Public engagement with sustainable wastewater management and hydrogen technologies

Triple Carbon Reduction project report

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Summary

This report presents the findings of the social science work package of the Triple Carbon Reduction project, a consortium led by Anglian Water and funded by the Water Breakthrough Challenge which aims to develop and demonstrate new technologies in wastewater processing to reduce process emissions, together with energy efficiency and renewable energy benefits. To do this the TCR project is seeking to generate green hydrogen from electrolysis of final effluent in one of Anglian Water's wastewater treatment facilities using a novel biological treatment process, called MABR (Membrane Aerated Biofilm Reactor).

The social science work package of the TCR project focussed on public engagement with sustainable wastewater management and hydrogen technologies and aimed to:

1. Map the different ways that citizens are engaging with wastewater management and hydrogen technologies in the East Anglian region and the UK more broadly.
2. Map and analyse customer and community perspectives on the installation of new hydrogen technologies at a water treatment works, and more broadly on the challenges of securing sustainable water futures in a changing climate.
3. Consider the responsiveness of actors and organisations associated with the TCR project to public views and make recommendations for how societal engagement with emerging technologies in wastewater management could be improved in the future.

To map already existing examples of public engagement with wastewater management and hydrogen technologies we used a comparative case methodology to search for relevant cases through academic and general search engines and identified further cases from our literature review. The 52 cases found were analysed to identify who was involved, how they were engaged, what the focus was, and when and where the engagement took place.

This mapping found that:

- Citizens in East Anglia and the UK in general are engaging in diverse ways around issues related to sustainable wastewater management and hydrogen technologies. Many of these cases are institution-led formal and invited spaces of engagement, such as those carried out by Anglian Water itself, but there are also more citizen-led forms of engagement which are often excluded from decision-making processes.
- Citizens are aware of and concerned about current and emerging challenges around water management, relating to increasing water shortages, shortcomings in water quality, and flood risk. Furthermore, many people articulate concerns about the future sustainability of water systems, in terms of water management and in terms of broader environmental impacts.
- There are a range of alternative ways of making water use and management more sustainable. These are often more low-tech and citizen-led solutions (e.g., compostable toilets), and highlight the importance of getting the basics right (e.g., preventing wastewater from being dumped in freshwater and saltwater environments).

- Most Anglian Water and other water company customers are accepting of the relationship with their service provider and use these services unthinkingly. However, recent controversies around the poor maintenance of water infrastructures, the dumping of sewage in freshwater and saltwater environments, and bonuses for water company executives, have raised considerable scepticism about the overall governance of water companies and the extent to which they are trusted to manage issues relating to sustainability.
- Citizen experiences of consultation by water companies and other bodies around relocations and redevelopments are often that the planned changes go ahead regardless of their responses and input, so this is likely to lead to scepticism and unwillingness to engage in future decision-making or consultation processes.

To more deeply engage with citizen perspectives the installation of new hydrogen technologies at a water treatment works and more broadly on the challenges of securing sustainable water futures in a changing climate, we organised and facilitated a day-long citizens' forum in April 2023. The community involved were based in the Norwich area served by Anglian Water but were not directly affected by the new installation related to the TCR project. The forum brought together 13 citizens to consider: *What qualities do citizens prioritise in sustainable wastewater management for the future, and how do they view the role of emerging technologies in achieving this?*

The citizens' forum found that:

- Many of the participants could see the value and potential of the MABR technology being trialled in the Triple Carbon Reduction project and were keen to know exactly what the environmental and energy generation benefits of the technology would be – highlighting the importance of the demonstration which is underway.
- Citizens framed the challenges associated with sustainable wastewater management much more broadly than the TCR project. So, for citizens immediate problems of sewage mismanagement and future problems like climate change and population growth were inseparable from assessing the MABR technology.
- Citizens recognised the systemic nature of the challenge of sustainable wastewater management. The participants identified key principles, including justice and fairness, effective governance, accountability and environmental enhancement to guide assessment of potential solutions to these problems.
- Participants emphasised the need to consider alternatives when assessing potential solutions. When appraising the MABR technology, participants always emphasised alternatives to substitute or supplement the technology, recognising that one solution will not solve the systemic challenges related to sustainable wastewater management.
- Problems and their solutions are inseparable from the ways in which citizens are engaged and how futures are imagined and desired.

To examine the responsiveness of the TCR consortium to public views and concerns we carried out 9 in-depth expert interviews with various members the TCR project consortium, encouraging participants to engage with and respond to findings from the mapping and the citizens' forum.

Our interviews with consortium members found that:

- Citizens tended to respond to the technologies in systemic ways while most members of the consortium often responded to public concerns in specific ways related to the direct aims of the TCR project.
- Experts tended to view public engagement instrumentally, as primarily about communicating information and cultivating social acceptability of new technologies.
- Some participants showed recognition and understanding of the need and responsibility to build public responses into the TCR project and move towards becoming more socially responsive. The dominant expert response was that the public concerns and organising principles were legitimate, valid, and for the most part fair, but not relevant at this stage.
- Different degrees of responsiveness emerged within and between respondents with different capacities for transformative learning about public engagement and public concerns.
- Experts recognised that the TCR project can and should be made more socially responsive if the demonstration is successful and the project is then trialled at a larger scale.

Based on this work we make the following recommendations for how customer and community engagement with emerging technologies in wastewater management should be handled in future:

A. Recognising citizens are already engaged in many different ways should be the starting point of any public engagement carried out, rather than assuming that citizens are deficient in their knowledge or engagement.
B. Attempts to engage or consult with citizens need to acknowledge diverse existing forms of public engagement with issues around sustainable wastewater management, to avoid ignoring and discounting alternative framings of the problem and alternative concerns and futures which are being articulated.
C. Public responses to (new) technologies must be understood holistically, recognising citizens do not respond in isolated ways but rather make assessments and give perspectives against a backdrop of their existing relationship with relevant organisations, like water companies, and broader concerns and hopes about the futures.
D. There should be long-standing public engagement with local and affected communities from idea conception through to delivery. Engagement should be ongoing, reflexive, and responsive to public perspectives in order to be more socially responsive and change public perceptions of water company public engagement strategies.

1. Introduction

This report presents the findings of the social science work package of the Triple Carbon Reduction project undertaken by Dr Helen Pallett, Professor Jason Chilvers and Dr Elliot Honeybun-Arnolda of the Science, Society and Sustainability (3S) Research Group at the University of East Anglia (UEA). Led by Anglian Water in partnership with Oxymem, Element Energy Ltd, Jacobs, Cranfield University, University of East Anglia, Brunel University and Severn Trent, Scottish Water, Northern Ireland Water and United Utilities, the Triple Carbon Reduction project (TCR) was awarded funding in the Ofwat Water Breakthrough Challenge and aims to use novel technologies to target a step change reduction in greenhouse gas emissions and electricity use in used water treatment, and provide a new renewable energy source through green hydrogen production. To do this the TCR project is generating green hydrogen from electrolysis of final effluent in one of Anglian Water's wastewater treatment facilities using a novel biological treatment process, called MABR (Membrane Aerated Biofilm Reactor).

By coupling an electrolyser and MABR, the project aims to achieve three main carbon benefits, in line with the aims of the Water UK Net Zero 2030 Route map (Water UK 2020): 1) demonstrate a viable alternative wastewater treatment process (MABR) targeting elimination of nitrous oxide (N_2O) emissions from secondary treatment (one of the most harmful greenhouse gases produced in normal wastewater treatment processes); 2) reduce the energy consumption of these water treatment processes by up to 85%; and 3) generate oxygen via electrolysis, to be utilised in the MABR process, and green hydrogen for use as a sources of green energy in Anglian Water's operations.[1]

Levels of public concern around climate change and interlinked sustainability challenges continue to rise, and over the last few years in the UK we have seen increasing instances of activism and community action to try to address and raise awareness of these challenges. Therefore, it is important that the TCR project fully engages with citizens in order to meet its sustainability goals. Water companies have a statutory and democratic duty to engage customers and affected communities with developments, but there is also abundant evidence that involving citizens in research and decision-making processes improves the quality of findings and decisions and increases the legitimacy of outcomes.

The social science work package of the TCR project has three aims:

1. To map the different ways that citizens are engaging with wastewater management and hydrogen technologies in the East Anglian region and the UK more broadly.
2. To explore and analyse customer and community perspectives on the installation of new hydrogen technologies at a water treatment works, and more broadly on the challenges of securing sustainable water futures in a changing climate.
3. To consider the responsiveness of actors and organisations associated with the TCR project to public views and make recommendations for how societal engagement with emerging technologies in wastewater management could be improved in the future.

[1] For more information about the broader project see the project website: https://waterinnovation.challenges.org/winners/triple-carbon-reduction/

This report is structured as follows. First, we briefly outline the relevant literature related to wastewater management, water futures and hydrogen energy. We then outline our methods and approaches for the three stages of our research: mapping public engagement, a citizens' forum, and expert interviews. Next, we present the findings from each of these stages of work. We concluded with some insights and recommendations for future public engagement with emerging technologies in wastewater management and beyond.

2. Public engagement with water and hydrogen

This section summarises an initial review of the academic literature on public engagement with water and hydrogen. We conducted a rapid review of the academic literature to gain an overview of research and practice on public engagement with water (including sustainable wastewater management and hydrogen technologies). In what follows we also draw on recent developments in research on public participation and engagement more generally to further contextualise the approach taken in this research.

We identify two dominant ways in which public engagement with water, wastewater management and hydrogen technology has been conceived. First, through traditional science-centred and technocratic approaches to wastewater management and technologies, 'the public' are assumed to be knowledge-deficient, creating an obstacle to positive engagement with and acceptance of technology (Wynne, 1991). Here water and wastewater management and are understood to be separate from society and better knowledge communication of benefits and technological proposals to the public is the main means of enhancing public engagement and to gain acceptance of decisions in a linear way.

Second, as the deficiencies of this technocratic approach have become apparent, the past few decades have seen a drive to more actively engage citizens with technology in different ways. Here the assumption is one of a deficit of public engagement which can be addressed through inviting the public to participate in discrete often one-off forms of engagement (Chilvers & Kearnes, 2016) – such as consultations, online fora, citizens' assemblies, and so on. This has become the dominant way in which public engagement with water is conceived in the literature and various fields of practice. This model of public engagement enrols citizens into pre-defined arenas and modes of engagement to express their views and cultivate a sense of involvement in technological development and decision-making.

In this review, we are interested in exploring the extent to which research and practice relating to public engagement with water and hydrogen is moving towards a third perspective which is emerging in the academic social science literature (see Chilvers & Kearnes, 2016, 2020). This third perspective views participation – and also sustainable wastewater management and technologies – not as fixed or specific but highly diverse and constructed through practice. It recognises that citizens are always already engaging with issues like wastewater management in diverse ways that interrelate with wider systems of participation. Our review finds that this third perspective is largely missing from the existing literature on public engagement with water and there is minimal explicit research on public engagement and wastewater management which adopts this perspective.

In the following subsections, we outline how the literature on public engagement with water relates to these three main ways of seeing and doing participation.

2.1. Public understanding of water and hydrogen

Water is a complex resource of public interest and concern. Yet despite the central role it plays in enabling and facilitating life, well-being and a functioning society, it is thought that the public are often unaware of the complex service of water provision (including wastewater treatment). The immediacy of access to water for most in the UK often obscures the complex realities of the processes and systems that occur to enable the provision of water. As a result, it is assumed that citizens are often unaware of the existing mechanisms of water provision and wastewater treatment (Ormerod 2016).

In the literature this is predominantly seen in works related to water re-use, public perception, and acceptance. The 'yuck' factor, in relation to waste water in particular, also appears to be an obstacle to overcome. The acceptance of water use is thought to be possible with increased communication of the challenges of water scarcity and the realities of water treatment (Baumann 1983; Smith et al. 2018) highlighting the framing of citizens as knowledge-deficient, motivating to accept new technologies and other changes through increased information and knowledge provision.

Water companies predominantly frame citizens as customers who lack knowledge of specific issues and use their own knowledge communication strategies to support customers in relation to water challenges, like droughts, flooding, and efficient water use in the home (Anglian Water 2023) and typically spend a lot of resources communicating these messages (Lewis et al. 2018).

Hydrogen as an energy and fuel source is also framed as something that citizens know little about (Cox and Westlake 2022; Ricci et al. 2008; Scott and Powells 2019). Citizens appear to be knowledge-deficient about the benefits and risks of hydrogen energy and consequently either appear neutral or feel ill equipped to make appropriate assessments (Ricci et al. 2008; Scott and Powells 2019) with the roles of cost, trust, risk (Gordon et al. 2022) being poorly understood as a consequence of lacking the relevant information to make decisions. This aside, as environmental challenges and the transition to net zero gain public traction, low-carbon energy sources, like hydrogen, begin to be viewed positively despite acknowledged uncertainties (Cox and Westlake 2022).

2.2. Public engagement with water and hydrogen

Research on flooding, droughts, water planning and other risks are often embedded within a broader framing of water governance and the anticipation of future challenges concerning water management. Often public engagement or 'dialogue' with citizens and 'stakeholders' occurs in discrete and one-off instances for specific management, governance or service purposes related to water management (Ainsworth et al. 2019; Bark et al. 2021; Holstead et al. 2021; Hoolohan and Browne 2016). The results from these forms of public engagement are then published to promote guidelines, inform other practitioners, shape future decision-

making or engagement work and help make developments or actions more socially acceptable (Moon et al. 2017).

In this type of research, engagement or participation is often orchestrated by institutions to recruit a representative sample of the general population to better inform decision-making, strategy and policy-making, and to make them more democratically accountable (Mehring et al. 2018). This approach to public engagement in instrumental terms assumes that *more* participation will be *better* in terms of views, expertise, collaboration and deliberation (Scott-Bottoms and Roe 2020). Prescriptive recommendations of action are often the output of these engagements (Moon et al. 2017) and can be quite novel or transformative for the practitioners embarking on this type of work (see Whitman et al. 2015).

There has been some attempt to situate these approaches in the wider contexts in which they emerge to understand better the social and cultural dynamics that shape public participation (Wesselink et al. 2017) that broadly are framed through the lens of a 'hydrosocial' understanding of the mutually reinforcing relationships between both society and water (Linton and Budds 2014). Notwithstanding, these approaches frame scientific knowledge and decision-making as something that can be supplemented by public participation and dialogue to legitimise technocratic courses of action, usually uncritically. If attempts are made to be critical of participation, it is to ensure appropriate demographic representation or to proactively involve marginalised groups (Wehn et al. 2018), rather than broadening the scope of participation and engagement to less formally organised spaces or recognising the limits of their representations as one part of a wider system of public engagement with water.

The dominant view emerging in this section is that public engagement is critical to ensure just, publicly accountable and responsible decisions in relation to all things water (and wastewater) but participation is often narrowly framed, and conducted under specific circumstances with constructed 'representative' publics. This approach, whilst helping to make projects and initiatives more socially acceptable, often obscure and ignores diverse public concerns and other modes of participation.

Similar to studies around water and wastewater management, public engagement with hydrogen technologies and demonstrations has gained traction as a means to better communicate information to citizens and to instrumentally gain acceptance (Robinson et al. 2022). Forms of participatory engagement – like focus groups, consultations, demonstrations – are organised as one-off events, inviting specific sets of publics like a representative sample of 'the local population' or a set of 'affected stakeholders' as a means to communicate and discuss the complexities around hydrogen technologies and communicate information more comprehensively to understand better the factors shaping acceptance (Ricci et al. 2008). Engagements with hydrogen technologies, in this vein, tend to frame particular settings and scenarios in which hydrogen energies are used or experimented with and citizens are then asked to give their views in a very static or hypothetical situation (H21 2021). Even still, public participation around hydrogen energy and technology remains low and the challenges that a transition to hydrogen may bring forward remain critically underexplored (Gordon et al. 2023).

2.3. Remaking participation with water and hydrogen

A third perspective takes a relational constructivist view of publics, participation and water management. Rather than beginning with a pre-conceived idea of 'the public', this approach emphasises how publics emerge in diverse ways, contingent on the issues or actions they are orientated around and the modes of participation they are engaged in. Remaking participation in this vein also unsettles dominant views of what counts as participation and seeks to broaden out, recognise and build responsiveness of alternative forms into public engagement practice (Chilvers & Kearnes, 2016). This approach takes seriously the view that public engagement matters but does not make a-priori assumptions of what counts as public engagement or who the public is. Instead, it recognises publics as multiple and emergent, and as collectives who can play many productive roles, and recognises participation as non-linear, relational and multiply productive.

Viewing participation through this perspective enables an acknowledgement of plural publics and recognition that often publics are already engaged in many different ways around water and wastewater management. This means that widening our perspective can enable a greater awareness of what is emerging, where, how and why, which is often not possible when viewing discrete, one-off instances of public engagement. Public engagements are continually emerging and tied to the systems in which they are embedded and so attending to this can lead to more socially responsive, democratic and just transitions (Chilvers et al. 2022).

In the water literature, there have been some moves in this direction but focusing on widening definitions of water, rather than participation. For example, proposing to understand 'water' as more than solely a resource or commodity that is separate to human and social lives. Instead, scholars have attempted to illuminate the centrality of water to the wider functioning of society and democracy (Boelens et al. 2016; Flaminio et al. 2022; Linton 2014; Linton and Budds 2014; Ross and Chang 2020; Swyngedouw 2009). This research, often framed as 'hydrosocial' work, emphasises how water and society are not distinct arenas which policy, management or decisions should be constructed around but rather are defined in relation to each other and the contexts in which they emerge. Wastewater management then would not be a distinct sub-aspect of water systems but an integral component of how we live well with water.

More constructivist approaches tend to focus on water only and do not unsettle public participation or engagement. In the absence of public engagement work related to wastewater management, assumptions can be drawn out from the above: wastewater management or governance is inseparable from the wider relations and system of living with water, and decisions and responses concerning solutions to challenges should always be taken in relation to, and as part of a wider systemic view.

3. Methodology

3.1 Mapping public engagement method

In addressing the first aim of the social science work package our first task was to map the different ways that publics are engaging with wastewater management and hydrogen technologies in the East Anglian region and the UK more broadly. To do this we used the comparative case analysis method developed in our previous work as part of the 3S Research Group and the UK Energy Research Centre's Public Engagement Observatory (Chilvers et al. 2017, 2021, 2023; Pallett et al. 2019). Comparative case analysis involves documentary analysis of diverse cases of public engagement to map *how* people are engaging, *who* is involved and *what* they are engaging in.

Following the comparative case analysis method, our approach to the mapping was informed by our review of the academic literature – and related reports from government, industry and NGOs – on water, water and wastewater management and governance and hydrogen. Through this we developed a set of search terms which were all synonyms of the 'how', 'what', 'who' and 'where' of public engagement around sewage, hydrogen and water management (see Appendix 1). Our approach aimed mainly to identify examples of public engagement in the Anglian Water region, but where local cases were not available, we included cases that were nationwide.

We ran the search terms through academic search engines Web of Science and Scopus to find relevant academic papers, 2010-present. We were not looking to collate all recorded instances of public engagement with water, sewage, hydrogen and wastewater management but instead to build a picture of more contemporary cases and to deliberately seek out diverse examples. Combining diverse synonyms meant that our searches produced a high proportion of irrelevant material. To overcome this, only cases found in the 'social science index' of the databases were extracted.

It was anticipated that recent and less formalised case-studies would not be adequately represented in the academic literature. Therefore, a 'multi-vocal' search strategy was adopted, conducting additional searches for relevant case-studies through web search engines. Given our interest in representing diverse engagements around water, hydrogen and wastewater management, Google Scholar, Google, DuckDuckGo and Ecosia – which each use different algorithms to produce results – were used. For these searches we used more targeted search terms and a simpler search strategy, to accommodate the additional search algorithms used by these search engines, starting with just one term for each of the 4 categories together – e.g., "public and engagement and sewage and East Anglia". Multiple searches were needed, and these were adjusted based on the relevance of the results brought up in each search and by deliberately seeking out cases which seemed to be missing from previous searches. Cases from both the academic database search and search engines were added to a meta-spreadsheet. This list of cases was explored by the research team and irrelevant cases were discarded, resulting in a final list of 52 cases of public engagement relevant to the TCR project (see Appendix 2).

Each case was analysed according to a common analytical framework to identify which publics were involved, how they were engaged, what the issue or object of focus was, and when and where the engagement took place. Additional qualitative analysis was conducted to identify broader themes emerging from each case to illuminate the public concerns and hopes relating to hydrogen, water management and wastewater, and to explore any forms of material action involved in the cases.

3.2 The citizens' forum

After our mapping work, we organised and facilitated a citizens' forum on 1st April 2023 to discuss challenges and solutions for sustainable wastewater management in the East Anglian region. The community involved were based in the Norwich area served by Anglian Water but were not directly affected by the new installation related to the TCR project. The forum brought together 13 citizens to consider: *What qualities do citizens prioritise in sustainable wastewater management for the future, and how do they view the role of emerging technologies in achieving this?*

The citizen participants were enrolled via two methods of recruitment:

- *Interested citizens*: one group was formed by recruiting archetype citizens already associated with the different forms of public engagement identified in our mapping. This led to a selection of 6 participants being recruited who were already interested or engaged in the issues under discussion, including: an *activist on public ownership of water, an activist on waste in water, a person involved in citizen science on water quality, an active citizen, a recreational user of local waterways, and a citizen living off-grid.*
- *Customers:* another group of 7 participants was recruited from a standing panel of Anglian Water customers which the company already engaged with in its own market research. The make-up of the standing panel reflected Anglian Water's customer base, and the sample of participants for the citizens' forum was selected to be reflective of the socio-demographic characteristics of the population in the Norwich area.

All citizens were compensated with an honorarium for their participation on the day. Whilst we ran the citizens forum on a weekend to counteract possible barriers to participation, our sample was skewed towards older populations despite our efforts for more balanced recruitment.

An outline of the citizens' forum process is presented in Figure 1. In the morning the citizens worked in two groups to discuss the problem of sustainable wastewater management and develop principles that should guide future practice, after an opening introductory presentation from the UEA research team. After lunch, a presentation on the MABR experiment was given by the technology specialist at Anglian Water and citizen participants had an opportunity to openly ask questions and discuss this in a plenary. Citizens then went into two groups to discuss alternative options for sustainable wastewater management before evaluating the different options against the principles they devised in the morning (see Figure 1). Conclusions and recommendations were drawn out in a final plenary discussion.

Citizens' Forum on sustainable wastewater management

Date: 1st April 2023.
Location: University of East Anglia.

Key question: What qualities do citizens prioritise in sustainable wastewater management for the future, and how do they view the role of emerging technologies in achieving this?

Part 1: Framing problem and establishing principles to guide sustainable wastewater management

10:30 Introductions and icebreaker.

10:50 Introduction to the citizens' forum, issues of sustainable water management, and the TCR project (by the UEA team).

11:15 Break-out group discussion of the challenges of sustainable wastewater management and establishing principles to guide sustainable wastewater management.

12:00 Feedback and sum-up back in plenary.

12:30-13:00 Lunch

Part 2: Introducing and evaluating potential options, with a focus on role of new technologies

13:00 Anglian Water presentation about TCR project installations followed by questions and discussion from citizen participants.

13:40 Information gathering and discussion of potential alternative options for sustainable wastewater management by citizens working in small groups, in discussion with experts and consulting a handout.

14:10 Break-out group discussion evaluating the different options for sustainable wastewater management in relation to the principles identified in Part 1.

Part 3: Summing up and conclusions
15:00 Round up discussion about how water companies and other bodies should engage customers and communities when introducing new technologies or other options for sustainable wastewater management.

Figure 1: An outline of the process for the citizens' forum on sustainable wastewater management.

The five possible options as solutions to the challenges of sustainable wastewater management discussed by participants included a business-as-usual scenario, the technological solution presented by Anglian Water and the focus of the TCR project, and three alternatives that had emerged from our earlier mapping work, namely: improving governance, citizen action, and alternative technologies (see Figure 2). These additional

solutions helped to guide responses to the challenges of sustainable wastewater management in broader frames with wider implications than purely focusing on technological solutions.

The citizen's forum was recorded throughout the day and transcribed. The transcription was qualitatively coded and analysed, alongside the research team's notes from the day and materials produced by participants in their groups, according to themes emerging from the deliberations.

Business-as-usual: Continue existing practices and operations.

Technological fix: MABR modules slot into existing tanks to increase the biological capacity of systems, absorbing carbon and nitrogen-based pollutants in the wastewater, improving nutrient removal, leading up to 50% reduction in sewage sludge. Air is pumped at low pressure through the membrane reducing the energy used to treat sewage.

Improving governance: Alternative or improved governance can include things like bringing water back into public ownership, collaborative partnerships or taking a holistic approach to managing and governing water on a catchment scale with the aim of ensuring environmental, social and economic benefits and protection of regional water resources.

Citizen Action: Volunteers, community groups and individuals have embarked on monitoring rivers to test water quality, identify pollutants and help assess the environmental health and management of water.

Alternative technologies: Includes solutions like 'composting toilets' which are predominantly dry toilets that use aerobic decomposition ('starter cultures') to provide microbes to help break down organic matter into compost. They are emptied every 6- 12 months as compost. There are many models available from simple, single-chamber ones to more complex 'active' ones that require heat and power.

Figure 2: Options appraised by participants in the citizens' forum.

3.3 Expert interviews

The final stage of research consisted of 9 in-depth expert interviews with various members of the TCR project consortium (see Table 1). Each expert participant was presented with a summary of public engagement findings from the mapping and the citizens' forum. Key themes of the semi-structured interviews were to explore each participant's initial views of public engagement with water and hydrogen technologies, their responses to the public engagement findings, and their views on the extent to which wastewater technologies like

those developed in the TCR project might become more responsive to societal values and public concerns. Interviews were recorded and transcribed and then subject to full qualitative coding analysis to establish and understand how members of the consortium responded to the public engagement findings and how the TCR project was, or could possibly be, responsive to public views and concerns.

Expert	Role	Sector	Date
A	Engineer	Industry	03/07/2023
B	Manager	Industry	04/07/2023
C	Technologist	Industry	05/07/2023
D	Manager	Industry	05/07/2023
E	Technologist	Industry	12/07/2023
F	Technologist	Industry	12/07/2023
G	Manager	Industry	12/07/2023
H	Engineer	Industry	03/08/2023
I	Manager	Industry	04/08/2023

Table 1: Expert interview respondents from the Triple Carbon Reduction project consortium.

4. Mapping diverse public engagement with wastewater management and hydrogen technologies

This section details the results from our mapping and analysis of existing examples of relevant public engagement with hydrogen and wastewater management, to understand customer and community perspectives on the TCR project's plans and more broadly on the challenges of securing water futures in a changing climate.

4.1 How are publics engaging?

In Figure 3 we plot the results on a mapping space developed in earlier research (see Chilvers et al. 2021) that shows the diversity of the 52 cases of public engagement identified according to the extent to which they were more institution or citizen-led, and the extent to which they involved engaging participants in the discussion of issues or in material actions. These two axes are spectrums, and our placing of the cases is indicative rather than exact.

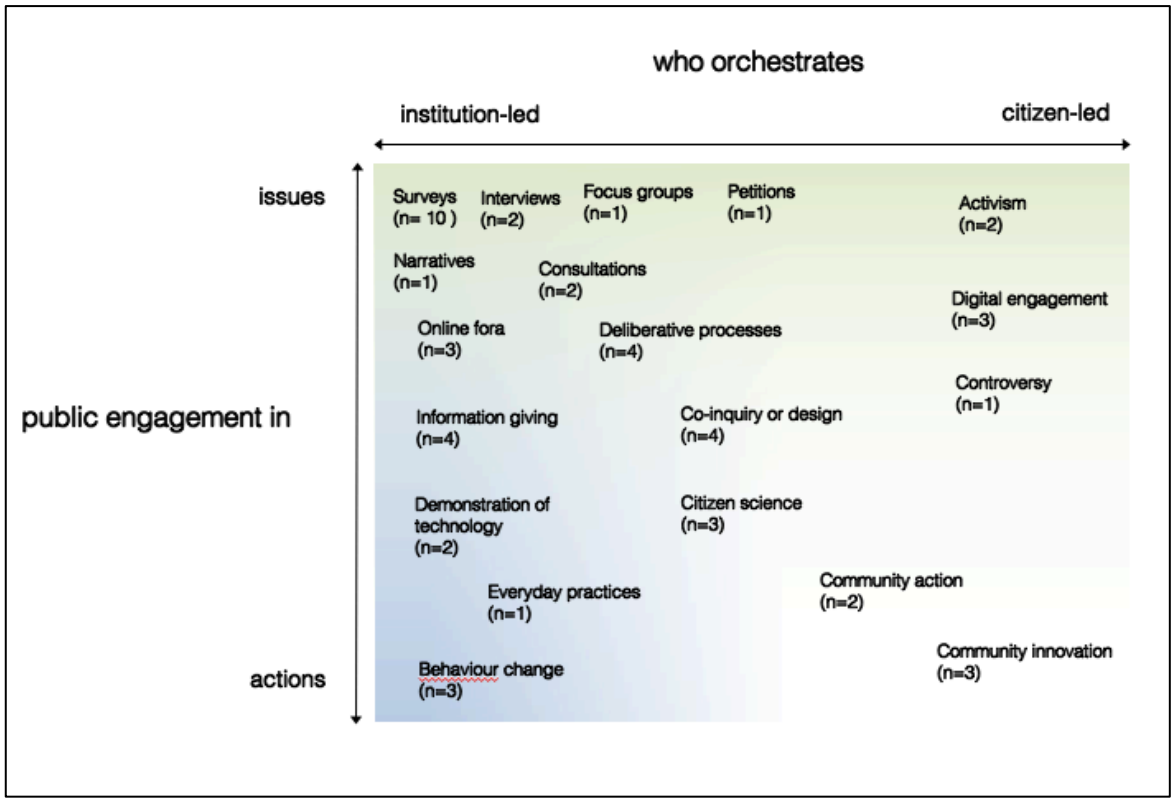


Figure 3: A mapping of diverse forms of public engagement with water management and hydrogen technologies in the UK, 2010-2022 (n= refers to the number of cases of public engagement identified).

As found in earlier mappings of public engagement with low carbon energy transitions (Chilvers et al. 2021), most of the cases of public engagement with water and hydrogen technologies are located in the top left-hand corner of the diagram, as cases which are largely institution-led (meaning they are led by governance or regulatory bodies or by water or energy companies) and issue-focussed. These forms of engagement include elicitation methods (e.g., surveys, interviews, focus groups and consultations), around specific water

issues or management challenges, or around emerging hydrogen technologies. These are institution-led and focus on constructing or shaping discourse and issues. Deliberative processes and co-design or co-inquiry around these issues are often also largely institution-led (but not always) but can produce a range of actions (like management plans) as well as contributing to issue-focused discussions.

Institution-led forms of engagement orientated around more around action (i.e., those in the bottom left corner of the diagram) are typically initiatives from water companies to encourage behaviour changes around water use and habits. Demonstrations of technology, like the TCR project, are an emerging form of engagement in this area which are particularly being used to engage citizens materially rather than just hypothetically with hydrogen energy (e.g., Case 31 in Appendix 2). They are institution-led as only large research centres, industry or government would have the resources to create them. By doing this, they diverge from the standard dominant issue-focused model of public engagement by putting more emphasis on material actions.

More citizen-led engagements to the right-hand side of Figure 3 have typically focused on actions of individuals engaging with discursive issues online like using interactive apps, and social media and commenting on news articles (those in the top right-hand corner) or concerned citizens working collectively to protest and bring new issues, like sewage and damaging practices of water companies to public light (those in the bottom right-hand corner). There are some community-led alternatives related to hydrogen energy use, alternative wastewater practices and community-led water management to secure sustainable water futures. Citizen science is also an emerging form of engagement in this space, particularly in response to recent controversies around water quality and sewage dumping. We have plotted these engagements as sitting between institution- and citizen-led approaches, as they typically combine elements of both, and are also both engaged in issues through forms of knowledge-making and action through, for example, taking direct measurements of water quality.

4.2 Who is engaging?

Across the 52 cases of public engagement mapped – which were relevant to the TCR project in terms of their links to hydrogen energy, water management or wastewater – there is a diversity of ways that citizens were framed as participants in these cases and a diversity of ways that they were engaged.

Figure 4 shows the different framings of participants or the kinds of citizens involved across all the cases. The most common categorisation of publics in our analysis is as interested citizens (n=9), which reflects the number of engagements which were either citizen-led (e.g., petitions, protests, community action) or involved significant action by motivated citizens, such as being involved in collaborative governance arrangements or volunteering as citizen scientists. The active communities (n=5) and activist (n=2) categories again reflect the wealth of more citizen-led action identified in our mapping, reflecting how motivated many citizens in the region and across the country are to lead or play a substantial role in efforts to improve water governance and management, investigate alternative approaches to water management and energy, or to draw attention to perceived problems.

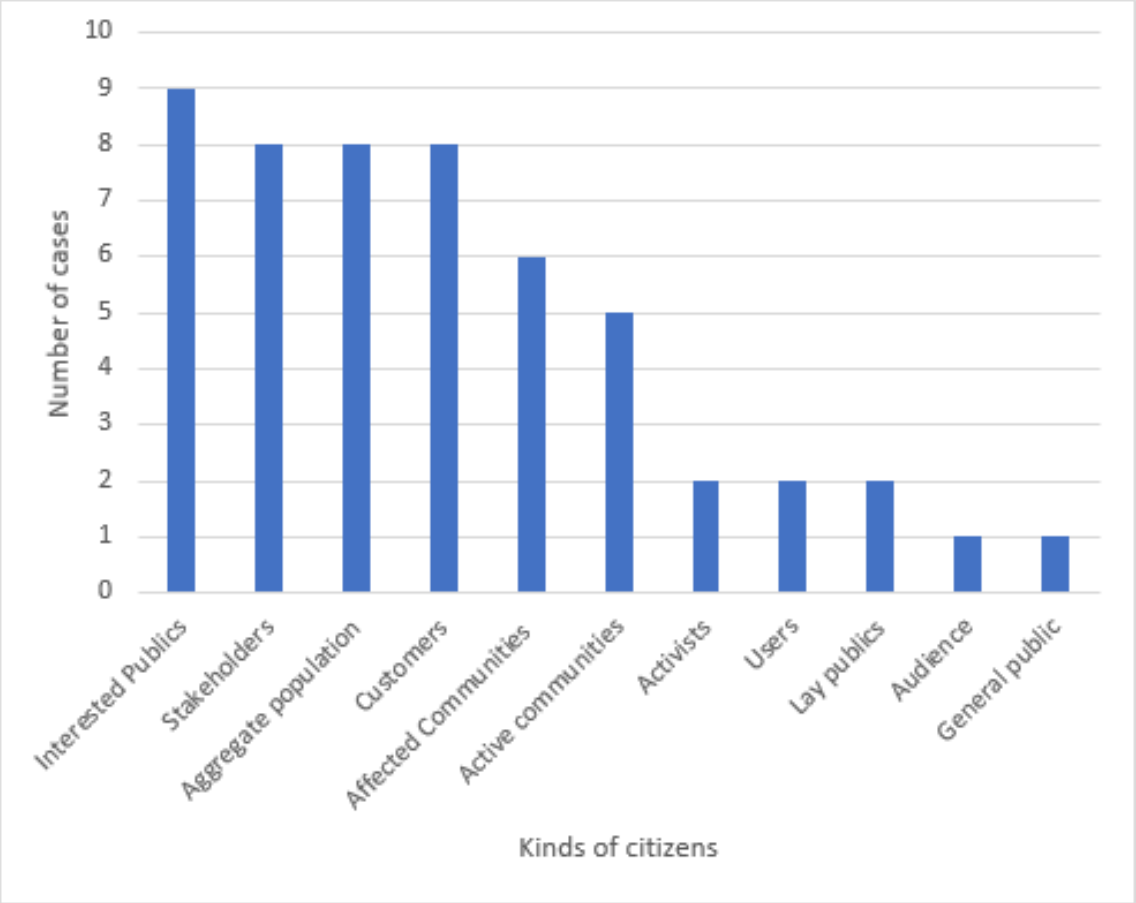


Figure 4. The different kinds of publics engaged in the cases of public engagement mapped.

Commonly citizens were engaged as an aggregate population (n=8), meaning that the engagement process involved a demographically representative sample of the UK or English population in order to represent the broad perspectives of this population. Another common way that citizens were engaged was as one group out of several relevant stakeholders (n=8) around a challenge or decision. This, alongside the framings of citizens as customers (n=8) or users (n=2), shows how citizens are often framed in engagement processes as having a predefined stake in challenges and decisions, through their service relationships with water companies and as people likely to be affected by changes and developments.

We categorised 6 cases as involving affected communities, which again shows how citizens are often engaged through targeted processes like consultations when new developments relating to water, and energy are likely to affect their neighbourhood or their service arrangements. Less common framings of citizens in the processes mapped were as lay publics (n=2), meaning people deliberately engaged because of their lack of interest in or knowledge of the issues, audiences (n=1) or as 'the general public' (n=1), though this latter

framing is one which strongly steers and motivates governance and regulatory arrangements around water and energy in the UK and the region.

4.3 What are people engaging in?

Figure 5 shows the main topics of focus of each of the relevant cases of public engagement mapped. Unsurprisingly, hydrogen is the most common topic (n=14) as this was a big focus of our mapping, due to the novel use of green hydrogen in the TCR project. There were some general topics of focus found across a number of the cases such as water companies (n=8), water management (n=6), and water challenges (n=4). There were a relatively small number of cases specifically focussed on sewage (n=3) or wastewater (n=2), but water pollution (n=7) and the specific issue of sewage dumping in fresh or saltwater (n=4), show the strength of interest more generally in this topic, and particularly in the issue of water quality.

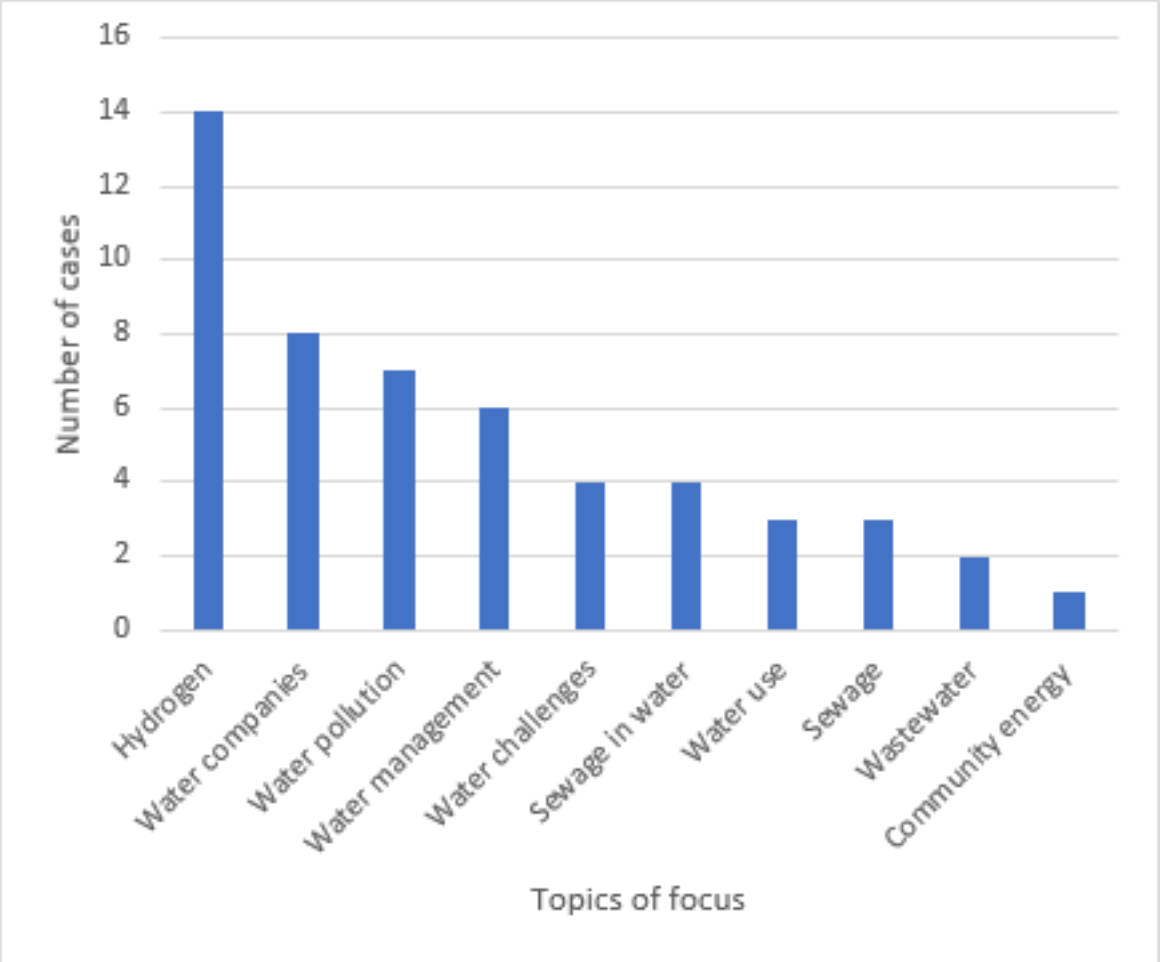


Figure 5: Key topics of focus in the cases of public engagement mapped.

In the remainder of this section, we explore 8 cases of public engagement with water and hydrogen from our mapping in greater depth, to illustrate contrasting framings of the issues and the different hopes and concerns reflected in each engagement. The case numbers correspond with the list of cases in part two of the appendices of this report.

Cases 1, 31, 50 and 52 (depicted on the following page) show the range of different approaches taken in cases of public engagement with hydrogen, with implications for how the object of hydrogen energy is framed and how citizens respond to it. Case 1 is representative of the most common approach to public engagement with hydrogen, where participants are engaged with the issue hypothetically, and researchers look for demographic differences and other factors likely to affect people's responses to the technology. Of particular interest to the TCR project are the findings that participants' concerns about the safety and cost of hydrogen energy could be mitigated by environmental benefits, trust is governance actors and distribution of benefits. Case 31 shows the results of a hydrogen demonstration project with similar findings about ways to mitigate participants' concerns. Another element of this project, which is relevant to the TCR project, however, is that the fact that people were unable to opt-out of the trial caused significant controversy.

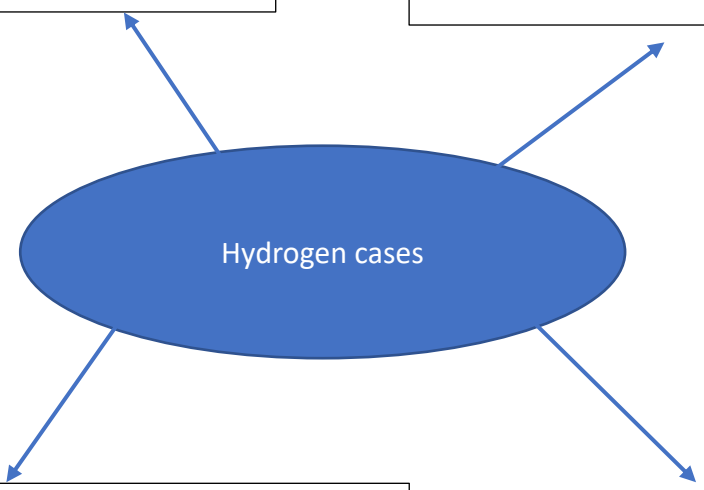
Case 50 is a more unusual case of public engagement with hydrogen which is more citizen-led, though still with significant input from government and research funders. It shows a much more large-scale example of a hydrogen project which is prioritizing the distribution of community benefits and foregrounding the need to satisfy energy security and sustainability goals for the area. Case 52 is an academic study which was interested in how hydrogen use for heating and cooking was likely to affect people's everyday practices. Participants in the project did not think the use of hydrogen for heating would affect their practices, and the same is probably true for the use of hydrogen for other forms of energy.

Case 1: Public perception study of hydrogen

In 2021, researchers at Cardiff University explored public perceptions of the hydrogen energy system through a representative survey of the UK general public (n=464) and two focus groups. The survey elicited perceptions on hydrogen production, transportation, storage and end-use with the focus groups gaining a deeper understanding of reasons for perceptions. Respondents were broadly favourable to "green hydrogen", made via low-carbon electrolysis. There were major differences between demographics with high-income men tending to respond more positively than others. Safety and cost were the main concerns, but the researchers demonstrated that these could be mitigated when possible environmental benefits were highlighted, if there are high levels of trust in the regulators, experts, and organisations governing the system, or if the benefits are distributed across affected communities.

Case 31: HyDeploy: a demonstration of technology

The HyDeploy Consortium conducted a blended hydrogen energy trial on the campus of Keele University. The HyDeploy trial demonstrated how a shift from full gas to 20% hydrogen could be completed within the existing infrastructure and elicited views from users across the university and living in halls of residence. As the trial went on, safety concerns dropped and there was little change in daily experience with energy. Concerns were raised about who would shoulder the cost of full-scale implementation which would include new installations, as well as the safety of a 100% hydrogen system as hydrogen as an end-use cooking fuel burns with a nearly invisible flame. Ethical concerns were also raised surrounding the inability of participants to opt out of this trial. The transition to hydrogen energy through a blended gas approach was deemed to be a success and residents were positive towards the potential future use of 100% hydrogen once information needs were discussed and met.



Case 50: Surf 'n' Turf - Orkney community hydrogen project

Surf 'n' Turf is a renewable energy project in Orkney, led by Community Energy Scotland. The Surf 'n' Turf project has attracted £1.46 million in development funding from the Scottish Government's Local Energy Challenge Fund. It is co-funded by the European Union Horizon 2020 programme, under the Fuel Cells and Hydrogen Joint Undertaking. It has built facilities to generate hydrogen from tidal and wind energy, and then use that hydrogen to overcome grid limitations and supply energy to local demands, including shore power for the inter-island ferries. The concept behind the Surf 'n Turf project is to enable Orkney to both make and use more electricity locally; to reduce fossil fuels imports and CO_2 emissions, and to support Orkney communities and companies to harness locally sourced energy. As Surf 'n' Turf aims to establish hydrogen as part of Orkney's energy mix, a hydrogen fuel cell has been situated on Kirkwall pier which has been designed to fulfil training needs for the transportation of hydrogen by or at sea. Orkney College UHI has designed a hydrogen safety awareness course to provide necessary training on island as the project will maintain management of shipments of hydrogen as part of the ongoing hydrogen economy in Orkney.

Case 52: Practice-focused study on the use of hydrogen in the home

Newcastle University researchers conducted a study in 2017 to illustrate how the physical and chemical properties of hydrogen may disrupt domestic practices of cooking and heating. It focused on one specific characteristic of hydrogen, that it burns with a near-invisible flame, and investigated through a survey and semi-structured interviews how 100 people in the Northeast of England believed this would change their practices of heating and cooking. Participants imagined their practices of cooking would be severely impacted while their practices of heating would be largely unaffected.

Cases 3, 37, 49 and 44 (depicted on the following page) show the range of different approaches taken in cases of public engagement with water, with implications for how water management is framed and how citizens respond to it. Cases 3 and 37 are illustrative of the significant citizen interest and mobilizations around the issue of sewage dumping in fresh and saltwater which we have seen from 2022 onwards in the UK. Surfers Against Sewage (case 3) have been a prominent group raising awareness of the issue and motivating a range of different forms of action including protests, citizen monitoring and engagement through apps and social media platforms. Although the TCR project is not directly linked to the issue of sewage dumping, this case shows the strength of citizen concern around the issue – which means it is likely to be raised in future Anglian Water engagements with customers and communities – and suggests a level of distrust in Anglian Water and other water companies' abilities to meet key sustainability objectives. The hydrogen cases suggest that finding ways to regain this trust will be crucial to the success of installations like the TCR project. Case 37 shows how this interest in and concern around water quality and its environmental impacts have been translated within a longer running form of collaborative governance where citizens are involved in partnership with water companies and local NGOs to inform approaches to water governance. The adoption of a citizen science water quality project by the Wensum Catchment Partnership again reflects concern about the issue and a lack of trust in water companies and governance actors to adequately address the problem without further oversight and citizen action.

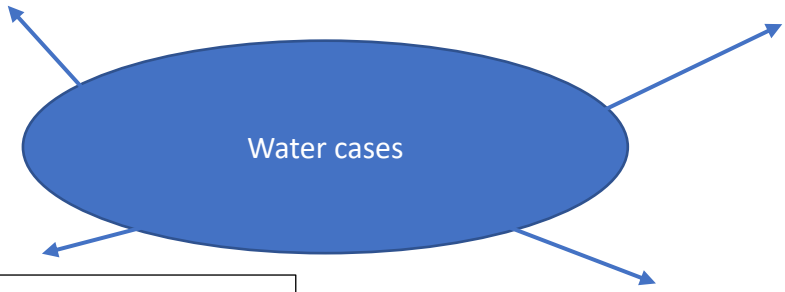
Case 49 is illustrative of more general concerns about the governance of public utilities, which have implications for trust in water companies. The 'We own it' campaign suggests that many customers need to be convinced more that water companies are being run in the public interest, rather than mainly for private profit. This means participants in the TCR project are likely to ask questions about the resources being devoted the project and whether they would have been better spent dealing with more foundational issues such as fixing broken pipes or bolstering reservoir storage to deal with future water pressures. Finally, case 44 gives an example of public engagement where citizens are actively trialing new low cost and low-tech approaches to the management of sewage and wastewater. The TCR project will need to show an awareness of alternative ways of making wastewater treatment more sustainable and understand the planned installations in this context.

Case 3: Surfers Against Sewage: #EndSewagePollution Protests

Surfers Against Sewage (SAS) began as a grassroots movement and has turned into one of the largest environmental charities in the UK. Funded predominantly through membership donations, SAS campaign for and organises various action and share information to increase awareness of water quality issues and damaging practices. In April 2022, SAS organised a nationwide protest in multiple locations to voice discontent and to increase awareness of the sewage pollution being dumped into water bodies nationwide. SAS has gained huge traction recently with the discourse on sewage pollution being reported regularly in mainstream media and local news outlets. SAS has also produced a 'Safer Seas and River Service' mobile and web app that allows users to track live water quality/sewage discharge updates in their local areas. This form of digital engagement has underscored the ongoing nature of sewage discharge in UK water and has compounded public concern. This case illuminates specific discontent toward and active campaigning against private water companies and their polluting practices and which has become a controversy of interest amplified in mainstream media and local news.

Case 37: Wensum Catchment Partnership (WCP) – Water quality and citizen Science

The WCP brings together relevant stakeholders like the Norfolk River's Trust, Environment Agency, Natural England and Anglian Water to help protect and manage the river Wensum and its catchment area. The Wensum is treasured by local communities and users and is of national importance for wildlife, being designated both an SSSI and Special Area of Conservation. There has been a major concern recently for the health of the river as it faces an ongoing challenge from agricultural run-off, sewage pollution and in some stretches, invasive species and physical modification. Consequently, in the summer of 2022, citizen scientists were recruited from a growing community of concerned individuals to become water stewards and trained to expand the capacity of regular water quality monitoring through citizen science. The main aim is to monitor changes in the water more frequently to help understand where and how pollution or damage is happening and be able to act accordingly and mitigate against these challenges. There is a real concern for the declining health and water quality of water bodies in the region and interested publics are getting involved where they can to help secure sustainable and healthy water futures in the region.



Case 49: 'We Own It'

'We Own It' is an independent group, reliant on individual donations, that since 2013 has campaigned against privatisation and supporting public ownership of public services, like water. They engage with the general public and recruit supporters for their campaigns through the sharing of information about the damaging practices of privatised public services and the enormous profits going to shareholders. They argue that water companies are run for profit for the shareholders and not in the public interest, unlike the public ownership of water in both Scotland and Northern Ireland. The monopoly water companies have in areas means that customers have no choice in the water company that is used or able to exercise the right to move supplier if unhappy with the wider environmental and social impacts of their actions, like the dumping of sewage into water bodies. Campaigns like 'We Own It' have gained traction recently in response to public discontent about the wider environmental/social responsibility failures and growing distrust of water companies and rising energy costs. This case demonstrates an alternative public view of water companies beyond customer satisfaction with more immediate services like water provision and wastewater management, uncovering views about the wider social and environmental responsibility of public services run by private companies.

Case 44: Findhorn eco-community: Living Machine toilet

Although based in Moray, Scotland, the Living Toilet is a good example of alternative ways communities are dealing with wastewater management. Since 1995, the Living Machine toilet it has been part of a broader eco-village set-up, Findhorn and services 300 individuals by mimicking natural processes found in marshes and wetlands. Through various stages, sewage is treated via digestion from various microbial communities that are encouraged through suspended racks with long-rooted plants that also help to consume excess nutrients and destroy harmful pathogens. Sewage sludge then becomes separated and sinks to the bottom of the next tank. Unlike the daily disposal of sludge found in traditional wastewater treatment, Findhorn disposes of its sludge every four to five years. Nitrogen processes are dealt with in the following sections through alternating anaerobic and aerobic treatments from air pumps. The water is then sent to a reservoir pond before being pumped underground to rejoin the water system. In its existence, the Living Machine toilet has not failed a compliance test. This system is an example of a less energy-intensive, less environmentally damaging and alternative and sustainable means of dealing with sewage implemented by a community concerned with the wider social and ecological impacts of wastewater treatment.

The discussion of the topics of focus in the 52 cases of public engagement mapped, and the 8 case studies highlighted in the boxes above, illustrate the public hopes, concerns and actions which emerge. The cases show that citizen perspectives on hydrogen as a source of power are broadly positive when they are engaged in studies. People do have some concerns about the cost, safety and practicality of hydrogen power, but these can be mitigated through close engagement, and particularly where actions are taken to improve trust in governance actors, and emphasise environmental and community benefits.

The cases mapped also show that citizens are aware of and concerned about emerging and future water management challenges around water shortages, water quality, and broader water sustainability, which suggests people will be receptive to new initiatives which aim to address these issues. These concerns motivate lots of community action and volunteering, which need to be recognised.

Citizen science research into water quality and forms of activism show the levels of concern and interest in sewage and water quality. This shows that people do not just care about the quality of the water service that they experience in their home but are also significantly invested in broader water management and its implications for their local environment. People's relationships with water companies have also been shown to be important through our highlighted cases. Our broader mapping confirms that as customers are generally happy with their water companies and the service they receive, however, as citizens people have concerns about the governance of water companies and whether they are meeting their environmental stewardship requirements.

Citizen engagement with the cases mapped has not been limited to contributing opinions and perspectives, but there are also examples of concrete citizen actions. These include the trailing of low-tech alternatives to sewage and wastewater management such as composting toilets and grey water reuse initiatives. Citizens are also involved in collaborative governance experiments such as the Cam and Ely Ouse Catchment Partnership. Behaviour change initiatives – often led by water companies – are another way that citizens are engaging materially with their water use, for example by being encouraged to use less water or to flush fewer things down the toilet.

5. A citizens' forum on sustainable wastewater management

As outlined in Section 3, we ran a citizens' forum with two groups of participants – interested citizens identified in our mapping and Anglian Water customers. The citizens' forum aimed to:

- Analyse customer and community perspectives on the installation of new hydrogen technologies at a water treatment works, and more broadly on the challenges of securing water futures in a changing climate.
- Make recommendations for how Anglian Water and other water companies should manage customer and community engagement around future work to improve the sustainability of their operations.

5.1 Framing the problem

Both the interested citizen and customer groups discussed multiple challenges of the water industry and wastewater management (and beyond) and both groups to some extent recognised the systemic and entangled nature of the wastewater management challenges with other areas of environmental and social concern. The main challenges that surfaced across both groups were issues of: climate change, population growth (including regional migration and urban development), damaging practices by water companies, domestic water and wastewater use, ineffective planning policy and regulation, and lack of education.

5.1.1. Climate change and environmental challenges

Both groups of participants mentioned concerns about climate change and the wider environmental challenges involved with water management and sewage treatment. This was a broad issue that encapsulated secondary concerns of population growth, damaging water company practices, domestic water and wastewater use, ineffective regulation, poor accountability and weak legislation identified throughout the discussion. The secondary concerns were all thought to exacerbate environmental challenges and increase pressures on regional water systems. The Anglian Water customer group tended to focus on broader framings of environmental and climate challenges, whereas the interested citizens group immediately challenged the systems in which water companies are embedded – like privatisation, weak legislation and regulation – to signal how entrenched environmental challenges are in existing modes of living.

However, more broadly, one participant from the Anglian Water customer group noted "*I would say one of the biggest challenges (for sustainable water and wastewater management) is the environment and the effect that it has on the environment...*". There was also a specific reference to the uneven water challenges experienced by different regions emerging from a warmer world,

> *"One of the strange things about global warming is that it's not just like it was in the summer with no water, you're getting some areas are getting too much at the wrong time and getting flooding."*

While both groups had concerns about climate change and the environment, the interested citizens group briefly focused on specific environmental challenges related to the problems of existing wastewater management like the use of toxic chemicals (via cleaning products) by domestic users in our water systems and the myriad damages of releasing sewage into local water environments and coastline,

> *"[Reconsidering] what we're allowed to flush down our toilets and our sinks, I know people that love bleach and just as a norm, pour something that's highly toxic and flush it away ... big companies can just pay and lobby and hide the fact that they're poisoning our water system... developers shouldn't be able to pay for credits, you should not be able to pay to pollute, that shouldn't be allowed."*

There was little reference in either group to the level of emissions of carbon emitted from existing wastewater treatment work.

5.1.2. Population growth

In relation to the potential pressures and environmental challenges associated with sustainable water and wastewater management, the idea of population growth and consequently, increased urban development and new builds was at odds – for both groups – with a vision of sustainable water and wastewater management. Two participants from the Anglian Water customer group mentioned concerns regarding the number of people migrating to the area and the role this will play on an already stretched water system and at-risk environment,

> *"My main concern is the number of people that are moving to Norfolk... they come along, they expect their taps to work, they expect their loos to work. Where is all this extra water and extra sewage management coming from to deal with the influx of people?"*

> *"...just another million people coming into the area, the effect that's going to have on the wildlife and the environment, that to me is the most overriding factor so forget any technologies or anything at the moment, how do we make that sustainable, not just for us but for the wildlife and the countryside as a whole?"*

A member of the interested citizens group thought that water companies need to become more proactive with urban planners to be able to cope with new demands more effectively or be able to reject new builds if the system cannot handle it in an environmental or sustainable way,

> *"I really think the important thing is that as regards to Anglian Water and similar companies, they have to take I think a much more robust view of planning permission and if they've got any concern about whether they can cope with the anticipated load or whether they think the anticipated load is underestimated, they've really got to put their foot down and say 'No, we don't want this, we can't do it'".*

5.1.3. Ineffective planning policy and regulation

Aligned with the challenge above, there was some discussion regarding ineffective planning policy that enables these challenges to proliferate. For instance, new builds do not have adequate drainage or green space in which to soak water away, there is no legislation that can reject planning permission based on existing environmental carrying capacity and so activities, use and practices increase to match demand. As one participant from the Anglian Water customer group mentioned that they have *"never heard that developers are paying Anglian Water because they've now got to provide the infrastructure and the sewage removal and everything for these new houses"*. As a result, there is little regulation to protect against further water resource use, and damaging practices or to encourage more sustainable systems (such as water drainage systems or less paved areas) being built within new developments. A member of the interested citizens group noted that existing regulations can be implemented but due to the nature of the process, environmental considerations are not always given equal weight against other criteria.

5.1.4. Damaging water company practices

Linked to the previous challenges, debate and discussion emerged around the extent to which damaging water company practices and the unsustainable ways in which they are operated, regulated and managed are core aspects of unsustainable water and wastewater management. Both groups noted that the existing monopoly model of water companies and weak penalties for damaging practices (like sewage dumping) meant that there is no real accountability or motive to change, and that the government or regulatory bodies need to toughen and reform their guidelines, as a participant from the Anglian Water customer group stated: *"the government has to crack down on the water companies".* The interested citizens group voiced concerns about current businesses models operating for profit and shareholders and not in the public interest being at odds with sustainable investment and practice, for example: *"how dare they talk to us about affordability when they're paying their shareholders huge dividends and not fixing their pipe, just how dare they?!".* The idea of reformed decision-making, governance and operating at a level with environmental and public interests in mind both groups thought would support more sustainable wastewater management.

5.1.5. Domestic water and wastewater use

A major and more immediate problem identified by both groups – in relation to growing populations, overstretched sewerage infrastructure and regional water challenges – was the perceived overuse of water and the implications this has on our wastewater production and the growing need for more energy-intensive treatment,

> *"...it's that reduce thing, if we don't need to use that energy, we shouldn't be using that energy, we should be using the minimum amount (of water) that we need..." (Anglian Water customer group)*

> *"I think one of them is the [decreasing the] amount of wastewater being generated ...one of the [challenges] is really just about the increasing amount of demand." (*Interested citizens group*).*

The idea that several of the challenges identified above could be 'solved' by reducing the amount of water that was used and entered the waste treatment works carried much weight among the groups.

5.1.6. Education

Directly related to domestic water and wastewater use is the challenge of educating the 'public'. Both groups discussed this but the Anglian Water customer group were more aligned with this as both a possible challenge and solution. The idea stems from the framing that the 'public' is knowledge-deficient about the regional water and wastewater challenges that the TCR project is seeking to solve and that an increase in information-provision can lead to more sustainable behaviour change – like reducing water use, improving drainage where possible in your homes and gardens.

> *"100% [it is] about education, I think that is vital because our society's predicated on convenience, we want to turn the tap on and we want to flush the toilet and most people and I'm generalising here, don't give a damn about it, they just want to have the convenience and that word "education" is what it comes down to, I think, at all levels from primary school right through to the teenagers, the 20-30 year olds and to the rest of the population... Anglia Water, should be putting people into schools, into university and give lectures, I think it would be a cheap, effective way of getting the message across." (Anglian Water customer group)*

> *"In terms of strategies to help with that, it's awareness and education isn't it?" (*Interested citizens group*)*

5.1.7. Problem framing summary

We now consider how the problem framings differed between the two groups. The Anglian Water customer group made reference to various interrelated challenges such as environmental damage, population growth, urban development and lack of knowledge and noted the relations between them, recognising the wider water and sewage challenges of the region as instrumental problems that will require multiple solutions (technological or otherwise), such as changing public attitudes and increased education for citizens and stronger regulation or incentives to promote more environmentally friendly and sustainable water company practices and operations. The Anglian Water customer group recognised that existing sewage treatment was ineffective and emphasised the need to solve this in one way or another.

The interested citizens group, on the other hand, was more explicit in its understanding of the systemic nature of the issues, recognising the need to re-evaluate the broader systems and visions of desirable futures in which the need for sustainable wastewater management and technological solutions are needed. The focus here was not on treating the symptoms to

continue the status quo, business-as-usual approach but to transform and address the systemic causes of the many different challenges (population growth, urban development, climate change, changing consumption and practices, alternative models of governance) associated with water and wastewater management. Most of the interested citizens group recognised that the sewage treatment issue signalled a society that failed to address socio-ecological issues effectively and focused on treating symptoms rather than root causes.

For both groups, it was apparent that for the challenges and problems of water and wastewater management that are facing the region and water companies, any possible solution is centred around the worlds and futures in which citizens want to live. For example, a participant from the Anglian Water customer group envisaged a world where technology and scientific rationality guide our solutions *"..we need lots of small technological solutions and ... it's got to be multi-solutional"*, whilst a participant from the interested citizens group envisaged a world in which we govern and organise in more sustainable ways,

> *"How [do] we measure everything in our society, how can there be a financial value on poisoning ourselves? There shouldn't be a situation where anyone can make a profit from poisoning the thing [environment] that we depend on."*

There are multiple ongoing and emergent challenges that relate to one another both in water and wastewater management and the spaces in which our lives operate and take place. Critically, the challenges which the TCR project seeks to alleviate (e.g. decarbonising sewage treatment works, producing hydrogen energy and making operations more environmentally sustainable) are interconnected with visions of how people want to live. The Anglian Water/TCR approach brings forward technocratic ideas and solutions that enable existing practices to continue in more sustainable ways which did not match the values and visions of some of the participants across both groups.

> *"The main questions we need to ask when we're making changes is a lot less to do with what's realistic and easy and a lot more to do with what do we actually need to do to reverse the ecological and climate crisis?" (*Interested citizens group*)*

Unprompted discussions about current private ownership and failing governance models also emerged for both groups in relation to damaging and unsustainable practices of sewage dumping in water bodies. The issue of failing sewerage infrastructure stimulated broader thinking about why multiple challenges are present and how they may be alleviated in the future, regardless of specific technological interventions. There was also a recurring interest about the 'new' and emerging problem of microplastics in our water systems and how these might be a challenge to sewage management and water safety in the future.

The ways that citizens framed the problems and challenges for sustainable wastewater management directly opened up discussions to alternative ways of managing and governing water and wastewater beyond the conventional ways it is currently managed and the technological fix that is presented in the TCR project. Importantly, for both groups, the ways that the challenges were problematised directly related to the visions of how our lives are ordered and arranged and how things ought to be from specific citizens' viewpoints, albeit to different extents.

5.2 Principles of sustainable wastewater management

The two groups produced a set of 21 principles statements that have been collated together into 8 key principles to help guide how water and wastewater should be sustainably managed and governed (Table 2).

Principle	Principle statements
Justice and fairness	Justice and fairness considered in decisions (e.g. access, distribution of costs and benefits considered and reflected in decision-making) (B) Public ownership of water (B)
Effective governance	Tighter regulation, better legislation (B) Dividends and pay-outs tied to environmental impact (B) Using existing frameworks that work (B)
Accountability and responsibility	Accountability and responsibility (A) Redistribution of pay in water companies – no CEO bonuses for failed service (environmental) (B)
Societal engagement	Education and engaging with society (A) Better education (B)
Cost effectiveness and efficiency	Address the challenge of cost (A) Reducing energy in wastewater treatment and improving energy efficiency (A)
Waste hierarchy	Reduce, reuse, recycle (A) Apply the waste hierarchy to wastewater: reduce, reuse, repair, recycle etc (B) Sewerage as a resource and investigating re-use of sewage (A)
Environmental enhancement	Enhanced environment, ensure environment flourishes (A) Prioritising equality of nature (healthy ecosystem approach) (B) Water quality upstream must be same as downstream (B) Having a water net gain initiative for developments (similar to biodiversity net gain) (B) Respect sewage (A)
Alternative solutions	Let nature help – natural treatments encouraged, reducing harmful chemical use (A) More research and development into alternative solutions: circular systems, making existing systems more effective (B)

Table 2: Key principles of sustainable wastewater management emerging from citizen deliberations (principle statements from the Anglian Water customer group = A; and from the interested citizens group = B).

The principles developed span social, technological, environmental, regulatory, governance and educational issues aligned with the key challenges the groups discussed and put forward. The Anglian Water customer group developed 8 principles that were similar to the 12 developed by the interested citizens group but with less emphasis on wider reform and a greater focus on tackling and managing the problem issues of sewage management directly. We have clustered similar statements together into 8 key principles across both groups (see Table 2). The principles that have emerged are representative of the ways in which groups framed the challenge of sustainable wastewater management and indicate what citizens view as important when deciding how and what solutions should be implemented.

5.2.1. Justice and fairness

> *"[I am] thinking about that distribution of the costs and benefits of any changes." (Interested citizens group)*

Justice and fairness emerged as a key principle from the interested citizens group who identified that a key challenge was, in their view, damaging water company practices and a perceived lack of recognition for just and fair decisions that appropriately consider who will gain or suffer (including the natural world) in direct response to damaging actions or proposed strategy. One proposal, they thought, would be to transfer water services back into public ownership and which may ensure a service that is run in the public interest rather than for profit.

5.2.2. Effective governance

> *"...CEOs appear to be paid on the basis of the profits that the companies make and they make profits although they've been discharging untreated sewerage numerous [times] into the Trent or the Severn, that's a principle which we cannot tolerate, surely?!" (Interested citizens group)*

Tied to the principle above, effective governance emerged from the need to ensure that just and fair decision-making practices run through the entire governance structures of water and wastewater management. This would include dividends and bonuses that are tied directly to environmental impact, reforming existing governance arrangements that enable sustainable practices to be effective and impactful. More broadly, effective governance would reform the legislation and regulation in which water companies operate to ensure unsustainable practices are penalised appropriately.

5.2.3. Accountability and responsibility

> *"Anglian Water's not being fined [enough], the accountability is not there because It's brush[ed] ... under the carpet. We've had a leak, we're turning our taps off and being really frugal at using our water resources at home... we might as well not even be trying." (Anglian Water customer group).*

Linked to the two prior principles, both groups felt that there needed to be some mechanism to improve the accountability and responsibility of water companies for their

operations to ensure sustainability practices are distributed fairly from company to customer.

5.2.4. Societal engagement

> *"It's got to be education of everybody hasn't it? The farmers, the government, the people doing the studies, it's a big circle..." (Anglian Water customer group)*

Engaging with society via awareness, communication and education campaigns was identified by both groups. A perceived lack of education of the 'general public' on the challenges of sustainable wastewater management and water use was identified as a problem for longer-term sustainability. As a result, ongoing and improved societal engagement on this was seen as a priority.

5.2.5. Cost-effectiveness and efficiency

> *"This is to do with cost [and] reduc[ing] the energy usage for wastewater treatment." (Anglian Water customer group)*

For the Anglian Water customer group keeping costs low for customers was a key principle to orient solutions for improving energy efficiency in existing treatment works. Although, the interested citizens group, despite not making this a principle, had mentioned that cost for customers would and should be *"hugely secondary"* to environmental sustainability.

5.2.6. Waste hierarchy

> *"Apply the waste hierarchy towards.. wastewater in the same way that it would to domestic waste." (Interested citizens group)*

In more practical terms, both groups had envisioned the implementation of the waste hierarchy (reduce, reuse, recycle) into wastewater treatment and management. The focus here is mainly to reduce water consumption to reduce wastewater production and need for treatment.

5.2.7. Environmental enhancement

> *"Enhanced environment ... we want it to flourish and get better than it is." (Anglian Water customer group)*

Both groups had identified the enhancement of the environment to be a core factor in assessing options for sustainable wastewater management: including a solution that improves the environment and making decisions with the equality of the natural world as a key stakeholder. This also included enhancing water quality. At a minimum, the quality of water put back into the water system after any treatment should not be compromised at any stage of the process. Ideally, wastewater treatment solutions would improve water quality and systems both in direct company remit and in the wider natural world.

5.2.8. Alternative solutions

> *"Lots more research and development into different ways of using ... circular systems" (Interested citizens group)*

Additionally, both groups also recognised that due to the complexity of the challenge of sustainable wastewater management, multiple solutions should be assessed (including natural treatments like reed-bed filtration) and areas where systems could be made circular and more sustainable investigated (e.g., production of hydrogen for community-use in TCR project).

5.3 Considering different options

In the second half of the citizens' forum, participants discussed and appraised both the MABR technology and alternatives that had emerged from our earlier mapping (see Table 3). As a core part of the citizens' forum, the participants were able to respond directly, as one group, to the proposed MABR technology presented by Anglian Water.

5.3.1. Responses to MABR

Participants were forthcoming with various questions to the project lead after an informative presentation on what the MABR technology is, how it is planned to be implemented in Anglian Water and the purpose of the technological demonstration. Some participants were keen to understand the benefits of the technology namely the increased use of wastewater as a potential resource in energy production, the reduction of carbon-intensive energy use and the role the new approach to wastewater treatment can play in wider sustainability transitions. In relation to the key principles in Table 2, participants also asked about specific reductions of energy and emissions, the amount of energy required to separate the hydrogen and oxygen compared to energy saved from traditional sewage treatment works, and the possible interference of microplastics in wastewater in all this.

As this was not yet known, due to the stage of the experiment, the conversation moved on. There was also interest in how the trade-offs between different technological pathways were taken to get to this stage and how the management of hydrogen as a potentially dangerous, yet low carbon, energy source would occur. Building on this, safety and risk concerns about hydrogen storage and use by the 'general public' were a key concern. However, the technology specialist addressed these concerns by comparing hydrogen to biogas, which is already in use and operating safely in Anglia Water.

Another concern emerged from multiple participants about the underlying motives behind embarking on this potentially dangerous form of energy production, stemming from a sense of general distrust of water companies' hidden practices, due to the ways in which water companies seem to currently operate outside of environmental regulation (e.g. sewage discharge). Some suspected that Anglian Water would like to gain a monopoly on low-carbon energy provision and are using potential financial gain to guide operational and strategic decision-making rather than being for environmental and sustainability impact. As a result, calls for public ownership surfaced again in this discussion.

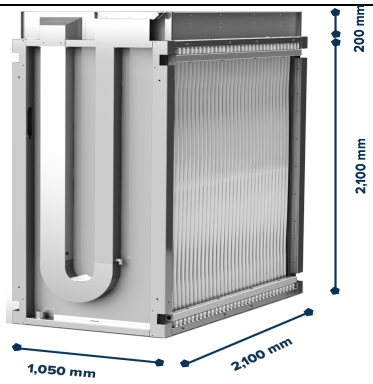
	**New technologies** **MABR installation** – MABR modules slot into existing tanks to increase the biological capacity of systems, absorbing carbon and nitrogen-based pollutants in the wastewater, improving nutrient removal, leading up to 50% reduction in sewage sludge. Air is pumped at low pressure through the membrane reducing the energy used to treat sewage, and it has the potential to be combined with the production of green hydrogen, as in the TCR project. **Examples of use:** Anglian Water's TCR project, Severn Trent Water
	**Improving governance** **Alternative governance models**– Improving governance can include things like bringing water back into public ownership to ensure. It can also involve collaborative partnerships, taking a holistic approach to managing and governing water on a catchment scale with the aim of ensuring environmental, social and economic benefits and protection of regional water resources. **Examples of use:** Scotland (publicly owned water); Wensum or Broadland Catchment Partnerships, 'We own it' campaign
	**Citizen action** **Citizen science** – Volunteers, community groups and individuals have embarked on monitoring rivers to test water quality, identify pollutants and to help assess the environmental health and management of water. **Examples of use**: Surfer's Against Sewage, Wensum Catchment Partnership, Norfolk Rivers Trust.
	**Alternative technologies** **Composting toilets** – Dry toilet, aerobic decomposition – 'starter cultures' provide microbes to help break down organic matter into compost, emptied every 6- 12 months as compost. There are many models available from simple, single-chamber ones to more complex 'active' ones that require heat and power. **Examples of use**: off-grid living, in motorhomes, houseboats, festivals, allotments.

Table 3: Options appraised by participants of citizens' forum.

There was disagreement and debate between participants with some arguing against the proposed technological solution as it enables us to continue with business-as-usual and focus on building "big" technological fixes that were not aligned to a number of principles outlined in the morning session (e.g. focusing on the waste hierarchy, accountability and responsibility or ensuring effective governance). Others felt that a quick fix is needed to achieve the level of sustainable change on the scale and pace that is required and so welcomed this experiment, in particular, due to its capability to reduce energy use, potentially improve costs to customers and contribute to wider environmental protection and enhancement. However, in relation to the principle of 'alternative solutions' in Table 2, it was recognised that was not the only solution nor should it emerge as just one solution with other alternatives brought forward unprompted at this stage.

In sum, there appeared to be uncertainties and questions about the MABR technology with participants debating and discussing the promises and pitfalls of this experiment. It was clear that more ongoing information is required for citizens to understand better what is being experimented and demonstrated in the TCR project, the challenges it seeks to reduce and the effect to which it is achieving this as the experiment matures. For most, it appeared that this solution may be effective in addressing a number of challenges set out in the morning session without being fully aligned to the key principles that would ensure long-term sustainable wastewater management.

The Anglian Water customer group systematically appraised each of the options provided by UEA and Anglian Water aligned to the extent each related to and followed the principles they set out in the morning session. The interested citizens group appraised each option in less systematic terms instead opting to discuss how they related broadly to the principles they had developed and proposed specific recommendations for ongoing engagement regarding the installation of the technological option (MABR). For both groups, it was clear that not one solution would solve all the problems identified in the earlier session, but some options were perceived to be better than others.

5.3.2. Citizen action

Citizen Action for both groups was a key tool in empowering citizens to act in positive and sustainable ways, to hold water companies and those who practice damaging activities to account by being able to present independently citizen-collected data. Whilst ensuring accountability and responsibility as a key principle both groups agreed that this solution was failed by existing legislation and consequently, the difficulty to enact real difference.

> *"...with the citizens action and the testing and stuff, that's only useful if it's legally binding. I totally agree that we should be able to test water and say, "look, our water's poisonous" and then there should be a legally binding aspect to that." (Interested citizens group)*

There was a minor split between participants in both groups with a member of the Anglian Water customer group arguing that the ability to independently challenge organisations was a good thing to *"hold them to account"* with members of the interested citizens group claiming that citizens should not have to be the ones to hold damaging practices or

unsustainable management to account and that our systems of governance and regulation are failing if citizens are having to act. Other members of the interested citizens group recognised the importance of citizen action in facilitating wider collaboration and supporting other solutions.

5.3.3. Improving governance

Improving governance appeared for both groups to be both a promising solution but also a risky endeavour. In relation to the principles, it was thought the solution of improving governance would be aligned with justice and fairness, accountability and responsibility and ensuring more effective governance.

More specifically, both groups discussed public ownership of water companies but with different concerns. Some of the Anglian Water customer group argued that through public ownership service could be improved with it being run for public interest rather than shareholders with others concerned that the level of service might decrease, for example:

> *"When people are decrying private ownership of a resource like water, they go back to the past and say, "look what happened to British Rail, it was rubbish", we need a new way of doing things which keeps the pressure on and makes it work, rather than becoming a bureaucracy."*

In the interested citizens group public ownership was discussed as a means to be able to change operations and decision-making processes to be more environmentally responsible, responsive and possibly even enhancing the environment. The idea here was that running and operating a service in the public interest with environmental protection in mind then removing large bonuses for CEOs and large shareholder payments would be worthwhile,

> *" 'Participant 1: 'We've got to pay our £200m profit to our shareholders so we can't ...'*
>
> *Participant 2: [We] need to be more radical than [another policy]*
>
> *Participant 3: Yeah! Renationalise... [water services]".*

Other governance models were discussed across both groups with an increased emphasis on collaboration with other stakeholders argued to be a positive way of wastewater management in more sustainable, equitable, just and fair ways that can protect the environment and benefit society. This solution was recognised as a key part of many possible solutions for the benefit of wider society and collaborative sustainable wastewater governance that may aid the decrease in reliance on existing systems and solutions.

5.3.4. New technologies

New technologies were the most divisive option for the interested citizens group and created some debate in the Anglian Water customer group. The MABR technology appeared to be a promising solution that was directly relevant to several of the organising principles in Table 2.

"I would also say it helps to enhance the environment, it's very much linked to that because it's a renewable energy resource so they'll be using less [energy]...". (Anglian Water customer group)

In particular, it was thought that if the demonstration is as efficient as suggested, it would be a clear solution to reducing energy use in existing wastewater treatment. This in turn would improve water quality discharged and contribute to more sustainable and low-carbon practices that could be scaled up effectively. While the benefits were recognised in the interested citizens group, it was also recognised that this solution would not solve some of the wider and systemic issues like financially motivated decision-making and lack of accountability or responsibility, reducing consumption and waste, reusing water and operating in a capitalist system. Some felt this solution would allow things to remain as they are, to continue to create environmental damage and perpetuate damaging practices, as one participant brought forward after the MABR technology presentation that,

"...the worry here is that it's just like 'oh carry on the status quo, carry on thinking about water in the same way' and we're just going to try and find a slightly more efficient way of dealing with that. It still is going to need quite a lot of energy consumption in terms of electricity at a time when ... we all need to be thinking about reducing energy consumption in all areas of our lives, so I just worry that in terms of 'reduce' in the first place, this carries on with the status quo, carry on as business as usual and we'll just try and use technological innovation to tackle that." (Interested citizens group)

The interested citizens group also queried this task as a 'tick box' exercise but had some thoughts on the implementation of the MABR technology, as shown below,

"Participant 1: We felt that Anglian Water were asking us to give approval to this new technology...

Participant 2: Yeah, it felt like a box ticking thing.

Participant 1: [but] there's some things that we want to ask them about it before we're in a position to judge that and we came up with what's the timescale, what are the risks, what are the emissions including the embodied emissions and what would be the impact on the local ecology...." (Interested citizens group)

5.3.5. Alternative technologies

Alternative technologies like the implementation of composting toilets appeared to be the most in line with the organising principles in Table 2. For both groups, the idea of a composting toilet would help support a reduction in water use and wastewater production, increase respect for sewage management and circular use of a new resource, protect and possibly enhance the environment, keep costs low for customers by reducing use and dependence on a flushing toilet and as a result, reducing the amount of waste needed to be treated in energy-intensive ways. This was thought to be aligned with several of the key principles presented in Table 2.

> *"The alternative kind of technology is more aligned with the principles that we set out this morning" (Interested citizens group)*

However, it was recognised that to implement this at the scale of change needed would be very difficult, impractical and not a short-term solution,

> *"...if you live on the 17th floor of a block of flats [it is not practical]." (Anglian Water customer group)*

There were additional solutions offered by the interested citizens group that involved changing legislation and regulations to ensure more environmentally sustainable operations and reforming planning policy to ensure new housing developments and water infrastructure can cope with new demand and ease pressure directly. The Anglian Water customer group also discussed the idea of sewerage water meters linked to pricing to encourage a reduction in the unnecessary use of chemicals or other materials in wastewater and unnecessary flushing or disposal of wastewater.

6. Expert responses to public engagement findings

We now examine the extent to which experts in the Triple Carbon Reduction consortium have been responsive to the emerging public concerns from the public engagement mapping and citizen's forum and the capacity to build social responsiveness into the project, aligned with our third project aim.

The responses from expert consortium members can be seen as broadly aligned with the first two waves of public engagement outlined in section 2: knowledge-deficit and engagement-deficit. There were some minor instances where expert respondents showed capacity and recognition of being much more responsive to societal engagement and the issues being brought forward from the public engagement work. We characterise this as 'degrees of societal responsiveness' to demonstrate how experts across the consortium recognised a third perspective on public engagement that goes beyond the previous two dominant models outlined above.

6.1. Public acceptance and social acceptability of the MABR technology

The majority of the respondents recognised the need for public engagement associated with technological demonstrations like the MABR installation. The linear model of getting society to accept technological developments was strong. Expert respondents typically framed public engagement as either providing information to knowledge deficient publics, as Expert I stated,

> *"I think public consultation might – if you go into the detail of what it comes up with hydrogen, to a lot of people it's an unknown gas that they wouldn't have worked with before so basically you'd want to allay those concerns by educating, by making them aware of what it's all about".*

Or they framed it as a means to gain acceptance for technological developments as Expert D noted how *"these days ... public consultation is critical in getting new acceptance from the public to get them [developments] through"*. Expert G re-affirmed that *"you do need to address them [publics]... if you want buy in and you want to keep a good reputation".*

Framing public engagement as a means to achieve social acceptability was also prevalent with Expert H recognising the ethical importance of enabling the 'public' to be involved and voice their concerns,

> *"Well from an ethical perspective I think [public engagement] matters a lot and we are all citizens and we should be part of a deliberative democracy that actually works, which we're not. But I guess it matters a lot for the company ... [I] mean it matters particularly in our highly regulated, privatised industry because the public, there's a huge polarisation and that massive level of distrust between the public and water companies, so I think [public concerns] matter".*

The idea that the projects need to incorporate public engagement in some form, throughout the project life, was seen as a means to gaining social acceptability more widely. This framed

public engagement as an instrumental task by which publics are invited on the organisers terms to give perspectives, learn more, or deliberate on tasks for particular purposes and aims. There is an assumption here that public views are secondary to expert views: the public are invited to give their views and perspectives but the decision to act on these remains entirely with the decision-making organisation. As Expert B noted public views would not be a deciding factor if the project was to continue or not e.g., *"I think there's a balance to be had, because we wouldn't just make a decision based purely on ... feedback."*

The limitation of this approach is that it ultimately continues to frame technological developments and expert knowledge as elevated above public knowledge or social concern. Issues of fairness, justice or ethics around technological development are satisfied, seemingly, if the 'general public' has had a chance to share their perspectives.

The majority of respondents recognised the concerns from the mapping and citizen's forum work and were surprised at the organisation of public concerns. As Expert E stated,

"I'm surprised at how little people are worried about their hydrogen and how they were much more interested in the water side of it" whilst Expert H countered this as being the exact sort of response they would imagine coming from a concerned public group, "*I think the public right now tend to be fixated on water industry issues and water companies...".*

The diversity of modes of engagement demonstrated through the mapping space also appeared not to be surprising to our respondents, for example: *"I think they're all valid. I think it comes back to [how] everyone is different so there will be a preference as to what they like or how they engage...."* (Expert G) and *"I don't think so"* (Expert A).

Yet, when asked if the TCR project recognised diverse modes of public engagement most conceded that the typical forms of engagement, they envisage would be the formally invited citizens via consultations. For example,

> *"I agree with you when you said the top left* [See figure 3 in section 4 of this report] *is what we tend to think of as public engagement, that is what I would've generally thought of public engagement being but... I agree it's broader and I think it's all valid"* (Expert F).

Notwithstanding, as one mentioned, being recognised as dominant modes of participation does not necessarily make them more meaningful or legitimate,

> *"In general, I think people would believe surveys and consultations are better and more relevant than activism, personally I'm not 100% sure"* (Expert E).

It was apparent that most of the members of the TCR project consortium recognised the multiple ways in which citizens are engaging in the issues of wastewater management and hydrogen production and recognised that different forms of participation were not necessarily better than others.

Yet, when considering the extent to which the TCR project recognises or responds to the organising principles and challenges or concerns of both the mapping and citizen's forum,

there was some difference in response. For some, there was an assumption that concerns with accountability, effective governance, and justice should have already been dealt with before the project began, for example:

> *"In this project, you're talking more about just how do we have better governance? Which backtracking to earlier is we probably have it already, I would assume, a proper governance structure"* (Expert A).

> *"I suppose it depends on what view you're coming at it with because from being inside the project, I think I can see there is quite a lot of accountability and responsibility, it's been approached in the right way, people are taking it seriously and they really want to know the answer for can this actually work at a larger scale"* (Expert F)

Additionally, others recognised the timing of these conversations was too late in the project's life as one respondent noted that discussions around accountability, fairness, justice and so on *"should have already happened before we get involved in projects"* (Expert E).

Tied to this, others recognised the concerns and principles but thought that they were not particularly relevant at this stage in the TCR project as *"[i]t's too small scale for them (the 'public') to have any input"* (Expert D) and that if there was public concern, they would still go ahead with it,

> *"...we're at the stage .... where we're just testing something, I guess we act with the whole we've got to try stuff, we can't just do nothing"* (Expert B).

For some, it appeared that the experimental nature of the trial and getting data on its feasibility were the most important factors to consider,

> *"I'm not sure... for a relatively small-scale innovation project I'm not sure it does need to respond to everything other than like I said, getting delivered in a way that is you can see with these principles. I don't think it should be a priority, the priority of the project is to test the new technology and gather some data and see how it works"* (Expert C).

> *"I think generally the project addresses a lot of these things, but a lot of the questions that you had on the other page we don't know the answers to some of them which is why we're doing the demonstration plant"* (Expert B).

This was particularly important, as when encouraged to think about the benefits of trialling social responsiveness in the early stages, some thought that this would be a hindrance or obstacle for the project. Interviewees spoke about the importance of the MABR installation being isolated and a pilot study for potentially larger-scale operations where these concerns would be more relevant. Some placed emphasis on that innovation attempts like these happen a lot and are often not communicated in the first place to avoid *"loads of people worry[ing] about it ... if we not even do this long term"* (Expert B) and that the knowledge

communication benefits of the trial would be valuable for public engagement and acceptance e.g.,

> *"If this project goes really well and you tell them about it, you tell them what's happened, think the key question they'll always have is what does this mean for me, so obviously the cost question can be answered and the efficiency question can be answered, part of the environmental enhancement can be answered but the project is not going to be able to answer things on water leaks and sewage dumping".* (Expert D)

Typically, these sorts of responses align with the first two modes of public engagement. They frame public engagement as an instrumental tool to help technological installations, like that of the MABR demonstration, be socially accepted which elevates the authority of technological expertise over public concerns.

6.2. Towards social responsiveness in the Triple Carbon Reduction project

During many points in the interviews there were moments of recognising the value of being socially responsive and the worth of building social responsiveness into the TCR project. The degrees of responsiveness differed but were present, nonetheless.

For example, Expert D began to recognise that responding and recognising society does have its place in large-scale projects, and that public concerns and organising principles should be listened to:

> *"I think bringing the public along at this early stage when we're trying to get the health and safety and we're on a learning journey ourselves, probably wouldn't be wise because ... I don't think I'd have done anything different there ... but I think longer-term going forward, whatever the results we get from this project, if we were going to implement this at scale, I think certainly they would need to be there from day one doing a bit of an outreach education about this is why we're doing it, this is what we're doing it for, this is where we're thinking about doing it, these are our ideas"*

However, this surfaces questions about why an increase in potentially affected citizens should necessitate greater concern from technologists.

Most respondents recognised the legitimacy of public concerns around existing wastewater management but felt challenged in recognising what the Triple Carbon Project could actually do to alleviate these concerns, with Expert F reflecting *"I don't think this project can effectively address all of these principles"* and another stating:

> *"Justice and fairness to me, I don't know how that applies to Triple Carbon, because I think that's more like a brush that tarnishes the water companies rather than the project-specific, in my experience"* (Expert D)

There was again minor recognition of the systemic view how citizens were developing their responses to the MABR technology, as Expert F recognised that,

> *"...the public can't separate their key concerns about water in general and this project. It's not related to what we're doing here but they can see … I guess they're worried, it's kind of a trust issue maybe, they're worried that this is just ... papering over the cracks which I think I can also appreciate from their point of view."*

Notably, with respect to the principles and wider concerns emerging from the mapping and citizen's forum, all interview respondents reflected in ways that they may not have done otherwise. For example, the entrenched and organisationally robust views of public engagement as an instrumental tool to gain acceptance and improve knowledge of actions dominated how most interviewees responded to public concerns meant that ethical reflection was not emphasised in many interviews nor was deep reflection on being accountable and trustworthy in the publics' eyes. Members of the consortium understood this but felt detached from the challenge in their own positions and from the wider impact of the TCR project. There was recognition that they should be responding and acting in line with the organising principles and public concerns, for the most part, even if it was recognised to be not practically possible especially within existing structures, "*I think it's hard for it to take place in the structure, particularly for us in the structure that we have. ...We need systemic change"* (Expert H).

The rigid view of public engagement as an instrumental tool also meant that considering the direction in travel was not a feasible action and the potential closures of alternatives brought by the MABR demonstration were not, for the most part, recognised or seen as critical conversations to be had. There were some exceptions to this from a few respondents after ongoing conversations through the public concerns that had surfaced, for example:

> *"I'm guessing a lot of the ... [existing] public engagement is probably project-specific at a stage where they've already got the planning permission ... they're going ahead with it, it's not, "Should we actually spend hundreds of millions of pound putting in chemical dosing, because that will actually give an incremental river water quality increase, or should we spend the same money actually properly tackling carbon emissions because no one else is going to do that for us? Do we want clean rivers for our kids? Or do we want a habitable planet?"* (Expert H).

In sum, some of the respondents did address all of the public concerns and principles to some extent. There were numerous occasions when respondents felt that the positive work they do regarding technological innovation, communication campaigns and providing great service to customers was overshadowed by negative media narratives. For example, *"the press always likes to publicise what companies are not doing as opposed to what they* are *doing"* (Expert D, emphasis added).

Concerns over issues of trust, accountability, effective governance, justice and fairness were largely poorly understood in direct relation to the aims of the TCR project, although a majority of interviewees recognised why these principles emerged as citizens viewed the water company and innovations in one holistic system.

6.3. Reflexive learning

For some respondents, engaging with the mapping helped to transform their understandings of public engagement and participation. The mapping space (Figure 3) enabled them to visualise the multiple and potentially excluded or hidden modes of participation from an organisational perspective and recognise that publics are emergent, active and innovative in their own ways. As Expert B responded,

> *"I think it's very easy when you work for a company to be institutionalised. I don't know if I mean institutionalised, but I call it focused, I'm just like this is what we're trying to do. I guess you're not paid to think ... no-one asks me on a daily basis to do that massive thing that you're doing, they ask me to communicate with stakeholders, it's a very specific ... Whereas this [mapping] is taking a much more bird's eye view. Yeah, just interesting."*

Expert F also noted how the mapping space encourages recognition of emergent, bottom-up citizen-led forms of participation "*I always thought of that as when a company or an organisation, somebody like Anglian Water, goes out and engages with the public but this more about when the public engage with you".*

For others, the mapping did not encourage greater reflexivity about their approaches remaining wedded to the idea that society and technology are separate sphere – as Expert C, a technologist, pointed out *"I must admit I don't really have a strong view on this, this isn't something I spend a lot of time thinking about"*.

7. Key insights and future implications

In the analysis presented across three stages of work, we have highlighted the diverse ways in which citizens are engaging with the challenges of sustainable wastewater management, hydrogen production and securing sustainable water futures more broadly. We have also explored expert responses to these public engagements and prospects for societal responsiveness. We now synthesise across these strands of work to drawn out key insights and future implications from the social science work package.

7.1 Public engagement

- Our mapping analysis has demonstrated that publics are not 'innocent' or knowledge deficient. Citizens are always engaged in multiple ways around sustainable wastewater management.
- Through our mapping, we have highlighted how citizens are engaged in numerous roles through discourse-orientated issue spaces (e.g. surveys) or embarking on material actions (e.g. community water management plans) which can be critical spaces of knowledge-making and innovation.
- Engagement is highly diverse and occurs beyond formal institution-led processes (by Anglian Water and others). Our analysis demonstrates how there is a crucial need to open up to citizen-led engagements. Moving beyond formal institution-led forms of invited engagement (like one off public consultations) can bring forward alternative perspectives, different forms of actions, and alternative visions of desirable futures.
- Public engagement is interrelated. Our analysis has challenged the static view of public engagement by showing how engagements with sustainable wastewater management are multiple, ongoing, emergent and related. Forms of engagement do not occur in isolation but occur in relation to one another. Previous engagements impact how future engagements occur (like cynicism toward water company consultation methods).
- We have shown how mappings can be used to inform design of participation. For example, in how you recruit citizens, open up the framing of the issues, think about alternatives.
- We have sought to open out the engagement processes to go beyond specific responses to specific questions of technology to account for a fuller range of publics, the diverse ways in which publics are engaged and demonstrate the interconnectivity of challenges, concerns and solutions.

7.2 Public perspectives on sustainable wastewater management and the role of new technologies

- The problems the TCR project is seeking to address – such as carbon reduction and making wastewater treatment more sustainable in the context of net zero – are framed in more narrow terms than those emerging from citizens. Wider problem framings were brought forward by citizens in relation to the entire system of water service and provision. Broad issues like climate change, population growth, domestic water use, ineffective regulation and policy tied with damaging water company practices and education were the prominent challenges citizens organised their discussions around. These wider framings illustrate how citizen responses to technologies are often broader

than assumed by water companies. Our analyses throughout the project revealed entangled concerns about the world in which we currently live and the world in which we want to live.

- Citizens are concerned with ensuring that wastewater is treated in sustainable ways that are not detrimental to the environment. Whilst the MABR technology has proposed to reduce carbon emissions and produce a low-carbon fuel source, the broader challenges of sewage being dumped in waterbodies were seen as not being sustainable or environmentally friendly. Citizens felt that this needed to be solved before new technological innovations were advanced.
- Our analysis revealed that public views of any technology or solution will always be cloaked in questions of accountability, trust and effective governance. This illuminates the wider distrust and suspicion citizens have of privatised water companies that are run for profit and in the interests of shareholders. This underlying aim of water companies leads many citizens to question the purpose, motivations, and in whose interest are solutions being brought.
- Citizens also responded to new innovations, aligned with the above, in ways that considered the fairness and justice implications of potential solutions. The citizens' forum revealed the challenges of private companies being seen to be making decisions in the public interest. Citizen participants perceived that proposed innovations were not decided in democratic or fair ways in relation to potentially affected citizens. Questions of who benefits or who bears the risk from new technological developments were not seen to be part of organisational decision-making.
- Citizens had varied views about the emerging technology in the TCR project. Hydrogen power is still not widely known about or considered by most citizens. When engaging with this issue, citizens raise concerns about safety, cost and supply of hydrogen, but also see the positive potential of hydrogen for clean energy and net-zero. Trust and safety are less of an issue if citizens trust the organisation managing or producing the hydrogen. The MABR technology piqued interest for many citizens and if the experiment is successful citizens could see the benefit implementing this on wider scales. However, for most citizen participants, current uncertainties around efficiencies and outcomes of the technological demonstration, including its carbon reduction potential, made it difficult to assess the benefits appropriately.
- When a new technology is proposed, alternatives are always brought forward by citizens. These surfaced as alternative solutions (e.g. reed bed treatment) or alternative practices (e.g. consuming less water and reducing the amount needed for treatment). Citizens questioned the direction of travel to achieving net zero, recognising that the TCR project framed the pathway primarily as a technological one and not as a socio-technical one.
- Our mapping analysis and citizens' forum findings show that citizens are becoming disillusioned with water company engagement strategies. Often, they feel as if participation is a tick-box exercise with no means of changing or shaping potential course of action.
- Problems and solutions to problems are inseparable from the ways in which citizens are engaged, how they frame and understand problems, and how futures are imagined and desired.

7.3 Societal responsiveness

- Our analysis has demonstrated that diverse forms public engagement bring forward different and often antagonistic public views.
- Our mapping approach can be used to explore, better appreciate, and account for diverse forms of public engagement in order to recognise and respond to diverse public views.
- If public engagement is to be taken seriously, public views need to be responded to or recognised. This is not to say projects should be stopped but attempts need to be illuminated and communicated how and what steps are being taken to ensure public views are being attended to throughout all parts of the project.

7.4 Future implications

- Recognising citizens are already engaged in many different ways should be the starting point of public engagement.
- Attempts to engage or consult with citizens should do more to acknowledge and attend to diverse publics and diverse forms of public engagement with issues around sustainable wastewater management.
- Public engagement is not and should not be viewed as a one-off, discrete process but rather is always ongoing, beyond the citizen's forum and public responses are contextual and conditional which need to be closely monitored and reflected in wider institutional or technological demonstrations.
- Understanding responses to technologies must be understood holistically, recognising citizens do not respond in isolated ways but rather make assessments and give perspectives against a backdrop of
- There should be long-standing public engagement with local and affected communities from idea conception (co-constructing innovations with affected publics) through to delivery. Engagement should be ongoing, reflexive, and responsive with public perspectives in order to be more socially responsive and change public perception of water company public engagement strategies.

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9. Appendices

9.1 Search terms

WHO (participants & subjects of participation	WHAT (issues, topics & overall framings)	HOW (models, forms & practices of participation)	WHERE
public	sewage	survey	UK
citizen	raw waste	dialogue	England
customer	wastewater	opinion	East Anglia
stakeholder	hydrogen	information	East of England
communities	Anglian Water	social media	Norfolk
activist	Ofwat	consultation	Suffolk
consumer	Net-zero/water management	experiment	Cambridgeshire
household	biosolids	demonstration	Essex
tenant	MABR	attitude	
homeowner	water companies	communication	
resident		complaint	
protestor		awareness	
user		sentiment	
Interest group		toilet	

9.2 List of cases from mapping

	Case study name	Year	Source(s)
1	Public perceptions of low carbon hydrogen	2022	https://ukerc.ac.uk/news/public-perceptions-of-low-carbon-hydrogen/
2	Annual review of customers views of water and sewerage services	2018	https://www.ccwater.org.uk/wp-content/uploads/2019/07/Water-Matters-Highlights-Report.pdf
3	#End Sewage Pollution	2022	https://www.sas.org.uk/news/join-the-endsewagepollution-protests-23rd-april/
4	Compositing toilets for London Canal Collective	2018	https://theconversation.com/eco-friendly-composting-toilets-already-bring-relief-to-big-cities-just-ask-londons-canal-boaters-96066
5	Information for Anglian Water customers	2022	https://www.anglianwater.co.uk/help-and-advice/
6	Public acceptability of indirect potable water re-use	2014	DOI:10.2166/ws.2014.051

7	Southern Water Universal Metering programme	2010- 2015	https://www.water-alternatives.org/index.php/alldoc/articles/vol9/v9issue2/318-a9-2-8/file
8	Anglian Water water meter retrofit	2020 - 2025	https://www.anglianwater.co.uk/news/anglian-water-on-course-to-install-over-1-million-upgraded-water-meters-to-help-tackle-covid-demand-increase/
9	Online comments on drought mitigation news articles	2012	https://doi.org/10.1080/1573062X.2014.993998
10	Discover Discuss Decide - online forum	2012 - 2014	doi: 10.2166/ws.2017.200
11	POWER Water Communities: Milton Keynes, Leicester	2018- 2020	https://ojs.library.queensu.ca/index.php/wdsa-ccw/article/view/12276/7875
12	Cam and Ely Ouse (CamEO) Catchment Partnership	2019 - ongoing	https://doi.org/10.3390/w13131737
13	Customer Engagement Forum - Anglian Water	2014 - onwards	https://doi.org/10.1332/030557317X15046029080815
14	Visits to Hydrogen Research and Demonstration Centre, South Wales	2011	https://doi.org/10.1016/j.ijhydene.2014.07.090
15	Video animation framings for water reuse	2018	https://doi.org/10.1016/j.watres.2018.08.006
16	Drought perceptions, capability and mitigation survey	2019	https://doi.org/10.1007/s11269-018-2175-2
17	Alde and Ore Futures	2009 -2011	http://www.aldeandore.org/wp-content/uploads/2016/02/Alde-and-Ore-Futures.pdf
18	Scientific-Stakeholder workshop for Broads Flood Risk Management	2020	https://doi.org/10.1016/j.envsci.2019.10.016
19	FAIRWAY Project	2019	https://www.anglianwater.co.uk/news/fairway-project--creation-of-a-successful-kid-initiative-in-south-lincolnshire/
20	Slug It Out - Farmer behaviour change	2015	https://www.anglianwater.co.uk/business/help-and-advice/working-with-farmers/slug-it-out/

21	MaRIUS Drought Project	2014 - 2019	https://doi.org/10.1111/tran.12288
22	Safe & SuRe: A new paradigm for urban water management	2013- 2018	www.safeandsure.info
232	Understanding Farmer behaviour and water pollution	2018	https://doi.org/10.1080/09640568.2019.1638232
24	Discontent on social media concerning polluting practices of water companies	Ongoing	https://twitter.com/Feargal_Sharkey
25	Save Honey Hill	2021	https://www.savehoneyhill.org/category/cwwtpr/
26	Survey with river users in Norfolk	2017	https://doi.org/10.3390/w9080621
27	Interactive Sewage Map	2021	https://theriverstrust.org/key-issues/sewage-in-rivers
28	Safer Seas and River Service	2022	https://www.sas.org.uk/safer-seas-service/
29	Acceptance levels of decentralised energy storage at household and neighbourhood scales	2018	https://doi.org/10.1016/j.enpol.2019.111194
30	Adopting or rejecting alternative fuel vehicles	2013	https://doi.org/10.3390/su10092997
31	HyDeploy	2019 - 2021	https://hydeploy.co.uk/app/uploads/2018/02/customer-perceptions-report.pdf
32	Public perceptions of public perceptions on 100% Hydrogen	2019	https://h21.green/what-do-the-public-think-about-hydrogen/
33	East Suffolk Greenprint Forum - Water	2015	https://www.eastsuffolk.gov.uk/assets/Environment/Green-Issues/East-Suffolk-Greenprint-Forum-Water-the-essential-element-14-09-15.pdf
34	Cambridge Wastewater Treatment Plant relocation	2020 -2022	https://cwwtpr.com/document-library/
35	Anglian Water Drainage and Wastewater Management plan	2022	https://www.anglianwater.co.uk/about-us/our-strategies-and-plans/drainage-wastewater-management-plan/
36	Testing the Waters	2021	https://brecks.org/bfer/projects/working-waters-heritage-skills-for-the-future/3-1-citizen-science-testing-the-waters/

37	Catchment Systems Thinking Cooperative - The Wensum Pilot Project	2022	https://basg.online/wp-content/uploads/2022/07/CSWQT-FINAL.pdf
38	Public perceptions on transition from gas to hydrogen: survey	2020	https://h21.green/app/uploads/2018/01/SBT2251-Leeds-Beckett-Leeds-Sustainability-Institute-H21-Report-Singles.pdf
39	Public perceptions on transition from gas to hydrogen: deliberative workshops	2020	
40	Blended Hydrogen: UK public's perspective	2019	https://eprints.ncl.ac.uk/file_store/production/261762/77656234-5E46-460F-8A9C-211C0458E36D.pdf
41	Public acceptability of hydrogen in the home (deliberative workshops)	2018	https://www.theccc.org.uk/publication/public-acceptability-of-hydrogen-in-the-home-madano-and-element-energy/
42	Public acceptability of hydrogen in the home (survey)	2018	https://www.theccc.org.uk/publication/public-acceptability-of-hydrogen-in-the-home-madano-and-element-energy/
43	Future of heat: workshop	2020	- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945290/transforming-heat-workshops-rpt.pdf
44	Findhorn eco-community (Scotland)	2010 -	https://theecologist.org/2010/jun/08/living-machine-ecological-approach-poo
45	Wensum citizen science	2022	https://norfolkriverstrust.org/project/wensum-citizen-science/
46	Cam Valley Forum	2022	https://camvalleyforum.uk/wp-content/uploads/2022/05/22-05-12-Defra-response-to-CSO-Consultation-12.5.22.pdf
47	Survation poll on public ownership of utilities	2022	https://www.survation.com/new-poll-public-strongly-backing-public-ownership-of-energy-and-key-utilities/
48	Change.org petition for renationalisation of water	2022	https://www.change.org/p/renationalise-the-water-industry?utm_source=share_petition&utm_medium=custom_url&recruited_by_id=def16140-297d-11e5-9a1d-d9709b34de83
49	We Own It	2013-present	https://weownit.org.uk/about-us

50	Surf 'n' Turf - Orkney community hydrogen project	2021	https://www.surfnturf.org.uk/
51	Net Zero Futurism - Tees Valley public art project	Forthcoming	https://www.tees.ac.uk/sections/news/pressreleases_story.cfm?story_id=7517&this_issue_title=March%202021&this_issue=334
52	Practice-focused study on the use of hydrogen for home heating and cooking	2017	https://www.sciencedirect.com/science/article/pii/S0360319919345252

9.3 Interview topic guide

Tell us about yourself and your role in the TCR project.

Now we'd like to explore your expectations and prior experience of public engagement around wastewater management and hydrogen.

- How does the public engage with this issue?
- What are the main ways that you know about public views?
- What are their main concerns?

We'd now like to explore your views on the implications of this for the Triple Carbon Reduction project and the new technologies being installed.

- With respect to these public engagements - does anything surprise you here or is anything missing?
- Do you recognise the public concerns and principles identified in the mapping and citizens' fora?
- To what extent are the public concerns and principles identified currently being addressed in the TCR project and MABR technology demonstrator specifically?
- What might need to be done to ensure that that are properly responded to?

Finally, we'd like to get your reflections on the broader implications from the findings of our citizen engagement work.

- Would you do anything differently in future projects?
- Does this suggest we need to do anything differently in terms of how customers and communities are engaged in general?
- Can you foresee any longer-term challenges or problems which may emerge with these kinds of approaches?