Strategic Regional Water Resource Solutions: Annex A3.2: STT Carbon Strategy Report

Standard Gate Two Submission for River Severn to River Thames Transfer (STT)

Date: November 2022

Severn to Thames Transfer

STT Carbon Strategy Report

STT-G2-S3-360

November 2022

Disclaimer

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STT Carbon Report

Document no: STT-G2-S3-358

Executive summary

This report presents a whole life carbon (WLC) emissions and cost assessment for the River Severn to Thames Transfer Strategic Regional Water Resource Option (SRO) and recommends approaches to mitigate capital and operational GHG emissions. The mass in tonnes of carbon dioxide equivalent (tCO_2e) emissions were analysed for the following STT Gate 2 solutions:

- ☐ Deerhurst to Culham Interconnector
- ☐ River Vyrnwy Bypass Pipeline
- ☐ Shrewsbury Redeployment

Capital emissions have been identified as the largest single source of emissions across two out of the three schemes, as highlighted in Table S-1 below. Sources of these emissions include concrete pipelines, valves, and concrete tanks. The breakdown of the main contributors to tCO_2e emissions for each of the schemes and sub-options was also analysed.

Table S-1 Whole Life Carbon Summary Table for the three schemes

Gate 2	Options	Capital carbon (tCO_2e)	Operational carbon (tCO_2e)	WLC Cost (M£/tCO_2e)
Pipeline Interconnector Deerhurst to Culham	300 Ml/d	243,191	139,258	81.5
	400 Ml/d	292,331	185,555	101
	500 Ml/d	325,863	231,634	116
River Vyrnwy Bypass Pipeline	105 Ml/d (25A)	6,398	20.6	1.63
	180 Ml/d (25B)	8,919	20.6	2.23
	180 Ml/d (27A)	16,390	28.5	4.19
	205 Ml/d (27B)	16,390	28.5	4.19
Shrewsbury Redeployment	-	171	18,767	10.7

Principles from PAS 2080 have been applied where possible for each scheme to identify mitigation options, providing a common understanding and consistent approach for managing WLC across the value chain. The carbon mitigation strategy has focussed efforts has prioritised efforts to reduce emissions during Gate 2 on areas where the largest and most efficient reductions can be made. The feasibility of each carbon mitigation approach has been analysed to ensure alignment with both the Water UK Net Zero 2030 Routemap, and the three water utility companies' energy and climate policies. WLC mitigation approaches were recommended for the following areas:

- ☐ Engineering Design and Capital Emissions
- ☐ Construction Emissions
- ☐ Operational Emissions
- ☐ Transport Emissions
- ☐ Power Consumption Emissions
- ☐ Resource Efficiency
- ☐ Offsetting and Insetting

To maximise alignment with PAS 2080 and the Water UK Net Zero 2030 Routemap, it is recommended to follow the emissions hierarchy when deciding which approach to prioritise to mitigate emissions. This prioritises in order demand reduction, efficiency gains and renewable energy integration before pursuing offsets to remove residual carbon emissions. Due to the complexity and long lifetime of the scheme, it is important to take a holistic approach to carbon mitigation.

A robust assessment of WLC emissions is recommended as the scheme progresses within the Gated process, with a detailed opportunity cost analysis to identify which interventions would allow the greatest reduction in emissions for the lowest cost. This report provides a high-level inclusion of the possible range of interventions, but further analysis is required to select those most appropriate for the chosen scheme.

At this design stage, there is still sufficient optioneering time to 'design out' capital carbon. Capital emissions represent the majority share of total carbon emissions in the short term - as such, focusing on reducing capital emissions will likely yield significant reductions across the early stage of a site's operational life. This can be achieved through close engagement with carbon subject matter experts (SMEs) at the design and procurement stages. However, the scheme also acknowledges the significant opportunity to work with the supply chain prior to the delivery of the scheme to support accelerated decarbonisation of external systems and supply chains to help reduce the carbon impact of the scheme.

Table S-2 summarises the recommended carbon mitigation approaches, providing a high-level ranking of their potential impact on emissions reduction and alignment with the emissions hierarchy.

Table S-2 Summary and ranking of carbon emissions reduction approaches

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for Emissions reduction	Ability to Influence	List of options
Energy management & efficiency (highest priority)	Emissions reduction	High	High	- Improved pump efficiency - Metering - Smart control systems - Catchment level analytics
Renewable energy on site	Renewable energy	High	High	- Solar - Wind - Storage
Procured Renewable Energy	Renewable energy	High	High	- Sleeved PPA - Synthetic PPA - Private Wire PPA - REGO-backed Green tariffs
Resource Efficiency and Chemical Supply	Emissions reduction	High	Low	- Supply chain contracts - Reduce resource use
Capital emissions reduction	Emissions reduction	Moderate	High	- Low carbon concrete - Low carbon steel - Recycled materials - Locally sourced materials
Engineering design	Emissions reduction	Moderate	Moderate	- Conveyance routes - Pipeline size - Land use
Construction emissions	Emissions reduction	Low	Moderate	- Reduced transport - Vehicle energy use - Renewable onsite power
Insets	Offset	Low	Moderate	- Peatland restoration - Grassland restoration - Tree planting
Offsets (lowest priority)	Offset	Low	High	- UK ETS - Voluntary Offset Markets

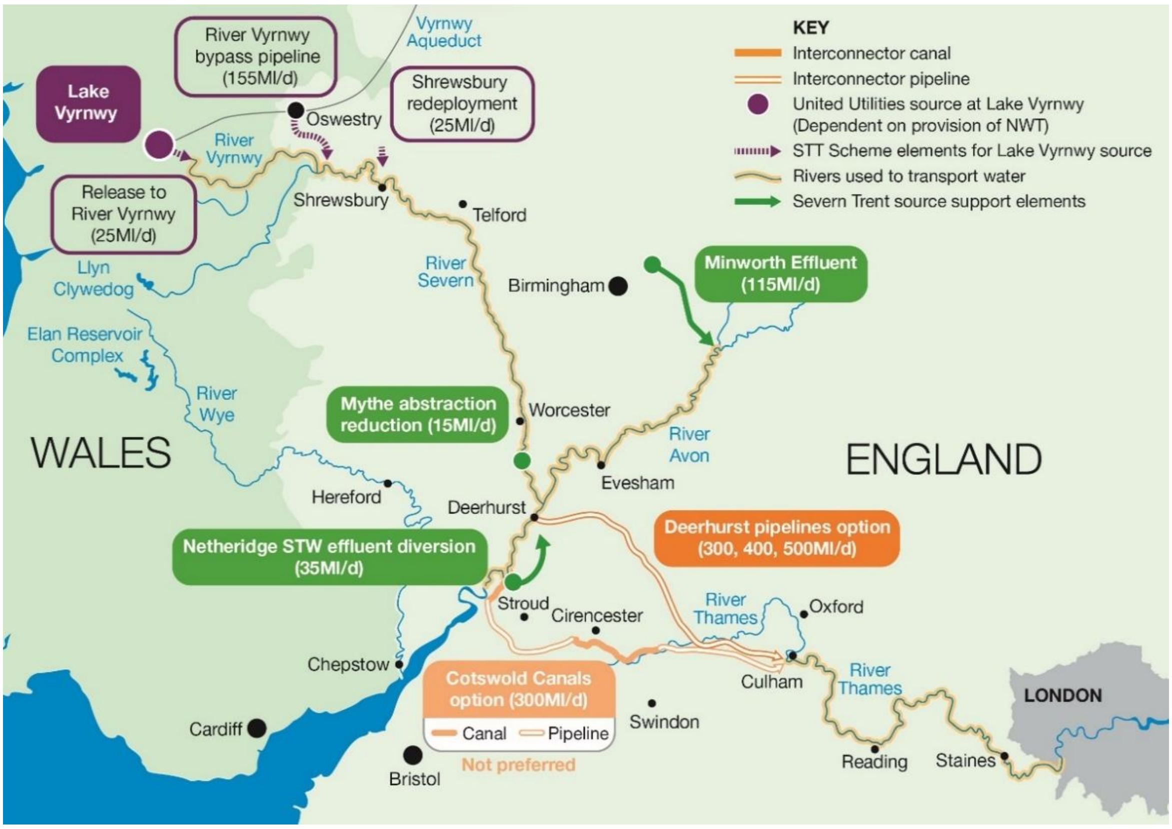
Contents

1 Introduction

1.1 Background and Purpose of Report

The River Severn to Thames Transfer (STT) Strategic Resource Option (SRO) aims to provide additional capacity of 300 to 500 Ml/d of raw water to the Southeast of England during drought events as part of the STT system. The scope of the scheme includes an Interconnector from Deerhurst to Culham which enables the transfer of raw water from the River Severn to the River Thames, and additional mitigation works associated with the release of water from Lake Vyrnwy, including the River Vyrnwy Bypass Pipeline and the Shrewsbury Redeployment.

Figure 1-1-1 STT system overview



These elements of the STT scheme are jointly promoted by Severn Trent Water, United Utilities and Thames Water. The SRO is managed through the Regulators' Alliance for Progressing Infrastructure Development (RAPID) gated process. In line with the UK water sector's commitment to net zero operational greenhouse gas (GHG) by 2030, and to contribute to Gate 2, the conceptual designs for each scheme have been further developed, providing estimated costs and the associated GHG emissions to reduce risk and uncertainty.

The purpose of this report is to provide a high-level analysis of the whole life carbon (WLC) emissions for the STT scheme, through the different components, and to recommend GHG mitigation approaches for the following areas:

- ☐ Engineering Design and Capital Emissions
- ☐ Construction Emissions
- ☐ Operational Emissions
- ☐ Resource Efficiency
- ☐ Offsetting and Insetting

2 Policy Background and Assessment Approach

2.1 Ofwat's Net Zero Principles Position Paper

As the water services regulation authority, responsible for economic regulation of the privatised water and sewerage industry in England, Ofwat have recently committed to strengthening the sector's approach to climate change mitigation and adaptation, whilst building on the companies' previous Public Interest Commitment (PIC) to achieving net zero (GHG) emissions by 2030. Within their position paper Ofwat outline three key areas that are crucial for the water sector to achieving net zero:

Expecting companies' plans to align with national government net zero targets.

Action on net zero should address operational and embodied GHG emissions in parallel.

Companies need to prioritise the reduction of GHG emissions before the use of offsets as set out in the GHG Management Hierarchy.

Ofwat have outlined their expectations for water utility companies to reduce both their operational and embodied emissions by 2030 for the following reasons:

Both operational and embodied GHG emissions must be reduced for government net zero targets to be achieved.

Requiring action on both types of GHG emissions will help to ensure one source of emissions is not acted and reported on to the detriment of the wider environment and future generations.

A parallel approach to reducing both operational and embodied GHG emissions will help to safeguard against decisions being taken in isolation such that operational emissions are prioritised ahead of action on embodied GHG emissions risking the unnecessary early replacement of assets to reduce operational emissions.

Innovation and cost savings can be maximised with solutions which address both sources of emissions.

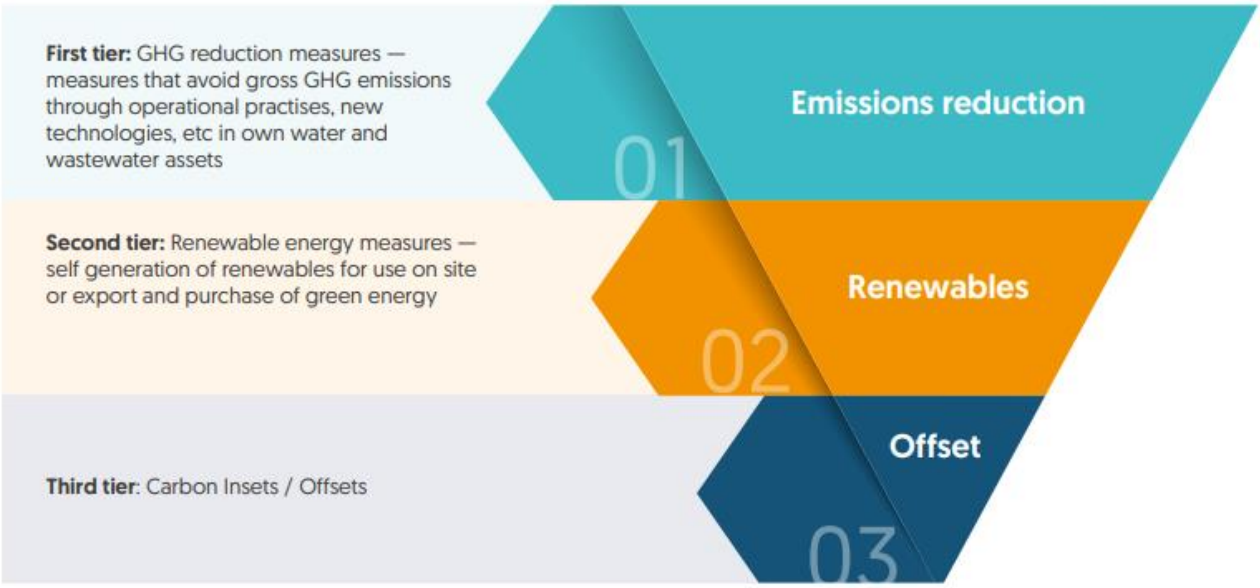
2.2 Water UK Net Zero 2030 Routemap

In April 2019, UK water companies agreed to a Public Interest Commitment, which included committing to achieve net zero operational carbon[1] for the sector by 2030. The Net Zero Routemap was produced to provide strategic guidance and options to decarbonise the sector. A baseline was established from historical emissions, finding that the main source of operational emissions was from power use, primarily using grid-based electricity. This was followed by process emissions, predominantly methane (CH_4) and nitrous oxide (N_2O) from wastewater and sludge treatment processes.

The Routemap analysed three 'pathways' to illustrate how effective different approaches to net zero could be in the context of future market forces, supply chains, policy and the availability of funding. These were created to align with the emissions reduction hierarchy, which is a means of prioritising decarbonisation interventions by encouraging tangible emissions reductions before pursuing renewable technology or offsets. This is detailed in Figure 2-1 below:

[1] 'GHG and carbon emissions can be used interchangeably, incorporating all six GHGs (CO_2, CH_4, N_2O, HFC, PCF, SF_6).

Figure 2-1 Emissions reduction hierarchy[2]



A summary of each pathway is detailed below:

- ☐ Demand led – decarbonisation focused on the application of energy efficiency and demand reduction. Renewables and other technologies are applied at a lower scale, followed by offsets.
- ☐ Technology led – assumed the acceleration of technological innovations, with large investments in renewables, process technologies and sustainable transport systems, targeting decarbonisation in the largest emissions contributing areas.
- ☐ Removals led – low adoption of emissions reduction and renewable technologies, leading to the need for natural sequestration solutions: insets, offsets and purchased offsets. This pathway focuses on natural sequestrations within water companies' own land and UK territory.

Due to the high proportion of operational emissions coming from the use of grid-based electricity and from process emissions, the routemap identified the technology led pathway as having the highest percentage reduction against the baseline before requiring offsets. However, this comes at the highest cost, requiring investment in innovation planning, technology acceleration and business case development. The removals led pathway was the least effective option, requiring significant effort by the sector to accelerate natural sequestration solutions without achieving a benefit until after 2030. There was also uncertainty around savings from peatland restoration towards 2050, as climate change poses a risk to their ability to sequester carbon, despite having significant savings in the short term. Overall, the routemap highlights the need for a holistic approach to net zero, which prioritises technology and demand reduction, with removals being used only to offset the hardest-to-abate areas in the water sector.

2.3 Thames Water Climate Change and Energy Policy

In line with the Water UK strategy, Thames Water aims to reach net zero operational carbon by 2030[3]. An energy strategy and climate change policy have been developed to describe their approach, goals and responsibilities in meeting this target.

Energy management objectives are summarised below:

- ☐ Use less energy
- ☐ Make more energy

[2] Water UK 2030 Routemap

[3] Thames Water Climate Change Adaptation Summary

- ☐ Pay less for energy
- ☐ Enhance resilience
- ☐ Ensure compliance

The approach to manage emissions is as follows:

- ☐ Calculate and report GHG emissions
- ☐ Go beyond net zero operational carbon by 2040
- ☐ Delivery energy efficient solutions across all activities
- ☐ Use at least 517 GWh renewable energy by 2025
- ☐ Reduced capital carbon emissions by 25% compared with AMP6

As part of Thames Water's progress to meeting this target, 311GWh of electricity were self-generated in 2022, covering 23% of their own electricity needs. Heat recovery and energy efficiency initiatives have been implemented, as well as buying certified renewable energy.

2.4 Severn Trent Climate Change and Energy Policy

Severn Trent Water have developed a Net Zero Transition Plan to deliver against the net zero emissions commitment by 2030[4]. They have identified that sooner, and more effective actions are the key to making cost effective decisions in relation to the climate crisis.

They have identified three paths for mitigating carbon emissions:

- ☐ Reducing demand
- ☐ Increasing on-site renewable technologies
- ☐ Removing carbon from the atmosphere through natural solutions

Their priorities and performance so far include:

- ☐ 46% reduction in scope 1 & 2 emissions by 2031, currently at 25%
- ☐ Use 100% renewables by 2030, currently at 85%
- ☐ Encourage 70% of suppliers to set science-based targets
- ☐ Increasing on-site renewable technologies
- ☐ 100% electric vehicle fleet where available by 2030
- ☐ Removing carbon emissions on site through novel technologies
- ☐ Trialling the conversion of sludge to fertiliser (S2F)

Severn Trent Water are on track to meet their commitments, through baseline assessments, demand reduction, replacing inefficient carbon intensive fuels, investing in technological solutions and purchasing green energy arrangements.

2.5 United Utilities Climate Change and Energy Policy

United Utilities have committed to achieve net zero by 2030 in light with the PIC, with six pledges to reduce their carbon footprint[5] as part of a wider climate change mitigation strategy. These pledges include:

- ☐ Meeting science-based targets for scope 1 and 2
- ☐ 100% renewable electricity by 2021
- ☐ 100% electric vehicle fleet by 2028
- ☐ 1,000 ha peatland restoration by 2030
- ☐ 550 ha woodland creation by 2030
- ☐ Set science-based target for scope 3 in 2021

United Utilities have demonstrated their commitment so far through a variety of actions:

- ☐ Reduced emissions over 70% since 2005/6

[4] Severn Trent Sustainability Report 2022

[5] United Utilities Climate Change Mitigation Strategy

- ☐ Generated equivalent of 205 GWh of renewable electricity in 2021
- ☐ Now 100% of their demand is met by renewable technologies
- ☐ Trialling alternate fuels in their treatment facilities
- ☐ Working with suppliers and sub-contractors to encourage decarbonisation

United Utilities have pledged to continually explore new technological solutions and encourage faster change in the wider industry.

2.6 PAS 2080 Framework

PAS 2080 was developed to provide a common framework to manage WLC emissions for organisations involved in delivering infrastructure projects and can be broadly applied to a range of different capital projects. The framework focuses on collaboration between all parties across the value chain and emphasises the need for strong leadership and robust governance systems to effectively mitigate carbon. The following outlines at a high-level the processes of managing and influencing carbon emissions throughout the life cycle of infrastructure projects:

- ☐ Determine an emissions baseline against which to assess carbon reduction performance
- ☐ Set appropriate carbon reduction targets
- ☐ Establish metrics for credible carbon emissions quantification and reporting
- ☐ Select an appropriate method to quantify carbon emissions
- ☐ Report emissions at appropriate stages in infrastructure
- ☐ Continually improve carbon management and performance

To claim conformity to PAS 2080, value chain members must be able to demonstrate relevant organisational capability appropriate the to the point(s) of infrastructure delivery at which they are involved.

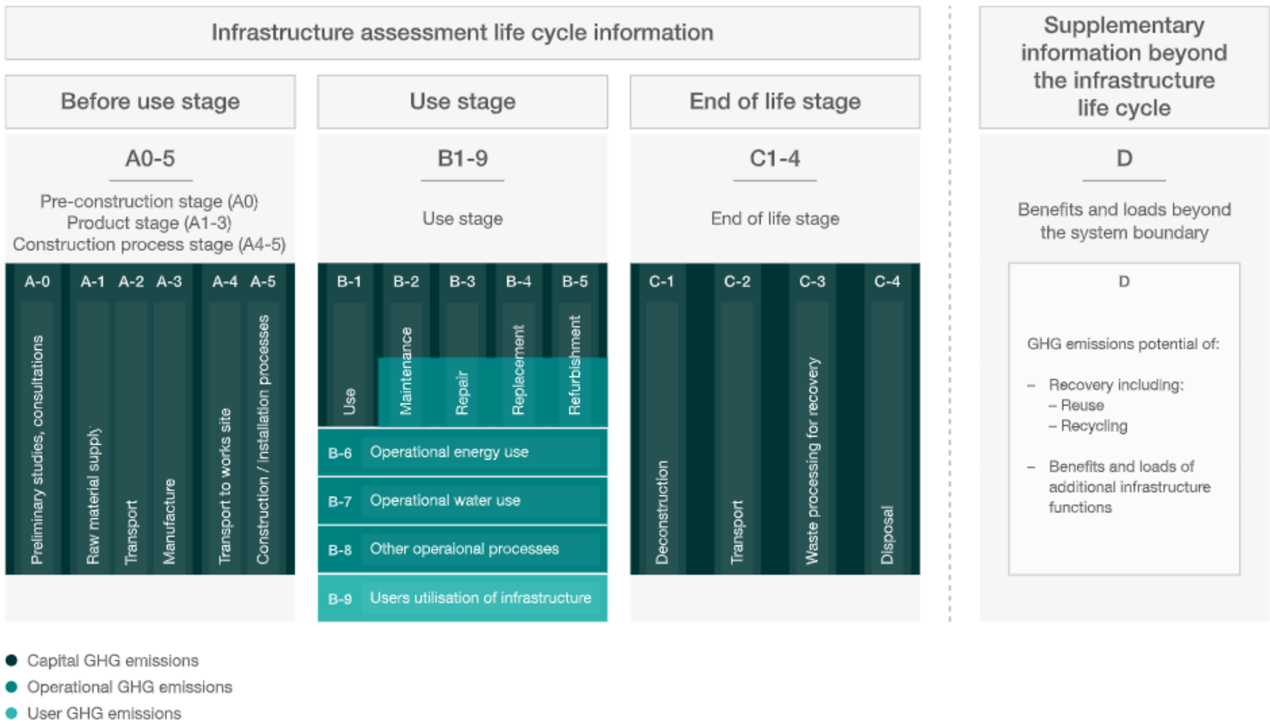
2.6.1 Carbon Management Process and Boundary Definitions

PAS 2080 approaches the quantification of the WLC emissions by breaking down emissions into discreet definable boundaries across the life cycle of infrastructure schemes, defined by three stages of the asset's lifecycle. The "before use" stage, which constitutes the construction phase, the "use stage" and the 'end of life' stage which typically involves the decommissioning of assets, with each stage then being broken down further.

Figure 2-2 shows the boundaries of each of the 3 stages. Capital, pre-construction, and construction emissions fall under the 'before use' stage, while operational emissions are covered in the 'use' stage. The 'end of life' stage considers deconstruction, transport, processing and disposal associated with decommissioning infrastructure.

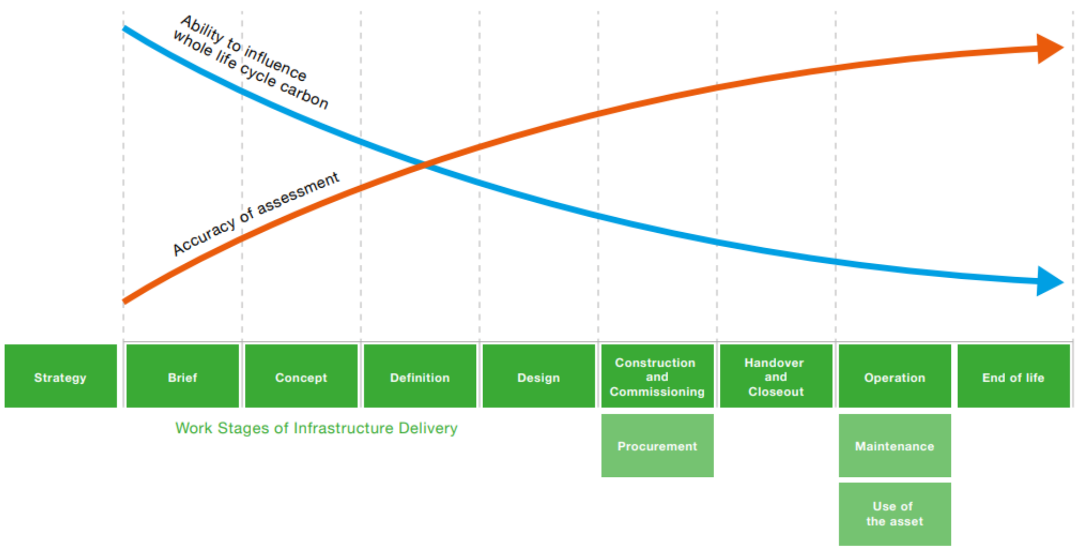
These boundaries enable ease of calculation and reporting of emissions sources, while also allowing for a clear comparison of emissions to be made between industries and projects. For the WLC assessment of the STT, "before use" and "use stage" were considered, taking into consideration capital carbon (carbon (including considerations for expected capital replacement) and operational carbon emissions for the life cycle of the scheme. The term capital carbon is used in this WLC assessment instead of embodied carbon, as recommended by PAS 2080, as it accords with the concept of capital cost. Embodied carbon is mostly used at a product or material level, while capital carbon have greater relevance at an asset level, related to the GHG emissions associated with the creation, refurbishment and end of life treatment of an asset.

Figure 2-2 Life Cycle Stages for Infrastructure GHG Emissions Quantification[6]



The work stages of infrastructure delivery against the ability to influence carbon emissions are shown in Figure 2-3. This highlights the importance of taking early action to reduce carbon emissions, as despite a lower accuracy of assessment, the ability to influence WLC is greatest at earlier stages.

Figure 2-3 Ability to Influence Carbon Reduction across Work Stages of Infrastructure Delivery[7]



[6] BSI - PAS 2080 Carbon Management in Infrastructure Verification
[7] PAS 2080 Guidance Document

2.6.2 Application to the STT SRO scheme

The carbon management process and quantification of WLC emissions and mitigation options are of particular relevance to the STT SRO scheme, as detailed in the STT Gate 2 Guidance. The STT has followed PAS2080 principles in its carbon management approach. While all stages should be considered for full alignment with PAS 2080 framework, the scope of analysis and mitigation planning that can be reasonably carried out at Gate 2 is limited to the before use' and 'use' stages. The 'end of life' stage is considered out of scope of the purpose of this analysis. Due to the long lifetime of each scheme (>80 years), estimation of the potential impact of decommissioning is not considered as it's expected that the systems in place to re-use, recycle or dispose of these assets will be substantially different in approach to and carbon intensity to what they are currently.

The carbon mitigation strategy has focussed efforts has prioritised efforts to reduce emissions during Gate 2 on areas where the largest and most efficient reductions can be made. This has been informed through updating the baseline quantification with the latest design information for the scheme to identify the key capital and operational carbon hotspots for the scheme. The STT also acknowledges that a significant proportion of its emissions in construction and operation are considered Scope 3 emissions and outside of the direct control of the companies and designers delivering the scheme. However, the scheme also acknowledges the significant opportunity to work with the supply chain prior to the delivery of the scheme to support accelerated decarbonisation of external systems and supply chains to help reduce the carbon impact of the scheme.

The mitigation efforts have been split into two areas:

- Opportunities directly under the control of the design team, including areas which can reduce emissions through design decisions that can be embedded and costed into the scheme.

- Longer term opportunities where the scheme and sector can influence external systems and supply chains to decarbonise major components of the scheme. These longer-term mitigation opportunities have been covered by a collaborative project commissioned by the All Company Working Group (ACWG) which has identified a consistent view across SROs how these external systems may decarbonise in the future to inform future decarbonisation potential and engagement priorities for individual SROs.

STT has already undertaken assessment of carbon contributions and opportunities for net zero at the RAPID Gate 1 stage which resulted in identifying the options with the highest carbon footprints. For RAPID Gate 2, the following has been conducted:

- ☐ Develop overall evidence-based carbon reduction strategy
- ☐ Define carbon management principles for design
- ☐ Carbon design challenge workshop
- ☐ Determine mitigation measures (post design) and cost
- ☐ Allocation of costs of carbon reduction and align with procurement model
- ☐ Develop carbon mitigation plan for RAPID Gate 3 and beyond

3 Overview of Scheme

The STT Gate 2 solution offered an ambitious, scalable, drought-resilient strategic option to increase water security and reduce the effects of periodic droughts via an interconnector to transfer treated water from the River Sever to the River Thames (Deerhurst to Culham), mitigation works associated with the release of water from Lake Vyrnwy (River Vyrnwy Bypass Pipeline), and the Shrewsbury Redeployment. Each scheme has different sub-options based on conveyancing, as detailed in Table 3-1 below.

Table 3-1 Project Overview – STT SRO

Scheme	Description of Scheme		Flow (Ml/d)
Pipeline interconnector Deerhurst to Culham	Pipeline and associated infrastructure (including pump station, treatment plant, break pressure tank) with three design capacity to convey river water from River Severn to River Thames		300 Ml/d
			400 Ml/d
			500 Ml/d
Vyrnwy mitigation: River Vyrnwy Bypass Pipeline	Pipeline from the Raw Water Vyrnwy Aqueduct to the lower River Vyrnwy.	Route 25 – 10.3 km	105 Ml/d (25A)
			180 Ml/d (25B)
		Route 27 – 16.5 km	180 Ml/d (27A)
			205 Ml/d (27B)
Vyrnwy mitigation: Shrewsbury Redeployment	Shrewsbury Redeployment is facilitated by a supply from Oswestry. This allows the reduction of the intake at Shelton WTW of 25Ml/d. This mitigation allows the reduction in the size of the River Vyrnwy Bypass Pipeline by 25Ml/d.		25 Ml/d

3.1 Key Design features of the Interconnector

The interconnector is the infrastructure required to transfer unsupported flow from the River Severn to the River Thames when there is a need and flow in the River Severn is above the hands-off flow. Then the flow in the River Severn is insufficient then a put and take arrangement would operate whereby water from the other source elements would be put into the River Severn, and then taken out at the point of the interconnector. A pipeline between Deerhurst and Culham has been selected and three different pipeline sizing options were investigated, with the 300Ml/d pipeline being chosen as the lowest capital carbon option. Table 3-2 below demonstrates key design features for the Option 300 Ml/d for each component within the STT interconnector.

Table 3-2 Key Design features of Interconnector Gate 2 Solution

STT Interconnector Component	300 Ml/d	400 Ml/d	500 Ml/d
River Intake	Two stage screening with bar and band screens		
	10 duty/ 2 standby	14 duty/ 2 standby	16 duty/ 2 standby
Low Lift PS (installed power)	4 duty/ 1 standby		
	956kW	1.34 MW	1.82 MW
	Outline surge analysis carried out and surge vessels sized for all scenarios		
Raw Water Pipeline	Inlet gravity pipe: Length = 365m		
	Rising main to WTW: Length = 1.1km		
	Inlet and delivery pipe diameters: Twin 1200mm pipe	Inlet and delivery pipe diameters: Twin 1300mm pipe	Inlet and delivery pipe diameters: Twin 1400mm pipe
Water Treatment Works	Treatment train unchanged. Unit processes re-sized based on water quality sampling data and INNS monitoring		
High lift PS (installed power)	5/1 standby configuration	6/1 standby configuration	7/1 standby configuration
	14.7MW	18.9MW	22.8MW
	Outline surge analysis carried out and surge vessels sized for all scenarios		

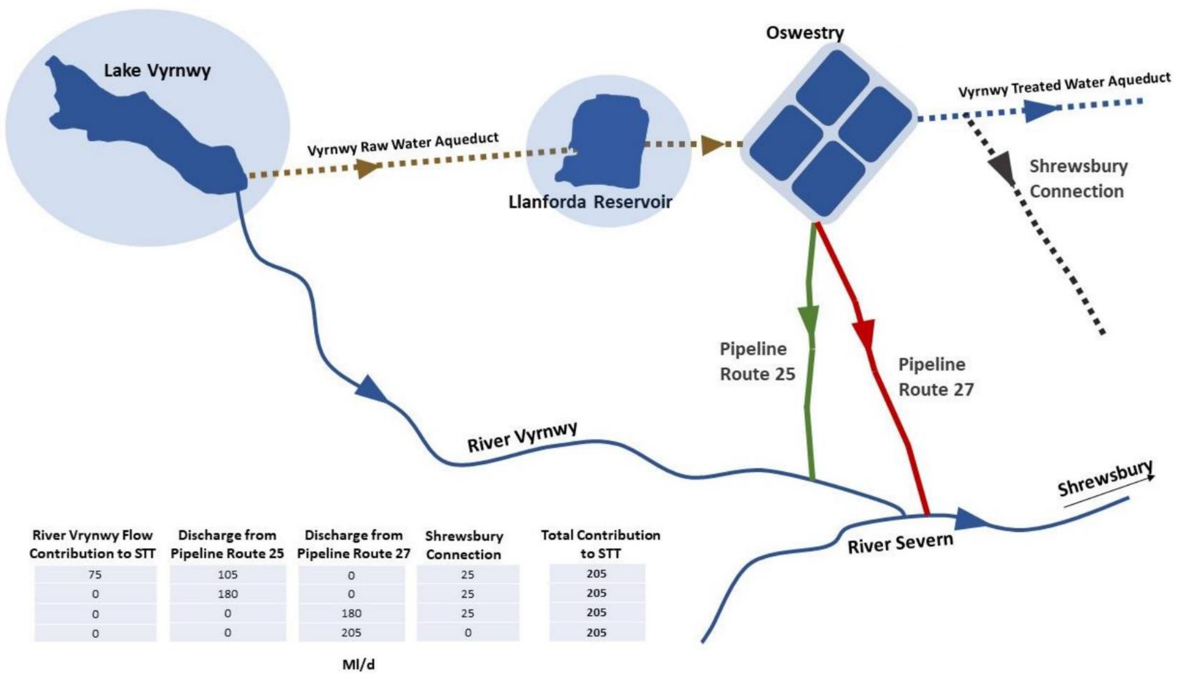
STT Interconnector Component	300 Ml/d	400 Ml/d	500 Ml/d
Transfer pipeline rising main	Length: 21.5km		
	1500mm diameter	1700mm diameter	1900mm diameter
Break Pressure tank	Single cell BPT provided. Sized as part of surge modelling, on basis of PSV stroke closure of 800s		
	Operating depth = 10m		
	V-1,440m^3	V-1,960m^3	V-2,560m^3
Transfer pipeline gravity main	Length: 65 km		
	1500/1400/1300mm diameter	1700/1600/1500mm diameter	1800/1700/1600mm diameter
Outfall Structure	Aeration cascade with actuated valve (dry inlet)		

The interconnector has inbuilt operational complexities as it involves pumping, treatment, and the retention (within the piped elements) of significant volumes of water. Therefore, to ensure the assets are kept in good working order and that the water quality does not deteriorate, it will need to keep moving. Therefore, a minimum base flow will be required throughout its operating life and this flow is referred to as the sweetening flow. The interconnector crosses the Severn Trent Water and Thames Water areas of supply and is for benefit of water companies and customers in the Southeast.

3.1.1 Key Design Features of River Vyrnwy Bypass Pipeline

The River Vyrnwy Bypass pipeline is a mitigation measure to the River Vyrnwy from the Vyrnwy release source support element. The pipeline has the capacity to convey up to 155Ml/d and is linked to the Shrewsbury Redeployment. The pipeline will go from the Raw Water Vyrnwy Aqueduct to the lower River Vyrnwy, thus mitigating any environmental impacts upstream.

Figure 3-1 Vyrnwy bypass pipeline schematic.



The Bypass pipeline is a gravity main pipeline and is contained within the licence area of Severn Trent Water. This will require limited operation and maintenance apart from an annual walk over inspection. The gravity main carries the treated water approximately 10. 3 or 16.5 km from Oswestry to the river Vyrnwy orSevern discharge outfall (Figure 3-1). It is assumed to a be a thin wall steel pipe. However, further assessment as to the optimal pipe material is to be undertaken at the next stage of design. Air release, washout, and line valves, located within buried chambers, will be located along the pipeline to enable operation and maintenance.

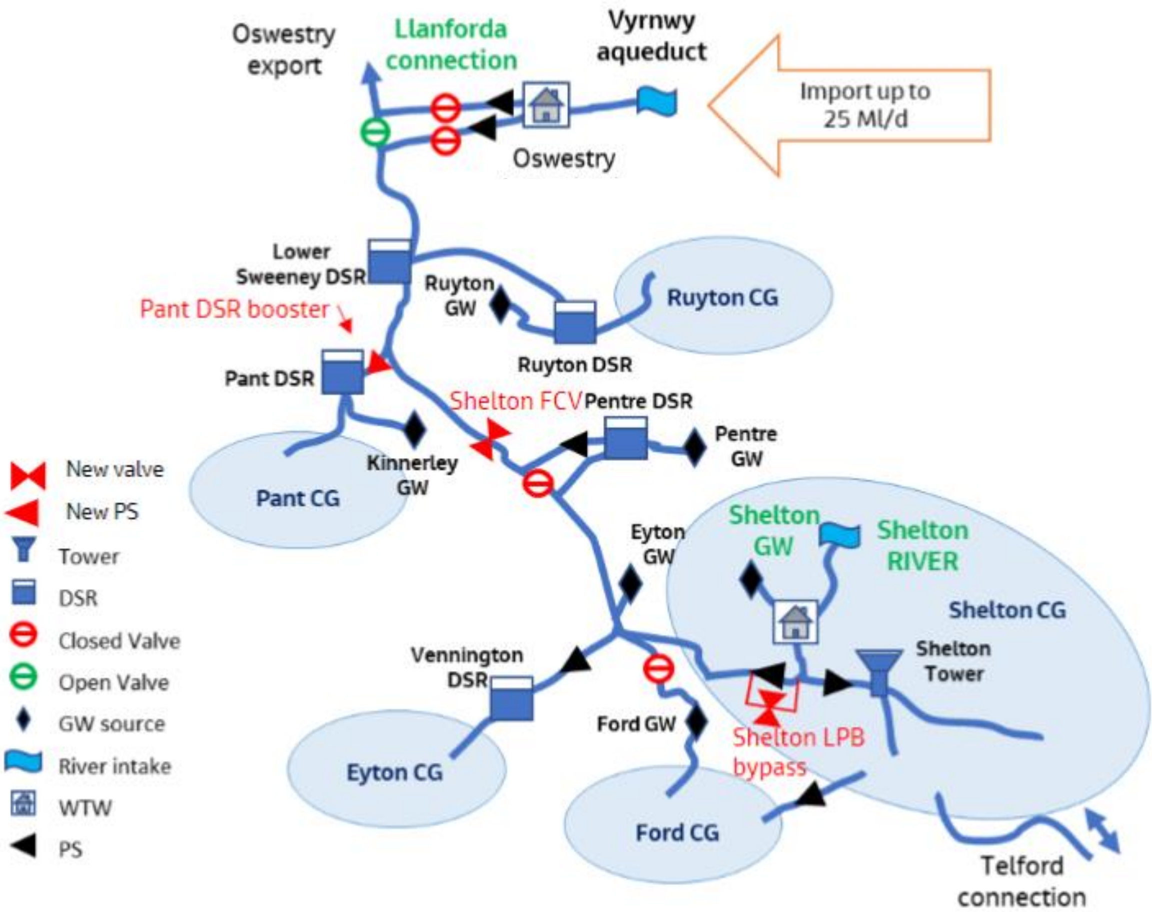
3.1.2 Key Design Features of Shrewsbury Redeployment

The Shrewsbury redeployment is facilitated by a supply from Oswestry. This mitigation allows the reduction in the size of the River Vyrnwy Bypass Pipeline by 25 Ml/d. The purpose of the Shrewsbury redeployment is the diversion of up to 25Ml/d treated water from United Utilities to supply Severn Trent Water's customers via an existing emergency import, the Llandforda connection, thus enabling a reduction in abstraction at Shelton, which is the normal supply forShrewsbury (Figure 3-2). Reducing abstraction from the River Severn would allow a temporary transfer of 25Ml/d licence to the STT interconnector transfer point of abstraction.

The preferred design option is comprised of a series of network and treatment upgrades:

- ☐ The Network reinforcements that allow to import treated water from United Utilities to supply STW's customers via the Llanforda connection.
- ☐ Network reinforcements to maintain resilience in the area shall one of the local ground water sources fail whilst the scheme is in operation.
- ☐ Upgrade of Shelton WTW to allow for a deployment of the maximum boreholes license and reduce the minimum output for the site.

Figure 3-2 Shrewsbury Redeployment preferred network schematic



4 Whole Life Carbon Assessment

4.1 Methodology

The WLC assessment have been carried out with the Severn Trent Water (STW) Carbon Model and Mott MacDonald carbon models. For capital carbon, these tools are supported by publicly available data, including the University of Bath's Inventory of Carbon and Energy on construction materials, the Inventory of Carbon and Energy (ICE) and the Civil and Engineering Standard Method of Measurement (CESMM4) Carbon & Price Book 2013. For operational carbon, specific emission factors are allocated per annual quantities to estimate emissions from energy use by the option's infrastructure and building-integrated systems. They also represent process carbon emissions arising from the option to enable it to operate and deliver services, such as chemicals for treatment. Emission factors are based on the UK Government GHG Conversion Factors for Company Reporting and the UKWIR Carbon Assessment Workbook (CAW).

The WLC assessment considered "before use" and "use stage" boundaries (A1-A5, B1 life cycle modules, PAS2080) for 80 years of operations to align with the whole life costing assessment. Capital carbon replacement have been considered and estimated for the interconnector and Shrewsbury Redeployment within the operational lifetime of the assets. For each item, an emissions factor (EF) has been applied to the cost and quantity, producing a quantifiable value for the carbon GHG emissions released by each constituent component and the associated operations. GHG emissions are measured in tonnes of carbon dioxide equivalent (tCO_2e) to allow for a standard metric to collectively quantify all emissions associated with schemes.

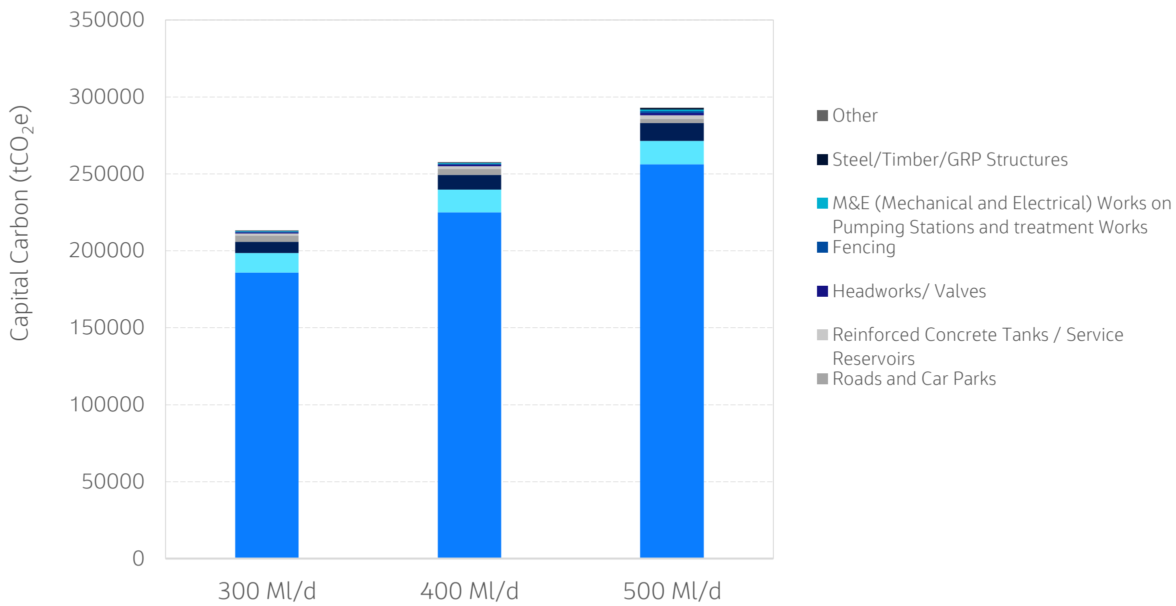
4.2 Capital Carbon

Capital carbon emissions assessment was conducting using the option development phase designs and aligned with asset scope inputs used to develop Gate 2 costs. Assessments were completed for three pipeline sub-options of the interconnector by Mott MacDonalds, and for all four Vyrnwy Bypass Pipeline sub-options and for the Shrewsbury redeployment by Jacobs.

4.2.1 Capital Carbon of Interconnector

Figure 4-1 summarises the total capital carbon estimate for the interconnector. The pipeline elements are the largest hotspot, accounting for 87% of the capital carbon. The pipeline category includes all pipelines required for the design intakes, including outfalls, crossings, and all water mains.

Figure 4-1 Capital Carbon for Deerhurst to Culham Interconnector (by pipeline capacity).



The capital emissions associated with the pipelines result from the construction of the pipe material, and the construction effort needed to install the pipes and all ancillary components. The assumptions for the construction of the pipelines include a cement lined steel pipe, diesel powered excavation plant, and the use of pre-cast concrete launch and reception shafts. The capital carbon emissions have also been categorised by asset type, using ACWG asset life categories to identify the major emissions areas across the chosen design option.

The next largest hotspot for capital carbon is the treatment works and pumping station civils, creating approximately 5% of capital carbon emissions. These works have such a high contribution due to the amount of concrete and steel reinforcement in the structures. There will be further opportunities to optimise concrete mix choices and reinforcement types and details closer to the detailed design and delivery stages.

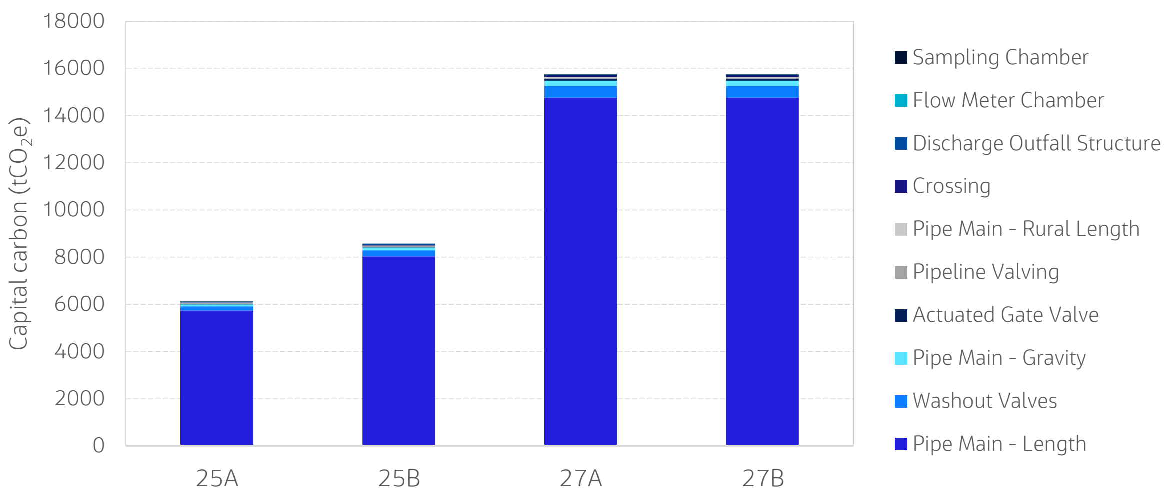
There are 9 other categories of capital carbon emissions, with a combined 7% of the total capital emissions across the three different designs. These will also be considered through the scheme design iterations but have not been identified as major hotspots at this stage.

In addition, capital carbon emissions associated with capital replacements have been calculated by assigning a standard asset life category, and associated predicted asset life (years), from the ACWG Cost Consistency report to each asset input line for cost and carbon. A full capital replacement has then been assumed at the end of the predicted asset life. The resulting capital replacement emissions for the three design options are 30,002 tCO_2e (300 Ml/d), 35,682 tCO_2e (400 Ml/d) and 38,445 tCO_2e (500 Ml/d).

4.2.2 Capital Carbon of River Vyrnwy Bypass Pipeline

Figure 4-2 below highlights the capital carbon hotspots for the River Vyrnwy Bypass Pipeline options, similarly to the interconnector, the pipeline elements are the largest hotspot. Within the Vyrnwy Bypass Pipeline, the pipeline elements are 95-96% of the total capital carbon emissions. Similarly, changes in the design of these components are crucial in reducing the capital carbon associated with the project.

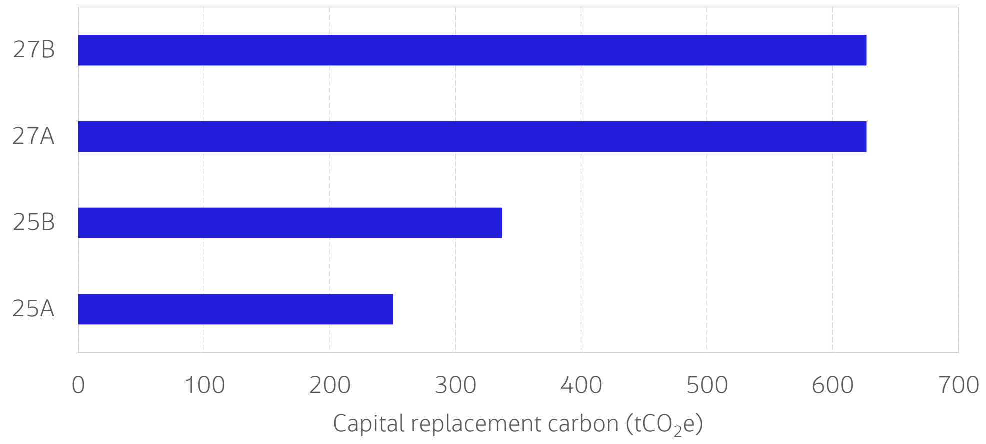
Figure 4-2 Capital Carbon of River Vyrnwy Bypass Pipeline design options.



The next largest hotspot for the Vyrnwy Bypass Pipeline sub-options, is the capital emissions associated with the valves, including washout valves, actuated gate valves, and pipeline valving. These emissions total 3-4% of the capital carbon emissions. There are 4 other categories of capital carbon emissions, with a combined ~1% of the total capital emissions across the four different designs.

The capital carbon emissions associated with capital replacements for the Vyrnwy Bypass Pipeline have been calculated with similar assumptions as for the interconnector, by assigning a standard asset life category and associated predicted asset life to each asset input line for cost and carbon. A full capital replacement has then been assumed at the end of the predicted asset life. The resulting capital replacement emissions for each of the options are depicted in Figure 4-3 below.

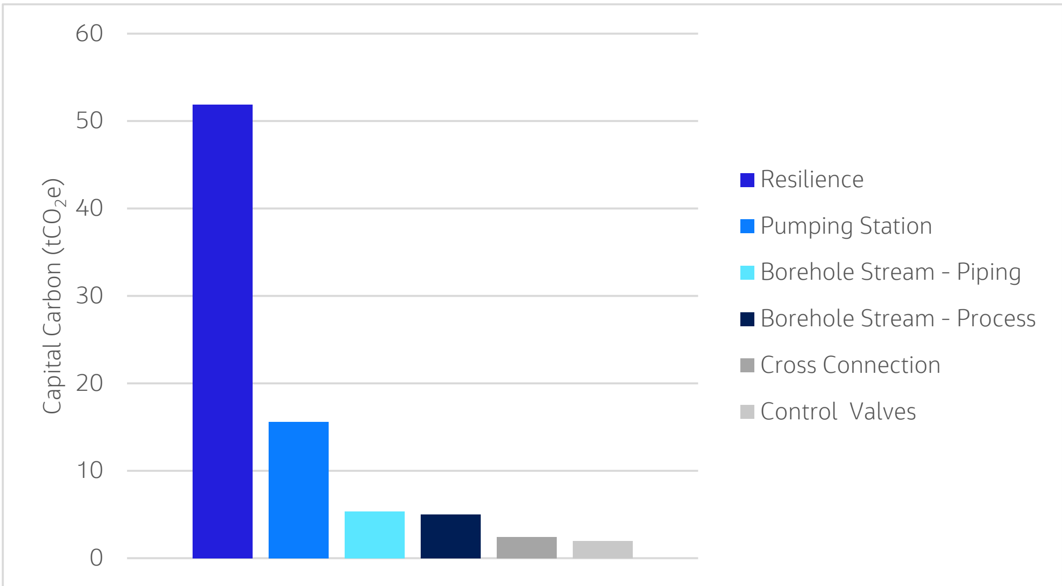
Figure 4-3 Capital replacement carbon for the Vyrnwy Bypass Pipeline



4.2.3 Capital Carbon of Shrewsbury Redeployment

Figure 4-4 highlights the capital carbon hotspots for the Shrewsbury Redeployment preferred option. Initially, the largest capital carbon hotspot was associated with the contact tanks for disinfection, which have been value engineered out of the scheme. Therefore, the largest source of capital carbon is now assets associated with network reinforcements to maintain resilience through the upgrade of the Ford pumping station and construction of a the new Ruyton booster pumping station (63%), following the construction of the new Plant booster pumping station (19%).

Figure 4-4 Capital carbon emissions for Shrewsbury Redeployment preferred option.



There are 4 other categories of capital carbon emissions, with a combined 18% of the total capital emissions, including rapid gravity filter, pipework, cross connections, and control valves.

The capital replacement carbon emissions associated with capital replacements for the Shrewsbury Redeployment have been calculated with similar assumptions, by assigning a standard asset life category and associated predicted asset life to each asset input line for cost and carbon. A full capital replacement has then been assumed at the end of the predicted asset life. The resulting capital replacement emissions are 85.32 tCO_2e.

4.2.4 Summary

In summary (Table 4-1), each of the three components of the STT SRO have been modelled to estimate the associated capital and capital replacement emissions. The largest component is the Deerhurst to Culham interconnector with estimated capital emissions, following the River Vyrnwy Bypass Pipeline and Shrewsbury Redeployment.

Table 4-1 Summary of capital carbon for STT

Scheme	Capital carbon (tCO_2e)	Capital replacement carbon (tCO_2e)
Pipeline interconnector Deerhurst to Culham	213,189 – 287,418	30,001 – 38,445
Vyrnwy mitigation: River Vyrnwy Bypass Pipeline	6,147 - 15,763	250 - 627
Vyrnwy mitigation: Shrewsbury Redeployment	85	85

4.3 Operational Carbon

An operational carbon emission assessment has been undertaken for the STT, including direct and indirect Scopes 1 and 2 emissions. Commonly direct emissions in the water sector result from the treatment process, fossil fuel use and owned or leased transport emissions. Indirect emissions are the product of purchase and use of grid electricity by water company assets notably for water and wastewater pumping and treatment as well as use in buildings.

For the WLC assessment, operational carbon emissions were based on the power and chemicals usage during the lifetime of the scheme. These elements were derived from asset information such as power rating of pump and assumed run-time or calculated chemicals usage for treating flow and have been based on operational consumables aligned with the OPEX estimate.

Key EFs used for the operational carbon assessment are:

- Current year grid carbon intensity utilises DEFRAs 2021 grid emissions factor representing the grid intensity for 2021, allowing for transmission and distribution losses[8].
- Forecast grid carbon intensity for future years utilising projected emissions factors from the BEIS Green Book Data Tables 1-19[9], using commercial/public sector values from table 1.
- Chemical EFs from the UKWIR CAW[10].

4.3.1 Operational Carbon of the Interconnector

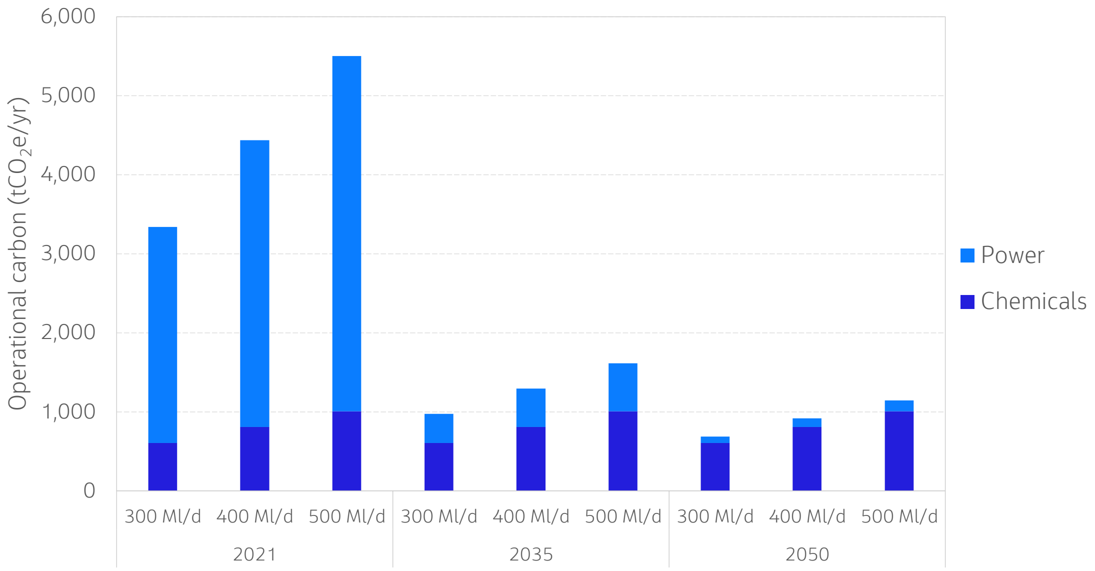
For the interconnector, the operational carbon assessment assumes the utilisation scenario where 80% of the time is sweetening flow (i.e., 20Ml/d) and 20% peak flow. Figure 4-5 summarises the operational carbon emissions associated with power consumption and chemicals usage during the lifetime of the scheme for the three design sub-options based on the 20Ml/d of sweetening flow. There is further potential reduction in operational emissions if the sweetening flow is optimised and reduced, which could result in significant operational savings in chemical and energy consumption across the whole life of the scheme. Given that the scheme is proposed to operate at the set sweetening flow for 80% of the time, small optimisations here could have significant carbon reduction impacts.

[8] Transmission and distribution losses would be accounted for as Scope 3 emissions under the GHG protocol.

[9] data-tables-1-19.xlsx (live.com)

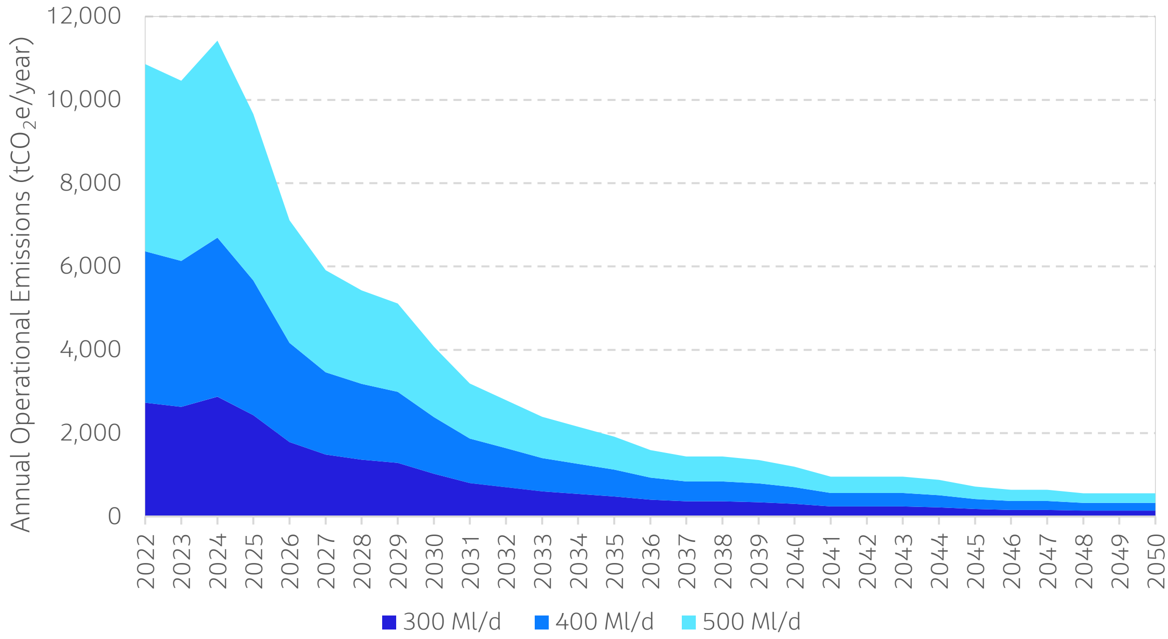
[10] CAW v15 (ukwir.org)

Figure 4-5 Operational carbon hotspots for all three design sub-options at the proposed sweetening flow.



Power consumption is a significant emissions hotspot during the early operation of the STT. Over time the significance of power related emissions as the grid decarbonisation projects take effect. Figure 4-6 shows the projections of the emissions associated with the three different design options of the interconnector between now and 2050.

Figure 4-6 Projections of operational emissions associated with power consumption of Interconnector options for the minimum sweetening flow.



The modelling shows that, where the current grid carbon intensity is used for power consumption, operational emissions associated with used power account for between 81-82% of total operational emissions. With the decarbonisation of the grid, the future projections of carbon emissions decrease. All three options show a gradual decrease from the year 2025 onwards. By 2030 it is estimated that emissions associated with power consumption drop to 41%, and then by 2050 further to 14%.

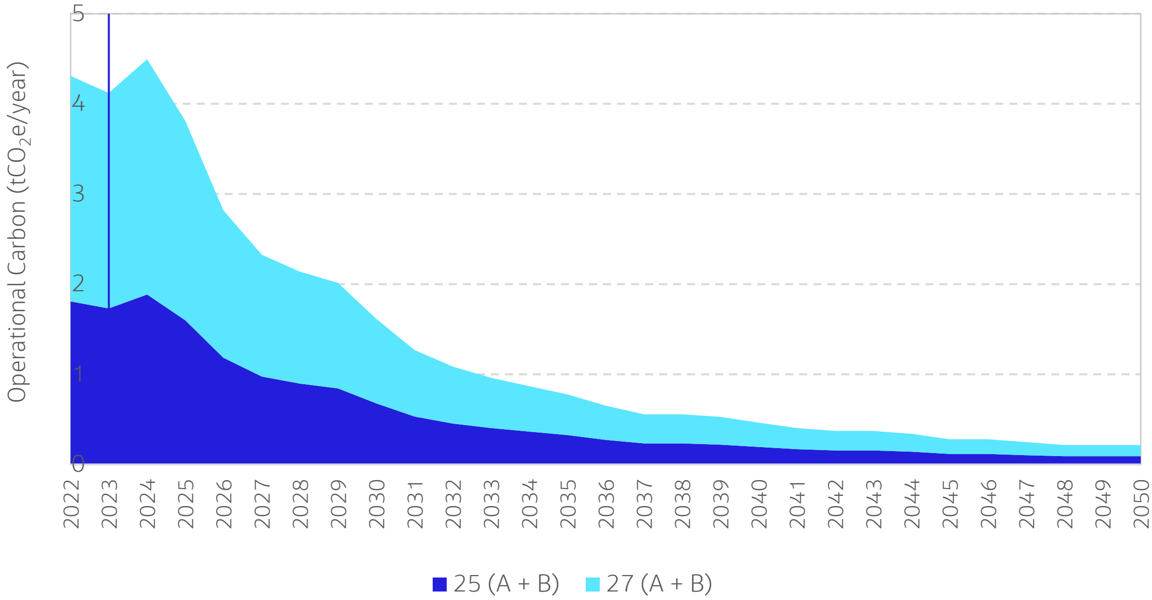
However, proactive steps have been highlighted, including improving the energy efficiency (see 5.3.2) of the scheme (see self-generating renewable supply of electricity (see 5.3.2) and renewable energy procurement options (see 5.3.2)

The emissions associated with chemicals are secondary to the power consumption. Chemical dosing of ferric and polymers forms a substantial part of the annual operational emissions and continues to remain a significant emissions source. The chemicals associated with the plant are inherently carbon intensive and have little scope to decarbonise over time. It is therefore strongly encouraged to engage with the chemicals supply chain to identify their plans for decarbonisation. This knowledge can then be passed to later gate stages.

4.3.2 Operational Carbon of River Vyrnwy Bypass Pipeline

The operational emissions for the River Vyrnwy Bypass Pipeline has been undertaken considering the OPEX costs for the total annual energy consumption for each of the sub-options (Refer to A7W13153-VC-SPR-201027-0A Vyrnwy Bypass Pipeline OPEX Estimate). Due to the gravity main design, there are minimal energy requirements related to the scheme, mostly regarding operation and maintenance of valves, flowmeters, ICA panels and telemetry. The total estimated annual energy demand is 13MWh for route 25 and 18MWh for route 27. Therefore, the operational carbon emissions associated with the River Vyrnwy Bypass Pipeline options are considered negligible when compared to the rest of the STT SRO scheme. Figure 4-7 shows the projection of operational carbon emissions.

Figure 4-7 Projections of emissions associated with power consumption of Vyrnwy Bypass Pipeline options.



4.3.3 Operational Carbon of Shrewsbury Redeployment

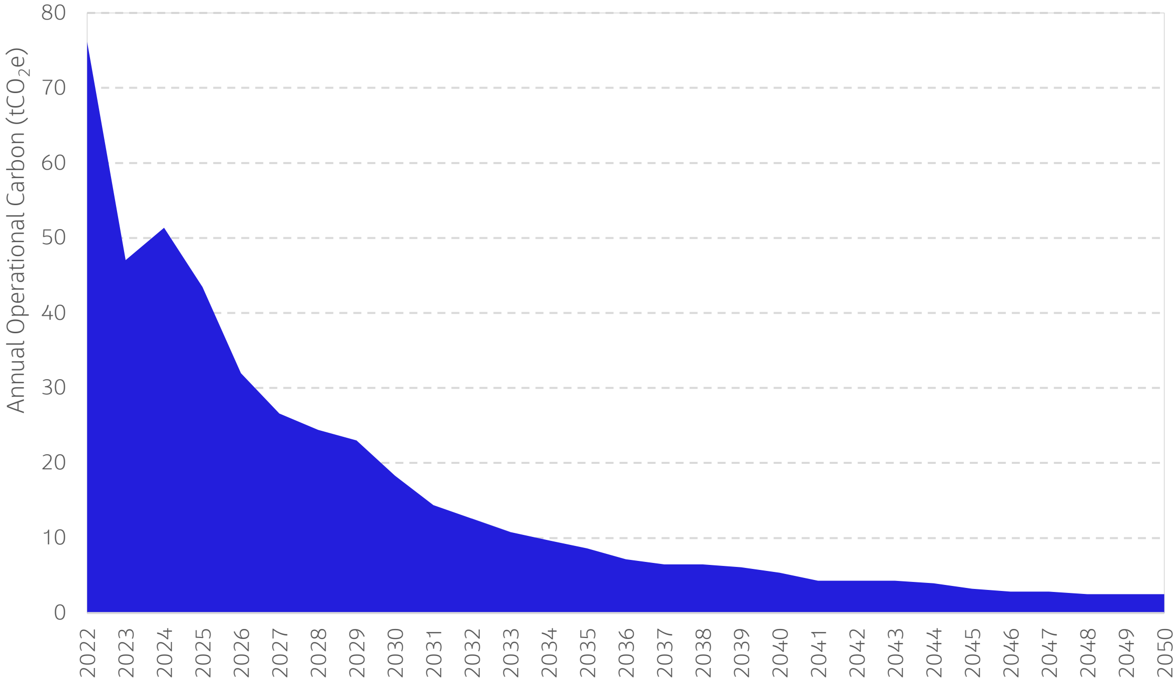
For the Shrewsbury Redeployment, the operational carbon assessment assumes both power consumption and chemical dosing for disinfection. Table 4-2 summarises the annual operational carbon until 2050.

Table 4-2 Annual operational carbon for Shrewsbury Redeployment preferred option.

Emission source	Operational carbon (tCO_2e)
Power	231.1
Chemicals	2.45

The majority of the emissions (98.6%) from the Shrewsbury redeployment come from the consumption of power, at approximately 231.1 tCO_2e per year, and an annual consumption of 1,089MWh. With the decarbonisation of the grid, the operational carbon emissions associated with the redeployment are expected to decrease as shown in Figure 4-9 based on the forecast grid carbon intensity from the BEIS Green Book Data.

Figure 4-8 Projections of emissions associated with power consumption of Shrewsbury Redeployment.



Operational carbon emissions resultant from chemical usage across the lifetime of the Shrewsbury Redeployment scheme is associated with Sodium Hypochlorite. To maintain a residual chlorine dose before the treated water enters the blending tank and mixes with the treated water from the river treatment stream it has been assumed a chlorine dose will be applied via a new sodium hypochlorite dosing plant post the UV plant. It is estimated 2.45 tCO_2e per year of operational carbon emissions, totalling 263 tCO_2e in its 80-year lifetime.

4.3.4 Summary

In summary, each of the three components of the STT SRO have been modelled to estimate the associated operational emissions. The largest component is the Deerhurst to Culham interconnector with estimated operational emissions between 3,340 and 5,504 tCO_2e per year for the minimum sweetening flow and 32,960 to 54,330 tCO_2e per year for the maximum flow, related to power requirement and chemical dosing.

The second largest component regarding operational carbon, is the Shrewsbury Redeployment. Emissions associated with the operational carbon of this mitigation option are approximately 18,8767 tCO_2e or 319.9 tCO_2e per year. For power requirements and chemical dosing.

Lastly, the component with the least capital carbon is the Vyrnwy Bypass Pipeline, with operational carbon associated with the power required only, and an estimated annual total of between 1.8 and 2.4 tCO_2e per year for route 25 and 27, respectively.

4.4 Whole Life Carbon

The outputs from the WLC assessment combine the outputs from the modelling of capital (including the capital carbon emissions associated with replacing assets) and operational emissions, outline in sections 4.2 and 4.3, respectively.

A summary of the WLC emissions associated with all three STT SRO components can be seen in the following tables Table 4-, 4-4, and 4-5 below. The WLC emissions have been assessed over 80 years, with a 5-year planning period, 5-year construction period and 70 years of operation.

Table 4-3 Interconnector WLC Emissions

	300 Ml/d		400 Ml/d		500 Ml/d	
	Absolute Emissions (tCO2e)	WLC Emissions (%)	Absolute Emissions (tCO2e)	WLC Emissions (%)	Absolute Emissions (tCO2e)	WLC Emissions (%)
Capital Carbon	213,189	56	257,649	54	287,418	52
Capital Replacement Carbon	30,002	8	35,682	7	38,445	7
Operational Carbon (Non-power related)	118,558	31	158,078	33	197,598	35
Operational Carbon (Power related)	20,700	5	27,477	6	34,036	6
Total WLC Emissions	**382,448**	**100**	**478,886**	**100**	**557,496**	**100**

Table 4-4 River Vyrnwy Bypass Pipeline WLC Emissions

	25A		25B		27A		27B	
	Absolute Emissions (tCO_2e)	WLC Emissions (%)	Absolute Emissions (tCO_2e)	WLC Emissions (%)	Absolute Emissions (tCO_2e)	WLC Emissions (%)	Absolute Emissions (tCO_2e)	WLC Emissions (%)
Capital Carbon	6,147	96	8,582	96	15,763	96	15,763	96
Capital Replacement Carbon	250	4%	337	4	627	4	627	4
Operational Carbon (Power related)	20.6	0.3	20.6	0.3	28.5	0.2	28.5	0.2
Total WLC Emissions	**6,419**	**100**	**8,940**	**100**	**16,419**	**100**	**16,419**	**100**

Table 4-5 Shrewsbury WLC Emissions

Asset	Preferred Option	
	Absolute Emissions (tCO_2e)	WLC Emissions (%)
Capital Carbon	85	<1%
Capital Replacement Carbon	85	<1%

Asset	Preferred Option	
Operational Carbon (Non-Power related)	263	1%
Operational Carbon (Power related)	18,504	98%
Total Whole Life Emissions	18,766	100

4.4.1 Whole Life Carbon Cost

The WLC cost estimates is based on the non-traded carbon price forecast from BEIS Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal (2021)[11], and the NPV discounting based on the standard discount factors in the BEIS Green Book supplementary guidance: discounting (2013)[12]. The monetised cost of carbon calculations were based on the following assumptions for the 80-year appraisal period:

- Planning (2022 – 2029): no carbon emissions associated with planning phase.
- Construction (2030-2034): all capital carbon emissions occur in year 1-5 with same proportion.
- Operation and capital maintenance (2035 – 2109): operational carbon emissions for the Pipeline Interconnector (for the sweetening flow) and the Shrewsbury Redeployment were included in the estimations. River Vyrnwy Bypass Pipeline was excluded as operational emissions are negligible. Year 1 is assumed to be 2035.

Table 4-6 summarises the WLC and the discounted monetised cost of carbon for the three components of the STT SRO. The range in cost of carbon of each component is between £1.63 M and £116 M, highlighting the extensive scope and requirement to choose lower carbon options throughout the design process.

Table 4-6 Whole Life Carbon Summary Table

Gate 2	Options	Capital carbon (tCO_2e)	Operational carbon (tCO_2e)	WLC Cost (M£/tCO_2e)
Pipeline Interconnector Deerhurst to Culham	300 Ml/d	243,191	139,258	81.5
	400 Ml/d	292,331	185,555	101
	500 Ml/d	325,863	231,634	116
River Vyrnwy Bypass Pipeline	105 Ml/d (25A)	6,398	20.6	1.63
	180 Ml/d (25B)	8,919	20.6	2.23
	180 Ml/d (27A)	16,390	28.5	4.19
	205 Ml/d (27B)	16,390	28.5	4.19
Shrewsbury Redeployment	-	171	18,767	10.7

[11] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal - GOV.UK (www.gov.uk)

[12] https://www.gov.uk/government/publications/green-book-supplementary-guidance-discounting

5 Carbon Mitigation Approaches

STT requires a robust strategy to mitigate carbon emissions for delivering such a significant capital asset programme. A structured approach to developing a carbon mitigation strategy which prioritises effort in areas where there are the greatest opportunities for reductions and feasibility of successful decarbonisation interventions is proposed.

This section provides a high-level range of approaches and interventions that could be used to reduce capital and operational carbon emissions for the STT SRO. The scope of this assessment does not include a quantitative analysis of the abatement potential. The intention is to provide an understanding of the type of options available based on the proportion of the share of emissions of each source and the potential abatement opportunity associated with each intervention. A high-level RAG (red, amber and green) rating is provided in the next chapter to indicate which approaches align best with the wider industry and Severn Trent Water's, Thames Water's and United Utilities' own strategic ambitions.

5.1 Engineering Design and Capital Emissions

To reduce capital emissions, there are numerous options to 'design out' carbon for each scheme of the SRO. Adjustments to engineering design can also impact operational emissions (e.g., pumping power requirements). However, it is important to note that a portion of the opportunity to reduce GHG emissions through redesigning schemes has been missed, as certain elements of the design may be fixed and may not be able to be any longer changed, particularly regarding conveyance routes. Nevertheless, there are still some benefits which could be realised at this stage.

In addition to engineering design, capital emissions can be reduced primarily through changes in the amounts and types of materials used in the civil works, such as pipelines, pumps, buildings, and other equipment. With capital carbon emissions ranging from 52% to 96% of the total emissions for Gate 2, the approaches detailed below will likely have a significant impact, unlike the options to reduce operational carbon emissions (detailed in Section 5.2). Therefore, engineering design and capital emissions will be of greater importance for the STT SRO.

A broad principle for reducing emissions through engineering design considers the principles below. Each principle can be overlaid with the design stage and carbon influence graph demonstrated in Section 2.6 in Figure 2-3. While only a general trend, an emissions reduction potential is included against each principle:

- ☐ **Build nothing –** Challenge the root cause of the need, explore alternative approaches to achieve the desired outcome (100% carbon reduction potential).
- ☐ **Build less** – Maximise the use of existing assets, optimise asset operation and management to reduce the extent of new construction required (80% carbon reduction potential).
- ☐ **Build clever** – design in the use of low carbon materials, streamline delivery processes, minimise resource consumption (50% carbon reduction potential).
- ☐ **Build efficiently** – embrace new construction technologies, eliminate water (20% carbon reduction potential).

5.1.1 Engineering Design

There is opportunity to reduce capital carbon emissions in in the design of the schemes, especially in pipelines, which are the largest emission hotspots. Notably, material selection, dimensions, crossings, installation method, and treatment processes which will be explored below.

Material selection: The pipe material selection is a key area for carbon emissions reduction as it accounts for ~70% of emissions. The material selection of steel has been driven by the diameter of the pipe required making steel the default choice for diameters in excess of 1200mm at the high-pressure ratings required. Lower carbon materials such as glass fibre reinforced plastic (GRP) would not comply with design standards and specifications. However, these standards could be reviewed before later Gate stages in conjunction with other aspects of the pipeline since there will be an interplay between the decisions on one another. For example, if the pipe diameter is reduced, there are feasible, lower carbon material alternatives.

Pipe size (diameter): the design team has calculated the pipeline diameter and optimised it based on the assumption of 20% utilisation at peak flow. Whilst the diameter optimisation has been based on realistic assumptions for the design, there is the opportunity for further review with additional optimisation profiles at later Gate stages, possibly leading to greater capital carbon savings.

Water treatment works: there is potential to consider nature-based solutions as an alternative treatment with a hybrid settlement lagoon/ constructed wetland followed by Mecana cloth filters being explored. This option will be further explored in Gate 3. This option could reduce both operational power consumption and chemical consumption, as well as improve biodiversity.

Concrete tanks: If some processes such as the manufacturing of cement have a high carbon content, consider maximising the reuse and recycling of material. Recycled aggregate is a prime example of an opportunity to abate capital emissions. There are many examples where similar material substitutes can be used, especially in non-critical components, fences, and covers for wastewater plants. Again, a methodical approach to identify such opportunities should be undertaken by the design teams. Looking at low carbon alternatives to steel, cement and glass is an additional option. The major concern is often around material properties and design specifications. While some materials are not appropriate for some applications, effective collaboration between engineering design teams and carbon specialists are resulting in increasing uptake of low carbon substitutes while still ensuring that components meet the safety and quality standards expected of the industry and regulators.

5.2 Construction Emissions

While the share of emissions typically attributed to construction operations is less than those produced from capital material sources or site operational emissions, construction is an area in which there is large scope to reduce emissions. Not only is the infrastructure sector at the start of its decarbonisation journey and so opportunities have yet to be capitalised on, but as this phase is yet to start, there is time to exert considerable influence to reduce emissions. Construction emissions are indirect with respect to the STT and fall into the supply chain's scope. However, through a carefully planned procurement programme, there is a path to exert positive influence over the construction phase. This can be enabled through clear and specific procurement specifications that favour sustainable and low carbon solutions.

Furthermore, a collaborative and pragmatic approach can leverage positive steps forward pushing the boundary beyond current norms. Key actions to be taken through future design development are:

- Engaging with the supply chain to understand what the carbon intensities of their products, this will happen in more detail at later stages in the scheme development alongside more generic horizon scanning of suitable alternative pipe materials
- Identifying whether lower carbon alternatives are available and provide required performance and reliability
- Developing appropriate material carbon intensity specifications based on materials and products available in the market
- Ensuring the procurement process for the scheme has steps in place to ensure that materials and products meet carbon intensity specification requirements.

Some of the opportunities for consideration include:

Infrastructure crossings: as part of the pipeline route, the number of crossings has been minimised, predominantly to reduce disruption to the traffic network. The major crossings construction has been determined to be trenchless through pipejacking with shafts at either side. Again, reducing disruption to the transport network is the fundamental reason for this method. There are deemed to be no feasible alternative installation methods at present due to the pipe diameter and disruption to the transport network and hence carbon mitigation opportunities are not proposed.

Backfill and reinstatement: Another aspect of pipeline installation is the backfill material. Where possible, use of as-dug material will be used for backfilling which reduces carbon emissions. To not overstate the carbon savings, the Gate 2 carbon assessment assumes imported backfill for the pipe surround and as-dug material for the remaining trench. Once further detail is known at later Gate stages, an updated assessment of the imported material required for the pipeline can be assumed and will potentially lead to carbon savings.

5.2.1 Transportation

Capital emissions are associated with the materials used in the assets and are a result of the processes used in the manufacturing material, usually split into the extraction and transport of raw materials. Processing and extraction are a much more complex challenge with regards to emissions which industries are allocating resources to overcome. Therefore, the transport of material is one of the largest opportunities for embodied emissions to be reduced.

The STT SRO design team has assessed options to reduce the volume of spoil removal and used early engagement to assess options to reduce transport distances. These assessments include suggestions to consider alternative low or zero carbon construction plant relying on alternatives to diesel fuel (i.e., biomethane, hydrogen, electric). The uptake of these technologies, especially in HGV vehicles has been slow, therefore as the sector decarbonises there will be further opportunities for the project to use these lower carbon options.

The STT SRO has accounted for the use of remote access for plant operation and increased remote functionality in order to ensure both immediate response to a process issue and reduce the requirement to have continuous site attendance. This would reduce carbon associated with travel for site operatives and maintenance teams. With regards to material transport, locally sourced construction materials should be used where possible. Due to the requirement of land clearance required for the construction, the reuse of as-dug material on site can minimise the soil transport distance required, reducing the distance travelled.

Avoiding or reducing travel is the easiest way to reduce such emissions. The introduction of an effective travel management plan, where journeys and travel are planned more efficiently is potentially the lowest cost option to reduce emissions from personnel, material, and equipment movements. While this scope of influence is more challenging, working with construction teams to ensure locally hired personnel can reduce emissions as well as boost local employment. More challenging would-be supporting initiatives to encourage workers to engage in ride sharing schemes. Maximising the efficiency of vehicles by ensuring they are well maintained and cycling out older vehicles for newer models can also help to reduce transport related emissions.

The next stage would be supporting a transition to vehicles that use an alternative source of energy to fossil fuels. Electric vehicles are an option for light goods vehicles and should be extended to all work mandates vehicles where viable. For heavy goods vehicles (HGVs) the current options are some forms of biofuel, as hydrogen supply chains are still being developed, though this is an option for future projects. There is a caveat with biofuels – not all biofuels are manufactured from sustainable materials or through low carbon processes. Ensuring verified sustainable biofuels is necessary to prevent the risk of inadvertently increased emissions, as some "biofuels" can produce emissions that are 1000s of times more polluting than fossil fuels.

5.2.2 Direct Energy Use and Plant Equipment

Plant equipment presents a slightly larger challenge to decarbonise. The main solution to decarbonise plant equipment is hydrogen. Original equipment manufacturers (OEMs) such as JCB are developing hydrogen ready engines for their large plant. Though like transport, such assets are early in their development and the hydrogen infrastructure to support such equipment is not widely available. Battery technology is limited due to the size of batteries required for the size of equipment. Similar problems exist for direct energy use, typically from generation assets. While hydrogen seems like the obvious alternative, the industry is not yet ready for large scale use of green hydrogen.

There is the opportunity for some power to be taken directly from the grid, but limits on mobility mean such power is limited to static assets such as offices and welfare cabins. There is a viable decentralised option to replace diesel generators, though careful planning and changes to behaviours are required to realise their benefits. The use of onsite batteries with either smaller diesel engines (hybrid engines) and/or renewable energy resources such as solar or wind coupled with battery storage are both becoming increasingly more common in construction. While there are additional costs associated with all of the above, other options include using lower carbon emitting fuels to replace diesel, though the same caveats exist as for transportation.

5.3 Operational Emissions

Operational emissions ranges from 35% to 99% of the WLC emissions as detailed in Section 4. This section describes approaches to reduce operational emissions through efficiency interventions, energy management, and the use of renewable energy. The reason for this focus is as the grid decarbonises, reducing energy consumption and balancing the demand side is a necessity to ensure a low carbon electricity network. Furthermore, it is imperative that organisations with large opportunities to add to the grid's capacity, such as the water industry, leverage their opportunities to enable supply side balancing.

While the projects are further along in the project lifecycle, it is still possible to follow the emissions hierarchy at this stage, prioritising energy efficiency and energy demand reduction before the usage of renewable energy.

5.3.1 Energy Management and Efficiency Improvements

Ensuring effective energy management principles are integrated into the operation of the site is key to minimising energy consumption and ensuring that opportunities to reduce demand are capitalised on. The introduction of procedures that align with ISO 50001 standards can be used to optimise control over energy demand for the site. However, like PAS 2080 it is important to first introduce appropriate governance and management systems to manage energy across the site. This would allow STT to identify and intervene for high energy consuming assets while ensuring they have the systems to effectively maintain lower demands following any intervention. The use of smart control systems and other digital mechanisms could also be used to streamline the process.

Following the intervention of effective demand reduction systems and feedback controls it would be recommended to engage in a programme of efficiency optimisation of components, most likely pumping systems. Effective energy management systems will help identify the largest consumers and engineering input can be used to ensure that the energy operation of assets such as pumps are optimised. Considering the projects are at a design stage, despite the higher CAPEX cost, higher efficiency pumps will significantly reduce energy demand and the total operational cost of the pump (including electricity). Looking to maximise efficiency prior to construction is a relatively simple option compared with others mentioned in this section, reducing the need for costly interventions at a later stage.

5.3.2 Renewable Energy

Once demand reduction and energy efficiency gains have been made, the focus should be to maximise the use of renewable energy. The following section outlines the potential options available and explains why opportunities for onsite generation should be utilised.

There will be electrical losses associated with renewable energy generation technologies, from subcomponents such as invertors. Furthermore, due to the intermittent nature of these sources, they cannot be relied on fully for energy supply without ancillary support. An option to mitigate this could be to use additional energy storage on site to smooth out the supply profile of onsite renewables. This would likely be a battery storage system, with high initial costs which would be offset across the lifetime of the project. A battery storage system could also be used to replace the (likely diesel powered) back-up generator used on site, meaning standby power can be entirely low/net zero carbon. While this will reduce the release of emissions in emergencies, this option can have significant capital costs and size constraints compared with conventional diesel generators which must be considered.

It should be noted that carbon reporting rules on onsite generation need to be adhered to and are not straightforward in how renewable electricity not used on site is accounted for across the organisation. Furthermore, the financing options for exporting excess capacity bring with it additional complexity which need to be considered as part of any decision to add onsite generation.

5.3.2.1 Interconnector

An initial assessment has been made of the possibilities to generate its own renewable power in and around the scheme based on the current design of the gravity-main pipeline for the maximum flow of 500 Ml/d. However, calculations showed that only 6% of the head (ca. 12.6m) would be available at the end of the pipeline, limiting the potential for energy recovery opportunity. As such, hydro generation has not been further considered for the pipeline at the highest design flow.

A further assessment was undertaken considering the lift pumping station at Deerhurst being operated with the part-flows based on 1 to 6 pumps (total of 7 duty pumps with one stand-by) and an increased sweetening flow of 50 Ml/d. This scenario demonstrated significant heads and flows available for energy recovery with potential hydro power outputs ranging from 1MW to 4MW depending on the particular discharge. Corresponding power requirements of the pumping station requires between 1.7MW to 16.5MW, thus overall energy recover percentages range from 16% at lower flows to 58% at higher flows.

5.3.2.2 Vyrnwy Renewable Power Generation

Hydro power generation was assessed for the Vyrnwy Bypass Pipeline assuming it would be operated at the full design flow for 10% of the time, with a sweetening flow of 5 Ml/d for 90% of the time if required. The designed pipe routes have a potential net head of between 60m and 90m dependent on the pipeline length, diameter, and design flow rate for each of the options. The intake has been assumed to be located at the Oswestry at a level of 172m above ordnance datum (AOD)[13] with each pipe route discharging into theRiver Vyrnwy or Severn at an elevation in the range of 59m – 70m AOD. It was also assumed that separateturbines would be provided for full flow and sweetening flow operation, as the main turbine would be unableto operate efficiently at very low flows.

Of the three types of hydro turbine have been initially assessed, the Turgo turbine has shown greater efficiency at lower flows and the potential for avoiding the need to install a separate flow control valve. The following tables outline the two pipeline options and their associated suitability with a Turgo turbine, showing installed capacity, net head, annual generation, and capital costs.

The potential annual energy generation ranged from 317 MWh/yr to 826 MWh/yr depending on the pipeline route and flow. In addition, it was demonstrated that for all pipeline routes it would be economically feasible to provide energy recovery turbines for all flow capacities, particularly for the cases with a flow rate of 108 Ml/d.

5.3.3 Purchasing Renewable Electricity Options

For all three schemes of the STT SRO there are likely to be periods where additional energy will have to be imported from the grid. In this case it will most likely require the use of either a corporate power purchase agreement (PPA) or to purchase green tariff electricity from their energy supplier backed by renewable energy guarantees of origin (REGO) certificates. Such instruments will be required if electricity is supplied via the grid or direct from distributed energy sources. A summary of the benefits and drawbacks of these energy procurement options are summarised in Table 5-1 below.

A PPA is a contract to purchase energy between an energy generator and an organisation. Historically such a contract would be between an organisation that generates the energy and a licenced supplier of energy who would then sell the electricity on to consumers. Sleeved PPAs are the most common form of corporate PPA in the UK, typically under such an agreement the generator and corporate consumer are on the same electricity network as power is transferred through the transmission and distribution network. Synthetic PPAs are structurally more complex, they are financial transactions, essentially a form of hedge with no physical power being traded via the agreement. The third type of corporate PPA is a private-wire PPA. While similar to a sleeved PPA where a corporate consumer purchases power from an electricity generator at an agreed price,

[13] AOD gives the actual elevation of the groundwater level referenced to the mean sea level at the UK Ordnance datum at Newlyn, Cornwall.

the difference is that electricity is supplied directly to the corporate consumers site or network, usually requiring the generation assets to be situated nearby.

REGO's are certificates issued by the UK regulator the Office of Gas and Electricity Markets (Ofgem) to generators for every 1 MWh of renewable electricity they produce. These certificates are then used by licenced suppliers as part of their fuel mix disclosures, demonstrating the proportion of electricity they supply that is generated from a renewable source. A summary of benefits/drawbacks of each is detailed in the table below.

Table 5-1 Benefits and Drawbacks of Renewable Energy Procurement Options

Commercial Instrument	Benefits	Drawbacks
Sleeved PPA	Can be used to provide additional renewable capacity to the Energy Mix. A fixed rate of power means that the contractor can control and reduce the cost of electricity. Costs are not subject to market fluctuations. Sleeved PPAs are the most common corporate PPA agreement in the UK, they are simpler in structure than Synthetic PPAs and require no additional regulatory compliance like private wire PPAs.	The contractor will be required to pay a sleeving fee to the licenced supplier to manage the supply of electricity. A sleeved PPA may tie the contractor into long term contracts, while short term PPAs are available they are less common. When compared to green tariffs the legal and commercial frameworks are complex.
Synthetic PPA	This is potentially the most structurally complex arrangement for the procurement of energy, though can be contractually more simple than other PPA options. Synthetic PPAs provide more flexibility in the source of power being supplied. With opportunities to procure energy from cheaper markets.	Operating across multiple markets has additional risks that may require a complex legal agreement to reconcile.
Private Wire PPA	Due to the direct connection made between the site and generation assets, such PPAs will support the growth of renewable generation assets proximate to the STT SRO. This may provide the most direct backing to local communities by enabling local and community renewable projects to become financially viable. The delivery of electricity is not through the transmission and distribution network which means that some licencing/regulatory costs and network charges can be avoided.	The generator will need to demonstrate to regulators they adhere to certain licencing exemption rules which are complex and may be challenging for local and community scale generators to manage. Issues around operations, maintenance, liabilities, and additional costs to manage the assets and land connecting generation assets to consumption site networks must be addressed. The commercial and legal frameworks for such agreements are complex and the benefits of bypassing distribution networks may be lost.
REGO backed Green Tariffs	The simplest commercial and legal route to access electricity from a renewable energy source. Provides much more flexibility than PPAs, in terms of cost and without the need for long term agreements.	Green tariffs do not necessarily provide additionality to the local electricity mix. Only a small handful of suppliers in the UK have been able to demonstrate that their green tariffs enable additional renewable energy capacity being added to the grid. And so, the use of green tariffs does not necessarily further enable carbon mitigation The use of green tariffs does not guarantee that low carbon electricity is being used at the point of consumption, the electricity supply could be from fossil fuel sources and matched by REGO certificates.

While Table 5-1 outlines the pros and cons of different procurement mechanisms for renewable energy, there are some key points than need to be considered in relation to prioritising the procurement of renewable electricity over onsite generation. They are as follows:

- ☐ Are the emissions in generating the electricity actually low or zero carbon?
- ☐ Is there additionality in low carbon renewable supply to the grid?

Looking at the supply of electricity and whether the power to site will truly be from low or zero carbon sources, both PPAs and green tariffs can facilitate such provisions, though with green tariffs this is not guaranteed. This is because of the unbundling of REGO certificates from the power being supplied. Without careful consideration for the tariff selected, the project may be able to claim “green credentials” for the power used, but it may be generated from fossil fuel sources which still release GHGs. This would mean the site could still be negatively impacting the environment through its electricity consumption despite efforts to avoid such an outcome. This issue could be addressed by additional procurement/contract specifications that ensure the purchase of electricity from licenced energy suppliers who can provide low emissions electricity.

Regarding PPAs, because the certificates are linked back to specific assets, the renewable power supplied and consumed are more directly linked. Though there is still a question about the physical power being consumed on site. The grid functions on a balance of power from multiple sources, the physical electricity being delivered is not necessarily from the asset linked through the PPA. Only a private-wire PPA can guarantee the power at the point of use is from a low carbon asset. Though there are geographic and supply constraints that may limit this option, as a site might not be appropriately near to such generation assets.

Addressing the question of additionality, if the power being supplied uses the UK electricity grids existing capacity, the site will not be providing growth opportunities through the introduction of new capacity onto the grid. As more companies choose to purchase “green” electricity, if generators are unable to match supply to meet demand this creates uncertainty in the future and risks price volatility. Potentially pushing energy prices up as demand outstrips supply. Out of roughly 120 Ofgem licensed domestic and non-domestic electricity suppliers in the UK, there are only three that have been confirmed by Ofgem to be truly creating additional green supply[4]. Therefore, if the site chooses to use green tariffs to provide green electricity, they may not be providing additionality to the UK.

PPAs provide additionality. Sleeved PPAs can be used to develop new assets anywhere within the UK, while the nature of synthetic PPAs means that such agreements could be used to develop new assets anywhere globally. However, only private-wire PPAs would guarantee local additionality around the SRO. The scale of water companies and the area and type of land they own or manage means they are in a prime position to support the addition of renewable capacity that can benefit themselves and the wider UK trajectory to net zero. While this chapter provides only a brief overview of considerations in procuring renewable energy, they are important considerations to ensure alignment with corporate sustainability objectives.

5.4 Offsetting and Insetting

As laid out in the PAS 2080 framework and emissions hierarchy, offsetting and insetting should be pursued only to remove residual carbon emissions once demand reduction and renewable energy approaches have been undertaken. This should be a last stage approach for emissions which can’t be abated in the short-term. It should not be considered a long-term solution to avoid action. In the long-term, as demand for credits increases, the cost of a limited supply of offset credits is expected to increase.

To reduce carbon emissions through natural sequestration, carbon reduction projects can be pursued on owned land by the Severn Trent Water, Thames Water and/or United Utilities (insetting) or purchase credible offsets from certified carbon reduction projects. Opportunities for insetting could be further evaluated in the next Gate stages. Carbon offsets can be purchased on the UK Emissions Trading Scheme (ETS), or in the voluntary market as part of a third party-verified net zero plan.

5.4.1 Carbon Offsetting Markets

The UK ETS is a mandatory offset programme, regulated by the UK government to achieve compliance with GHG emissions reductions requirements. The eligibility of offsets is strictly regulated, requiring carbon credits to be verified by an accredited UK ETS verifier. Offsets are sold on an auction market, with a clearing price of between 40 and 80 GPB/tonne between 2021 and 2022.

Voluntary markets are outside regulatory regimes, with trading and demand created by voluntary buyers rather than a mandate. As such, offset credits tend to sell at lower prices than compliance markets. However, due to the unregulated nature of the market, there is significant risk in the reliability of offsets. It is not required to verify the quality of an offset resulting in a loss of transparency and credibility. To overcome this, the buyer can choose to only purchase accredited offsets, by entities such as the Gold Standard, Verified Carbon Standard or Climate Action Reserve.

5.4.2 Natural Sequestration Methods

Natural sequestration of carbon can be achieved through a variety of methods. Most common are restoration of peatland and grassland, or woodland expansion.

Peatland restoration aims to reverse damage to peatlands by covering bare peatland areas with vegetation and blocking drains nearby – this returns the peatland to waterlogged conditions, which is required for carbon storage. Doing so can increase the amount of carbon stored in peatland areas, while also avoiding loss of carbon already stored in degrading peat areas. Grassland in the UK has the highest carbon stock of any habitat. Carbon is stored within the grassland soils, and there are numerous approaches to increase the amount of sequestered carbon. Land use change from grassland to wetland or afforestation has a carbon sequestration potential of 0.37 to 14.30 tCO_2e/ha/yr, while direct restoration of grassland can sequester 4.03 to 11.62 tCO_2e/ha/yr. Expansion of woodlands involves the planting of new woodlands and trees as well as the improved management of existing woodlands. New woodlands can sequester carbon at a higher rate than other habitats.

Both peatland and grassland restoration have the advantage of having faster carbon removal benefit than for tree planting, which has a more gradual carbon sequestration. A downside to natural sequestration approaches is that projects will eventually reach a limit of absorption, typically after 10 years. As such, there is a need to either continually expand restoration or increase offsetting over time. This will also result in higher carbon credit costs, as the amount of natural sequestration projects available will decrease with time. To avoid this, further investment in efficiency/renewable energy options over the duration of the scheme lifetimes can be pursued. In the long-term, direct-air carbon capture technologies may be a viable option, however there is currently a high degree of uncertainty regarding costs and viability of projects.

6 Approach and Recommendations

To maximise alignment with PAS 2080 and the Water UK Net Zero 2030 Routemap, it is recommended to follow the emissions hierarchy when deciding which approach to prioritise to mitigate carbon. This prioritises demand reduction, efficiency improvements and renewable energy integration before pursuing offsets to remove residual carbon emissions. Due to the complexity and long lifetime of these schemes, it is important to take a holistic approach to carbon mitigation, which uses a combination of approaches discussed in Section 5.

This report provides a broad overview of the range of options available to the SRO and should not be considered a complete appraisal of all decarbonisation pathways. A more detailed opportunity cost analysis should be conducted to identify which interventions would allow the largest reduction in emissions for the lowest cost. This should entail effective continued collaboration between carbon subject matter experts and design teams. This report provides only a high-level inclusion of the possibility of interventions, but further analysis is required to select those most appropriate for the chosen scheme. It is recommended that Severn Trent Water, Thames Water and United Utilities account for a collaborative approach to carbon emission reductions during the Gate 3 design stage, following the recommendations of this report.

Table 6-1 summarises the approaches discussed in Section 5, providing a high-level ranking of their potential impact on emissions reduction and is aligned with the emissions hierarchy. It can serve as a guide in the next stages of imbedding low carbon initiatives into the schemes. Though it should be noted that the success of such initiatives will require a continuous improvement approach with established management systems, leadership and processes.

Table 6--1 Summary and ranking of carbon emissions reduction approaches

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for Emissions reduction	Ability to Influence	List of options
Energy management & efficiency (highest priority)	Emissions reduction	High	High	- Improved pump efficiency - Metering - Smart control systems - Catchment level analytics
Renewable energy on site	Renewable energy	High	High	- Solar - Wind - Storage
Procured Renewable Energy	Renewable energy	High	High	- Sleeved PPA - Synthetic PPA - Private Wire PPA - REGO-backed Green tariffs
Resource Efficiency and Chemical Supply	Emissions reduction	High	Low	- Supply chain contracts - Reduce resource use
Capital emissions reduction	Emissions reduction	Moderate	High	- Low carbon concrete - Low carbon steel - Recycled materials - Locally sourced materials
Engineering design	Emissions reduction	Moderate	Moderate	- Conveyance routes - Pipeline size - Land use
Construction emissions	Emissions reduction	Low	Moderate	- Reduced transport - Vehicle energy use - Renewable onsite power
Insets	Offset	Low	Moderate	- Peatland restoration - Grassland restoration - Tree planting
Offsets (lowest priority)	Offset	Low	High	- UK ETS - Voluntary Offset Markets