions being developed to be able to maintain the carbon removal benefit by 2030 and beyond. **Government and other relevant stakeholders would need to:** • Review support schemes targeted at tree planting and provide further incentives if required.
Offsets	**Sector would need to:** • Be working with the woodland trust and Defra forestry team to identify suitable locations within the UK territory that would bring clear carbon sequestration benefit for the highly ambitious option of planting of an additional 22 million tress within the UK by 2028 This is more likely to follow schemes such as the Woodland Carbon Code or equivalent carbon credit schemes. The engagement would need to be started immediately. • Engage with relevant stakeholders to better understand the accounting principles of natural sequestration options in a potentially new carbon market from land use change in the UK. • It is recommended that detailed planning and consultation with appropriate experts and regulators is taken to ensure that the implementation of each intervention is appropriate and provides the highest level of all-round benefits. This requires a focus on ensuring suitability of planting or restoration and additional benefits, such a biodiversity and habitat improvements, is included when planning the implementation of each intervention. **Government and other relevant stakeholders would need to:** • Be working towards increasing the size of the carbon market in the UK for land use change to be able to accommodate the carbon benefits from the water sector's natural sequestration option implementation within the UK territory. This will have to be in place by 2028 (to include trees, peatland and grassland interventions) and hence the scheme would have to be developed before 2028. • As there is not an industry methodology for accreditation of grassland restoration the water sector may wish to agree a standard preferred approach, and then engage with stakeholders in the development of a methodology.	**Sector would need to:** • Plant 22 million broadleaf and coniferous trees by 2028. This is the equivalent of 13,500ha, which is approximately 0.65% of current UK Woodland, based on CORINE 2012 data which states there are 2,079,400ha of woodland in the UK. • Restore 1% of the UK's degraded peatland and 1% of the UK's degraded grassland by 2028. **Government and other relevant stakeholders would need to:** • Have a suitably large carbon market in the UK and relevant standards to accommodate the offset interventions that are considered under this pathway to be implemented by the water sector within the UK territory.

25. UK natural capital: developing semi-natural grassland ecosystem accounts (19 April 2018). Office for National Statistics. Sourced: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/uknaturalcapitaldevelopingseminaturalgrasslandecosystemaccounts

26. Government launches new scheme to boost tree-planting (4 November 2019). UK Government Press Release. Sourced: https://www.gov.uk/government/news/government-launches-new-scheme-to-boost-tree-planting

4.3.6.3 Key areas of uncertainty

The development of the removal-led pathway has considered the accelerated adoption of Table 4-8.

The most significant areas of uncertainty in this pathway include:

- Lack of certainty around the science behind the carbon removal potential for interventions such as peatland, grassland restoration and other interventions like soil management.
- Lack of information around the extent of land type in the water sector that may be suitable for accommodating the level of insets for trees, peatland and grassland restoration assumed in this pathway. This knowledge is being developed by water companies so may not be a blocker soon.
- Deployment rates for all-natural sequestration options considered in the pathway to reflect actual peatland and grassland restoration practices and tree planting cycles.

Further discussion in the above uncertainty areas is included in section 4.3.6.3

4.3.6.4 Cost of implementing the removal-led pathway

This section provides indicative 10-year NPVs and upfront capital investment cost ranges. There is significant uncertainty behind the costs of natural sequestration options and not much actual data exists in the UK for different types of options, especially for peatland and grassland restoration. These costs should not be used to inform the sector's individual project investment decisions and should be only looked at in the context of comparing the relevant costs between the different pathways (NPV and capital costs).

The NPV estimates for the removal-led pathway range from -£160 million to -£260 million over 10 years. These were calculated based on the marginal abatement costs produced for each option and multiplied by the total tCO_2e abated by each option within the pathway.

The major option NPVs and key uncertainties are summarised in Table 4-9.

Table 4-9: Summary of major decarbonisation intervention NPVs and associated key cost uncertainties

Decarbonisation intervention	10-year indicative NPV	Key cost uncertainties
Insets – Including: **Planting of 11 million trees** **Restoration of 10,000ha of degraded peatland** **Restoration of 10ha of degraded grassland**	-£100 million to -£150 million	Costs based on range of £5 to £10[27] per tree planted and incorporating historical project costs for peatland and grassland restoration. Costs do not include for ongoing maintenance and management of any of the interventions or rental or purchase of land as these will vary according to water companies existing site maintenance arrangements and the specifics of the scheme, such as if tree thinnings can be sold. Peatland costs are estimated at £5,000/ha based on previous restoration projects and grassland restoration at £1,000/ha based on seed and spreading costs. The key uncertainties in the costs are related to are the existing level of degradation of the land and the requirements to restore this and also the existing planting regimes in place which may control the cost to some degree.
Offsets – Including: **22 million trees planted** **Restoration of 18,735ha of degraded peatland (1% of the estimated UK degraded peatland)** **Restoration of 5,375ha of degraded grassland (1% of the estimated UK degraded grassland)**	-£80 million to -£125 million	As above

The average abatement cost to implement all options in this pathway over 10 years is between £150 and £230 per tCO_2e abated.

In addition to the NPV, one of the major considerations for investment is the considerable upfront capex requirement for this pathway. These capital costs have been scaled up to sector level estimates from limited individual project level costs and are only provided as an indicative guide to the magnitude of capital finance likely to be required deploy this pathway. The estimated capital investment required for each of the natural sequestration options are summarised below:

- Planting 11 million trees: between £55 million and £110 million.
- Restoring 10,000ha of degraded peatland ~£50 million.
- Restoring 10,000ha of degraded grassland ~£10 million.
- Planting 22 million trees within UK territory: between £110 million to £220 million.
- Restoring 18,750ha of degraded peatland within UK territory ~£100 million.
- Restoring 5,375 of degraded grassland within UK territory ~£6 million.

These overall costs of implementing the pathway decarbonisation options are likely to be split between all stakeholders equally, and there are often multiple ways in how options could be funded. See Table 4-10 for a summary of what the potential cost implications of the major decarbonisation options within the removal-led pathway could be.

Table 4-10: Summary of cost implications of largest contributing decarbonisation options in removal-led pathway

Decarbonisation option	Water company cost (not recovered through price control)	Customer bill impact	Government/ regulator cost	Other
Planting 11 million trees within own land	Companies are expected to identify appropriate sources of funding to cover the cost of this commitment	None	Nature for climate funding and green recovery fund	None
Restoration of 10,000ha of degraded peatland and grassland respectively	Companies would need to seek alternative sources of funding, possibly outside the price control, to cover the cost of this activity (see section 4.3 on potential funding mechanisms)	Potential to cover activities above and beyond this 10,000ha through potential outperformance payments in PR24 and AMP8	Potentially may need to provide some funding on developing a robust UK-wide scheme to help credibly capture the benefits of these sequestration improvement activities.	None
Planting 22 million trees	Companies would need to identify appropriate sources of funding to cover the cost of this commitment but may look to partnership funding spread the cost of this. However, this may then also split the carbon reduction between partner organisations.	None	Nature for climate funding and green recovery fund	None
Restoration of 1% of degraded peatland and grassland across UK territory respectively	Companies would need to identify funding sources to cover the cost of this commitment but may look to partnership funding to spread the cost of this. However, this may then also split the carbon reduction between partner organisations.	Potential to cover activities above and beyond this 1% through potential outperformance payments in PR24 and AMP8	Potentially may need to provide some funding on developing a robust UK-wide scheme to help credibly capture the benefits of these sequestration improvement activities.	None

27. Forestry commission England, English woodland grant scheme, standard costs, 2011 and water company experience.

When looking at the feasibility or cost benefits of a carbon sequestrations intervention, the cost should be considered alongside the vast additional environmental benefits of each restoration or planting scheme.

4.3.6.5 Risks and opportunities

There are several areas of risks associated with this pathway.

Climate change

Climate change could create huge impacts on restoration or planting schemes, requiring consideration of schemes that are suitable for changing climates, for example ensuring the tree species chosen for planting will not be impacted or growth limited by predicted changes in temperature and rainfall. A changing climate could also require increased management, for example due to more frequent droughts or flooding. Climatic risks (e.g. fires and drought) could damage or revert natural carbon sinks, causing reduction in sequestration potential or even an increase in emissions and these risks could be exacerbated by climate change. Peatlands are particularly susceptible to increased temperatures and so annual sequestration rates from restored peatland cannot be guaranteed after 2050, however this should not detract from the significant carbon savings that can be achieved prior to then and the contribution that restoring them now plays to reducing the climate impact that may put the savings from them at risk.

UK policy

Policy changes could also provide uncertainties, due to changes to funding or policy focuses for certain crops, for example a policy focus on biofuel cropping over biodiversity could impact natural grassland restoration. The UK agricultural policy will also change following the transition period after the UK's exit from the European Union and the Common Agricultural Policy. However, it is expected a new agricultural policy will focus on biodiversity and natural capital improvements, in line with the carbon sequestration clusters. Policy to encourage the UK offset market will better enable water companies to use UK offsets for residual emissions rather than global offsets.

Carbon sequestration calculation

Transparent and credible accounting procedures are needed to ensure only credible offset options that prove additionality are considered. These need to be appropriately detailed to account for the significant variables in the calculations such as state of the land prior to the activity, plant type, ongoing maintenance of the site, tree planting cycles (rate and volume of planting) etc. Water companies will need to follow best practice guidance for any insets (within water company land).

Carbon sequestration calculations are heavily influenced by several variables including selected carbon flux coefficient, plant species, soil type, state of the land before the intervention, and so site-specific savings may vary considerably from those calculated for the sector. It is recommended for the assessment of carbon sequestration potentials be done on a site level.

It should be noted that even when fully restored, peatlands by their nature, still emit a small amount of GHGs. However, this is considered minimal compared to the significant emissions which degraded peatlands create. Therefore, any restoration of degraded peatlands can be assumed to contribute towards a significant net reduction in carbon emissions and is therefore a key step in controlling emissions. In addition to this there are other long-term benefits gained from peatland restoration such as providing wildlife habitat, drinking water filtration, flood prevention, and recreational areas.

Site selection — Availability and optimising additional benefits

A detailed assessment of the availability and suitability of land for carbon sequestration needs to be conducted. It is recommended that detailed planning and consultation with appropriate experts and regulators is taken to ensure that the implementation of each intervention is appropriate and provides the highest level of all-round benefits. This requires a focus on ensuring the suitability of planting or restoration and additional benefits, such a biodiversity and habitat improvements, is included when planning the implementation of each intervention. The complexity of the restoration will vary by site due to the variation of degraded status of land and associated restoration requirements.

Land management will be needed on an ongoing basis and this should be factored into plans and costings.

There is a risk that competing land uses will reduce the area of land available for natural sequestration. This will need to be assessed as part of the water companies assessing their land holdings. Caution should be taken to ensure converting a site doesn't result in higher emissions at another site, for example if the site was used for agricultural purposes another area of land may be converted to replace the original site.

Funding

The benefits associated with carbon sequestration options tend to be indirect (compared to interventions such as energy efficiency which have direct cost savings from reduced energy consumption). When looking at the feasibility or cost benefits of a carbon sequestration intervention, the cost should be considered alongside the vast additional environmental benefits of each restoration or planting scheme. Funding sources are potentially limited, although there are some funding streams such as Government's Woodland Carbon Guarantee (£50 million) and Government grants for peatland restoration. If land outside the water company boundaries are required there may be an additional cost and other longer-term management requirements associated with acquiring the land.

Credibility

It is important that the carbon sequestration interventions and the calculation of their savings are credible. To achieve credibility criteria should be applied:

- Additionality– planting or restoring in addition to what would happen anyway (e.g. the UK Woodland Carbon code identifies four conditions in that regards). This is the most challenging requirement in practice. Additionality is also related to possible double counting of GHG removals.
- Leakage avoidance – while creating carbon reductions in one place does the project increase emissions from another source elsewhere, thus reducing the benefits gained?
- Perpetuity (i.e. is the future of the newly created wood or restored peatland assured?). Companies would need to consider what interventions and management are required over the years of operation of each GHG removal measure to maintain its effectiveness and prevent sinks becoming sources over time.
- Verification (i.e. the planting or restoration site is independently audited according to an internationally compliant standard and globally recognised methodologies).

There is also a perception that carbon sequestration is 'planting a way out' of the problem of achieving net zero and is not addressing the problem of the emissions. However, natural sequestration not only plays an important part in supporting the offsetting of future emissions but also sequestration of historical emissions. This pathway may be less aligned with national and international decarbonisation policies if not combined with other interventions higher up the emissions reduction hierarchy. Natural sequestration options should be considered only when steps to avoid and reduce other emissions have been planned.

Opportunities

- **Enhancing natural capital**: There is scope to build on existing work with stakeholders, such as the Woodland Trust, wildlife trust, RSPB, Regional NGOs, natural England and local communities in the development/restoration of sequestration sites. The additional benefits associated with these interventions would benefit the sector's and UK territory natural capital.
- **Identifying additional inset opportunities**: There are additional sequestration activities, such as urban greening, salt marsh restoration, land change and planting other types of fauna that have not been modelled due to their scale and/or company specific nature. These may be considered by the sector in more detail to help complement other types of insets, however the carbon removal benefit of many of those options has not yet been proven to scale.
- **Water sector carbon trading scheme**: There is an opportunity to develop a carbon trading scheme to maximise and accelerate the deployment of insets (removal options in water sector land). This would help companies with limited land bank, particularly smaller water only companies who may not be able to fully benefit from other large-scale decarbonisation options associated with biosolids management, to be able to account for sector insets in their decarbonisation plans. This would also benefit water companies who can achieve more natural sequestration than they need for their action plan as they could then sell the carbon credits for these to water companies who need them.

A water sector carbon trading scheme would however need to be designed on existing national and standards to ensure additionality, transparency and fair allocation. It is unlikely that the water sector will be a net absorber of CO_2 through insets so the purpose of the carbon trading scheme could be to facilitate trading and net zero planning between individual companies.

4.3.6.6 Consideration of company characteristics

This routemap has been written with a sector level net zero ambition in mind. However, it also acknowledges the significant variations in company types, size and geography between each of the companies. This section looks to highlight some of the company specific challenges and opportunities that may be faced by different company types.

Water-only companies (WoCs) versus water and sewerage companies (WaSCs)

The removal-led pathway focuses on natural sequestration options which are applicable to WoCs and WaSCs. There are no specific constraints in this pathway related to whether a company is a WoC or a WaSC.

Urban versus rural companies

The removals-led pathway is likely to be significantly affected by the characteristics of the catchments which each company covers. Those with large rural areas are likely to have significantly more scope to implement natural sequestration improvement options in their own land (insets) due to the land available. The types of land area within these rural catchments will also play an important factor, companies whose land areas cover large areas of peatland clearly have greater opportunity to influence the rehabilitation of these to generate emissions benefits.

For companies covering more urban areas they are likely to have to rely more on partnerships and market schemes to influence natural sequestration improvements beyond their own company boundaries. The implementation of a UK-wide scheme that supports and encourages ease of accounting and trading of sequestration improvements is seen as a key enabler to accelerating natural sequestration improvements by the sector.

4.3.7 Pathways comparison

Section 4.3 has presented the detailed analysis of the three modelled pathways for net zero. This has identified that none of the pathways in isolation can achieve net zero for the sector and all require significant levels of investment to achieve their potential.

In this section we compare the key points arising from each pathway and use an illustrative combined pathway to demonstrate how the decarbonisation options from different pathways can be combined at the sector level.

4.3.8 Combined pathway

The combined pathway is an indicative pathway to show how the most practical or timely elements from the three pathways can be bought together. It is not a fixed pathway for the sector as each water company will need to produce their own combined pathway based upon their own circumstances. This pathway has been based upon what are generally the most secure interventions elements of the three pathways (those most within the water companies' control, with fewer enablers or with lower levels of risk/uncertainty associated with their implementation). The results of this pathway are shown in Figure 4-12.

The interventions this pathway are taken from at least one of the other three pathways, though in some areas their deployment rates or assumed emission savings have been reduced. The options included in this pathway are:

Biomethane: The pathway assumes a lower uptake of biomethane upgrade in the sector compared to the technology pathway. Accounting for 40% of total biogas being converted to biomethane for export and the remaining continues to be used in CHP plant and boilers. This is to represent the uncertainty in the ability of all sites to secure appropriate grid connection points and also uncertainty as to whether the Green Gas Support Scheme (GGSS) will cover alternative, non-grid injected supplies of biomethane. It also reflects companies potentially choosing not to write off relatively new CHP assets before the end of their useful natural life. This scenario also assumes natural gas prices remain low and no additional carbon tax is applied to this and therefore, natural gas CHP continues to be a cheaper power generation option for the sector.

Renewables generation: This pathway assumes 20% of electricity demand is met by solar and 17% by wind generation as companies focus on sites with suitable adjacent land for easy to implement PPAs. This reflects the uncertainty in organising widescale sleeving arrangements required to maximise benefits of larger scale deployment of renewables, as included in the technology pathway, as well as likely planning barriers to wind deployment.

Conventionally digested sludge is upgraded to advanced digestion (THP): This pathway assumes an increase through centralisation of treatment through existing AAD plants and some major schemes. Overall, this accounts for 40% of existing CAD capacity (based on 2018-19 values plus known additional planned AAD upgrades/capacity in place by 2020) being upgraded to AAD. The funding mechanisms for this remain unclear. The opening of the bioresources market and a move to the average revenue control at PR19 may restrict the investment in enhancements for bioresources treatment sites. However, depending how Net Zero may be considered in the next sector price review, especially due to the UK's legal obligation to be a Net Zero economy by 2050 and the role AAD may have, and depending whether customer support can be demonstrated for cases where there are not suitable AAD market opportunities, Regulators may choose to consider whether investments could be considered within the price control.

Government-led mandatory water labelling to reduce PCC: This pathway assumes a government-led mandatory water labelling schemes is deployed but only comes into force at the start of AMP8. This reflects the level of engagement needed across government, multiple sectors, supply chain and time needed to develop a suitable scheme. This also delays the benefits from such a scheme, which is assumed to progressively increase the stringency of water labelling requirements in 3-year blocks from the year of deployment.

Energy efficiency interventions: This pathway assumes that all typical energy efficiency interventions, included within the demand and technology pathway are implemented. This reflects their relative ease of implementation and offer a good return on investment. The pathway assumes that wider scale transformative catchment scale monitoring to drive energy efficiency interventions will be deployed after 2030.

Trialling and scaling up alternative treatment options to reduce power demand and processes emissions (e.g. MABR/anaerobic treatment): This pathway assumes a slower development of these technologies, accounting for up to 10% of flow being treated by some form of alternative wastewater treatment by 2030, compared to the technology pathway. This reflects that the sector will have other R&D focus areas to meet their AMP7 requirements and therefore only implement these at scale in AMP8.

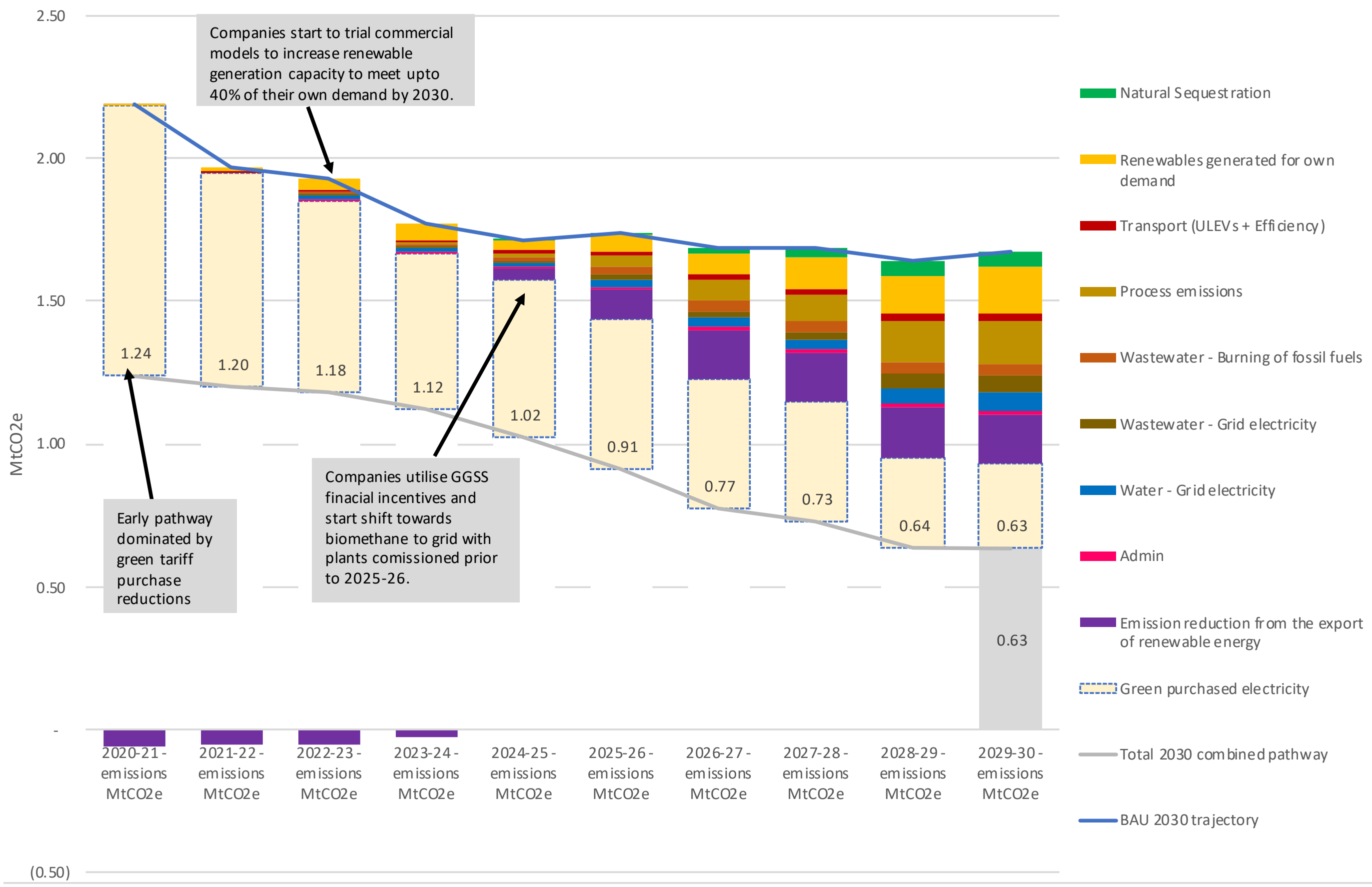
Minimising fugitive emissions: Assumes only a few large WaSCs implement appropriate monitoring at large sites that leads to identifying operational interventions to reduce process emissions. As not all sites implement monitoring only a 25% reduction in methane and 20% reduction in N_2O emissions is achieved.

Transport: Assumes the efficiency interventions are implemented but that companies follow market pace of change in adopting alternative low or zero carbon vehicle technologies, which is already accounted for in BAU, so there are not additional savings from the use of alternate transport technologies.

Natural sequestration: It is assumed that tree planting and peatland restoration starts late in AMP7 and full benefits in AMP8 and that grassland restorations is not implemented as a suitable standard and accounting protocol for grassland restoration is not in place to incentivise companies to take action. It is assumed an additional 11 million trees are planted beyond the commitment as it is easier to expand the existing UK Woodland Carbon code to allow companies to claim benefits of additional tree planting within UK territory. Grassland and peatland restoration beyond the water companies' boundary is assumed not to take place as a UK-wide carbon accounting protocol around land management changes is not in place.

Alternatives to fossil fuels for standby generation: It has been assumed this does not take place as companies focus on biggest impact areas. This assumption aims to reflect the relative low impact of fossil fuels used for standby generation, and that the maturity of supply chain to deliver cost effective and reliable alternatives to current standby generation options may not be in place until closer to 2030.

Figure 4-12: Timeline graph showing deployment of decarbonisation actions for combined pathway



4.3.8.1 Cost of implementing the indicative combined pathway

This section provides indicative NPVs and upfront capital investment cost ranges. The sector, external stakeholders and individual companies will need to develop more robust costs based on specific costs relevant to themselves. The costs in this report should not be used to make individual investment decisions.

The NPV estimates for the combined pathway range from +£30 million to -£120 million over 10 years. These were calculated based on the marginal abatement costs produced for each option and multiplied by the total tCO_2e abated by each option within the pathway.

Table 4-11: Summary of major decarbonisation intervention NPVs and associated key cost uncertainties

Decarbonisation intervention	10-year indicative NPV	Key cost uncertainties
Mandatory water labelling to reduce PCC	n/a	An NPV for this scheme has not been calculated as the costs of the scheme are not assumed to be incurred by the sector. The EST independent review[28] of implementation of the scheme was estimated at £60 million, with manufacturers bearing the vast majority (£55 million) of these costs.
Accelerated leakage reduction to 2% greater than existing 2030 forecasts	-£80 million to -£200 million	There is significant uncertainty to how this additional accelerated level of leakage above and beyond current commitments would be achieved. The NPV assumes that this additional leakage reduction would likely rely on targeted mains replacement beyond what is in company plans and therefore incur a higher unit cost than current mains replacement allowances. These are based on current estimates of range of mains replacement costs. These have not allowed for future innovations that may reduce these costs significantly, or for alternative ways to achieve this additional leakage other than mains replacement. Key factors to consider are: Current levels of leakage, those companies with already low levels of leakage are likely to incur higher unit costs to reduce leakage further. Research[29] has shown that in certain cases with low levels of leakage, mains replacement may increase leakage. Therefore, it is important mains replacement is targeted to areas with greatest impact. Mains replacements costs do not increase in a linear pattern, initial interventions will be significantly cheaper and increase as more is implemented. The static unit rate used for this cost estimate does not allow for this.
Upgrading 40% of conventional digestion capacity to advanced digestion to reduce process emissions	-£90 million to -£180 million	Range of costs for £ per tDS capacity increase ranged significantly between £1,000 and £2,000 tDS. Site-specific factors have a significant impact on costs. These costs only account for upgrade costs and benefits of reduced process emissions, not additional biogas and associated income.
Solar, wind and hydro generation	£200 million to £300 million	These costs assume private wired connections to treatment sites and sleeving arrangements which allow the transfer of excess power at one site to another within the same half hour period. The costs assumed that all 20% of demand generated by solar and wind respectively will be used onsite, and no sleeving arrangements to export to other sites will be required. The estimated NPV is based on a saving against the retail power tariff of between 2p/kWh and 3p/kWh. The costs do not allow for long term retail power price inflation that may increase the savings from private wired schemes in the longer term.
Process emissions monitoring	Monitoring is expected to be of relatively low cost and have assumed would be covered through existing water company innovation programmes	The cost of this monitoring has been included as an enabler to process emissions reductions and therefore, has not been linked to any single decarbonisation option.
Energy efficiency interventions	-£10 million to £20 million	Although costs are well known for conventional energy efficiency interventions in the sector. This pathway also looks to bring in more transformative interventions to drive greater energy efficiency, such as wider scale monitoring within catchments and through company's treatment and distribution networks to maximise data analytics potential to identify further unknown energy efficiency potential. The costs and potential benefits of this wider connected monitoring remains uncertain.

28. Independent review of the costs and benefits of water labelling options in the UK, Energy Saving Trust, 2019

29. UKWIR Report Number 09/WM/08/38 - Linking Distribution Mains Rehabilitation to Performance

Overall, considering the total tCO_2e abated against the total estimated costs of the pathway the average abatement cost of the pathway over 10 years is between £-40 and £130 per tCO_2e abated.

Estimated capex requirements for the major options include:

- Costs of accelerated leakage reduction is estimated to incur additional capital costs of between £300 million and £600 million. There are significant uncertainties related to these costs. These include the unit capex cost increase as more mains replacement is implemented, which does not follow a linear pattern. There is also uncertainty on the alternative approaches that could be deployed to achieve this additional 2% leakage reduction by 2030.
- Upgrading to 40% of CAD capacity to AAD is estimated to require between £200 million and £500 million of capital investment. This is assumed to cover the most significant elements of upgrades but is unlikely to cover all site-specific costs.
- Solar, wind and hydro renewables, the current assumption is that these would largely be deployed through PPAs. Therefore, they would largely avoid upfront capital investment costs for the sector. However, there may be costs associated with private wire infrastructure that companies would need to review on a site by site basis. If the sector were to invest in this scale of renewables itself, it is estimated these costs could be between £500 million and £800 million.

4.3.8.2 Tailoring the pathways – Differences between water companies

This routemap has been written with a sector level net zero ambition in mind. However, it also acknowledges the significant variations in company types, size and geography between each of the companies. This section looks to highlight some of the company specific challenges and opportunities that may be faced by different company types.

Water only companies (WoCs) versus water and sewerage companies (WaSCs)

When looking across the pathways and the combined pathway presented, there are clearly some large options related to biogas production and wastewater process emissions that are only appropriate for WaSCs. The options most appropriate to WoCs are related to deploying widescale renewables to power their treatment and pumping, while reducing leakage and the demand for wholesome water. This aligns with the baseline carbon emissions for water services where over 90% of emissions are related to grid power consumption.

Urban versus rural companies

The characteristics of the areas which companies operate in will likely have a significant impact on the types of decarbonisation options deployed by them. This is particularly relevant to natural sequestration options, where companies in larger rural catchments will have an advantage in implementing natural sequestration improvement schemes, especially where they also own this land.

For companies covering more urban areas they are likely to have to rely on partnerships and market schemes to influence natural sequestration improvements beyond their own company boundaries. The implementation of a UK-wide scheme that supports and encourages ease of accounting and trading of sequestration improvements is seen as a key enabler to accelerating natural sequestration improvements by the sector.

4.3.9 Pathways summary

The comparative impact of each pathway discussed in the previous sections is shown in the pathway's projection graph below (Figure 4-13). The graph shows the residual emissions resulting from each of the modelled pathways.

The key points to note from this are:

1. The BAU trajectory already represents a significant level of decarbonisation against a 'do nothing' scenario. As BAU represents the commitments the sector has already made through its combined business planning, this is the appropriate start point from which all net zero actions should be modelled (i.e. this is the counter-factual for comparison purposes). Therefore a 'do nothing' pathway was not calculated in detail for this study but is represented on the graph by a potential range of emissions based on external influences on the sector only. It should be noted that the BAU trajectory has not accounted for any significant change in regulatory policy that may drive further carbon emissions from the water sector, regulators will have a role to play in the challenge by identifying options to delivery policy outcomes through low carbon approaches.
2. None of the modelled pathways can achieve net zero in isolation, each providing a residual emissions challenge that would need to be met through identifying further decarbonisation options as they emerge between now and 2030, accelerating deployment of known decarbonisation options across all pathways or offsets or emissions trading.
3. The extent of the residual emissions challenge varies significantly between the pathways:
   a. The removals pathway has the highest level of residual emissions and demonstrates that net zero cannot be achieved by the sector solely by planting trees and improving its own land. This pathway also leaves the sector with the highest ongoing cost burden, as investment in many of the interventions will need to be repeated annually beyond 2030.
   b. The technology pathway delivers the greatest overall reduction in emissions and the fastest route to decarbonisation. However, this also presents the highest risk pathway, placing a significant emphasis on external factors such as the ability of the supply chain to respond to the demand for new technology and the mechanisms required to support the market developments.
   c. The demand pathway decarbonisation accelerates during the second half of the decade and the next business planning period. This reflects the opportunity that regulatory price controls can play in emissions reduction, but also the challenge they pose if there is not an aligned approach to incorporating net zero into price review.
   d. The combined pathway illustrates that the level of ambition shown by the sector regarding net zero will clearly require continued commitment and challenge. This pathway shows that there is no single or guaranteed 'easy or otherwise' route to follow.

Figure 4-13: Sector decarbonisation pathways residual emissions comparison

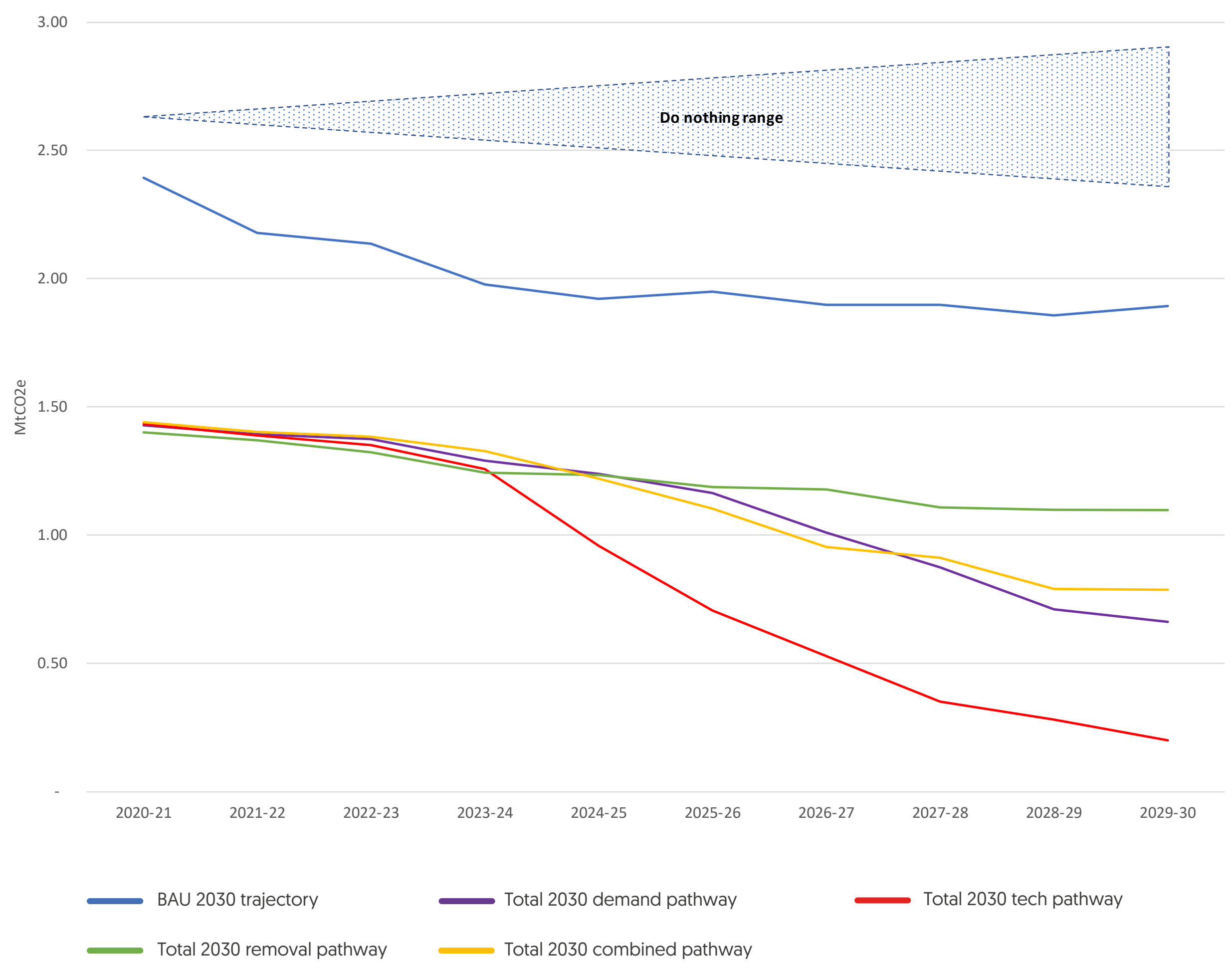


Table 4-12 summarises the emissions reductions and costs associated with each pathway. The key highlights are:

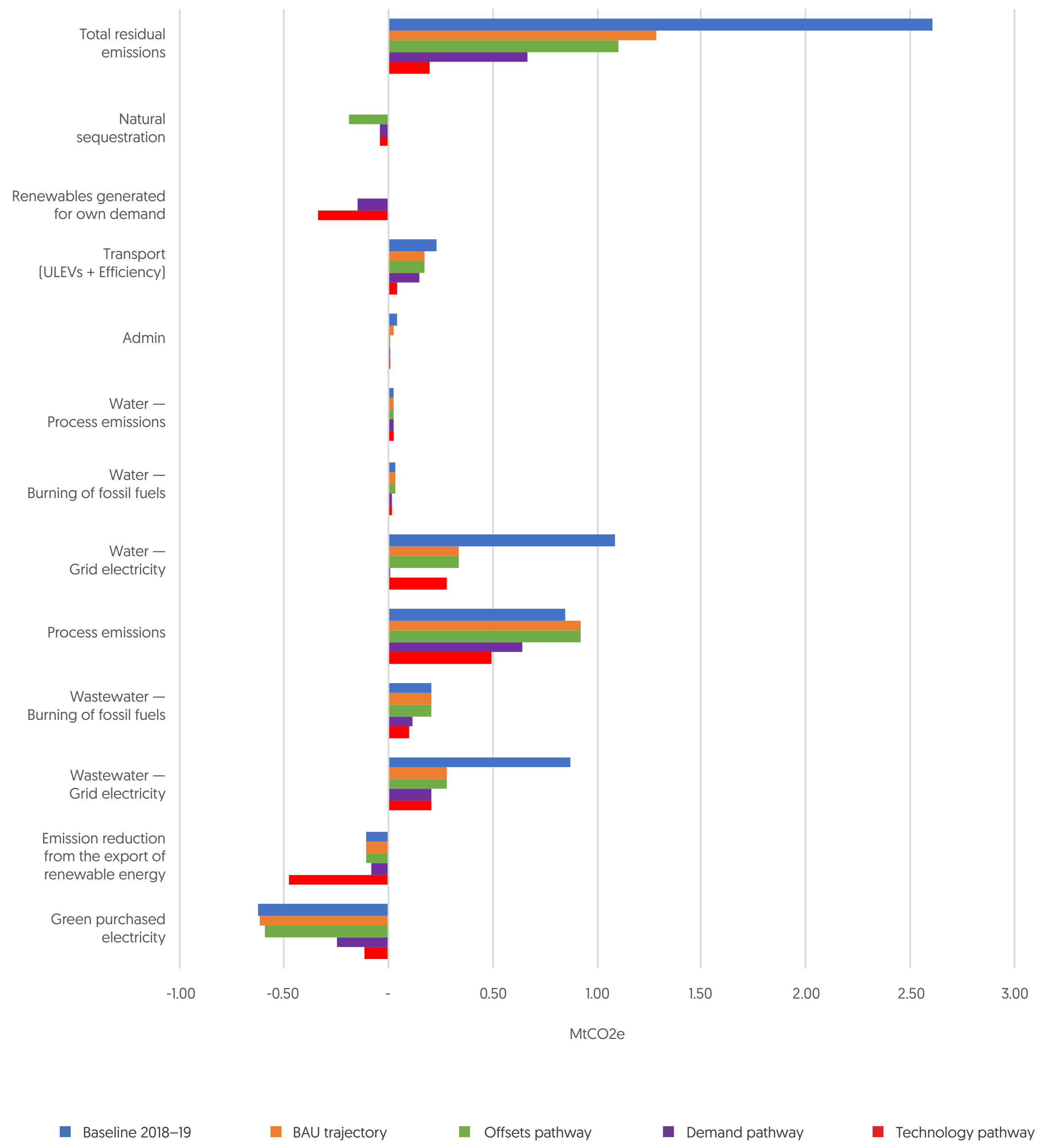
- The technology and demand pathways achieve the greatest level of reduction but also incur the highest upfront costs. However, the technology pathway demonstrates the lowest abatement cost per tCO_2e.
- The removals pathway achieves the least reduction and upfront cost but demonstrates the highest abatement cost per tCO_2e.
- The indicative combined pathway demonstrates potentially an overall balance between capital investment and carbon reduction potential, with potentially the lowest abatement cost ranges than the technology, demand and removal pathways.
- Note that each of the pathways has a lower emissions start point in 2020-21 than the BAU trajectory due to the accelerated procurement of REGO backed green electricity supply via the national grid compared to baseline.

Table 4-12: Pathways emissions saving and comparison

Emissions (Mt CO_2e)				Reduction (%)	Indicative Capex Investment range (£M)	Indicative 10-year NPV (£M)	Estimated Abatement cost (£/t CO_2e)
Pathway	Baseline (2018-19)	2030	Change				
BAU*	2.41	1.68	-0.73	30%			
Demand	2.41	0.54	-1.87	77%	1,700 to 3,300	-250 to -650	70 to 180
Technology	2.41	0.10	-2.31	96%	1,800 to 3,200	-250 to -550	30 to 100
Removals	2.41	0.88	-1.53	63%	200 to 500	-160 to -260	150 to 230
Combined	2.41	0.63	-1.78	74%	1,000 to 1,900	+30 to -120	-40 to 130

*excluding Green Tariff purchasing

Figure 4-14: Comparison of residual emissions sources from each pathway



As Figure 4-14 shows there are still residual emissions requiring further action of offsets across all of the pathways. Across all pathways there are further reductions possible, beyond 2030, for grid power, transport, fossil fuels and particularly process emissions. To tackle these the sector may look to:

- Adopt anaerobic treatment processes as this technology matures and their larger sites reach the end of their asset lives and justify large scale refurbishments.
- Hard engineering solutions and cover wastewater process units to capture and treat remaining process emissions
- Production of alternative fuel sources such as hydrogen and look to develop commercial arrangements that co-locate hydrogen production near wastewater treatment sites that can then use the oxygen by-product for aeration.
- Continue decarbonisation of transport focusing on HGVs, for example looking at hydrogen, biomethane or electric options.
- Further increase renewable generation through expanding wind capacity and looking at potential emerging alternative sources such as tidal generation.
- Adopt large scale battery storage that can use less renewables capacity to meet its own demand and free up renewable capacity for wider UK consumption.

There are also likely to be a number of additional options that develop between now and 2030 as we communicate the scale of the challenge to their supply chain and encourage them to innovate to drive further reductions in the goods and service they provide to the sector. A review of potential emerging opportunities is provided in section 6.

4.3.10 Low-regret options

Despite the different pathways to net zero the sector may choose to follow at any given point in time, there are a number of existing techniques which are common to all pathways and have a favourable balance of trade-offs and costs. These include:

- **Maximising energy efficiency potential**: Maximise energy efficiency interventions in water and wastewater to include accelerating deployment of interventions already utilised by individual water companies across the sector.
- **Increasing monitoring and modelling of process emissions to inform operational adjustments to reduce these**: Optimising control to minimise nitrous oxide process emissions from secondary wastewater treatment.
- **Catchment wide optimisation using digital enablers and risk-based approaches**: Assess early opportunities and implement pilots of larger scale transformational efficiency interventions at catchment-scale using digital enablers, for water networks, water quality and wastewater/flood management. Regulators, companies, government and supply chain will need to work together to better understand the trade-offs between net zero, performance and environmental quality to incorporate in PR24 and beyond.
- **Demand management**: Accelerate water efficiency interventions and leakage management. Government-led mandatory water labelling scheme.
- **Upgrade to AAD**: Upgrading conventionally digested sludge to advanced digested processes, which has the potential to significantly reduce process emissions and also increases biogas production.
- **Transition to biomethane**: Maximising renewable export potential of biogas by upgrading biogas to biomethane and providing green gas into gas grid and/or utilised as a green fuel to decarbonise other areas such as HGV transport.
- **Deployment of renewables** to meet at least 20% of sector power demand by a combination of solar, wind and hydro renewables generation.
- **Reducing reliance on green tariffs over time**. Although an important measure in the short-term, it is recommended that the sector accelerates other decarbonisation interventions including renewable energy generation, or energy efficiency to be able to reduce its overall power consumption and reliance on green tariffs in the future.
- **Transport efficiency**: Increasingly replace light goods vehicle (LGV) fleet to EVs and consider alternative fuels for HGVs. Maximise efficiency in transport journeys for LGVs (especially through remote working rather than traveling to sites/meetings, which has been significantly improved during COVID19) and for HGVs through better journey rationalisation.
- **Planning for and investing in nature-based solutions to maximise natural sequestration benefits**: The sector will need to start engaging with stakeholders to better understand the carbon removal benefits across its land holdings and other potential locations within UK territory from peatland and grassland restoration and identify suitable sites to restore. The sector will need to meet its commitment of 11 million trees as soon as possible to maximise the carbon sequestration benefit by 2030.

5 Next steps for the sector

A number of recommendations for next steps have been identified for the sector (water companies, regulators, supply chain, government and other stakeholders) to help the net zero 2030 commitment through any of the identified pathways discussed in this routemap. These recommendations are summarised below:

5.1 Water UK and water companies

- Consider the enabling actions for PR24 and PR29 as summarised in individual pathways for the relevant decarbonisation options to be followed.
- Considering full Scope 3 emissions (such as chemicals and capital carbon) within net zero boundary post 2030. This will ensure the sector is fully aligned with the SBTi principles and can enable more collaborative working with the supply chain to reduce whole life carbon.
- Develop individual company action plans aligned to the sector's net zero target. In developing such plans companies should consider the guidance and tools for embedding carbon management in their organisation and assessing whole life carbon in all projects to be implemented by the sector going forward. These action plans could then be brought together to show the sector pathway to net zero.
- Continue to review the latest best practice and science regarding estimation and reporting of greenhouse gas emissions and update the CAW accordingly.
- Consider updating the CAW to be compatible with the net zero 2030 routemap, particularly adding options presented in the different pathways that are not included, aligning the structure to the sector net zero boundary and addressing the uncertainties around the process emissions and aligning key emissions factors to the latest national and international guidance.
- Consider a sector level reporting framework for net zero to monitor progress against the 2030 net zero target. Monitoring and reporting should be transparent to external stakeholders.
- Consider reporting the sector emissions using market and location-based approaches to align with Government guidance.
- Assess all potential sources of funding outside the current business plans, such as the BEIS Industrial energy efficiency fund, Defra afforestation fund, Ofwat innovation fund that can be utilised. Prioritise business cases for the sector to accelerate the deployment of decarbonisation interventions, especially the most uncertain ones such as process emissions reduction, natural sequestration, among others, as these may require more time for solutions to be developed and implemented.
- Consider having net zero as a key theme during customer engagement during PR24 and beyond.
- Consider the introduction of a water sector carbon market trading scheme to help individual companies trade carbon credits.
- Continue engagement with Government and regulators by presenting sound evidence around the balance between GHG emissions impacts and other water resources management, quality and performance decisions to facilitate discussions for PR24 and beyond.

5.2 Supply chain

- Engage with water companies through existing frameworks and supply chain events to help showcase industry innovations for all low regrets decarbonisation options as a minimum (particularly process emissions, renewable energy, biogas, catchment management approaches with digital enablers, water efficient products, low carbon transport options).
- Engage with water companies to work together in developing further emerging options that are not fully commercialised. Further detail is included in Section 7.
- Build carbon management capability in own organisations for supporting the sector transition to net zero by 2030.

5.3 Regulators

- Ofwat: Develop a net zero assessment framework for assessing company business plans in PR24 and beyond. The framework should consider how company performance against net zero could be measured, how different targets may be set and how different trade-offs could be assessed (e.g. with resilience and customer affordability). How companies propose to operate within a net zero environment and the cost implications of this will need to be a consideration in the next price reviews.
- Environment Agency: Consider net zero in any assessment framework for water resources management planning and environmental quality standards being set for PR24 and beyond. This should take in to particular consideration the impact and balance of atmospheric GHG emissions, with similar land and aquatic emissions. This will allow a better understanding of the trade-offs from future major schemes and delivery of business plans.

5.4 Government and other stakeholders

- Consider implementing a mandatory water labelling UK-wide scheme to help accelerate demand management options.
- Promote a policy framework for the price of carbon.
- Consider accelerating the development of a UK-wide carbon trading scheme from land use changes. This will enable the water sector to accelerate any actions for deploying natural sequestration solutions within UK territory, outside the sector land holdings. Consider developing an assessment framework and associated guidance on how individual natural sequestration schemes can maximise natural sequestration and other co-benefits, particularly for emerging options such as grassland restoration and other options beyond the woodland and peatland carbon code.
- Consider level of incentives and conditions to support the acceleration of biomethane supply in all forms and not just through grid injection.
- Consider additional funding available to the water sector to help accelerate the deployment of the largest decarbonisation opportunities associated with process emissions and bioresources. Bridging this gap in funding will be important to avoid delays in action prior to the next price review for the sector.

5.5 Opportunities where we can enable carbon reductions in the wider UK system

The routemap has identified some priority areas we could focus on to drive further decarbonisation benefits above beyond those considered in the current pathways. The options below consider system levels benefits of exporting the value within the water, and other sectors, to help support decarbonisation across the UK in the most cost beneficial approach. The sector is strongly encouraged to consider these opportunities early to help contribute to the wider UK decarbonisation challenge.

Co-digestion: There is an increasing potential opportunity for co-digestion with other industrial and household organic waste. This has the clear benefit of potentially boosting biogas production within the sector and enabling generation more power and/or heat to be utilised to meet demand within the sector or export to enable decarbonisation in other sectors. Policy drivers in the UK could already align to support co-digestion deployment, such as increasing collection of household food waste and reducing landfilling of these organic wastes and the associated GHG emissions[30]. However, there are also several barriers to implementation of co-digestion, such as:

- Commercial: Current gate fee prices for alternative substrates along with declining value of renewables incentives has increased the payback period associated with the operational and infrastructure costs. There is also relatively limited headroom at existing STCs to incorporate large quantities of additional organic digestate, without requiring significant additional investment.
- Regulatory: Current standards such as PAS110[31] related to producing quality anaerobic digestion digestate cover source segregated organic wastes only. Therefore, co-digested wastes with mix different organic substrates would not meet the requirements of PAS110. There has already been efforts to compare and align the requirements of PAS110 and existing sewage sludge to agriculture standards[32,33], to allow agricultural recycling of BAS assured biosolids, which contains a small amount of alternative organic waste. However, no agreement has yet been reached. There is also a continued risk that agricultural landbank is restricted over time due to public perception, emerging contaminants or quality standard requirements that are unrealistic to meet cost-effectively. The sector has taken considerable action already to maintain quality and confidence in the land recycling route through the Biosolids Assurance Scheme (BAS).
- Technical: Technical issues relate to the additional pre-processing required for other organic wastes such as food waste (reception, screening, contaminant removal and mixing to produce a slurry) and different optimal solids retention times. Food waste generally requires a longer solids retention time to achieve a stabilised product suitable for use on farmland and maximise biogas generation. However, there are successful examples of co-digestion, such as the Billund plant in Denmark[34], which looks to incorporate circular economy principles and recover as much high value product from AAD of multiple organic wastes.

30. https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england/resources-and-waste-strategy-at-a-glance
31. http://www.wrap.org.uk/content/bsi-pas-110-producing-quality-anaerobic-digestate
32. Sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland (link)
33. Biosolids Assurance Scheme (BAS) (link)
34. https://stateofgreen.com/en/partners/billund-biorefinery/solutions/billund-biorefinery-1/

The sector could continue its engagement with Defra and relevant stakeholders to develop an evidence base for why removal of regulatory barriers, is not only safe but also helps meet wider climate change and sustainability requirements. It can also engage the supply chain and utilise the bioresources market to overcome the commercial and technical issues highlighted.

Renewable waste heat: The sector already produces significant amounts of renewable heat through CHP plant, this is largely utilised on site to meet heat demand of digestion processes, which reduces the requirement to import additional natural gas to provide this demand. However, in many cases there is excess heat produced compared to on-site demand. There is a potential opportunity to export this heat to adjacent sources of heat demand. This could include to commercial and residential buildings through district heating networks, or to structures such as greenhouses to boost agricultural production and reduce heat demand.

A potentially more significant source of waste heat could be from the sewerage network, which has significant amounts of potential latent heat that could be recovered to power residential and commercial heat demand and offset current fossil fuel sources of this heat. The technology to achieve this is already deployed in the UK and by some water companies. However, some key enabling actions have been identified to help further develop this technology and exploit the benefits in regards to decarbonisation, these are:

- Establishing a carbon accounting protocol for waste heat: There is a lack of UK-wide benefits accounting protocol for waste heat. The introduction of a UK-wide accounting protocol for waste heat would allow the sector to engage externally with other stakeholders to develop business cases that can clearly and credibly account for the full costs and benefits of these heat recovery schemes and accelerate their adoption. This could then lead to understanding the market value of units of heat recovered and any potential policy and incentives required to fully exploit this benefit.
- Understanding the scale of waste heat recovery potential from sewers: There is no robust understanding of the actual scale of feasible waste heat recovery from sewers. There is a need to review the technology available to recover heat from different parts of the sewer networks, the infrastructure required to maximise the beneficial utilisation of this heat and any impacts on the performance of the sewers or downstream treatment processes associated with the extraction of heat from sewage.

Potential contribution to a future UK hydrogen economy: This is a highly uncertain area and still under development at UK level. Unlikely to see an active contribution by the water sector by 2030. Current discussions in the UK around the production of green hydrogen coming from water through electrolysis may mean that more sectors in the UK may approach the water sector to see whether and how it could contribute to a future hydrogen economy in the UK.

6 Conclusions

Good progress already made

We have made considerable progress in achieving emissions reductions to date and in our business as usual 2030 trajectory. If we had not been proactive in our efforts, it is possible emissions would have increased further due to factors such as population growth and increased environmental and water quality requirements. However, it is important to note that our decarbonisation progress to date has been greatly assisted by the decarbonisation of the UK electricity grid and green tariff purchases. To achieve net zero will require a step change in operations and considerable additional effort by the sector – water companies, regulators and supply chain.

The sector already has incentives in place to encourage efficiency and cost reductions and now needs to look beyond this to incentivising emissions reductions.

The impact of grid decarbonisation

As discussed in the business as usual projection the UK electricity grid is expected to continue to decarbonise. This diminishes the benefit to exporting renewable electricity over time, and places greater emphasis on the exporting of other resources such as biogas, biomethane, hydrogen and heat as the carbon benefits from this are not expected to diminish at the same rate. The decarbonisation of electricity also means that process emissions will account for a greater percentage of the residual emissions in the water sector and the UK if no action is taken.

Pathways to net zero by 2030

The 2030 net zero sector routemap shows three main pathways towards net zero. These are based on a number of future scenarios where the sector increases the decarbonisation ambition through early planning and access to other sources of funding and on policy frameworks and market incentives external to the sector. All three pathways represent accelerating selective decarbonisation options over and above the business as usual 2030 trajectory.

The technology-led pathway has the lowest level of residual emissions that still need to be resolved through identification and adoption of further decarbonisation technologies or purchased through purchase of offsets in the global carbon market. However, it also has the highest implementation cost and relies heavily on external policies and market forces to help support the acceleration of any adopted interventions. If this pathway was combined with additional interventions from the demand and removal-led pathway net zero could theoretically be achieved without the need for offsets, however this would require a level of investment that may not be feasible and all associated enabling actions to be achieved.

An indicative combined pathway has also been developed to prioritise the implementation of decarbonisation options under the sector's control, such as power reduction, process emissions, bioresources, renewable generation, and natural sequestration insets, without relying heavily on external market forces and future incentives, as these are highly uncertain. The combined pathway also gives a more balanced view of the likely order of magnitude implementation costs. The combined pathway is indicative for the sector to help engage more strategically with regulators, supply chain partners and other stakeholders to implement appropriate actions before PR24.

Low regrets actions for the sector

Despite the different routes to net zero illustrated by the different pathways, there are a number of low regrets actions that the sector can take to start implementing immediately. These include:

- **Maximising energy efficiency potential**: Maximise energy efficiency interventions in water and wastewater to include accelerating deployment of interventions already adopted by individual water companies but scaling them up at sector level.
- **Increasing monitoring and modelling of process emissions to inform operational adjustments to reduce these where possible**: Optimising existing process operation to minimise nitrous oxide process emissions from secondary wastewater treatment processes.
- **Catchment wide optimisation using digital enablers and risk-based approaches**: Assess early opportunities and implement pilots of larger scale transformational efficiency interventions at catchment-scale using digital enablers, for water networks, water quality and wastewater/flood management. Regulators, companies, government and supply chain will need to work together to better understand the trade-offs between net zero, performance and environmental quality to incorporate in PR24 and beyond.
- **Demand management**: Accelerate water efficiency interventions and leakage management. Government-led mandatory water labelling scheme covering building regulations.
- **Upgrade to Advanced Anaerobic Digestion**: Upgrading conventionally digested sludge to advanced digested processes, which has the potential to significantly reduces process emissions and also increases biogas production.
- **Transition to biomethane**: Maximising renewable export potential of biogas by upgrading biogas to biomethane and providing green gas into gas grid and/or utilised as a green fuel to decarbonise other areas such as HGV transport.
- **Deployment of renewables** (solar, wind and hydro) to meet at least 20% of sector power demand by a combination of solar, wind and hydro renewables generation.
- **Reducing reliance on green tariffs over time**. Although an important measure in the short-term, it is recommended that the sector follows the decarbonisation to accelerate other decarbonisation interventions including renewable energy generation, or energy efficiency to be able to reduce its overall power consumption and reliance on green tariffs in the future.
- **Planning for and investing in nature-based solutions to maximise natural sequestration benefits in sector's land holdings**.

Next steps

The 2030 Net Zero Routemap has identified a number of enabling opportunities for the water companies, supply chain, regulators, government and other stakeholders to help the sector transition to net zero by 2030. These include:

- Development of individual water company action plans aligned to the sector's net zero target (these will be informed through the net zero sector guidance document).
- Begin engagement with supply chain to better understand the available innovations in the market to help tackle the most difficult emissions, such as process emissions, among others.
- Begin engagement with regulators and government to help the sector align the PR24 to net zero and other trade-offs.
- Capitalise on existing decarbonisation funding opportunities outside the current price control to focus and accelerate action targeting the most difficult or costly decarbonisation areas.
- Develop a sector level reporting net zero framework to monitor progress against the sector net zero target.
- Consider widening the scope and boundary of the sector net zero target in the future by incorporating Scope 3 emissions, post 2030.

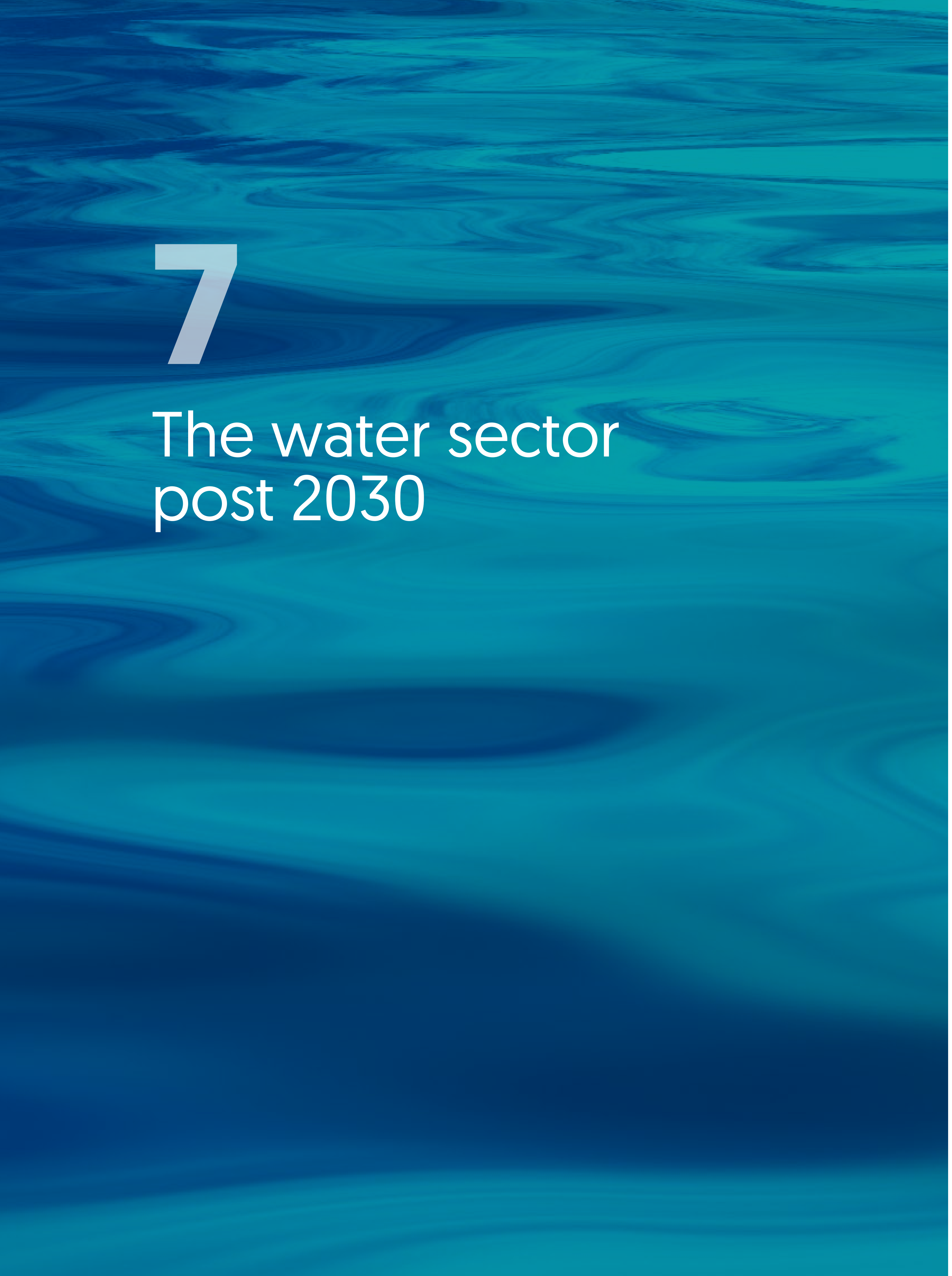
Developing net zero post 2030

The routemap has identified many technologies that could potentially assist with net zero that will not be ready for full deployment until post 2030. As such it is key that actions are taken over the next decade to prepare for and enable full deployment of these options over the subsequent 20 years.

It is important that the 2030 target date does not inhibit long term decisions, such as tree planting where the full sequestration benefits are not achieved for 20 to 40 years. As such the long-term net zero picture should be considered when companies develop their action plans.

External factors

Climate change risks are likely to affect the sector over this time period. Water companies need to assess their exposure to climate related risks and plan their mitigating actions in parallel with the development of their net zero action plans.



7 The water sector post 2030

The routemap has identified many decarbonisation interventions that have lower levels of maturity and are more likely to be ready for full implementation after 2030. These will support the water sector maintaining their net zero status post 2030 and will become more important if they increase the current net zero boundary to cover wider Scope 3 emissions. Some of these are discussed in this section.

7.1 Focus on innovation

The routemap has identified some priority areas the sector could focus on trialling and developing in AMP7 and AMP8 to bring further decarbonisation benefits above beyond those considered in the current pathways. The barriers to these additional decarbonisation areas mainly relate to lack of appropriate existing policy incentives and/or carbon accounting protocols that incentivise greater systems level considerations. Some areas for consideration are summarised below:

- **Nutrient recovery**: The sector already plays a significant role in recycling nutrients back into agricultural land through the recycling of treated sludge to land, this has a wider economic decarbonisation benefit by displacing use of chemical fertilisers. However, there is the opportunity to recover more nutrients from wastewater and sludge treatment: The recovery of phosphorous (P) from wastewater and sludge treatment is already at a commercialised stage and has been for a number of years, particularly from dewatering liquors. However, the current market price of P means it rarely justifies the increased investment in the capital infrastructure required to recover it. Companies rely on additional capital maintenance benefits, such as avoidance of struvite build up in pipework, to justify this type of investment. However, at a systems level there is likely to be a carbon value of fertiliser developed through recovered P over manufacture red alternatives using virgin P. The sector could look to engage with the agricultural sector and Defra to develop the evidence base of the true value of P for the UK, particularly as it becomes increasingly scarce globally. This could be used to drive up the market price or introduce incentives for P recovery, similar to those that have been successfully used to incentivise renewable power generation. There are already examples of a drive for greater P recovery with the new EU fertiliser directive and countries like Germany introducing legislation to require P recovery from large WwTWs.[35]
- **Co-location of hydrogen and pure oxygen aeration**: Hydrogen as a potential fuel source for the sector, for its power demand and transport is a clear opportunity for the sector. However, the water sector could also play a role in accelerating the production of hydrogen within the sector. Research in Australia[36] has shown that there are possible capital and operational benefits from co-locating the production of hydrogen on wastewater treatment sites and utilising the oxygen by-product to aerate activated sludge processes. This has shown particular benefits with MABR processes and there could also be an additional benefit to direct process emissions through this approach, which has not yet been considered. This along with the substantial potential of additional renewable power generation capacity, an excess of which could be used for green hydrogen production, could be a significant area the sector could look to explore. The sector could look to engage with the Department for Business, Energy & Industrial Strategy and other relevant stakeholders to develop a systems level strategy that maximises the co-benefits of this type of approach. This option could increase the renewables export potential of the sector by providing clean and renewable energy for the wider UK economy.

Wider emerging decarbonisation opportunities for the sector, which are not fully commercialised are summarised in section 7.2.

35. https://www.consilium.europa.eu/en/press/press-releases/2019/05/21/eu-adopts-new-rules-on-fertilisers/
36. https://www.jacobs.com/sites/default/files/2020-06/jacobs-yarra-valley-water-towards-a-zero-carbon-future.pdf

7.2 Emerging opportunities

Table 7-1 summarise a range of emerging areas for consideration by the sector that could be kept on the radar for innovation trials or as alternative approaches where the sector may have to adapt to how other sectors are progressing on their decarbonisation journeys.

Table 7-1: Summary of emerging areas that the sector may consider implementing post 2030 and by 2050

Emerging areas	Description
Biohydrogen production through AAD process	Hydrogen production during Anaerobic Digestion
Wastewater reducing power demand - alternative treatment anaerobic treatment	Alternative anaerobic treatment process
Wastewater reducing power demand - alternative treatment algal treatment approaches and use as biofuel	Use of algae for wastewater treatment and production of biofuels
Wastewater alternative treatment processes - Microvi MNE	Potentially transformative technology utilising engineered microenvironments focused on the specific microbes required for treatment processes. Could significantly reduce power consumption at existing works and reduce the need for capital footprint increases by increasing load capacity of existing processes.
Enhanced catchment management utilising digital transformation and monitoring at a catchment level	Catchment management which utilises catchment wide monitoring and digital twins to understand interactions across the whole water and wastewater network and mitigate pollutants at source to drive efficiency at a system level.
Alternative to fossil fuels - (Hydrogen generators)	As hydrogen production ramps up across the UK it could be adopted as an alternative to current fuel sources for standby generation.
Alternative heat sources for processes - sludge treatment (Alternative to using 30% of biogas for heat demand (e.g. electric blankets powered by renewables to heat and retain heat in processes)	Alternatives to utilising 30% of biogas in efficient boilers as per the transitioning to biomethane option could be reviewed. This could include electric blankets around digesters to minimise heat loss reduce power demand. Or it could be utilising other renewable heat sources, such as, ground source heat pumps. This could free up more biogas to biomethane production and further increase renewables export potential.
Alternative treatment methods- sludge treatment	Advanced thermal conversion processes could be introduced, which could increase the amount of energy recovered from sludge. They would likely only be considered at scale if agricultural land bank was restricted and volume minimisation was required alongside valuable resource recovery. Likely to be as a bolt on to AAD plants rather than replacing them, options could include: Pyrolysis Gasification Alternatively, mono-incineration of sewage sludge or with municipal wastes could be implemented.
Recovery of alternative resources to decarbonise external systems beyond 2030 net zero boundary	As the UK decarbonises and priority areas of decarbonisation potentially shift away from energy production. The recovery from methane from AAD processes may not be the most optimal value product for the sector and the UK-wide decarbonisation. This could lead to revising the set-up of AAD processes to focus on maximising recovery of other products (not all of these will be completely instead of methane), such as: Nutrient recovery (to reduce carbon intensity of fertilisers) Bioplastics (to reduce reliance of fossil fuels for virgin plastics) Low carbon materials (reducing carbon of current construction materials) Platform chemicals/VFAs (reducing carbon associated with production of current industrial chemicals) The recovery of these alternative products from renewable sources in the future could help decarbonise other UK sector with more difficult to tackle emissions.

Emerging areas	Description
Co-digestion opportunities maximised (note that these can be accounted for within 2030 net zero boundary, as long as additional emissions related to the processing of these substrates are also accounted for)	Potential substrates include: - Household waste - Industrial waste - Bio-crops
Rainwater harvesting to reduce wholesome water demand.	Targeting areas of carbon intensive water supply and introducing rainwater harvesting to reduce levels of wholesome supply and potentially reduce carbon emissions.
Rationalising treatment works to optimise energy of water supply.	Mainly consolidating smaller works to larger centralised networks, but also more local supply where it is low carbon. Very company and regional specific opportunities.
Water reuse (grey or black)	These are not typically considered lower energy or carbon, however there may be areas which are difficult to supply where this can be considered lower carbon.
Technological advances that help manage demand better - IoT and even smarter individual appliances	Digital enablers in customer appliances and other industrial processes that can help better predict and influence water use patterns.
Optimising the chemistry of WwTWs to reduce chemical emissions.	These are beyond the 2030 net zero boundary.
Coastal wetland creation/restoration (marine)	Potential additional sequestration opportunities to explore, again would require similar UK-wide accounting and carbon credit schemes to claim benefits.
'Blue carbon' (marine) stored in sea, ocean (not very much explored - emerging)	Potential additional sequestration opportunities to explore, again would require similar UK-wide accounting and carbon credit schemes to claim benefits.
CO_2 sequestration - Enhanced rock weathering… experimental	Experimental method
Small-scale carbon capture and storage (CCS) – demonstration scale	Consider smaller scale CCS technologies relevant to industrial sectors such as water. CCS is currently tested at demonstration sites in the power sector.
Direct air capture – experimental	Experimental method with potential to become viable in the future however unlikely before 2030
Low carbon concrete (altering constituents of concrete to capture CO_2) – experimental	This could be a potential alternative sequestration option, even if at a small scale, that also tackles capital carbon. Concrete mixes which can potentially sequester carbon over time being tested.

Appendices

A. Pathways supporting information

A.1 Technology-led pathway summary of interventions and carbon reduction impact

Summary of options within technology-led pathway, associated emissions reduction by 2024-25 and 2029-30

2018-19 Baseline emissions			**2.41 (MtCO2e)**
Savings achieved by BAU trajectory (excluding green tariff purchases)			**-0.73**
		Green purchased electricity	-0.116
		Emission reduction from the export of renewable energy	-0.481
Wastewater	**Grid electricity**	Wastewater reducing power demand - 01 (Typical interventions)	-0.025
		Wastewater reducing power demand - 02 (Smart control/analytics) Control or analytics upgrades	-0.020
		Wastewater reducing power demand - 03 (Next generation efficient products) High efficiency blowers and small pumps	-0.011
		Wastewater reducing power demand - alternative treatment MABR	-0.015
	Burning of fossil fuels	Alternative to fossil fuels - wastewater (Gas oil replaced by HVO)	-0.030
		Alternative to fossil fuels - wastewater (Hydrogen generators)	-
		Alternative to fossil fuels - sludge (divert 30% of biogas to boilers to provide heat demand for sludge treatment and stop natural gas to CHP plant as more power generated from other renewables and decarbonised grid.	-0.076
	Process emissions	Implement monitoring	-
		Minimising fugitive emissions Operational optimisations of current technology to minimise methane emissions from… short term storage of sludge, sludge transport etc…	-0.026
		Operational optimisations of current technology to minimise N_2O emissions from secondary treatment	-0.074
		Alternative treatment processes - anaerobic treatment/MABR/alternative ammonia removal processes	-0.026
		90% of conventionally digested sludge is upgraded to advanced digestion (THP)	-0.183
Water	**Grid electricity**	Water reducing power demand - 01 (Typical interventions)	-0.034
		Water reducing power demand - 02 (Replacing ageing equipment with modern equivalents)	-0.002
		Water reducing power demand - 04 (Smart control/analytics) Control or analytics upgrades	-0.027
	Burning of Fossil Fuels	Alternative to fossil fuels - water (Gas oil replaced by HVO)	-0.015
		Alternative to fossil fuels - water (Hydrogen generators)	-
	Process emissions	Incorporating water sludge into construction materials	-
Admin		Admin - energy management	-0.004
		Admin - energy efficiency	-0.003
		Admin - Fossil fuel alternatives	-0.007
		Admin - Onsite generation	-0.002
Transport		Transport - Efficiency (journey reduction)	-0.019
		Transport - Efficiency	-0.005
		Transport - Alternative technologies Biofuels Hydrogen EVs	-0.105
Renewables onsite (solar + wind + hydro)		CHP - Reduction in power generated from CHP	0.095
		Solar - 40%	-0.220
		Wind - 40%	-0.187
		Hydropower – dam head and run of river (mostly Archimedes' screw) – 5% total annual electricity consumption – PPA	-0.028
Natural sequestration improvements		Companies meet commitment to plant 11 million trees by 2030	-0.005
		Peatland restoration (land)	-0.024
		Grassland restoration (land)	-0.011
		Total emissions ($MtCO_2e$)	**0.10**

A.2 Demand-led pathway summary of options and carbon reduction impact

Summary of options within demand-led pathway, associated emissions reduction by 2024-25 and 2029-30

2018-19 Baseline emissions			**2.41 (MtCO2e)**
Savings achieved by BAU trajectory (excluding green tariff purchases)			**-0.73**
Wastewater	**Grid electricity**	Wastewater reducing power demand - 01 (conventional energy efficiency interventions)	-0.025
		Wastewater reducing power demand - 02 (Smart control/analytics) Control or analytics upgrades	-0.038
		Wastewater reducing power demand - 03 (Next generation efficient products) High efficiency blowers and small pumps	-0.013
		Wastewater reducing power demand - 04 (Site reorganisation to increase onsite CHP power use) Site electrical rearrangement to allow additional CHP power to be used on site rather an exported	- -0.003
		Wastewater reducing power demand - 05 (Catchment management) Catchment approaches to reduce treatment power demand	
	Burning of fossil fuels	Alternative to fossil fuels - sludge (divert 5% of biogas to boilers to provide heat demand for sludge treatment) and 85% to CHPs	-0.080
		Alternative to fossil fuels wastewater - Electric/battery powered (by CHP) standby generation to reduce need for grid imports	-0.012
	Process emissions	Implement monitoring	
		Minimising fugitive emissions Operational optimisations of current technology to minimise methane emissions from... short term storage of sludge, sludge transport etc...	-0.031
		Operational optimisations of current technology to minimise N_2O emissions from secondary treatment	-0.078
		35% of conventionally digested sludge is upgraded to advanced digestion (THP)	-0.071
Water	**Grid electricity**	Water reducing power demand - 01 (Typical interventions)	-0.034
		Water reducing power demand - 02 (Replacing ageing equipment with modern equivalents)	-0.002
		Water reducing power demand - 03 (Catchment management) Catchment approaches to reduce treatment power demand	-
		Water reducing power demand - 04 (Smart control/analytics) Control or analytics upgrades	-0.051
		Water labelling EST Scenario 2: Mandatory Government-led labelling associated with Building Regulations & minimum standards	-0.169
		Accelerated leakage reduction – million litres/day leakage reductions beyond current commitments	0.000
		Water reducing power demand - Rainwater harvesting to reduce wholesome water demand.	
	Burning of Fossil Fuels	Alternative to fossil fuels water - Electric/battery powered (by CHP) standby generation to reduce need for grid imports	-0.015
	Process emissions	Incorporating water sludge into construction materials	
Admin		Admin - energy management	-0.004
		Admin - energy efficiency	-0.003
		Admin - Fossil fuel alternatives	-0.007
		Admin - Onsite generation	-0.002
Transport		Transport - Efficiency (journey reduction)	-0.019
		Transport - Efficiency	- 0.005
Renewables generation for own demand		CHP - Reduction in power generated from CHP	0.001
		Solar - 20% of total annual electricity consumption - PPA	-0.080
		Wind - 20% of total annual electricity consumption - PPA	-0.068
Natural sequestration improvements		Companies meet commitment to plant 11 million trees by 2030	-0.005
		Peatland restoration (land)	-0.024
		Grassland restoration (land)	-0.011
		Total estimated emissions by 2029-30 (MtCO2e) required to be offset through carbon credits in the global market	**0.98**

A.3 Removal-led pathway summary of options and carbon reduction impact

Summary of options within removal-led pathway, associated emissions reduction by 2024-25 and 2029-30

2018-19 Baseline emissions			**2.41 (MtCO2e)**
Savings achieved by BAU trajectory (excluding green tariff purchases)			**-0.73**
Green purchased electricity			**-0.589**
Emission reduction from the export of renewable energy			**-0.115**
	Grid electricity	Wastewater reducing power demand - 05 (Catchment management) Catchment approaches to reduce treatment power demand	
	Burning of fossil fuels		
	Process emissions		
	Grid electricity	Water reducing power demand - 03 (Catchment management) Catchment approaches to reduce treatment power demand	-
	Burning of Fossil Fuels		
	Wastewater Process emissions		
Admin		Admin - energy management	-0.004
		Admin - energy efficiency	-0.003
		Admin - Fossil fuel alternatives	-0.007
		Admin - Onsite generation	-0.002
Transport			
Renewables generation for own demand			
Natural sequestration improvements (Insets)		Companies meet commitment to plant 11 million trees by 2030	-0.005
		Peatland restoration (land) 10,000ha	-0.048
		Grassland restoration (land) 10,000ha	-0.022
		Planting of 22 million trees	-0.010
Natural sequestration improvements (Offsets)		Grassland restoration equivalent to 1% of UK degraded peatland (land)	-0.091
		Peatland restoration equivalent to 1% of UK degraded grassland (land)	-0.013
		Total estimated emissions by 2029-30 ($MtCO_2e$)	**1.37**

B. Key definitions

Net Zero: The UK Government has defined 'net zero carbon' as the 'means any emissions would be balanced by schemes to offset an equivalent amount of GHGs from the atmosphere, such as planting trees or using technology like carbon capture and storage'. This is in the context of the UK territorial boundary and emissions from human activity. There is no current official definition of net zero carbon at economic sector level in the UK so there is some flexibility on what territorial boundaries to include.

Considering the above, a 'net zero carbon' water industry in England may not necessarily imply that any offsets are within the territorial boundary of the water companies as it may be most economical (from a UK perspective) to consider any offsets in the wider UK territorial boundary, or even global offsets as a last resort.

Scope: The emissions to be included within the GHG emissions total figure which will then require reducing, renewables use and offsetting to reach net zero.

Boundary: The organisational boundary within which the emissions in scope must be included in the GHG total.

Emissions reduction hierarchy: The best practice order in which to conduct interventions that will lead to net zero, starting with emissions reductions, followed by renewables, and final offsets. This is to encourage interventions with additional benefits, such as cost saving or revenue generation for the company first, and then using offsets for unavoidable emissions.

Emissions reduction: interventions that avoid gross GHG emissions through operational practices, new technologies, etc in own water and wastewater assets.

Offsets: As per PAS 2060. Discrete reduction in GHG emissions not arising from the defined subject, made available in the form of a carbon credit meeting the requirements of 9.1.2 and used to counteract emissions from the defined subject. NOTE: Carbon offsets are acquired to compensate for GHG emissions arising from a defined subject. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project that generates the offsets. A carbon credit is a generic term to assign a value to the carbon offset. One carbon credit is usually equivalent to one tonne of CO_2.

GHG removal interventions, that are implemented outside the water sector's own boundary and that are made available in the form of a carbon credit. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project/measure that generates offsets. Offset calculations need to meet the requirements of PAS 2060 and/or internationally recognised standards. Note: Carbon offsets can be achieved through natural methods (natural sequestration) or engineering interventions (e.g. technology enabled GHG sequestration such as carbon capture and storage (CCS) in the power sector).

Insets: interventions/projects that remove GHG emissions and that are implemented in the water sector's own boundary or sphere of influence. Carbon insets may not require to be available in the form of carbon credits however any calculations need to follow the same approach as offsets. Note: Carbon inset interventions/projects can be achieved through natural methods (natural sequestration) or engineering interventions (e.g. technology-enabled GHG sequestration such as CCS in the power sector).

Carbon sequestration: Carbon sequestration describes long-term storage of CO_2 or other forms of carbon to mitigate or defer global warming and avoid dangerous climate change. This can be by natural means, such as tree planting, or engineered means.

C. Net zero routemap and net zero guidance document

The table below gives an overview of the content of the net zero routemap and guidance document and their purpose.

Net zero routemap and net zero sector guidance document overview

	Net zero routemap	Net zero sector guidance document
Purpose	To communicate the progress the water sector has made on carbon management and how the water sector can achieve Net Zero by 2030. The purpose is to also communicate key enablers needed for this (internal and external to the water sector). This will support the sector with any net zero discussions with policy makers, national and international climate communities and other external stakeholders	To provide guidance for the water companies on relevant considerations for developing their action plans Outline available tools and methodologies for companies to help plan for and implement Net zero in their organisation. Provide detailed narratives and assumptions behind each decarbonisation option and selective case studies. Focus is how water companies should assess such options in their own company
Content	Introduction and scene setting Where we started from – sector baseline Looking ahead to 2030 – the approach, sector business as usual trajectory and sector pathways Low regrets actions for a net zero 2030 water sector Next steps for Water companies The water sector post 2030 Conclusions	Introduction and scene setting Where you started from – company baseline Looking ahead to 2030 – the approach and developing a company business as usual trajectory Decarbonisation interventions – detail on these and how to assess them Developing company pathways Developing a company action plan – including actions and enablers for companies to address Monitoring progress

D. Non-cost criteria for decarbonisation option assessment

Non-cost criteria developed for the options assessment

Decarbonisation option non-cost criteria

Non-cost criteria	Description
Co-benefits	The benefits of the option beyond carbon savings were assessed. This was done to assist in the prioritisation of interventions.
Technical feasibility and futureproofing	The options' technical feasibility, constraints and considerations were assessed. This informed enabling actions for the options and their deployment rates. Options were checked for their alignment to the wider UK route to net zero, including the Climate Change Committee net zero report, to ensure they would be futureproof. The options were also checked to see where they were mutually exclusive or co-dependent on other options so they were appropriately combined in the pathways.
Customer acceptability	The customer acceptability of the options of the options was assessed. This was done to assist in the prioritisation of interventions.
Regulatory requirements and incentives	The regulatory requirements and incentives associated with the options were assessed, along with how the options are perceived. This was done to assist prioritisation of the interventions, identify enablers and to inform deployment rates.
Maturity of technology for 2030	The options maturity for 2030 was assessed to inform the deployment rates that could be expected pre-2030 and the enabling actions required for wide scale deployment.
Deployment rate	The expected deployment rates of the options were assessed, drawing on the other non-cost criteria. These were used when developing the pathways.

E. Water sector interdependencies with wider systems

The links to other infrastructure sectors and the built environment and key interdependencies (relevant to carbon reduction opportunities in the wider system such as waste heat, biomethane, etc) are discussed in the table below.

The primary linkages are areas where activities can be undertaken to decrease water demand or to decrease water treatment. There are wider interventions being taken to encourage water efficiency as part of the governments net zero plan, such as white good labelling, building regulations and encouraging an increased use of greywater. This is being encouraged by companies through means such as the 'Why not water' campaign. Catchment management is key for water companies in limiting treatment requirements of their incoming water, though for many companies this is only able to limit further treatment requirements and avoiding further emissions rather than getting savings.

Secondary linkages are areas where activities will facilitate the water sector in decarbonising. The wider government actions relating to this area include incentives for renewables, biogas and biomethane, encouragement of district heating, electrification of transport and grid decarbonisation.

Links to other infrastructure sectors and built environment

Sector	Link to water sector and key interdependencies
Construction and housing	Increasing the use of grey water and rainwater decreases water demand and the emissions associated with its supply. Some water companies think there could be as much as a 50% reduction in their treated water demand from greywater and rainwater use. This is cheaper to implement in new builds although can be retrofitted.
White good manufacturing	Making white goods more water efficient reduces treated water demand. This would be encouraged by white good labelling.
Agriculture	Working with farmers on better ways to spray chemicals and chemical alternatives improves water quality and so limits the requirement for treatment.
Local authorities	Local authorities can encourage water efficiency and grey and rainwater reuse through interventions such as planning regulations. They can also support decarbonisation interventions by providing favourable planning regulation and encouraging enabling technologies such as district heating systems which can facilitate the use of waste heat. The enactment of the floods and water management act removes developers right to connect surface water to sewers which will reduce carbon pressure on the sector.
Power	As the grid decarbonises this decreases the emissions associated with the water sectors electricity consumption. The water sector will potentially benefit from any developments that make renewable energy easier/cheaper to implement such as technology improvements and commercial framework developments. The development of storage technologies will better enable the water sector to meet a great portion of its demand from a smaller renewable capacity. The water sector will also potentially benefit from the development of hydrogen technologies – as an option for hard-to-treat emission areas, such as HGVs, or as a potential resource to produce and use to increase self-sufficiency or to export to reduce net emissions.
Transport	The availability of electric and other low carbon modes of transport and associated charging/refuelling infrastructure affects the water sector's ability to decarbonise its transport fleet.
Chemicals	A reduction in the emissions associated with chemical generation will reduce the water sector's emissions from chemical production.

Water UK is the representative body and policy organisation for water companies across the UK. Together, our members provide drinking water to nearly 64 million people every day.

The Net Zero 2030 Routemap has been developed as part of our Public Interest Commitment, which included a pledge by English water companies to achieve net zero carbon emissions by 2030.

Supported by Anglian Water, Northumbrian Water and Yorkshire Water, it has been developed in partnership with leading experts at Ricardo and Mott MacDonald under the guidance of a sector-wide Net Zero Steering Group. We have also consulted with a large number of external stakeholders and are grateful for the extensive comments, advice, insights and constructive challenge from the many individuals that have provided their time.

www.water.org.uk/Routemap2030