D3.4 Public engagement through Living Labs

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DATE: JANUARY 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Technical References

Project Acronym	NextGen
Project Title	Towards a next generation of water systems and services for the circular economy
Project Coordinator	KWR
Project Duration	01/07/2018 – 30/11/2022

Deliverable No.	D3.4 Public engagement through Living Labs
Dissemination level [1]	PU*
Work Package	WP3
Task	3.2, 3.3
Lead beneficiary	UNEXE
Contributing beneficiary(ies)	IVL, ESCI, ICCS, NTUA
Due date of deliverable	30-11-2022 (M53)
Actual submission date	29-11-2022 (M53); revised 10-01-2023

[1] PU* = Public, but temporary embargo (restricted for members of the consortium, including the Commission Services) until published (parts) in open access paper form.

Document history

V	Date	Beneficiary	Author
1	11/12/2020	UNEXE	Kate Baker (outline)
2	17/11/2022	UNEXE, IVL	Kate Baker, Staffan Filipsson
3	29/11/2022	UNEXE	Kate Baker (final, after QR by Jos Frijns, KWR)
4	10/01/2023	UNEXE, IVL	Kate Baker, Staffan Filipsson

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Updates of previous version

Reviewer comment: It is also noteworthy to mention that the focus of the report was on citizen engagement, not much on technology, which per se is rather irrelevant in this aspect. E.g. the task description mentioned a number of technologies, which seem irrelevant for the result. However, the deliverable does not specify the particular activities and results of living labs within each demo. This should be further elaborated

We thank the reviewer for this comment. Indeed the focus of this task is not on technology but on citizen engagement.
We have now added a table in Chapter 2 which outlines the activities and results of living labs within each demo. It highlights how the AR and SG technology was fundamental to ensuring that the outreach activities were cutting edge and innovative

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Summary

Since the industrial revolution, water has been viewed in a linear way. Water is withdrawn from rivers, reservoirs and groundwater aquifers; used by agriculture, industry, society and the environment; and then returned to the water basin directly or via a treatment facility. This current system is often inefficient as water is lost, polluted and wasted. In recent years, society and business have started to move away from this linear model of 'make, use and dispose' and instead develop a system that is closed looped to increase efficiency and optimize reuse. For water re-use to be successful, society need to understand and have confidence in the technology and feel comfortable with the process. Creating a circular economy with water presents opportunity and challenges whereby government, industry and the public need to work together.

Even when there is a shared goal and understanding between parties, successful collaboration and engagement takes time. Involving citizens by engaging them with the technology development, increase collective learning and shape solutions and behavioural change was a central part of the NextGen project. Throughout the NextGen project, citizens have participated and collaborated by engaging at the (large) demo scale, through Augmented Reality (AR) and Serious Gaming (SG) around specific innovations and sites, involving both on-side and public events, exploiting the concept of Living Labs.

Based on the concept of living labs, citizen engagement was organised at the 10 demonstration case studies in the NextGen project with the aim of involving the citizens by offering an engagement environment around the innovations demonstrated. Some key recommendations for a successful public outreach activity from the NextGen project include:

- The variety of citizens that join the events are important for creating a broad discussion and a high level of engagement; young-old, woman-men, entrepreneurs, social workers etc.
- Include a variety of activities, for example on-site visits and tours will create interest of participants to get to know the technology
- Various options for citizens to interchange opinions and knowledge on personal level will stimulate the curiosity and creativity.

In the NextGen project, we contributed further to the discourse of citizen engagement tools with the development of a novel, inclusive, accessible, and portable citizen engagement tool that utilizes Augmented Reality (AR) technology. The CirculAR study demonstrated significant improvement in context-specific citizen engagement. Specifically, both the municipality citizens and a global sample of participants demonstrated high motivation towards CE and an enhanced self-efficacy in the same topic. Upon exposure to the AR engagement tool, citizens who did not have higher education felt more confident towards CE and are more likely to recommend the experience to their friends. Such an outcome points towards the ability of AR-driven engagement to make information that affects public matters accessible to everyone.

Another public engagement tool that was used in the NextGen project was serious games (SG), which are "games used for purposes other than mere entertainment". In the NextGen project the aim was to introduce a serious game that raises public awareness of circular

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economy for water, to increase understanding of the interactions between different components of the urban water cycle in circular economy, and to facilitate the dialogues between different stakeholders to reach consensus in decision making. The game modelled a virtual urban catchment named "Toy Town" built to be representative of many common medium-sized towns. The project found that playing the NextGen SG led to an average improvement of 26% in the number of correct answers (where some of the given questions required understanding fairly technical concepts linked to the urban water cycle). The game was also used as a debate facilitation tool, for example the NextGen serious game was used to support and illustrate points made by experts during a debate involving a panel of experts discussing at a "Net Zero roundtable" webinar; and it was showcased at Aquatech Innovation Forum in Amsterdam (November 2021) where several companies expressed an interest in using the Serious Game to showcase their newest products (e.g. a novel type of greywater reuse filter for example) in a virtual catchment. This underlines the potential for a novel form of Serious Game based engagement akin to interactive marketing. The NextGen SG has contributed to public understanding of the circular economy at a time where the water industry struggles to engage the public to the problems and reality of water in the context of climate change, growing resources scarcity, and environmental decline.

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1. Introduction

1.1 What is Public Engagement

There are a range of different definitions of public engagement. The National Co-ordinating Centre for Public Engagement define it as:

"Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit."

Collaboration and engagement takes time to build. These partnership do not happen overnight and the level of interaction is on a spectrum, from 'communication' activities, defined as a one way process of transferring information, through to 'engagement' activities, a two way process where outputs are co-created (NCCPE, 2019; Figure 1). Where the interaction sits on this spectrum is dependent on the aim and level of investment (both time and money).

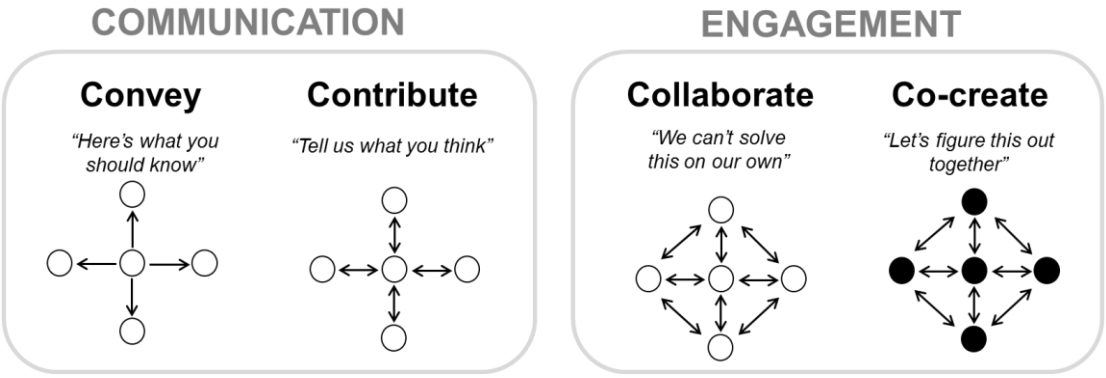

Figure 1. Spectrum from communication to engagement. Diagram adapted from American Association for the Advancement of Science (AAAS) Centre for Scientific Collaboration and Community Engagement (AAA, 2019).

1.2 Public Engagement & Circular Economy

Since the industrial revolution, water has been viewed in a linear way. Water is withdrawn from rivers, reservoirs and groundwater aquifers; used by agriculture, industry, society and the environment; and then returned to the water basin directly or via a treatment facility (Tahir et al, 2018). This current system is often inefficient as water is lost, polluted and wasted. In recent years, society and business have started to move away from this linear model of 'make, use and dispose' and instead develop a system that is closed looped to increase efficiency and optimize reuse (Abu-Ghunmi et al, 2016; Ness, 2008). The overarching idea is to breakdown the connection between growth and finite resource consumption.

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Water is considered as essential to the circular economy due to its importance for human life but also because of the energy and material it contains (Veolia, 2014).

The Ellen MacArthur Foundation have defined the three dimensions of water in terms of the circular economy to include water as a service, a material (or carrier), and as a source of energy (Tahir et al, 2018; See Figure 1 and table 1). Water is used as a service providing sanitation in homes and businesses, cooling and heating buildings, and in the production processes for businesses. For water as a service to become circular it is essential that society is engaged to become water wise communities who realise their role is instrumental (IWA, 2016; Abu-Ghunmi etr al, 2016). Water is used as a materials pathway or carrier of chemicals and particles which can be a potential resource or pollution. Re-use is a challenge as industry and agriculture are reliant on competitive prices, efficient delivery and products of high quality. At present resource recovery is on a small scale and it's difficult to control quality (IWA, 2016).

For water re-use to be successful, society need to understand and have confidence in the technology and feel comfortable with the process (Harris-Lovett et al, 2015). Energy use is intertwined with water use. On average 10-15 % of national power produced is for water networks and treatment plants, and most domestic energy is used to heat water either for heating or for domestic use. In a society that has a circular water sector individuals need to reduce their carbon based energy consumption by improving the quality of housing to reduce the need for heating, and to be more water efficient in the home.

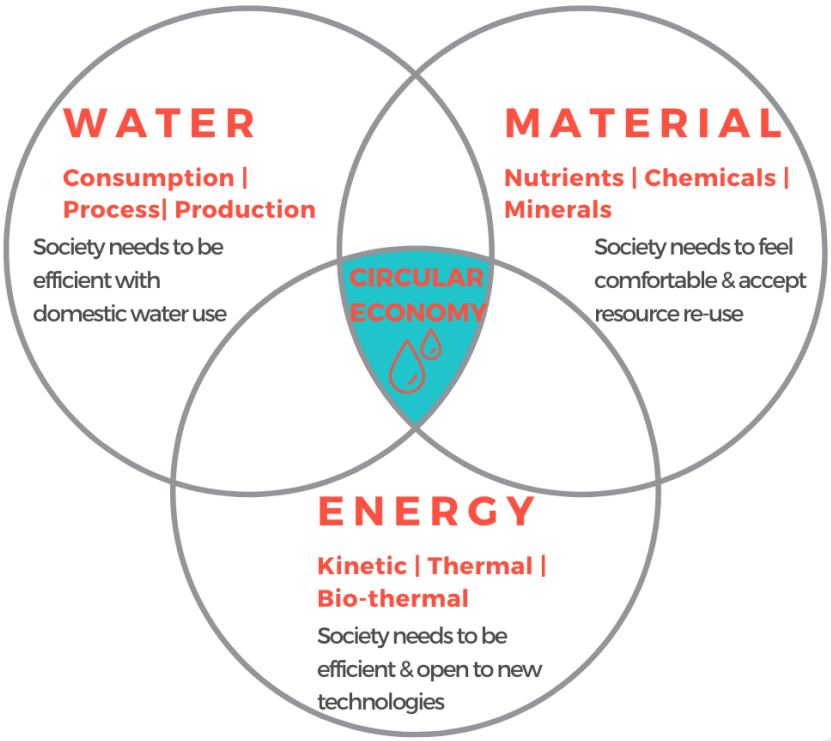

Figure 2 Diagram of the three dimensions of water and the circular economy including water (as a service), energy and material. Diagram is adapted from Water and Circular Economy: A White Paper

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Table 1 Examples of the technologies and methods required for the three dimensions of water (water as a service), energy and material, and the challenges if the public are not engaged in the process

Dimensions of Water	Examples of circular technologies & methods	If public are not engaged in the circular water economy?
Water as a service	Reuse at multiple scales supported by nature-based storage, optimal management strategies, advanced treatment technologies, engineered ecosystems and compact/mobile/scalable systems	- Society will not understand the importance of conserving water - Uptake of new technology in homes will be low - Technology will not fit with the needs of people & therefore not be used - Society will not want to invest or trail new technologies
Water & Energy	Combined water energy management, treatment plants as energy factories, water-enabled heat transfer, storage and recovery for allied industries and commercial sectors	- Society will not reduce energy use & create insulated homes - Society to feel comfortable with new technologies such as direct dry cooling in the power sector
Water & Materials	Nutrient mining and reuse, manufacturing new products from waste streams, regenerating and repurposing membranes to reduce water reuse costs, and producing activated carbon from sludge to minimise costs of micro-pollutant removal	- Society will not consume food from farmers that use nutrient mining - Society will not buy products that are manufactured from waste - Industry will not understand public perception & uncertainties

Creating a circular economy with water presents opportunity and challenges whereby government, industry and the public need to work together. The demand for water in manufacturing is expected to increase by 400% by 2050 (from the 2000 baseline) (Tahir et al, 2018), and if we continue with business as usual the global demand for freshwater will exceed resources by 40% by 2030 (Water Resources Group, 2019). In order to address the predicted increased demands of water and cope with the changing climate, everyone needs to be involved. The approach will only work and be effective if it is co-created with the public so they are comfortable with the transformations and champion them in their homes. Harding (2006) suggests that it is not helpful to see science as separate from local knowledges, cultures and politics, and decision making. Instead, research should take a more holistic approach and from the beginning the research should be co-produced with society, industry and government. Lessons learnt from successful transitions from the linear economy to a circular one show that there is active involvement from all members of society and there is strong levels of collaboration (Ghisellini et al, 2016).

To understand the importance of public participation in relation to the circular economy, it is important to learn from policies and projects that have not succeeded. One example is 'The Green Deal' which was launched in the UK in 2013 and offered loans to the public to improve the energy efficiency of homes (Peake et al 2018; Rosenow and Eyre, 2016). The UK

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government said it had the potential to improve the energy efficiency of 14 million homes i.e. nearly 2 million homes a year (DECC, 2011). However, the importance of engagement with the public was not properly understood by the ministers and because of this only 0.05% of households took out the loan and it was scrapped in 2015 (Peake et al 2018; DECC, 2016). Furthermore, it saved negligible amounts of CO^2 and cost the government £240 million (National Audit Office, 2016). The scheme was criticised for failing to understand the public's motivations the scheme was so complex that only 50% of those who started the application process completed it (Peake et al 2018). The scheme's failure highlights the importance of understanding public attitudes and to ensure there is alignment between goals.
Even when there is a shared goal and understanding between parties, successful collaboration and engagement takes time.

1.3 NextGen Living Labs

Involving citizens by engaging them with the technology development, increase collective learning and shape solutions and behavioural change was a central part of the NextGen project. Throughout the project, citizens have participated and collaborated by engaging at the (large) demo scale, through Augmented Reality (AR) and Serious Gaming (SG) around specific innovations and sites, involving both on-side and public events, exploiting the concept of Living Labs.

In the next three sections of this report, we will feedback on using the Living Labs concept in NextGen as a dedicated physical engagement activities for citizens. This includes technology festivals and tasting events for reclaimed potable water at selected demo cases (Chapter 2). Along with using Augmented Reality (AR; chapter 3) & Serious Gaming (SG; chapter 4) in public engagement activities and the final chapter are for the conclusions.

Chapter 3 on AR is based on the published NextGen paper:

- Katika, T., Bolierakis, S.N., Tousert, N., Karaseitanidis, I. and Amditis, S.A. (2021) Building a mobile AR engagement tool: evaluation of citizens attitude towards a sustainable future. 18th EuroXR International Conference
- Katika T., Karaseitanidis I., Tsiakou D., Makropoulos C., and Amditis A., (2022) Augmented Reality (AR) Supporting Citizen Engagement in Circular Economy, Circular Economy and Sustainability 2, 1077–1104

Chapter 4 on SG is based on the submitted NextGen papers:

- Khoury, M., Evans, B., Chen, O., Chen, A.S., Vamvakeridou-Lyroudia, L., Savic, D.A., Djordjevic, S., Bouziotas, D., Makropoulos C. and Mustafee, C., NEXTGEN: a Serious Game showcasing circular economy in the urban water cycle. Journal of Cleaner Production
- Evans, B., Khoury, M., Vamvakeridou-Lyroudia, L., Chen, O., Mustafee, N., Chen, A.S., Djordjevic, S. and Savic, D., A new modelling testbed to Demonstrate the Circular Economy in the Context of Water, Journal of Cleaner Production

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2. NextGen Living Labs

2.1 Introduction

Involving and engaging citizens and other stakeholders to give feedback on technology development, increase collective learning and shape solutions and behavioural change was a central part of the NextGen project. This was conducted stakeholder engagement in communities of practice (CoP) (see D3.5) and citizen engagement in Living Labs (this report).

Public engagement and outreach activities have been established for the 10 demonstration case studies in the NextGen project (Figure 3), with the aim of involving the citizens and end-users by offering an engagement environment around the innovations demonstrated. The citizens can also be stakeholders, e.g. farmers that are strongly dependent of the water resources for their business.

The pandemic has hit activities with a slightly less number of activities carried out and often with a smaller number of participants than planned before the pandemic. However, the use of the Living Labs concept, based on dedicated physical engagement activities for citizens has proven to be efficient when used.

Figure 3 Map showing the ten demonstration sites in the NextGen project

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2.2 Public outreach activities

The public engagement strategy for the case study sites was based on diagnosis and support actions in combination with the use of communication resources and support tools.

For the development of a public engagement and outreach plan, the activity of existing Living Labs connected to each NextGen demo case needed to be understood. The level of activity, the scope for the case study and the local stakeholder structure at a citizen´s level was important for identifying the optimal engagement opportunity. The table below provides an overview of the public engagement activities that took place including using innovative technology such as AR and SG.

Table 2 Overview of the public engagement activities that took place at each demo site

Demo site	Activity	Main result
Spernal & Filton Airfield	Talks and seminars	Enabled people to understand what is circular economy with water through a local real life example
Gotland	World Cafés, panel discussions, seminars, talks, reportages and interviews in national and local newspapers, beer tasting, plus AR	Direct interaction and discussion with citizens; information given, advice and local knowledge taken- Increased awareness and knowledge in the community of the research project and has created a wide and deep engagement in circular solutions
Westland Region	Panel discussions, seminars, talks	Creation of a good momentum for linear to circular thinking for scarcity of natural resources, less pollution of the environment with pesticides
La Trappe	Visiting center, beer tasting and visits to treatment facilities, talks	Direct interaction and discussion with citizens ensured that public concerns and aspirations was consistently understood and considered.
Altenrhein	Talks and seminars	The public learnt about energy-efficient sludge management technologies
Costa Brava Region	Panel discussions, seminars, talks. Plus a serious game that focused on a Mediterranean touristic setting with aquifer management and desalinisation	Good experience of using the engagement model Consensus where local citizens was not just involved in the vision of the future, but they were also given the political role of being an overseer of the new policy and its implementation. The concept has become totally accepted for the uses applied. The serious game allowed participants to understand how circular economy for water works by observing interactions between different components in the urban water cycle and energy and their effects on flows of water and energy and material recovery.
Timisoara	Panel discussions, seminars, talks	Developed knowledge on how to arrive to a united critical mass for circular economy community

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Athens	Panel discussions, seminars, talks, visits to treatment facility. Plus, a serious game and AR that focused on sewer mining	Public opinion is becoming more positive regarding water reuse. The serious game allowed the public to visualise how circular economy for water works as they could adjust the different factors. The AR enabled the public to understand complex phenomena which would have been tricky using

To support the demo cases in identifying the right engagement opportunities, the following diagnosis and support actions have been done:

- Front runners to inspire: Gotland (Figure 4), Costa Brava and La Trappe have been used as front runner demo cases which was able to set the example and inspire others. A short case study was prepared and shared with the other Living Labs. The Swedish case at Gotland offered insight into larger public actions, including World Café discussion techniques and focus groups. Costa Brava used a recognized engagement model called ConCensus and La Trappe used a Visitor Centre, beer tasting and visit to the purification/treatment facilities.
- Diagnosis questionnaire & in-project consultancy was also used: A questionnaire to help pinpoint engagement and outreach assets and context has been developed and used by most of the demo cases.
- The demo cases used this pint pointed engagement to establish the landscape and benefited from a follow up consultation call with IVL and ESCI which developed outreach events in more detail.
- ConCensus methodology: Costa Brava demo case used a process for municipal administrations to effectively engage citizens in policy development and implementation for sustainability using social networks, traditional media channels, and technical support for developing long-term policies.

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Figure 4 Discussions with one of the local groups for planning of public outreach activities within the Gotland case study

To support public engagement as well as to identify one event per demo case, a toolbox with outreach actions was developed:

- Project meeting session: this session profiled front runners, developed a further demo case and had an open Q&A or working session on engagement and outreach.
- Webinar to demo sites: Above session was made available to interested parties as a webinar, plus consultation and brainstorming on demand
- Communication tools: IVL and ESCI remained on hand for development of communication tools specific to the local context and language, including visual identity guidelines and presentation materials. A back-bone of materials is available, such as project presentation, NextGen logo and visuals, circular economy icons, infographics about water–energy–materials nexus, project videos etc.

Based on the experiences an Outreach Inspiration guide was developed in the format of a presentation that was given to all case study leaders. The Inspiration guide included information and description of tools useful to create successful outreach activities. Some of those are listed here:

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There are several good and free tools for outreach activities. Some of these were used in the project:

- IAP2 Spectrum of public participation: A brief but rich infographic with descriptions of engagement levels and examples of activities that correspond to that. Great help in early-stage planning.
- Consensus method for engagement to reach acceptance for the used techniques in the general public. With this method, the local citizens are not just involved in the vision of the future, but they are also given the political role of being an overseer of the new policy and its implementation.
- Hyper Island Toolbox includes guidelines for the concepts that includes learning by doing including learning new skills, knowledge, behaviours and attitudes through active reflection on direct experienced. It centres around a four-step process: first, a concrete experience; second, reflection on that experience; third, drawing conclusions and insights; and finally, applying new learning.

The main lessons learned from the three front runners (Costa Brava, La Trappe Brewery and Storsudret case study) include the following:

- The municipality connection is important as it oversees the process, to overcome conflict or cultural differences. The used method must be adapted for each case, but it can be done in a short time
- By using the space to invite local entrepreneurs the case can get an inflow of new ideas while acting as an innovation hub for the community. By receiving national and international attention through social medias, newspapers etc, it is possible to reach more visitors which gains more inspiration and good ideas.
- A case study is a way to get in contact with different stakeholders, e.g, by the use of other project partners. When the neighboring citizens and landowners are contacted, it is easier to send local project partners to discuss the benefits and impacts of the techniques used in the case study, than if it would have come from authorities or politicians.
- There are situations where the public outreach could impact the policy work. By using contacts of a board, discussions could happen and make it easier to introduce new technologies and systems. The public outreach and publicity of the area are probably helpful in making that happen.
- Since the case studies are research projects, there needs to be a balance between the focus on what creates local impact compared to what is most interesting from a researcher`s perspective.
- The use of smaller, local group fills an important role in establishing such a balance which includes legitimacy, communication, and acceptance among the broader public stakeholder group.
- Activities like public consultations, technical descriptions, tasting or smelling events can be used to raise awareness and knowledge in the community of the research project and corresponding techniques. Through this method, the citizens can be

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positive from the start-up of a project, even though the research project is complex, and a lot of changes have had to be made when the developed technology meets reality at the case study.

- When receiving a lot of positive publicity in social medias, newspapers etc, the public outreach to the local community should still be prioritized to ensure the public engagement, and to minimize the risk for misunderstandings from what could be read in simplified information in the medias.

2.3 Public outreach results

Public outreach survey results

To extract some more general findings from the public outreach activities, a survey has been answered by the NextGen representatives. The questions of the survey is enclosed as Annex 1. Some of the findings could be summarised as follows:

- The NextGen representatives answered that the aim of the information campaigns was to provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.
- More than half of the respondents answered that the aim of the involvement activities was to work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.
- Only one quarter answered that the purpose of the empower activities was to place final decision making in the hands of the public
- For public engagement almost all respondents have been using talk and panel discussions, more than half have been using tours and walking talks and TV and radio interviews as well as reportages in newspapers. Less than half of the respondents have been using interactions with schools.
- The audience that has been the target for the public outreach activities has to high extent been young people (18-30 years), city communities and communities with water related issues. Only a quarter of the respondents have had low-socioeconomic communities as a target group.

Respondents to the questionary have shared their recommendations for a successful public outreach activity:

- Just to arrange the events brings a lot to the people, they see that something is happening and wants to be involved.
- Inform and involve the public with all information needs and share ideas together to make them part of the decision.
- To make the event interesting, share the story behind the project
- The variety of citizens that join the events are important for creating a broad discussion and a high level of engagement; young-old, woman-men, entrepreneurs-social workers etc.
- Various activities like on-site visits and tours will create interest of participants to get to know the technology

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- Various options for participants to interchange opinions and knowledge on personal level will stimulate the curiosity and creativity.
- Good mix of theoretical presentations, round-table discussions and active elements is also stimulating the curiosity and knowledge building,
- To add a coffee break on the agenda will stimulate the number of participants.
- A novelty of the subject will also higher the interest for the event e.g. circular water

The respondents have also shared what has been challenging and some fears:

- During peak moments of pandemic there are no events
- To reach out to the older people during the pandemic are not easy due to lack of experiences with web-based meetings and the internet
- Difficult to engage public remotely through online meetings.
- As far as possible some respondents kept the events as face-to-face events as they made the experience that those meeting stimulate the motivation for citizens to exchange and open discussion much more.
- Online events are kept small with maximum 10 persons to maintain interest and engagement of the citizens.
- Critical topic how to arrive to a critical mass for circular economy community, united, in Timisoara.
- Fear of losing the connection to the public after the end of the project.
- The number of outreach activities has been limited during the pandemic but active before (2019) and after (2022)

Public outreach results from demo cases

Covid-19 hampered the possibilities for public outreach and visits to the NextGen sites. Nevertheless, the targeted public outreach activities at the demo cases reached about 500 citizens. The total number of visitors to the demo cases, before and after the pandemic, was well above 150 000 (the by far largest group being visitors to the La Trappe brewery that were introduced to circular solutions for water management). The experiences from those events was gathered from interviews with people responsible for the three front runner demo sites.

Every case has had its own successes and difficulties, and this is reflected in their descriptions. They all act as puzzle pieces and combined they can create a comprehensive picture that can provide some insights to anyone embarking on this journey.
Below some of the main conclusions are listed

- The public opinion is becoming more and more positive regarding water reuse, especially for irrigation purposes, fire protection and cleaning needs (Athens)
- We are not aware of statistics related to public opinion regarding water reuse in Athens today, unless this is for ornamental irrigation purposes where the public is receptive. We still believe, however, that psychological concerns remain due to a lack of information and inadequate information from potential users and the general public about the benefits of reuse and its potential to be exploited while preventing potential impacts. (Athens)
- Positive! We get a lot of positive feedback. There was already a lot publicity. And the Abbey won two prices in the Netherlands: Waterinnovation public prize and Circulair award waterboards (La Trappe)

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- The public opinion about nutrient recovery from wastewater is more positive as the agricultural application of sewage sludge is seen as high environmental risk. Using secondary fertilizers instead of sewage sludge is pushed by policy decision makers. (Braunschweig)
- The concept has become totally accepted for the uses applied (Costa Brava)
- The outreach activities as created a good momentum: from linear to circular thinking for scarcity of natural resources (e.g. P), less pollution of the environment with pesticides or PPP (plant protection products) (Westland)
- The many outreach activities in smaller and larger groups with different kinds of activities has created a wide and deep engagement in circular solutions. (Gotland)
- The sharing of the possibilities for the use of circular water management has created a high expectation among the citizens that the solutions will solve the problems with water shortage. This is good but the patience for waiting for the implementation is a little bit hard to handle. (Gotland).
- The use of some smaller, local groups of citizens to decide on next step for communication and outreach activities has been very successful. The local groups have good knowledge on which kind of communication that is necessary. This is a success factor for the outreach activities. (Gotland)

Figure 5 A so called "Coffee-dialogue" within the Gotland case study

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3. Public Engagement using Augmented Reality

3.1 Overview of Augmented Reality (AR)

New technologies and digital transformation[1] play an essential role in the process of citizen engagement and active participation, helping to reconfigure social relations and empower citizens, connect individuals, and facilitate knowledge exchange across ever-widening cities (Lekan and Rogers, 2020). Several engagement tools have thus been developed to engage people in their physical communities and enable participation (Olphert and Damodaran, 2007). Such initiatives have demonstrated that empowered and committed citizens transform from passive audiences to interactors, and immersive technologies and interactive media are well placed to generate such transformative experiences (Olphert and Damodaran, 2007)

Over the past decade, media, technologies, software, and cultural practices that change how we experience and interact with the environment have emerged. Various Information and Communication Technologies (ICT) tools, including websites, mobile solutions, social media, and platforms, have been proposed to improve the understanding of public matters and engage citizens in a great variety of topics (Olphert and Damodaran, 2007). Nevertheless, despite these efforts, such initiatives often fail since they are not inclusive (Olphert and Damodaran, 2007; Church, 2020) or they are designed for a specific target group (such as expert users and stakeholders), or they tackle appropriately either young or senior audiences. Their content is often limited, not engaging enough, and the engagement tools appear restrictive in terms of portability, usability, and accessibility; or they do not comply with a specifc framework or measures (Olphert and Damodaran, 2007).

Given the immersive nature of AR technology, the extended use of smartphones and the internet on the go, and the ability to couple them together with advanced location and camera settings, AR can be part of the citizen participatory process. AR has been reported to be achieving a turning point for large-scale adoption, while vast expansion is expected in the upcoming years (Giganti and Falcone, 2021). Having the ability to fundamentally alter how we interact with content, allowing end-users to feel closer to global issues, enabling a form of telepresence that evokes empathy levels as if one were present, AR's immersive nature helps the audience see details, believe in actions, and make connections between the events in the story and their own lives (Hall and Takahashi, 2017). Consequently, end-users are able to understand the positive impact of specific policies and changes (Brooks, 2003). Digital media are conveyed interactively, and physical experiences are recreated and enhanced with virtual content that enables participants to move beyond static images and gives them the freedom to choose any viewpoint and explore (Billinghurst and Duenser, 2012). Mobile AR offers the advantage of portability, mobility to the end-user, being accessible and available (Bilge et al, 2016).

[1] This chapter is based on Katika et al (2021) and Katika et al (2022).

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3.2 AR in NextGen

In the NextGen project, we contribute further to the discourse of citizen engagement tools by developing and exploiting a user-friendly mobile application to engage citizens in CE principles and empower a sense of action towards this change. Our motivation is to effectively apply an AR-based tool to motivate and educate citizens around the notions of a CE model. Using an AR application to foster engagement, we exposed a municipality's citizens to digital content related to a CE approach.

A web survey was utilized to recruit the citizens and collect the required data. We recruited 127 citizens of a municipality in Greece to investigate which attributes and factors affect their engagement and self-efficacy. Concurrently, we collected data from a second sample (of 101 participants) outside this municipality to investigate the validity of our questions and extract preliminary results to an extent more significant than that of one municipality. This chapter presents the results of this study and tries to draw some conclusions in the primary research hypothesis that the use of AR can prove a valuable tool for a mental shift towards CE approaches at a citizen level in an inclusive, accessible, and educative manner.

To develop the engagement tool, we take advantage of AR's capabilities, such as object manipulation, outdoor localization, vivid digital content, a virtual assistant, and other gamification and educational features, to positively affect citizen engagement related to CE and foster an inclusive and accessible learning environment. To address the limitations of previous efforts, we built an AR engagement tool aiming to improve social cohesion by considering factors such as age, disability, low income, low education, cultural or language differences, and geographical or social isolation (Olphert and Damodaran, 2007).

A guiding factor of our research is also to determine an inclusive environment for educating citizens in complex and novel concepts that they have not been exposed to in the past. The qualitative study of citizen engagement used across these contexts was guided by the following three questions:

1. Is citizen engagement through AR technology inclusive for participants with low CE literacy and confidence on this topic?
2. Is citizen engagement through AR technology inclusive for participants of all age groups, educational levels, and genders?
3. Is citizen engagement through AR technology inclusive for participants who have never been exposed to similar technologies?

Answers to these questions are important as more extensive knowledge concerning citizen engagement may assist in designing inclusive and adaptive engagement tools with educative character and ultimately impact the adoption of CE principles. We also sought to provide insights that would help transform citizens of all ages from passive audiences to interactors regardless of their tech-savviness and prior exposure to technology.

In our study, we exposed 127 citizens of a municipality and 101 citizens outside this municipality to the AR engagement tool and investigated at first the impact of specific attributes on user engagement and, ultimately, how specific factors affected them. The nine

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attributes that affect citizens' engagement, as described above, and three factors affecting these attributes (demographics, tech-savviness, and CE literacy, and confidence) were assessed.

The AR mobile application (CirculAR) used in this study aims to improve citizen awareness and engagement towards CE principles. The app was developed using ARCore and Mapbox for the Unity game engine. RestAPI was used for server communication. CirculAR is compatible with Android smartphones and requires Global Positioning System (GPS) tracking as it supports both marker and location-based applications to overlay the digital data. Marker-based experiences are enabled after scanning a unique QR code for the digital media. The digital data consist of single image and video reveal, image gallery and multiple videos, and static three-dimensional (3D) models. More information regarding the system design and architecture of the AR application can be found in D3.6 and Katika et al. (2021). Figure 1 shows four user interfaces (UIs) of the AR app (Figs. 2, 3, 4).

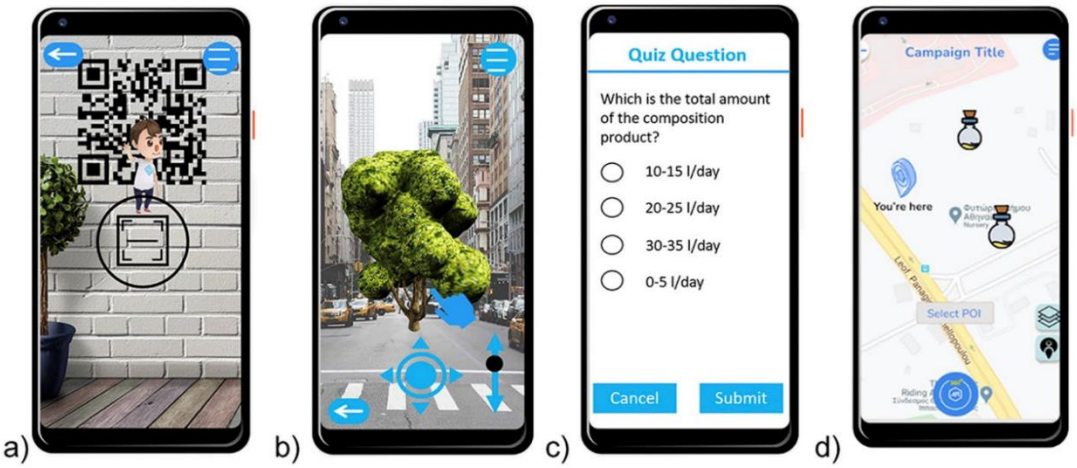

Figure 6 The user interface (UI) of the AR engaging tool with an open camera setting, showing the virtual assistant. The user is prompted to scan the QR code and view the digital media. b) A UI with an open camera setting, demonstrating CE-related content to the user. c) A UI with a quiz question that enables the user to test and validate their knowledge and understanding based on the virtual content they were previously exposed. d) The map with instructions navigating the user to the nearest AR experience

The user of CirculAR can utilize finger gestures for object manipulation (both rotation and positioning) on the touch-based display of their smartphone. A virtual assistant guides the user; gamification and learning elements ensure a captivating and fun yet educative and engaging experience (Harvey et al, 2015). The gamification elements include, among others, a scoring system, badges, and a leaderboard. Surveys and quiz questions embedded in the AR content challenge the user's understanding and provide feedback to enhance the process's learning effectiveness (Pashler et al, 2015).

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3.3 Methodology to gain feedback of AR in NextGen

Web Survey

For the period that the present study was conducted, in situ tests were not allowed due to the COVID-19 restrictions in the country. Therefore, virtual material and consultation, as well as online distribution were the sole means to expose participants to our AR engagement tool. To assess the information required regarding the attributes and factors affecting engagement, and to inform users about the AR engagement tool, we conducted an extended web survey

Recruitment of Citizens of a Municipality

The web survey was distributed to the citizens of Karditsa, Greece. Karditsa is an evolving peripheral town that belongs to the Municipality of Karditsa, Region of Thessaly — Central Greece. The survey was translated to the native language of the citizens (Greek) to avoid any language barriers or bias. The city of Karditsa was selected primarily due to the sectors, related objectives, and priority axes set in the public space strategic management plan [39]. The city aims to establish citizens' interaction and cooperation, promote the CE model, adopt and use ICT tools, reduce their energy footprint, adopt participatory processes in local decision-making and good practices, cultivate environmental consciousness, and integrate new green spaces and sustainable urban mobility. Therefore, the use of an AR application to improve Karditsa's citizens' engagement in CE is very relevant.

Recruitment of General Population

To support the model suggested to the municipality, we distributed our web survey through open channels to address citizens outside of the municipality, as part of a general population. The survey was distributed in English. To ensure that many interested stakeholders participated in our study, we recruited users via groups related to AR and CE on popular social platforms, such as Facebook and LinkedIn. Thus, this was a purposive sample with individuals chosen based on their interaction with the applications of interest to this study. The survey was posted online for 2 weeks (March 15–31, 2021). For the first 5 days, we collected feedback from 20 participants to optimize the survey and correct any technical issues. These responses were discarded by the analysis.

3.4 Results & Discussion of using AR in NextGen

Guided by the research questions, our study suggests that AR, acting as an engagement tool, can increase end-users' perceived interest and engagement in CE concepts. At the same time, it can help narrow the gap between public authorities and citizens, which has been found to impact CE adoption (Huijts et al, 2012). Results reported here support findings by other researchers who argued that AR could help change one's perspective or frame of reference, allowing them to understand complex phenomena such as novel economic models and concepts (Dede, 2009). They also support research findings investigating the positive impact of ICT technologies on citizen engagement (Stern, et al, 2009). Finally, addressing the significant limitations of current ICT engagement practices, our results indicate increased

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social inclusion and community cohesion, fast technology diffusion, and relevance (Olphert and Damodaran, 2007)

Answering the first research question, one of this study's main findings is that our AR tool had a more pronounced effect on the engagement of participants who have low CE literacy on the topic. It should be noted that general public exposure to CE principles is relatively low and new, providing confidence in our tool's relevance (European Commission, 2020). The ability to influence citizens with low CE literacy is of high importance as it demonstrates this tool's ability to foster citizen engagement in matters that have not reached a maturity of understanding which is a prerequisite for broad adoption. Such an approach adds to the list of ICT tools that may contribute to citizen engagement promoting transparency, participation, and collaboration between government and the citizenry (Olphert and Damodaran, 2007; Ferro et al, 2013).

A very promising finding, revealing the relevance of the second research question, is that the gender of the end-users is not affecting the engagement and interest in the topic we convey via AR. A thorough investigation on the motivational factors regarding the climate change mitigation performed by Brink and Wamsler (2019) demonstrated that females are more inspired by social matters while similar inspirations among both genders were observed for technical issues. Since the present research focused mainly on assessing technological attributes affecting engagement, similarities among the genders participating in the study were expected.

Upon exposure to the AR engagement tool, more than 75% of all users in this survey reported a high interest in CE, and more than 83% of all participants demonstrated high self-efficacy and perceived learning in the same topic. The results are higher for users who do not have higher education, agreeing with Billinghurst and Duenser (2012) who demonstrated that AR might enhance the traditional learning models as interactivity seems central to content engagement. Similarly, Makransky et al. (2016) reported that end-users with lower literacy levels on a specific topic benefit more from immersive techniques, especially when combined with traditional learning establishments. Thus, compared to other citizen engagement initiatives based on web-based platforms that demonstrated a significant increase in participation among citizens of higher education, the AR engagement tool is more inclusive towards the population with a lower education level (Stern et al, 2009).

To further support the AR engagement practice's inclusivity and answer the third research question, the citizens of the municipality demonstrated high self-efficacy regardless of any exposure to similar technology. Self-efficacy is a significant predictor of success associated with the ability to complete tasks, and was not affected by the low prior exposure to AR (Walker et al 2006). Nearly all participants reported that they were motivated and more confident to practice CE principles, while almost half of them had never been exposed to this technology. Overall, our findings suggest that an AR app is valuable to teach complex concepts and empower competencies that are hard to attain, especially for people who do not have access to higher education.

The citizens of Karditsa have articulated their need to follow a more circular approach by expressing their dissatisfaction due to the lack of effective waste management processes in

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the town center and with their access to information that affects public matters [39]. They have also disclosed their interest in increasing their environmental awareness and effective waste management while also expressing a positive stance to engagement through digital participation means (Krommyda et al, 2019). Our findings come to an agreement with the citizen's beliefs since more than three-fourths of all participants felt interested in the AR-specific CE-related context, which emphasized the need for change towards a more circular and sustainable future. The increased relevance and value of solutions proposed and later generated through the engagement process contribute to increased community cohesion (Olphert and Damodaran,2007).

Younger age groups in the municipality of Karditsa demonstrated high dissatisfaction in terms of environmental issues, which appear to be their preferences on prioritization of local resource distribution for meeting citizens' expectations (Krommyda et al, 2019). Such a factor could explain the significant increase in the engagement attributes for participants aged less than 45. The improved engagement was anticipated since a citizen engagement tool is more successful when it considers the participants' input and demonstrates an understanding of needs, problems, and priorities. At the same time, the success of an engagement process is dependent on the ability to acquire local knowledge and experience and consider the citizen's aspirations and values (Olphert and Damodaran, 2007). More research is required to define whether the increase in engagement among younger participants reflects their established dissatisfaction with current city initiatives or their highest exposure to mobile games.

Upon exposure to our AR engagement tool, the citizens of Karditsa agreed that an AR app would positively affect their understanding of CE principles and their ability to apply them in real life to a degree of 88%. Such a promise is fundamental to improve the use of the city resources since the citizens of Karditsa are not committed to an inclusive, sustainable, city- and citizen-specific, strategic public space management and regeneration plan, and their perception of it as a "common good" is relatively poor (Krommyda et al, 2019). There is a lack of open governance regarding public space management since the local community has no role in relevant decision-making processes.

3.5 Conclusions

In this work, we reported on the development of a novel, inclusive, accessible, and portable citizen engagement tool that utilizes AR technology. We assessed its ability to improve the attributes that the literature suggests to predict engagement, along with the factors that affect these attributes. The research was conducted both in a closed urban environment, the municipality of Karditsa, and globally. The study demonstrated significant improvement in context-specific citizen engagement. Specifically, both the municipality citizens and a global sample of participants demonstrated high motivation towards CE and an enhanced self-efficacy in the same topic. Overall, all attributes demonstrated a good correlation with end-user engagement. With regard to inclusivity requirements, the tool was found to be more useful to citizens with low CE literacy and confidence than to CE-proficient participants. The tool's usability also increased with the dissatisfaction with the current city initiatives towards a more sustainable environment. Upon exposure to the AR engagement tool, citizens who did not have higher education feel more confident towards CE and are more likely to recommend

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the experience to their friends. Such an outcome points towards the ability of AR-driven engagement to make information that affects public matters accessible to everyone.

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4. Public Engagement using Serious Gaming (SG)

4.1 Overview of Serious Gaming (SG) & the circular economy

Serious Games[2] were introduced by Abt (1970) as "games used for purposes other than mere entertainment". Now viewed as an integral part of Simulation based Education (SE), they have taken advantage in substantial advances in the field of computing to allow innovative methodologies to be applied for educational purposes, decisions support, and public policy making (Campos et al., 2020). Many serious games have been developed on the topic of sustainability (Katsaliaki and Mustafee, 2012; Stanitsas et al., 2019) as a broad concept related to people, the planet, and the economy.

Digital Serious gaming is being applied to topics such as the impact of renewable energy policies on carbon emissions (Climate Change Serious Game, 2020), the economic, environmental and security trade-offs and opportunities associated with different energy sources (Energyville, 2020), energy conservation for householders (Encon City - Stanitsas et al., 2019), and industrial training to support sustainable practice (Rai and Beck, 2017). Although serious games on Circular Economy do often mention and include water as an important of part of the problem, they do not, to our knowledge show in a cohesive way how combinations of components inside the urban water cycle such as households water reuse technologies can have for example a major impact on water stress, energy use, and water quality; how wastewater treatment technologies like biogas generation and sewer mining can lower carbon emissions; and how nature based solutions such as sustainable drainage systems can deliver cost-effective ways to limit discharges of untreated water into rivers. Similarly, although surveys looking at the use of Serious Gaming in the domain of water (Savic et al., 2016; Mittal et al., 2022) show a focus on the management of water systems (Savic et al., 2016; Games at the World Water Day, 2015; Tygron Engine, 2016), flood and drought prevention (Rijcken and Christopher, 2013; Khoury et al., 2018; Hill et al., 2014), training for emergency response (De Kleermaeker et al., 2012), and conflict resolution (Seibert and Vis, 2012), there is no systematic emphasis on a link to Circular Economy.

4.2 Using SG in NextGen to engage the public

In the NextGen project the aim was to introduce a serious game that aims to raise public awareness of circular economy for water, to increase understanding of the interactions between different components of the urban water cycle in circular economy, and to facilitate the dialogues between different stakeholders to reach consensus in decision making. The game models a virtual urban catchment named "Toy Town" built to be representative of many

[2] This chapter is based on Khoury et al (submitted) and Evans et al (submitted).

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common medium-sized towns. Water supply problems are considered by allowing scenarios to start with a lowered rainfall or a depleted reservoir, or by allowing the user to change these parameters. Rainfall has an immediate impact on the ability to satisfy water demand and to maintain river flow. Heavy rainfalls also have the capacity to overwhelm wastewater treatment and can lead to uncontrolled discharges of untreated water.

It was decided to focus on a virtual Toy town (Figure 7) due to its capability to interest a larger audience. This type of setting presents a broad array of problems and solutions that is representative of most urban water catchments and is the most successful at facilitating the engagement of diverse groups of citizens and other stakeholders in the innovation chain itself, through NextGen Communities of Practice and Living Labs. In addition, the NextGen Serious Game was developed specific for the conditions at the demo cases Athens and Costa Brava. A full description of the serious game is given in D3.7.

The aim of NextGen SG application was to build and demonstrate for selected NextGen demo cases, which drastically increase the learning value of the showcases by making visible 'hidden' or 'intangible' elements of the cycle and demonstrated solution to visitors.

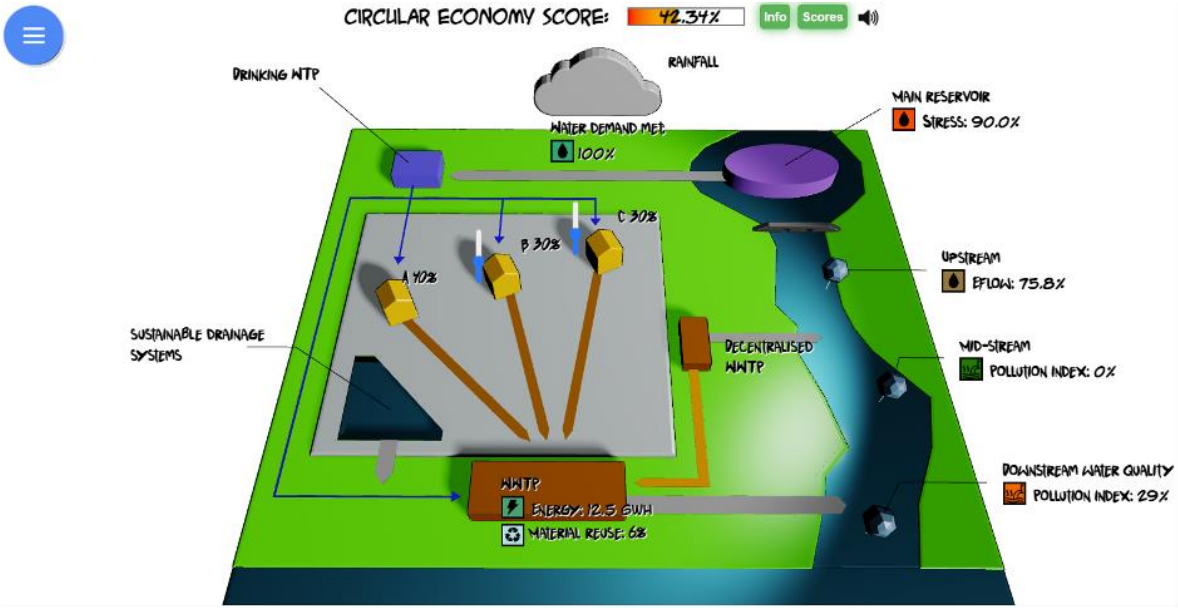

Figure 7 Screenshot of the ToyTown serious game showing selected urban water cycle components.

The Serious Game was used during three types of events: a supervised training session, a debate, and an e-sport tournament. The supervised teaching sessions involved a total of 44 participants. They were organized in early 2022 to gather information to see if playing the game changed the players' understanding of the Circular Economy for water problems by measuring differences in the way they answered the pre and a post-game questionnaires.

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4.3 Results & Discussion

The NextGen Serious Game was successfully used as a teaching tool in student classrooms. Participants who joined the supervised training sessions were on average 26% more likely to answer correctly technical questions despite the added complexity of the subject studied: Circular Economy in the context of the urban water cycle (where some of the given questions required understanding fairly technical concepts linked to the urban water cycle). As a debate facilitation tool, the NextGen serious game was used to support and illustrate points made by experts during a debate involving a panel of experts discussing at a “Net Zero roundtable” webinar organized by the Water Industry Process Automation & Control in November (2021). Firstly, potential energy savings for wastewater treatment plants were put into perspective compared to the households energy footprint (where the former represent about 2% of the water related energy footprint, while the latter represents around 98% of it), showing where the most savings could be achieved (see video available online at Water Industry Process Automation & Control, 2021; at minute 28).
Secondly, the potential benefit for recycling metals going into the inlet of the wastewater treatment plant for a town of 300,000 inhabitants was emphasized because of the benefits in terms of exergy. Due to the fact that some metals have a relatively high and always increasing thermodynamic rarity, with the passing of time, they can take a substantial and greater amount of energy to mine further into the earth crust, refine, and transport. The exergy saved by recycling them when expressed in terms of carbon emission can be considerable. When expressed in equivalent Carbon sequestered quantified by the numbers of hectares of temperate forests planted yearly (same video at minute 31), interesting conclusions emerge regarding the overall potential of metal recovery technologies for the reduction of carbon emissions in the future.

Finally, the NextGen Serious Game was used inside the Aquatech Innovation Forum in Amsterdam (November 2021) to create the world's first e-sport tournament event adapted to a professional water industry conference. Water experts from diverse backgrounds were first exposed to a generic demonstration of the virtual catchment and were then able to compete while contributing their own solutions to given problems of Circular Economy for water using the game interface, leading to one participant being elected as the winner at the end of the event. During the event, several companies even expressed an interest in using the Serious Game to showcase their newest products (e.g. a novel type of greywater reuse filter for example) in a virtual catchment. This underlines the potential for a novel form of Serious Game based engagement akin to interactive marketing. In any case, as a form of engagement, the NextGen Serious Game has brought a contribution to public understanding at a time where the water industry struggles to sensitize a wider audience to the problems and reality of water in the context of climate change, growing resources scarcity, and environmental decline.

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5. Conclusion

The NextGen team knew that for research projects to have real impact it is important for them to be co-created with communities and not just disseminated (or communicated) at the end of the project. It is not helpful to see science as separate from local knowledges, cultures and politics, and decision making. Instead, research should take a more holistic approach and from the beginning the research should be co-produced with society, industry and government. Even when there is a shared goal and understanding between parties, successful collaboration and engagement takes time.

The NextGen project was designed to ensure that public engagement was an integral part of the project, and not just an afterthought. The model of the Living Lab worked well as it links into the 'place, based' model which is a bottom-up approach used to meet the unique needs of people in one given location by working together to gain local knowledge and insight. By working collaboratively with the people who live and work locally, it aims to build a picture of the system from a local perspective. Although Covid impacted some of the public engagement activities many case studies were imaginative and were able to conduct activities online. The SG and AR helped built in resilience to the project as both these engagement tools can be conducted at home.

The beauty of the NextGen Living Labs was that demo cases were able to support and inspire one another. One example of this includes Swedish case at Gotland who offered insight into larger public actions, including World Café discussion techniques and focus groups. Whilst Costa Brava showcased a recognized engagement model called ConCensus and La Trappe used a Visitor Centre, beer tasting and visit to the purification/treatment facilities. Creating a space to share learnings and challenges is vitally important and a real success of the project.

The use of AR in the NextGen project was a novel, inclusive, and accessible citizen engagement tool. The NextGen project shows that for communities aiming to change their participatory approaches and governance schemes towards climatic and economic issues, AR engagement tool supports sustainable change and adoption. It provides an inclusive and democratic engagement platform appropriate for citizens of all ages, education levels, tech-savviness, and genders. The use of the NextGen Serious Game has brought a contribution to public understanding at a time where the water industry struggles to sensitize a wider audience to the problems and reality of water in the context of climate change, growing resources scarcity, and environmental decline.

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Annex I

Public Engagement: What lessons have we learnt?

In Deliverable 3.4 we need to report what lessons we have learned from our public outreach activities.

We want to capture learnings at different stages of the project. Please help us to do this by filling in this short form.

It will take 5 minutes to complete.

Many thanks!

* Required

Quick overview of your project

1. Gotland *

2. What is the purpose of the public engagement activities? *

Check all that apply.

- [ ] Inform: To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.
- [ ] Consult: To obtain public feedback on analysis, alternatives and/or decisions
- [ ] Involve: To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.
- [ ] Collaborate: To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.
- [ ] Empower: To place final decision-making in the hands of the public.

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3. What public engagement activities have you conducted? *

Check all that apply.

- [ ] Talks & panel discussions
- [ ] Tours & walking talks
- [ ] Social media
- [ ] Video
- [ ] Radio & TV interviews
- [ ] Working with schools
- [ ] Community radio
- [ ] Serious games
- [ ] Augmented reality
- [ ] Online festival
- [ ] Other: _____

4. What public engagement activities are you planning for the future? *

Check all that apply.

- [ ] Talks & panel discussions
- [ ] Tours & walking talks
- [ ] Video
- [ ] Radio & TV interviews
- [ ] Working with schools
- [ ] Community radio
- [ ] Serious games
- [ ] Augmented reality
- [ ] Online festival
- [ ] No plans

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5. Who is your audience? (please tick all the communities that you are trying to target) *

Check all that apply.

- [ ] Children (under 18 years)
- [ ] Young people (18 - 30 years)
- [ ] City communities
- [ ] Rural communities
- [ ] Low socio-economic communities
- [ ] High socio-economic communities
- [ ] Black and minority ethnic communities
- [ ] Communities with water issues (eg flooding &/or drought)
- [ ] Other: _____

Tell us about your public engagement activities

6. How many public engagement events have you conducted during the NextGen project? *

Mark only one oval.

- ( ) 0
- ( ) 1-3
- ( ) 4-7
- ( ) 8+

7. How many people have approximately been reached through your outreach activities? *

_____

8. Estimate the number of direct citizen involvements (e.g. through the living labs, SG, AR, questionnaires etc.) *

_____

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9. Estimate the number of engaged citizens in your pilot *

10. What made your events successful? Any top tips you'd like to share with your NextGen partners?

11. What was challenging? It's been a tough year to organise events, please share with us how you have coped with the various lockdowns, turning in person events online etc. And any other more general issues?

Your comments

Thank you for filling out this survey. Please use the space below for any further feedback

12. Any other comments

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