ANNEX A4

Netheridge Carbon Report

This document has been written in line with the requirements of the RAPID gate two guidance and to comply with the regulatory process pursuant to Severn Trent Water's statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solution presented in this document be taken forward, Severn Trent Water will be subject to the statutory duties pursuant to the necessary consenting process, including environmental assessment and consultation as required. This document should be read with those duties in mind.

STSources SRO
Severn Trent Water

Severn Trent Water

SEVERN TRENT SOURCES STRATEGIC RESOURCE OPTIONS

Netheridge Carbon Report

70088464-WSP-NETHSRO-RP-GT-2005
OCTOBER 2022

CONFIDENTIAL

Severn Trent Water

SEVERN TRENT SOURCES STRATEGIC RESOURCE OPTIONS

Netheridge Carbon Report

TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. 70088464

OUR REF. NO. 70088464-WSP-NETHSRO-RP-GT-2005

DATE: OCTOBER 2022

Severn Trent Water

SEVERN TRENT SOURCES STRATEGIC RESOURCE OPTIONS

Netheridge Carbon Report

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QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	For STW Review	For STW Review	For STW Review	For STW Review
Date	15 July 2022	1 August 2022	05/09/2022	19/10/2022
Prepared by	[redacted]			
Signature				
Checked by				
Signature				
Authorised by				
Signature				
Version	V1.1	V2.1	V3.1	V4.1
Project number	70088464			
Report version	V4.1			
File reference	70088464-WSP-NETHSRO-RP-GT-2005			

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APPENDICES

ABBREVIATION AND ACRONYM LIST

Table 1 – Abbreviation and acronym list

Abbreviation or Acronym	Meaning
ACWG	All Company Working Group
ASP	Activated sludge process
BAF	Biologically Active Filtration
BFRP	Basalt fibre reinforced polymer
BoQ	Bill of quantities
CRT	Canal River Trust
EA	Environment Agency
GAC	Granular activated carbon
GFRP	Glass fibre reinforced polymer
GHG	Greenhouse gas
ha	Hectare
ICA	Instrumentation, control and automation
kW	Kilowatt
m	Metres
MBBR	Moving bed biofilm reactor
Ml/d	Megalitres per day
mm	Millimetre
MW	Megawatt
NPV	Net present value
PV	Photovoltaic
RAPID	Regulators' Alliance for Progressing Infrastructure Development
SRO	Strategic resource option
STS SRO	Severn Trent Water strategic resource option
STW	Severn Trent Water
tCO_2e	Tonnes of carbon dioxide equivalent
UK	United Kingdom
UV	Ultraviolet
WTW	Water treatment works
WwTW	Wastewater treatment works

1 INTRODUCTION

1.1 CONTEXT

In 2019 Ofwat formed the Regulators' Alliance for Progressing Infrastructure Development[1] (RAPID) to help facilitate the development of large-scale strategic solutions in response to population growth, economic development, and climate change; with decision making done through a gateway process.

Severn Trent Water (STW), together with other Water Companies, collaborated to create 17 Strategic Resource Options (SROs) submitted to RAPID for appraisal at Gate 1 in July 2021. All SROs were approved and are undergoing further development for submission to Ofwat at Gate 2 in November 2022.

This carbon report supports Severn Trent Water's (STW) Gate 2 submission for the Severn Trent Sources SRO (STS SRO) and details the carbon accounting carried out for the Netheridge (Netheridge SRO) Concept Design option.

It should be read in conjunction with the Severn Trent Sources Strategic Resource Option Netheridge Concept Design Report and is part of a suite of reports completed in support of Severn Trent Water's (STW) RAPID Gate 2 Submission.

Other reports completed as part of the Gate 2 concept design development include:

- Severn Trent Source SRO - Netheridge Concept Design Report (Annex A1)
- Severn Trent Sources (Netheridge) SRO – CDR Addendum – Alternative (No treatment) options (Annex A1.1)
- Severn Trent Source SRO – Pipeline Route Appraisal Report (Annex A2)
- Severn Trent Source SRO - Netheridge Process Basis of Design (Annex A3)
- Severn Trent Source SRO - Netheridge Cost Report (Annex A5)

1.2 REPORT SCOPE

This report captures the detail relating to the estimation of carbon emissions associated with the options for the Netheridge SRO. The estimates are based on the asset lists developed for cost estimation purposes which are detailed in the Severn Trent Source SRO - Netheridge Cost Report.

1.3 CARBON OVERVIEW

This section has been written in line with PAS 2080 (2017) and it is concerned with the 'capital' and 'operational' greenhouse gas (GHG) emissions or carbon associated with infrastructure (defined as: transport, energy, water, waste, and communications sectors):

[1] Comprising Ofwat, Drinking Water Inspectorate and the Environment Agency

- **'Capital' carbon**[2]: "GHG emissions associated with the extraction and production of materials and products, including the energy use in production" for example, the capital carbon associated with construction materials for a motorway.
- **'Operational' carbon**[3]**:** "GHG emissions associated with the operation of infrastructure required to enable it to operate and deliver its service" for example, the energy used to power motorway lighting.

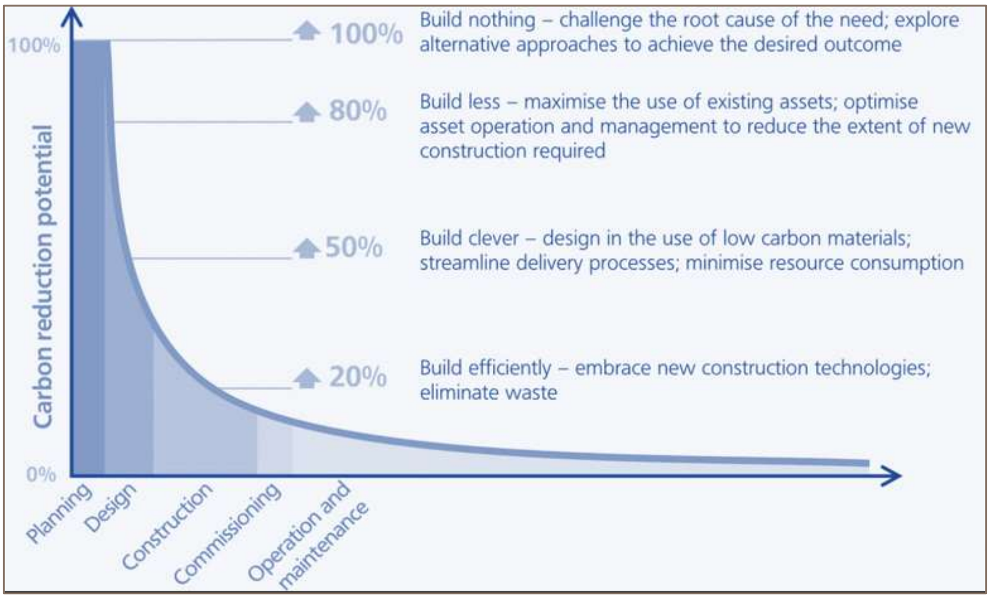
Note that 'user' carbon or the GHG emissions associated with users' utilisation of infrastructure has not been quantified and not included in this report.

The approach taken for the estimation of carbon from the options considered is summarised in the following sections. Owing to the early stage of the options design, for the carbon modelling it is likely that the results of the calculations are subject to change as the project develops and the scope becomes more detailed.

At this stage the feasibility of some options is still heavily dependent on external factors (i.e., decisions from main stakeholders and regulators), however the quantification of carbon during the early stages of the project offers the potential to identify likely carbon emissions 'hotspots' and the opportunity to influence the design, which could be proactively addressed in pursuit of reductions before the design is finalised.

Following STW's 'Low Carbon Hierarchy' diagram for early programme (Gates 0-2), presented in Figure 1-1, it is expected that theoretical carbon saving can be achieved as the project progresses through the gateways.

Figure 1-1 - STW's Low Carbon Hierarchy - Gateways 0-2



2 this is an update on the definition in UKWIR (2012) and reflects the definitions from PAS2080.

3 PAS2080: 2016

The following options have been assessed in terms of both, capital and operational carbon:

OPTION 1 – RIVER SEVERN - DEERHURST

A pipeline from Netheridge wastewater treatment works (WwTW) to the River Severn just downstream of the new STT SRO Deerhurst Water Treatment Works (WTW). Treatment will comprise iron based coagulant dosing into the existing activated sludge process (ASP) – ammonia removal (moving bed biofilm reactor (MBBR)) – phosphorus removal (ballasted flocculation (CoMag™)) – metals and organics removal (ozonation, biologically active filtration (BAF) and granular activated carbon (GAC)). The pipeline is approximately 18 kilometres (km) in length.

OPTION 2 – RIVER SEVERN - HAW GAUGING STATION

A pipeline from Netheridge WwTW to the River Severn just upstream of the environment agency (EA) gauging Station at Haw Bridge. Treatment will comprise iron based coagulant dosing into the existing ASP – nitrification (MBBR) – phosphorus removal (CoMag™) – metals and organics removal (ozonation, BAF and GAC). Pipeline approximately 15.5 km in length.

OPTION 3 – RIVER SEVERN - EAST CHANNEL

A pipeline from Netheridge WwTW to the east channel of the River Severn downstream of the existing Canal and River Trust (CRT) pumping station to Gloucester Docks. Treatment will comprise iron based coagulant dosing into the existing ASP – nitrification (MBBR) – phosphorus removal (CoMag™) – metals and organics removal (ozonation, BAF and GAC and ion exchange). Pipeline approximately 5 km in length.

OPTION 4 – GLOUCESTER AND SHARPNESS CANAL

A pipeline from Netheridge WwTW to the G&S Canal. Treatment will comprise iron based coagulant dosing into the existing ASP – nitrification (MBBR) – phosphorus removal (CoMag™) – metals and organics removal (ozonation, BAF and GAC and ion exchange) and disinfection (Ultraviolet (UV) treatment). Pipeline approximately 400 metres (m) in length.

OPTION 5 – SOUTHWEST REGION BRANCH PIPELINE

Additional pipeline for diversion of flows from the Netheridge to Deerhurst (or Haw Bridge) pipeline for discharge to the East Channel of the River Severn downstream of the intake for Gloucester Docks. This branch will discharge at the same outlet as Option 3. The carbon data represented in this report for option 5 considers the additional pipeline branch and ion exchange carbon impact only. This is to represent the additional carbon impact the option will have.

Carbon due to the above options has been calculated using the STW Carbon Calculator (Jacobs). This tool uses industry average, proprietary data, providing a conservative estimate of the emissions associated with each option.

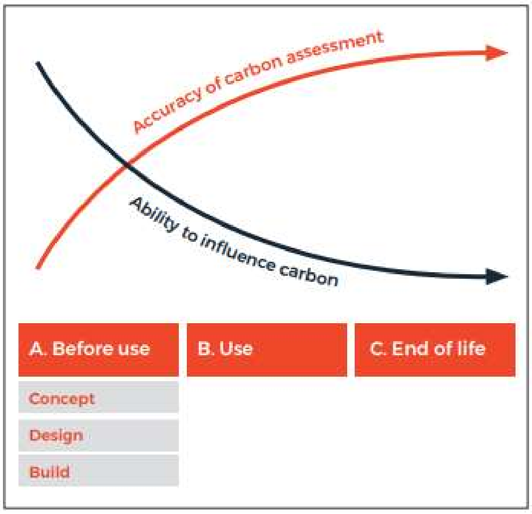
These carbon calculations can also be further supported by considering the ‘build clever’ and ‘build efficiently’ approaches to the use and application of different materials. This is not part of the scope of this report.

The following sections present an overview of the inputs and calculations in relation to capital and operational carbon, as well as mitigation opportunities and the cost implications associated with these projected emissions for each option.

1.4 CARBON OPTIMISATION APPROACH

The approach at Gate 2 has been to continue and enhance work carried out in the development of the scheme at Gate 1.

WSP supports STW in their commitment towards achieving zero net emissions by 2030 to help meet the United Kingdom's (UK) stretching targets, by committing to halving the carbon footprint of our designs and advice by 2030.



WSP are aligning themselves with PAS 2080 and currently seeking accreditation, and accordingly appreciate that the earlier carbon is considered in an asset's lifecycle, the greater the scope for managing and reducing emissions. As such, WSP have aligned their solutions development process with the PAS 2080 decisions hierarchy consisting of; build nothing, build less, build clever, build efficiently.

Approaches to decarbonisation in the water sector are generally based on emissions reduced before any sequestration options are considered to ensure that level of required offsets are minimised.

Netheridge SRO – Gate 2 approach to carbon net zero can be summarised as follows:

- Prioritise all efforts to reduce emissions (e.g., managed water and wastewater demand/ capital carbon related to construction)
- Identify opportunities to consider renewable approaches (introducing new technologies)
- Establish opportunities to offset emissions (e.g. nature-based solutions to increase carbon sequestration).

Robust optioneering is critical to selecting the most practicable solution, avoiding a detrimental development impact, and to help prevent delays, excessive or over-running costs, planning issues and final adoption by STW.

The design team identified a high-level list of potential options, starting with 'Do Nothing' and prioritising low impact operational changes over engineering solutions/ capital upgrades. Netheridge SRO options have been initially developed to include its two main elements:

- Additional treatment of the diverted flows to meet the higher water quality standards at the new discharge location
- Transfer of flows to the discharge point via a pumped pipeline

Typical carbon considerations for the options included:

- Reduction of earthworks
- Transport and disposal of material to and from site
- Potential for reuse of existing assets
- Length and size of pipeline
- Material choice/ recycled materials
- Inclusion of treatment
- Nature based solutions

- Diversions
- Construction methods
- Energy sources
- Power consumption

These were considered for all options throughout the various stages of the delivery process, from inception to built asset, and the operational stages.

2 CARBON ESTIMATION

2.1 CAPITAL CARBON

Capital carbon has been calculated using the STW Carbon Calculator (Jacobs) for all options 1 to 5 for the two main elements.

- Transfer pipeline
- Treatment plant upgrade

This carbon tool was developed for use across all projects within STW to provide consistency when calculating capital and operational carbon, therefore allowing an impartial assessment.

Note that Option 5 is the additional carbon for the construction of the branch line plus the additional treatment process above that required for Option 1 or 2. Operational carbon for the treatment will be the same as Option 3 and for the pipeline would be in addition to operational carbon for Option 1 or 2.

Carbon emissions associated with the two main elements were calculated by the tool using a top-down approach in terms of tonnes of carbon dioxide equivalent (tCO_2e per quantity unit rates for different asset types and sizes (e.g., 2.78 (tCO_2e) per 50 kilowatt (kW) submersible pump).

For each option the treatment process upgrades were broken down by major process units then further split into the major components of each unit. These components have been matched, as close as possible, to an 'Asset Index' included within the tool. The 'Asset Index' includes the following main categories:

- Cross Functional
- Distribution (Infra)
- Distribution (Non-Infra)
- Sewage Treatment (Non-Infra)
- Sewerage (Infra)
- Sewerage (Non-Infra)
- Sludge Treatment (Non-Infra)

Assets and quantities have been derived in the form of a bill of quantities (BoQ) which was developed for costing[4] purposes.

The use of tCO_2e per quantity unit rates for each asset type is not affected by interannual/regional cost variations and would allow for a comparative assessment between options at a later stage. However, not all assets derived as part of the BoQ are a perfect match to the 'Asset Index' included within the tool. Where a match has not been possible, assumptions have been made to represent the carbon emissions associated with the component.

[4]Capital cost estimate were developed using the Severn Trent Water 'Cost Tool Lite' (Atkins/Arup).

The main assumptions in relation to the BoQ for both, pipeline and treatment plant upgrade are included in the Netheridge SRO Cost Report.

Carbon emissions associated with external finishes and environmental mitigation have not been included at this stage.

Capital Carbon (tCO_2e) as calculated by the STW Carbon Calculator (Jacobs) for options 1 to 5, separated for pipeline and treatment, are presented in Figure 2-1 and summarised in .

Figure 2-1 - Capital Carbon Emissions for Construction

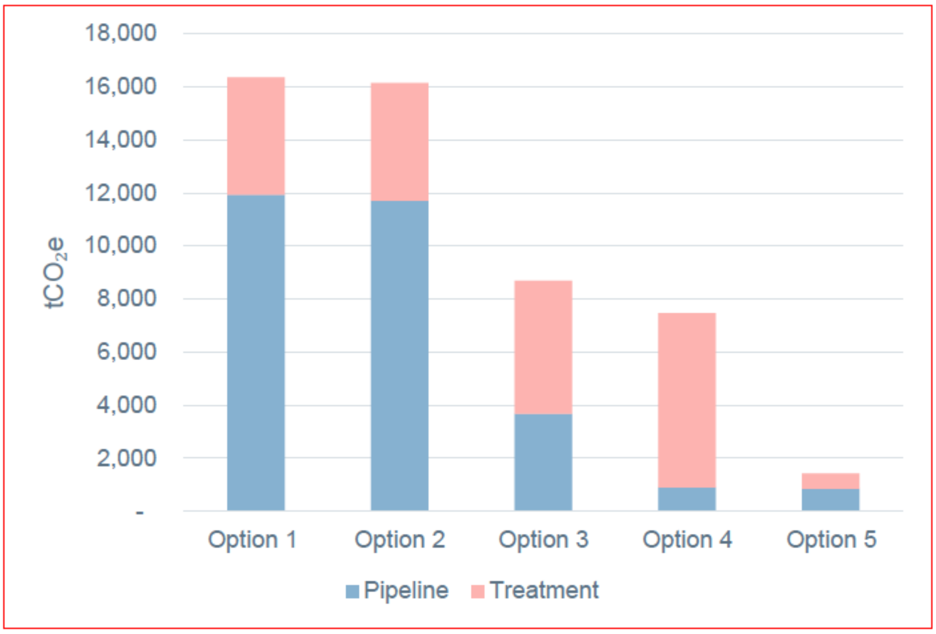


Table 2-1 - Summary of Capital Carbon Emissions for Construction (tCO_2e)

Capital Carbon	Option 1	Option 2	Option 3	Option 4	Option 5
Pipeline	11,931	11,713	3,674	903	841
Treatment	4,439	4,439	5,014	6,562	575
Total	**16,370**	**16,152**	**8,688**	**7,466**	**1,416**

In terms of pipeline related capital carbon emissions, Options 1 and 2 incur significantly more than the remaining options as a result of the length of pipeline required and associated enabling works. The pipeline carbon includes the transfer pump station/ final effluent chamber. Transfer pumps are included in all options except for option 4 where final effluent flows via gravity to the canal, and option 5 which considers the additional branch into the East Channel from option 1 or option 2 pipeline only.

In terms of carbon emissions due to treatment, options 3 and 4 incur more emissions than options 1 and 2 due to the additional treatment steps included, although these differences are not significantly large.

Option 5 provides the carbon for the construction of the pipeline branch and for inclusion of ion exchange treatment which would be required in addition to the carbon incurred in Options 1 or 2.

2.2 OPERATIONAL CARBON

Operational carbon has been calculated using the STW Carbon Calculator (Jacobs) for Options 1 to 5. The tool divides the inputs into the following categories:

- Power for pipeline pumping operations
- Power for treatment operations
- Fuel
- Chemicals
- Sludge tankering

Operational carbon emissions associated with the above categories were calculated by the tool based on operational activities and annual requirements. These activities and inputs have been matched, as close as possible, to a list for each category included within the calculation tool.

Operational activities and annual requirements have been derived from the BoQ used for costing purposes.

All options would require power for pumping, and it has been assumed that the pumps will be used to pump 35 megalitres per day (Ml/d) 35 days a year and 20 Ml/d for 120 days a year for the purpose of carbon calculations (in line with costs calculations). For the remaining 210 days per year, a sweetening flow of 20 Ml/d will be provided through the SRO treatment process and will be pumped to the existing outfall. Options 1 to 4 include treatment plant upgrades which require additional power and chemicals. The transfer pump station power has been included in the pipeline element of the calculation.

Operational Carbon Emissions (tCO_2e) as calculated by the STW Carbon Calculator (Jacobs) for Options 1 to 5 for the relevant categories are presented in Figure 2-2 and Table 2-2.

Figure 2-2 - Annual Operational Carbon Emissions

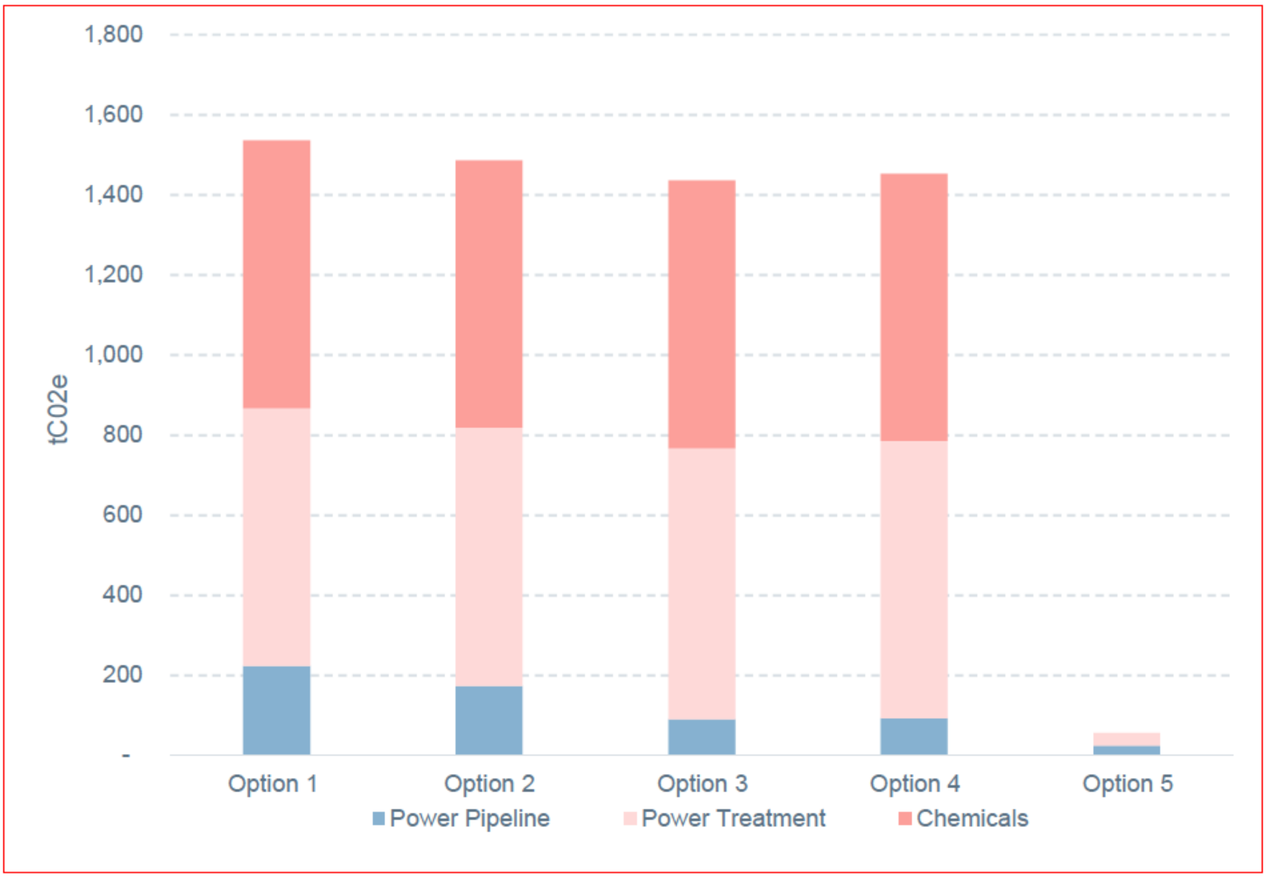


Table 2-2 - Summary of Annual Operational Carbon Emissions (tCO_2e)

Operational Carbon	Option 1	Option 2	Option 3	Option 4	Option 5 (branch only)
Power Pipeline	223	174	91	93	25
Power Treatment	645	645	677	692	32
Chemicals	668	668	668	668	-
Total	**1,536**	**1,487**	**1,436**	**1,453**	**57**

There is little difference in the operational carbon of the treatment plant for each option despite Options 3 and 4 requiring additional treatment process (ion exchange and UV). Options 1 and 2 have the higher operational carbon due to the length of the pipeline requiring more power to pump flows between Netheridge and the discharge points.

2.3 ASSUMPTIONS AND EXCLUSIONS

The following assumptions and exclusions have been considered for the calculation of capital and operational carbon using the STW Carbon Calculator (Jacobs).

- The pipeline will be constructed using the open cut method with tunnelled sections (for qualifying options) required only for the railway, canal, and river crossings.
- Small watercourse crossings will be constructed using the open cut method with flows managed through pumping.
- The pipeline is [redacted] millimetres (mm) diameter for all open cut sections.
- The tunnelled sections are [redacted] mm diameter to facilitate construction with [redacted] mm pipeline within.
- All washout, air valves and isolation valves are to STW standard specification.
- The surge vessel has been sized without detailed surge analysis.
- All concrete is cast-in place reinforced concrete.
- Foundations are piled based on poor alluvium ground conditions.
- Site drainage is based on hard surfacing
- Excavation on site is based upon 200 mm of topsoil removal, 0.75 m of spoil removed from the mound currently behind the cake storage on site and the volume of the proposed underground structures.
- Where process and connection pipeline size has been not specified, pipe diameters have been assumed as the average value of the tool range for the asset selected.
- A single ballasted coagulation (CoMag™) process stream is provided.
- All package plant units include instrumentation and control required and additional cost is not included in the instrumentation control and automation (ICA) line item.
- No carbon offsets, reinstatement or biodiversity net gain have been considered at this stage
- Carbon emissions associated with external finishes and environmental mitigation have not been included at this stage.

2.4 GATE 1 CARBON COMPARISON

The options developed at Gate 1 have not been carried forward directly for development at Gate 2. The pipeline routes and treatment processes have been modified and adjusted as the requirements for the project have been determined. In particular, the current treatment process is far more onerous than anticipated at Gate 1. For comparative purposes the Option 1 from Gate 1 has been compared to Option 1 for Gate 2 as these options are similar in that they comprise treatment at Netheridge WwTW and pipeline transfer to Deerhurst.

Table 2-3 - Gate 1 to Gate 2 Comparison

Option		Operational Carbon (tCO_2e)	Capital Carbon (tCO_2e/Ml/d)[1]	Capital Carbon (tCO_2e)
Gate 1	Netheridge to Deerhurst	98	185	6,478
Gate 2	Netheridge to Deerhurst	1,536	1,040	36,425
1 – Based on 35 Ml/d				

The data available for carbon analysis at Gate 1 shows the operational and capital carbon for the treatment and pipeline combined, so it is not possible to directly see the impact of a slightly reduced pipeline length and increased treatment requirement. However, overall the operational carbon appears to have reduced, but the capital carbon has almost doubled.

Given the pipeline capital carbon for Gate 2 is now ~12,000 tCO_2e which alone is higher than the total capital carbon for the Gate 1 option including treatment, this implies that the Gate 1 calculation was completed on a different basis.

3 WHOLE LIFE CARBON AND NET PRESENT VALUE

3.1 WHOLE LIFE CARBON

Whole life carbon is the total carbon, i.e., the sum of carbon across all the lifecycle stages of an asset, that should be assessed and reduced. This is to avoid making a carbon reduction in one lifecycle stage which leads to an increase in carbon in a later lifecycle stage and therefore to a net increase in whole life carbon. For example, making sure that using low-carbon materials to reduce 'capital' carbon during construction does not lead to more carbon from material replacements during the operational stage. For the Netheridge SRO the demolition and decommissioning of the assets is not included in the calculation as it is anticipated that the life of the system assets will be greater than the 80-year assessment period.

Whole life carbon has been calculated using the STW Carbon Calculator (Jacobs) over an 80-year appraisal period. Capital carbon emissions are incurred in years 1 to 9 of the project during construction. Operational carbon emissions are incurred throughout the appraisal period from years 10 to 80.

To calculate repeat capital carbon over the 80-year assessment period, the assets of the carbon model were grouped into mechanical and electrical (M&E) and civils. The capital carbon associated with instrumentation, automation, and control (ICA) is included with M&E items.

The capital carbon associated with M&E items is automatically calculated by the STW carbon tool. For capital carbon associated with civil items, the tool categorises this into site preparation, foundations, pipework, manholes, concrete tanks, buildings, walls, site access, refurbishment activities and other civil materials. Capital carbon associated with site preparation and foundations has been excluded in NPV calculations as it is anticipated these will not be replaced during the 80-year assessment period.

Capital carbon has been repeated every 20 years for M&E items, and every 60 years for civils items to align with the NPV cost tool. The repeat capital carbon for M&E and civils items is shown in Table 3-1. Option 5 includes the additional capital carbon only (difference between option 2 and 3).

Table 3-1 – Repeat capital carbon (tCO_2e)

	Discipline	Option 1	Option 2	Option 3	Option 4	Option 5
Treatment	M&E (every 20 years)	1,189	1,189	1,467	2,967	278
	Civils (every 60 years)	2,260	2,260	2,313	2,332	53
Pipeline	M&E (every 20 years)	1,428	566	429	27	0
	Civils (every 60 years)	9,943	10,587	2,685	727	281
TOTAL		20,055	18,111	10,686	12,040	1,167

Figure 3-1 and Table 3-2 provide a summary of the whole life carbon broken down by category and calculated over an 80-year appraisal period.

Figure 3-1 - Whole Life Carbon Comparison (tCO_2e)

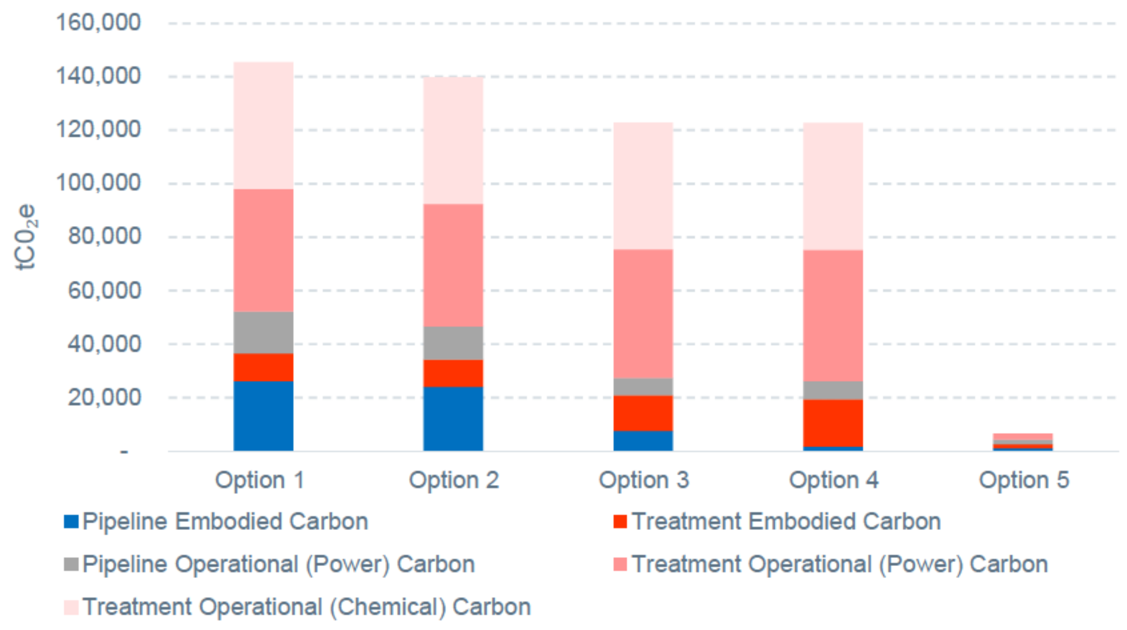


Table 3-2 – Summary of Whole Life Carbon Emissions (tCO_2e) - 80-year period

Option	Pipeline Capital Carbon	Treatment Capital Carbon	Pipeline Operational (Power) Carbon	Treatment Operational (Power) Carbon	Treatment Operational (Chemical) Carbon	Total Whole Life Carbon
Option 1	26,159	10,266	15,838	45,781	47,428	145,473
Option 2	23,997	10,266	12,347	45,781	47,428	139,819
Option 3	7,646	13,276	6,455	48,051	47,428	122,856
Option 4	1,710	17,796	6,618	49,117	47,428	122,669
Option 5	1,122	1,462	1,746	2,270	-	6,599

Table 3-2 shows that overall, there is approximately a 16% difference in the total carbon of the options over an 80-year period. The high capital carbon of the longer pipelines combined with the higher operational associated with pumping means that the total carbon for Options 1 and 2 remains marginally higher than the shorter pipe routes, despite the increased operational carbon required for the extra treatment steps.

For an additional ~5% total carbon to Option 1 and 2, the Netheridge SRO could provide additional water resources to the Southwest region via the branch line to the East Channel of the River Severn (Option 5).

3.2 NET PRESENT VALUE CARBON

Monetisation of emissions due to the different options under appraisal has been carried out over the 80-year appraisal period and the results are presented as Net Present Value (NPV).

The value of carbon has been adopted from the time series issued by the Business, Energy, and Industrial Strategy (BEIS, 2021[5]) which presents carbon values, inflated to 2021 prices from 2020 to 2050 assuming an annual growth rate of 1.5% year on year. This time series includes low, central, and high values.

Monetised carbon has been discounted using HM Green Book's standard rates (3.5% from year 1 to year 30, 3% from year 31 to 75 and 2.5% from year 76 to year 99).

Table 3-3 presents a summary of the net present value carbon costs broken down by category and calculated over an 80-year appraisal period using central series carbon values. The £NPV for option 5 represents the additional £NPV for the branched pipework, not the total cost of the solution which would include either option 1 or option 2.

Table 3-3 – Summary of NPV Carbon Costs (£NPV) - Discounted over an 80-year period (Central Series)

Option	Pipeline Capital Carbon	Treatment Capital Carbon	Pipeline Operational Carbon	Treatment Operational Carbon	Non-Power Operational Carbon	Total Whole Life Carbon Cost
Option 1	£3,851,232	£1,533,272	£1,908,089	£5,515,324	£5,713,731	£18,521,648
Option 2	£3,574,726	£1,533,272	£1,487,437	£5,515,324	£5,713,731	£17,824,490
Option 3	£1,153,073	£2,092,580	£777,586	£5,788,748	£5,713,731	£15,525,718
Option 4	£263,193	£2,579,000	£790,908	£5,869,724	£5,667,890	£15,170,716
Option 5	£206,154	£219,983	£210,326	£273,424	£-	£909,887

When monetised and a discount rate applied there is a 18% difference between Option 1 which is the most expensive and Option 4 which is the least expensive.

3.3 SENSITIVITY ANALYSIS

To assess the £NPV sensitivity, £NPV values have also been calculated using low series and high series monetary values. The results are displayed in Table 3-4 and Table 3-5.

[5] BEIS (2021) Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Table 3-4 – Summary of NPV Carbon Costs (£NPV) – Discounted over an 80-year period (Low Series)

Option	Pipeline Capital Carbon	Treatment Capital Carbon	Pipeline Operational Carbon	Treatment Operational Carbon	Non-Power Operational Carbon	Total Whole Life Carbon Cost
Option 1	£1,923,092	£765,697	£954,055	£2,757,690	£2,856,895	£9,257,429
Option 2	£1,784,885	£765,697	£743,726	£2,757,690	£2,856,895	£8,908,894
Option 3	£575,759	£1,044,902	£388,797	£2,894,404	£2,856,895	£7,760,757
Option 4	£131,405	£1,288,112	£398,656	£2,958,629	£2,856,895	£7,583,843
Option 5	£102,899	£109,870	£105,164	£136,713	£-	£454,647

Table 3-5 - Summary of NPV Carbon Costs (£NPV) – Discounted over an 80-year period (High Series)

Option	Pipeline Capital Carbon	Treatment Capital Carbon	Pipeline Operational Carbon	Treatment Operational Carbon	Non-Power Operational Carbon	Total Whole Life Carbon Cost
Option 1	£5,777,596	£2,300,452	£2,865,360	£8,282,312	£8,580,258	£27,805,978
Option 2	£5,362,278	£2,300,452	£2,233,671	£8,282,312	£8,580,258	£26,758,970
Option 3	£1,729,753	£3,139,214	£1,167,694	£8,692,910	£8,580,258	£23,309,829
Option 4	£394,771	£3,870,131	£1,197,305	£8,885,801	£8,580,258	£22,778,437
Option 5	£309,111	£330,102	£315,845	£410,598	£-	£1,365,656

The total whole life carbon cost between the low series, central series and high series for all options are compared in Figure 3-2.

Figure 3-2 - NPV Carbon costs (£NPV) Sensitivity analysis

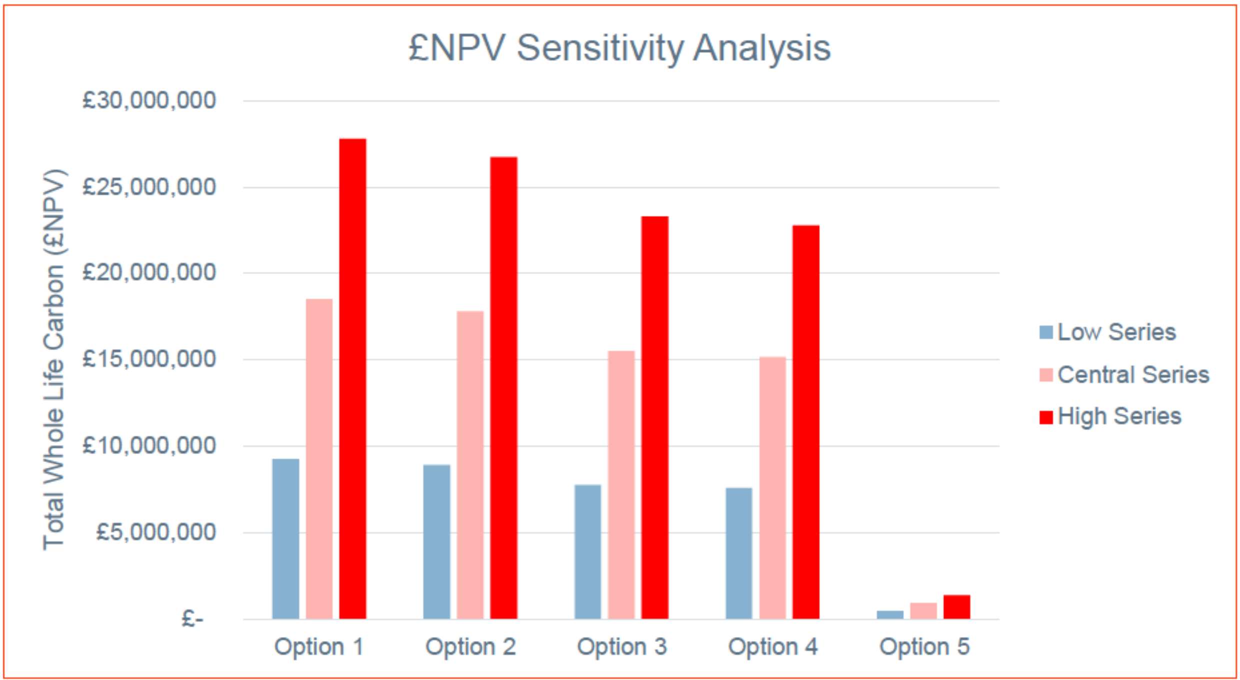


Figure 3-2 shows the reduction between central and low series NPVs is 50%, and the increase between central and high series NPVs is 50%. The variation between option 1 and option 4 in the low series is approximately £1.67 million, in the central series £3.35 million and in the high series £5.03 million. The £NPV sensitivity (low series NPV subtracted from high series NPV) is summarised in Table 3-6 below.

Table 3-6 - £NPV sensitivity

Option	£NPV Sensitivity
Option 1	£18,548,549
Option 2	£17,850,076
Option 3	£15,549,071
Option 4	£15,194,594
Option 5	£911,009

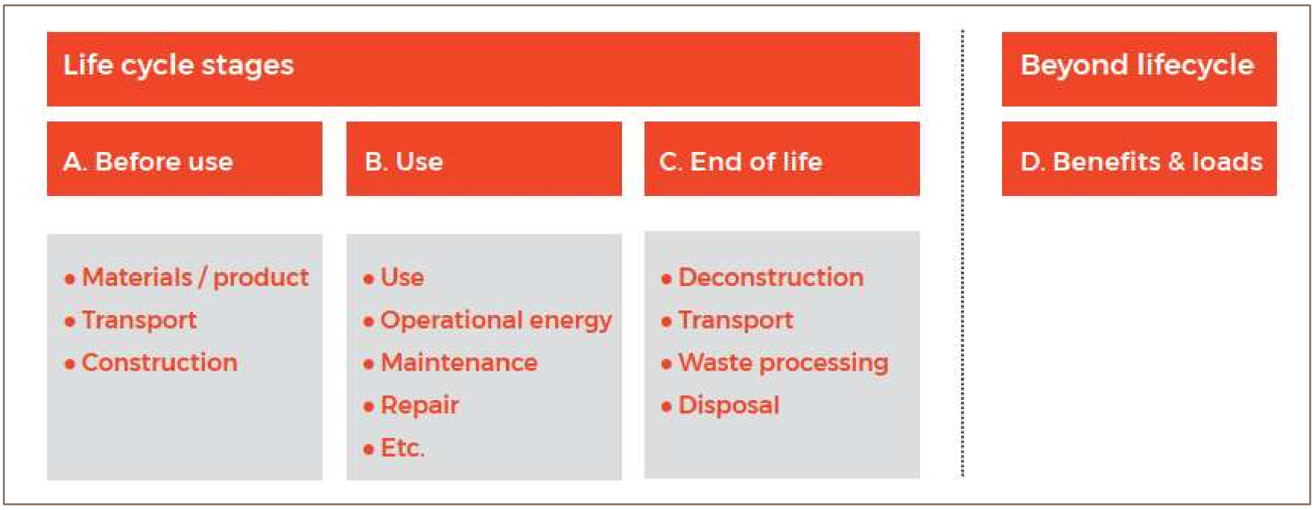
Across options 1 to 4, there is a very high £NPV range when calculated using the difference between the low series values and the high series values. As stated previously, option 5 represents the additional £NPV sensitivity to option 1 or option 2.

4 CARBON MITIGATION OPPORTUNITIES

This section aims to highlight the carbon mitigation techniques that have been identified at gate 2, and the potentials that could be realised at gate 3 and detailed design.

The earlier that carbon is considered in an asset's lifecycle (as shown in section 1.4), the greater the scope for managing and reducing it; the later it is considered, the greater the number of opportunities for reduction that will have been lost.

Figure 4-1 - Life Cycle Stages



The use of the term 'Scope' first appeared in the Greenhouse Gas Protocol of 2001, and today are the basis for mandatory GHG reporting in the UK. Emissions can be categorised into three scopes:

Scope 1 – Direct emissions from a company. In the case of this assessment, emissions from operations (operating boilers, vehicles etc).

Scope 2 – Indirect emissions generated on the company's behalf. In the case of this assessment, emissions from electricity generation.

Scope 3 – The indirect emissions associated with organisations up and down the company's value chain. In this assessment, scope 3 is considered as capital carbon (construction) and repeat capital carbon emissions.

Where a carbon mitigation opportunity has been identified, the category (scope) it can address has been defined.

At this early stage of the project a number of generic strategies can be applied to reduce capital carbon:

- Reduction of material being used (Scope 3)
  - Building or material reuse
  - Prefabrication to reduce bulk material quantities
  - Design efficiently in modules to facilitate simplification of construction programmes and maximise use of resources

- Use of alternative materials (Scope 3)
  - Consider alternative structural design
  - Consider different assembly methods
  - Consider material which naturally sequester carbon or utilise natural features
- Product alternative (Scope 3)
  - Consider material that can be reused from other projects
  - Source material locally if possible
  - Consider the sustainability of the materials being used
- Treatment design (Scope 1, 2 and 3)
  - Consider whether treatment is necessary
  - Utilise gravity as opposed to pumped system where possible
  - Consider alternative nature-based treatments

Similarly, the selection and adoption of low energy or more energy efficient technology (scope 2) will reduce the operational carbon of the project over the lifecycle of the assets.

4.1 TREATMENT PLANT

The treatment plant comprises largely of concrete tanks and plinths with specialised premanufactured equipment. At concept design phase the volume of concrete is estimated and there is scope at the detail design stage to reduce the volume of concrete required. At the construction stage there is scope to utilise a low-carbon concrete to reduce the overall impact of the scheme.

The primary driver for design of the treatment process at concept design has been to establish a robust and reliable process that will meet the required discharge water quality standards to demonstrate the feasibility of the scheme as a whole. Preference has been given to low energy solutions to reduce operational costs and carbon impact. In some cases, low carbon technology has been discounted as it cannot reliably produce effluent of the quality required for discharge to the receiving waters.

In subsequent project phases, as quality standards are confirmed and dilution modelling improved it may be possible to modify, adapt or even remove treatment processes, especially if a pilot plant is established to determine the most efficient dosing and treatment regime.

The impact of carbon on the chosen design, lower carbon alternatives and the opportunity to reduce the carbon in the treatment process stream is discussed in detail in the Severn Trent Source SRO - Netheridge Process Basis of Design report. A summary of the key design items is summarised below.

Areas where carbon impact has been minimised:

- Reducing the throughput through some of the treatment process to a minimum to keep the process viable when not transferring flows to the STT SRO (Scope 2).
- Filtration processes such as reverse osmosis and ultrafiltration have been discounted because of the high energy demand (Scope 2)
- Gravity Belt thickeners have been provided as low energy alternative compared to centrifuges (Scope 2)

- The chosen ion exchange process is a lower energy consumption compared to membrane processes (Scope 2)
- Interstage pumping reviewed and reduced where possible (Scope 2 and 3).

Opportunity to reduce carbon further in the treatment process:

- Improve the efficiency of the existing treatment process which may negate the need to apply secondary ferrous dosing and reduce ammonia load in subsequent process (Scope 2 and Scope 3)
- Replace the MBBR with biological trickling filters (subject to item above) (Scope 2)
- Consider alternative to the CoMag™ process (or work with manufacturer to reduce carbon impact) (Scope 2 and 3)
- Utilise a wetland process for phosphorus removal (see section below) (Scope 2 and Scope 3)
- Utilisation of high efficiency UV systems intended for potable water use (Scope 2)
- Utilise powdered chemicals to reduce vehicle movements for delivery (Scope 1 and Scope 2)
- Utilise next generation high efficiency pumps and motors (Scope 2)
- Shutting down the treatment process when not transferring flows to STT SRO and recommissioning when required (Scope 1 and 2)

4.1.1 WETLANDS TECHNOLOGY FOR PHOSPHORUS REMOVAL (SCOPE 2 AND SCOPE 3)

There is good evidence to suggest that constructed wetlands can improve water quality while also providing a wildlife habitat[6]. They can also reduce energy use and carbon emissions[7]. Given the availability of land adjacent to the Netheridge WwTW there maybe scope to create a wetland that could contribute to the overall treatment process whilst improving the biodiversity and creating new habitat in the area.

Wetlands are a low carbon technology that can provide phosphorus removal. Tertiary solids removal processes will still be required for low phosphorus permits, however, if after discussion with regulatory bodies the assumed phosphorus permit is relaxed, wetlands may present themselves as an attractive low carbon and more environmentally sustainable option.

4.1.2 PV ARRAY FOR ELECTRICITY GENERATION (SCOPE 2)

The treatment process is a very energy intensive process and even with the adoption of low energy technology the electricity demand will be high. There is opportunity in the Netheridge SRO to offset some of the electricity requirement with the installation of a photovoltaic (PV) array in the land adjacent to Netheridge WwTW. STW own 2.3 hectares (ha) of land to the southwest of the existing WwTW site and this land could be utilised to install a PV array to offset the carbon generated by the project.

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[6] https://www.epa.gov/sites/default/files/2018-07/documents/constructed_wetlands_for_wastewater_treatment_and_wildife_habitat_17_case_studies_epa832-r-93-005.pdf
[7] https://carboncopy.eco/initiatives/ballykelly-sustainable-wastewater-treatment

Initial calculations indicate that approximately 1 megawatt (MW) of electricity could be generated, and if the PV array installation were to operate in normal UK conditions it would generate in the order of 24 MW/day which could supply up to ~17% of the power required to treat the 35 Ml/d flow and ~30% of the 20 Ml/d flow.

4.1.3 METHANE CAPTURE AND GREEN GAS PRODUCTION (SCOPE 1 AND SCOPE 3)

Potent greenhouse gasses such as methane are emitted during the processing of wastewater, which contributes to the overall carbon footprint of the works. Methane can also be captured and used as a fuel source[8]. This presents an opportunity to capture a potent greenhouse gas and then put it to good use. It may be possible to inject it into the National Grid gas supply as 'green gas' or use it to fire a generator on site, reducing the demand for gas imports.

4.1.4 CONSTRUCTION (SCOPE 3)

For option 1, site access, buildings, tanks and foundations account for 63% of capital carbon, and 39% of repeat capital carbon. Some of the decarbonisation methods included in the All Company Working Group (ACWG)– Low capital carbon alternatives for SROs report (Aug 2022) for treatment and construction are listed below and include:

4.1.4.1 Concrete

- **Low carbon concrete**– The use of supplementary cementitious materials (SCM's) could be used to reduce total capital carbon. Here materials such as alkali-activated materials (AAM's), limestone powder, fly ash, calcined clay and volcanic ash. There is also potential for carbon negative synthetic SCMs, AACMs or aggregates for direct injection of carbon dioxide into fresh concrete, and for concretes that cure by carbonation.
- **Legislation** – Ensure contractors abide to PAS 2080 to ensure they are contractually liable for the carbon management of their projects.
- **Steel reinforcement** – Use of recycled rebar to avoid the carbon intensive oxygen furnace production technique. Alternative fibre reinforcement technologies include glass fibre reinforced polymer (GFRP), basalt fibre reinforced polymer (BFRP), but are yet to be adopted as a replacement to steel. The use of BFRP could provide a saving of up to 22% of global warming potential compared to 100% recycled steel rebar (based on current carbon emissions, likely to decrease with the decarbonisation of the electricity grid.

4.1.4.2 Buildings

- **Structural members and cladding** – Cladding materials for steel frame buildings are typically carbon intensive brick or steel. Additionally, mortar for brick cladding has a high carbon intensity. At present, steel cladding, particularly recycled or reused steel, offers a lower carbon solution to brickwork. Alternatives to steel have not been considered due to structural loads and spans required within the buildings.

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[8] https://www.globalmethane.org/documents/ww_fs_eng.pdf

- **Piled foundations** – Carbon emissions of piled foundations are associated with the carbon intensity of concrete and rebar (90% of capital carbon estimates). The decarbonisation potential largely depends on the decarbonisation of concrete and rebar manufacturing. The most immediate means of decarbonising piled foundations is in design efficiency (reducing overdesign and adopting innovative pile designs).

4.1.4.3 Tanks

As for piled foundations, concrete and rebar accounts for 90% of capital carbon for tanks, and therefore the decarbonisation of these assets depends on the decarbonisation potential or concrete and rebar.

4.1.5 CHEMICALS (SCOPE 3)

There is a potential for chemical usage to be decarbonised, however it is not well documented in industry. Some potential decarbonisation techniques for the production of chemicals proposed for Netheridge which fall outside of this project's include:

- **Sodium hypochlorite** - Decarbonising the electricity sector as power and sodium chloride are the main requirements.
- **Ferric sulphate** – Change to poly-aluminium chloride for phosphorus removal, where 60% of the emissions are from electricity consumed during smelting. Using an inert material instead of carbon in anodes could eliminate direct emissions from electrolysis. The use of scrap aluminium would remove the carbon impact of producing virgin aluminium.
- **Polymer** – Change to biological hydrocarbon source instead of an oil-based hydrocarbon source.

It is proposed the low carbon alternatives identified in the ACWG low capital carbon alternatives are reviewed in further detail during gate 3.

4.2 PIPELINE

There are limited opportunities for reduction in carbon in a pipeline at the concept design stage. The key consideration is to design for the shortest route and limit the head losses to create the most energy efficient system.

During the concept design stage, the shortest routes were adopted with minor modifications to enable maximum hydraulic efficiency with scope 2 and scope 3 in mind. It is not possible to calculate carbon accurately as the total carbon will depend on the distance materials need to travel to site, the availability of backfill local to site and the construction methods adopted. During the detail design stage, the carbon may be reduced by selection of local materials and the use of low carbon alternative for bedding or backfill (recycled aggregates etc).

At Gate 1 it was proposed to run the pipeline continually with 10% of the flow to prevent septicity of the effluent in the pipe. At Gate 2 this was modified, and the decision made to stop pumping and drain the pipe when flows are not required for the STT SRO, addressing scope 2. This provides an energy saving of 15-20% depending on the actual days of operation of the Netheridge SRO.

To further address scope 2, operational carbon has been minimised by selection of pipe size to reduce friction loss in the pipeline and create minimum static head for pump operation. There is a balance of capital carbon during construction against operational carbon required though energy use for pumping. During the detailed design stage, the selection of efficient pumps will be an important consideration to minimise the long-term carbon impact.

The latter part of the pipeline flows by gravity from the break-pressure tank. There is opportunity to install a mini turbine at this location but given the limited operation of the pipeline this is unlikely to provide much benefit long term.

At Gate 2 the opportunity to reduce the carbon impact of the pipeline has been explored by the introduction of Option 2. This option reduces the pipeline by ~2.5 km and reduces the static head by ~20 m and therefore is the lower carbon option. Selection of this option is dependent upon the EA agreeing that reduced flow in the Deerhurst to Haw Bridge section of the River Severn is acceptable but would reduce emissions associated with scope 2 and scope 3.

Once the discharge location has been confirmed, there is further opportunity to mitigate carbon through pipe material selection, installation technique and installation surface type during the detailed design stage. Some of the areas (hotspots) for carbon mitigation as highlighted in the ACWG – Low capital carbon alternatives for SROs (Aug 2022) for pipelines include

- **Pipeline materials (Scope 3)** – Capital carbon associated with the pipework accounted for 75% of option 1's total capital carbon for the total pipeline solution. The use of steel can generate 36% less carbon than ductile iron per meter, high performance polyethylene (HPPE) a 20% reduction, GRP up to 40% and molecularly orientated polyvinylchloride (MO-PVC) up to 64%.
- **Decarbonising construction plant (Scope 1 and Scope 3)** – The operation of construction plant can account for up to 25% of the carbon associated with pipe laying activities. Savings could be made through efficiencies in haulage, excavation, pipe laying and backfill.
- **Ancillary items (Scope 1)** - The remaining percentage of carbon emissions include ancillary items such as fuels for construction plant, thrust restraints and commissioning. Wheel to wheel carbon savings against diesel vehicles could be made by using electric vehicles, hybrid vehicles (20% carbon saving) or vehicles powered by hydrotreated vegetable oil (92% carbon saving) or hydrogen (100% carbon saving if 100% renewable electricity is used) could contribute to carbon reductions from emissions, though the fuels are limited to availability and electric vehicles by their size.

4.3 ALTERNATIVE LOWER CARBON SOLUTIONS

The Gate 2 concept design was a continuation of the Gate 1 concept of 'bolt on' treatment process at Netheridge and pumping to the abstraction point of the STT SRO. There is limited scope to reduce the carbon of that concept as the requirement for a pipeline and the predetermined nature of the treatment process units do not allow for a great deal of variation.

If a lower carbon alternative is required, then there will be a need to deviate from the existing concept design to consider other design solutions. There has been ongoing dialogue between STW and EA regarding this and STW have initiated some early investigation into the following alternative solutions:

- A more holistic approach to improving effluent quality by upgrading the entire WwTW to improve the water quality of the Netheridge WwTW (Scope 3). This could provide significant efficiency over the 'bolt on' approach and have benefit of improved effluent quality at Netheridge.
- Nature based solutions such as wetland that have low capital and operational carbon (Scope 2 and Scope 3).

- No treatment solutions that transfer river water between similar water quality zones (i.e., tidal and non-tidal) and so remove the need for any additional treatment process (Scope 1, Scope 2 and Scope 3).

There may also be other innovative technologies that could be considered as part of the scheme. Northern Ireland Water's 'Power of Water' report[9] included ideas for embedding wastewater treatment works into green energy systems. Two of these ideas may be relevant to the proposed works at Netheridge. WwTW:

- Use of the waste heat from treatment works to provide a district heating system for local properties (Scope 3). It may be worth investigating whether this idea could provide a low carbon energy source to the communities to the south and east of the Netheridge WwTW on the other side of the canal.

- Use of electrolysis to split water into hydrogen and oxygen (Scope 2 and Scope 3). The hydrogen can then be used as a fuel source while the oxygen can be used to improve the efficiency of the treatment works. Alternatively, the two can be re-combined to release energy. This essentially creates a grid scale battery, which has the potential to help balance intermittent renewable energy supplies with peaks and troughs in electricity demand.

4.4 CARBON MITIGATION SUMMARY

In summary, there are carbon mitigation opportunities for both the treatment plant and transfer pipeline. As mentioned above, it is important that carbon is considered in an asset's lifecycle as early as possible, as there are greater opportunities to manage and reduce it.

It is proposed that the treatment plant will comprise of largely concrete tanks and plinths with specialised premanufactured equipment. However, at concept design the volume of concrete is estimated and so there is limited scope to reduce this. Therefore, the majority of the carbon savings to be made through the use of concrete will need to be defined at the detailed design stage. Additionally, there will be an opportunity to specify a low-carbon concrete for construction.

There are opportunities to create a wetland, a low carbon technology that can provide phosphorus removal or to offset some of the electricity demand with the installation of a PV array in the land adjacent to Netheridge WwTW. Also, potent greenhouse gases such as methane are emitted during the processing of wastewater. These gases could be captured and used as a fuel source by injecting it into the National Grid gas supply as a 'green gas' or use it to fire a generator on site, reducing the demand for gas imports. It is recommended that these carbon mitigation opportunities should be explored further in the next stages of design.

Regarding the pipeline, the key consideration to reduce carbon is to design the shortest route and limit head losses to create the most energy efficient system. During the concept design stage, the shortest routes were adopted with minor modifications to enable maximum hydraulic efficiency. It is not possible to calculate carbon accurately in further detail than this as it will depend on the distance

[9] https://www.niwater.com/the-power-of-water-report/20/

materials need to travel to site, the availability of backfill local to site and construction methods adopted. Similarly, to the recommendations mentioned above for the treatment plant, the pipeline carbon reductions will need to be considered in greater detail at the detailed design stage.

To conclude, there have been limited opportunities to reduce carbon at the concept design stage and whilst the carbon impact has been minimised where possible, the main focus has been to establish a design that will demonstrate the feasibility of the scheme as a whole. The carbon mitigation opportunities including those in the ACWG – Low capital carbon alternatives for SROs report (Aug 2022) will need to be explored again at the detailed design stage once there is more information available and the main design elements have been finalised.

Appendix A

STW CARBON SUMMARY SHEET

Figure A-1 - Step 1: Emissions footprint

	A	B	C	D	E
1	**Step 1: set out emissions footprint**		**Footprint**		
2			**Capital Carbon tCO_2e**	**Operational Carbon tCO_2e (80 years)**	**Whole Life Carbon (80 years) tCO_2e**
3	Gate 1 solution		6,478	98	Not calculated
4	Gate 2 baseline (unmitigated) - Option 1 Deerhurst only (Assume today's technology for the baseline ie Water UK ambition for 2030 not yet achieved)		36,425	109,048	= Capital carbon + operational carbon = 36,425 + 109,048 = 145,473
5		CO_2 reduction owner for Treatment and Pipeline	Designer/Contractor	Operations	Energy
6			Designer/Contractor	Operations	Chemicals
7			Designer/Contractor	Operations	Materials
8			Designer/Contractor	Operations	Transport

Figure A-2 - Step 2: Carbon and greenhouse gas mitigation

	A	B	C	D	E	F	G
9	**Step 2: how has the project designed down carbon and GHGs**						
10	What policies, frameworks and approaches have been used to drive down whole life carbon in option choices and within solution design? e.g. those listed in RAPID Gate 2 guidance, STW policies, consultant policies	e.g. Ofwat, ACWG, PAS 2080, consultant's own policies					
11	**Describe the Design Mitigation**	**Carbon reduction hierarchy?** Build Nothing Build Less Build Clever Build Efficiently	**Are Scope 1, 2 or 3 emissions reduced?** Scope 1: emissions from Operations Scope 2: emissions from electricity Scope 3: indirect emissions in value chain	**Which part of the STW Triple Pledge does this mitigation contribute to?** A. net zero carbon emissions; B. generating 100% of our power from renewable sources; C. making our fleet of vehicles 100% electric	**Carbon reduction – Capital** **tCO_2e**	**Carbon reduction – Operational** **tCO_2e**	**Whole life carbon reduction** **tCO_2e**
12	e.g. Deerhurst Consider reed bed technology for removal of substances in further detail at G3. This will reduce the amount of treatment processes, energy use and supply chain carbon. Need for chemicals would be reduced, therefore reduced emissions as a result of chemical production and transport.	Build Less	Scope 1 Scope 2 Scope 3	A. net zero carbon emissions	None – it is unlikely that reed bed technology will eliminate any of the process treatment stages, the expectation being that partial treatment would be achieved	ST trials on Green Recovery programme to be undertaken over next 12 months to determine potential operational CO_2 savings	TBC
13	Non treatment options to be developed further during G3, range of carbon reductions calculated at G2 for information	Build Less	Scope 1 Scope 2 Scope 3	A. net zero carbon emissions	= Capital carbon during construction (treatment only) + repeat capital carbon (treatment only) = 4,439 + 5,827 = 10,266	= Power operational carbon + operational carbon associated with chemical dosing = 45,781 + 47,428 = 93,209	= Capital carbon reduction + operational carbon reduction = 10,266 + 93,209 = 103,475
14	Reduce length of conveyance pipeline and pumping requirement through discharge at Haw Bridge (G2 preferred option – carbon reduction realised)	Build Less	Scope 1 Scope 2 Scope 3	A. net zero carbon emissions	= Pumping to Deerhurst construction and repeat capital carbon – Pumping to Haw Bridge construction and repeat capital carbon = 26,159 – 23,997 = 2,162	= Pumping to Deerhurst operational carbon – pumping to Haw Bridge operational carbon = 15,838 – 12,347 = 3,491	= Capital carbon reduction + operational carbon reduction = 2,162 + 3,491 = 5,653
15	Minimise treatment required to keep plant operational during periods when STT not calling for sweetening flow to be developed in G3. The reduced demand is the difference between transferring 35 MLD to Deerhurst for 365 days per year, and operating at 35 MLD for 35 days per year, 20 MLD of sweetening flow for STT for 120 days and a sweetening flow through the treatment process only for the remainder of the year.	Build Clever	Scope 1 Scope 2 Scope 3	A. net zero carbon emissions	0 (No change in capital carbon)	= (365 days per year pumping operational carbon – optimised pumping operational carbon) x years of operation during 80 year assessment period = (1,716 – 903) x 71yrs = 57,723	= Capital carbon reduction + operational carbon reduction = 0 + 57,723 = 57,723
16	A 20% reduction at G5 associated with: Low carbon concrete, substituting cement with other materials/ additives Novel alternatives to steel reinforcement in reinforced concrete (e.g., fibre-reinforced polymer bars). Reduce demolition trough trenchless techniques and avoid infrastructures such as railway lines, canals, motorways, highways, and urban areas. Re-use demolished material. Re-use existing available materials, e.g., processing, re-use of excavated material as fill. Sustainable construction materials.	Build Clever Build Efficiently	Scope 3	A. net zero carbon emissions	= (Pipeline capital carbon (construction only) + Treatment capital carbon (construction only)) x 20% = (11,931 + 4,439) x 20% = 3,274	0 (Not applicable for scope 1 and Scope 2))	= Capital carbon reduction + operational carbon reduction = 3,274 + 0 = 3,274
17	**Total mitigation reductions against baseline realised at G2**				**= E14 + E15 + E16 = 2,162 + 0 + 3,274 = 5,436 (excludes savings from no treatment option (E13))**	**= F14 + F15 + F16 = 3,491 + 57,723 + 0 = 61,214 (excludes savings from no treatment option (F13))**	**= Total capital carbon reduction + Total operational carbon reduction = 5,436 + 61,214 = 66,650**
18	**Total remaining whole life carbon emissions for offsetting to achieve Water Industry target for Scope 1 and 2 being net zero by 2030**				**0 (Capital carbon not included in Scope 1 or Scope 2)**	**= ((G2 Baseline Operational carbon – total operational savings)/71 years operation during 80 year assessment) x (end of carbon assessment period (year) – year of operation) = ((109,048 – 61,214)/71) x (2103-2033) = 47,160**	**= Total operational carbon to be mitigated = 47,160**
19	**Total remaining whole life carbon emissions for offsetting to UK Government target for Scope 1 , Scope 2 and Scope 3 being net zero by 2050**				**= G2 baseline capital carbon – total mitigation reductions = 36,425 – 5,436 = 30,989**	**= ((G2 Baseline Operational carbon – total operational savings)/71 years operation during 80 year assessment) x (end of carbon assessment period (year) – year 2050) = ((109,048 – 61,214)/71) x (2103-2050) = 35,707**	**= Total remaining whole life carbon to be mitigated + Total remaining operational carbon to be mitigated = 30,989 + 33,707 = 66,696**

Figure A-3 - Step 3: Oppurtunities in relation to Water Industry net zero targets

	A	B	C	D	E
20	**Step 3: if there are still emissions after Step 2, explore offsetting opportunities in relation to Water Industry net zero targets eg:** **Solar - 1 Ha (0.5MW) Ground mounted solar array generates a saving of 95tCO_2e per year. Net saving (costs less income) = £83,000/Ha/year (at July 2022 prices)** **Trees - The amount of carbon dioxide a tree will offset depends on many factors, such as the type of tree, where it is planted and the amount of room it has to grow. On average, one British broad-leaved tree will absorb in the region of 1 tCO_2e during its full lifetime.** **Wind turbines -** **Air Carbon capture - £249.29/tCO_2e** **Reed beds - TBC**		**Offsetting opportunities**	**Asset in use by 2030 - required offset (tCO_2e) to achieve Water Industry target for Scope 1 and 2 being net zero** **Offset required = Operational carbon per year x (yr2103 - yr2030).** **yr 2103 = 80 years from construction if construction begins in 2024.**	**Asset in use by 2050 - required offset (tCO_2e) to achieve UK Government target for Scope 1 , Scope 2 and Scope 3 being net zero** **Offset required = Operational carbon per year x (yr2103 - yr2050).** **yr 2103 = 80 years from construction if construction begins in 2024.**
21	What are potential offsetting opportunities identified during the Gate 2 process		e.g. Collaboration with Gloucester Eco Park to install additional solar arrays.	= Total operational carbon to be mitigated from year 2030 = 47,160	= Total whole life carbon to mitigated from year 2050 = 66,696
22				Required area = 47,160/(95x20) = 24.8 ha	Required area = 66,696/(95x20) = 35.1 ha
23			All power to be renewable generated inhouse or sourced as net zero by ST by 2030 as part of triple pledge commitment	47,160	66,696
24			Air carbon capture	47,160	66,696
25			Onshore wind turbines	47,160	66,696

Appendix B

CARBON TOOL OUTPUT

Figure B-1 - Jacobs/ STW Carbon Tool Output Sheet – Pipeline Carbon Values (September 2022)

	Capital Carbon (tCO_2e)				
Element	Option 1	Option 2	Option 3	Option 4	Option 5
Site Preperation	560	560	560	150	560
Foundations	0	0	0	0	0
Pipeworks	8,993	7,670	2,291	515	202
Manholes	23	22	18	0	0
Concrete Tanks	134	134	45	24	24
Buildings	66	66	0	0	0
Walls	0	0	0	0	0
Site Access	727	2,694	331	187	54
Refurbishment Activities	0	0	0	0	0
Nature Based Solutions	0	0	0	0	0
Other Civil Materials	0	0	0	0	0
M&E	1,428	566	429	27	0
Total	**11,931**	**11,713**	**3,674**	**903**	**841**

	Operational Carbon (tCO_2e)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Power	223	174	91	93	25
Fuel	-	-	-	-	-
Chemicals - Water	-	-	-	-	-
Chemicals - Wastewater	-	-	-	-	-
Sludge Tankering	-	-	-	-	-
Total	**223**	**174**	**91**	**93**	**25**

	Repeat Capital Carbon (tCO_2e)				
	Option 1	Option 2	Option 3	Option 4	Option 5
M&E (20 years)	1,428	566	429	27	0
Civils (60 years)	9,943	10,587	2,685	727	281
Total	**14,227**	**12,284**	**3,972**	**807**	**281**

	Whole Life Carbon (80 year assessment period. 71 year operation period) (tCO_2e)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Capital	11,931	11,713	3,674	903	841
Operational	15,838	12,347	6,455	6,618	1,746
Repeat Capital	14,227	12,284	3,972	807	281
Total	**41,997**	**36,344**	**14,100**	**8,328**	**2,867**

Figure B-2 - Jacobs/ STW Carbon Tool Output Sheet - Treatment Carbon Values (September 2022)

	Capital Carbon (tCO_2e)				
Element	Option 1	Option 2	Option 3	Option 4	Option 5
Site Preperation	0	0	0	0	0
Foundations	990	990	1,234	1,263	244
Pipeworks	407	407	417	417	10
Manholes	26	26	26	26	0
Concrete Tanks	561	561	581	581	21
Buildings	58	58	58	74	0
Walls	0	0	0	0	0
Site Access	1,208	1,208	1,231	1,234	23
Refurbishment Activities	0	0	0	0	0
Nature Based Solutions	0	0	0	0	0
Other Civil Materials	0	0	0	0	0
M&E	1,189	1,189	1,467	2,967	278
Total	**4,439**	**4,439**	**5,014**	**6,562**	**575**

	Operational Carbon (tCO_2e)				
Element	Option 1	Option 2	Option 3	Option 4	Option 5
Power	645	645	677	692	677
Fuel	0	0	0	0	0
Chemicals - Water	1	1	1	1	1
Chemicals - Wastewater	667	667	667	667	667
Sludge Tankering	0	0	0	0	0
Total	**1,313**	**1,313**	**1,345**	**1,360**	**1,345**

	Repeat Capital Carbon				
Element	Option 1	Option 2	Option 3	Option 4	Option 5
M&E (Every 20 years)	1,189	1,189	1,467	2,967	278
Civils (Every 60 years)	2,260	2,260	2,313	2,332	53
Total	**5,827**	**5,827**	**6,714**	**11,233**	**887**

	Whole Life Carbon (80 year assessment period. 71 years operation) (tCO_2e)				
Element	Option 1	Option 2	Option 3	Option 4	Option 5
Capital	4,439	4,439	5,014	6,562	575
Operational	93,214	93,214	95,483	96,549	95,483
Repeat Capital	5,827	5,827	6,714	11,233	887
Total	**103,480**	**103,480**	**107,211**	**114,345**	**96,945**

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