DEPARTMENT OF
APPLIED SOCIAL SCIENCES

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

TECHNOLOGY ASSESSMENT FOR SUSTAINABILITY IN WATER USE

OPERATIONALIZATION OF A RESPONSIBLE GOVERNANCE BASED IN RESPONSIBLE RESEARCH AND INNOVATION (ANTICIPATION AND INCLUSIVENESS)

ANDREIA SOFIA ALBINO ROMEIRO
Master in Landscape Architecture

DOCTORATE IN TECHNOLOGY ASSESSMENT

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Adviser: Doctor Andoni Ibarra Unzueta
Full Professor, University of the Basque Country

Co-advisors: Doctor António Brandão Moniz
Associate Professor, NOVA University Lisbon

Examination Committee:

Chair: Doctor Maria Paula Baptista da Costa Antunes
Full Professor, NOVA School of Science and Technology, NOVA University Lisbon

Rapporteurs: Doctor Manuel Johann Baumann
Integrated Researcher, Karlsruhe Institute of Technology, Germany
Doctor Pedro Ricardo Neto Póvoa
Independent Consultant, PWater Consulting, Lda., Portugal

Advisor: Doctor Andoni Ibarra Unzueta,
Full Professor, University of the Basque Country

Members: Doctor Lia Maldonado Teles de Vasconcelos
Associate Professor NOVA School of Science and Technology, NOVA University of Lisbon

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Technology Assessment for sustainability in water use

"Without uncertainty, it is doubtful whether intelligence itself would exist." (Knight, 1921)

ABSTRACT

The management of sustainability in water resources has underscored the critical importance of determining appropriate decision-making processes and establishing effective governance structures. Gaining comprehensive insights into the decision-making mechanisms and actors involved is pivotal for tackling present as well as prospective issues related to water efficiently. This research evaluates the interplay among water scarcity, responsible technologies for water use, and systems of governance for sustainability amid swift technological progress. Furthermore, it delves into the congruity of said endeavors with the Sustainable Development Goals (SDGs), other sustainability water frameworks and the social and political ecosystem. In this context, the active engagement and participation of societal actors, and not only stakeholders, assume a pivotal role as it significantly impacts the decision-making processes and molds the results of sustainability initiatives. An innovative approach to the concepts of responsibility and sustainability is predicated on the quality of the relationship between the network of societal actors as a key point. This work underscores the importance of establishing strong and comprehensive relationships to address the challenges concerning water management and promote the adoption of sustainable approaches, in co-creation, not only of knowledge but the epistemic subject in the process. This work sheds light on the interrelated domains of water management, sustainability, and regulation. A novel proposal is presented via a simulation exercise and use the socio-technical framework for the purpose of fostering responsible water use. The comprehension and use of responsible technology and innovation in the realm of water u management will be enhanced through the technique of operationalizing open anticipatory governance and executing a simulated experiment. By using a digital deliberation space and establishing a systematic approach towards technology assessment and sustainability, using the relational quality of the network of actors as the key element for co-production of knowledge, science and technology, the present study has produced and materialized an innovative framework.

Keywords: Anticipatory Governance, Relational Quality, Anticipation, Digital Space, Sustainability, Technology Assessment, Water Use.

RESUMO

Na sustentabilidade da gestão da água reveste-se de especial importância determinar processos de tomada de decisão adequados e estabelecer estruturas de governação eficazes. Obter uma visão abrangente sobre os mecanismos de tomada de decisão e os atores envolvidos é fundamental para abordar questões presentes e futuras relacionadas ao uso eficiente da água. Este trabalho procura conhecer a interação entre gestão de água, tecnologias responsáveis pelo uso da água e sistemas de governança para a sustentabilidade. Adicionalmente, pretende conhecer a relação com os Sustainable Development Goals (SDGs), outros programas de sustentabilidade, bem como com o ecossistema social e político. Neste contexto, o envolvimento e a participação ativa dos atores sociais, e não apenas de stakeholders, assume um papel fundamental, uma vez que, não só, impactam significativamente os processos de tomada de decisão, mas, também, moldam os resultados das iniciativas de sustentabilidade. Nesta nova aproximação ao conceito de responsabilidade e sustentabilidade encontra-se a qualidade da relação entre a rede de atores sociais como ponto-chave. Sublinha-se a importância de estabelecer uma qualidade relacional enriquecida e abrangente para enfrentar de forma mais estruturada os desafios relativos à gestão da água de forma eficiente e promover a adoção de abordagens sustentáveis. Com este trabalho, procura-se aprofundar os domínios inter-relacionados da gestão da água, sustentabilidade e regulamentação. É elaborada uma proposta de simulação, utilizando uma perspetiva sociotécnica com o objetivo de capacitar a co-constituição como sujeitos e a compreensão e utilização de tecnologia responsável e inovação no âmbito da gestão do uso da água utilizando operacionalização da governação antecipatória aberta. O presente estudo materializa seu carácter de inovação ao utilizar um espaço de deliberação digital e ao estabelecer uma abordagem sistemática para a avaliação da tecnologia e sustentabilidade, usando a qualidade relacional da rede de atores como elemento-chave para a coprodução de conhecimento, ciência e tecnologia e co-constituição do próprio sujeito no processo de deliberação

Palavras-chave: Governança Antecipatória, Qualidade Relacional, Antecipação, Espaço Digital, Sustentabilidade, Avaliação de Tecnologia, Uso da água.

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ACRONYMS

AG	Anticipatory Governance
AI	Artificial Intelligence
APA	Portuguese Environment Agency
API	Application Programming Interface
ANI	National Innovation Agency
B-On	Online Knowledge Library
CCO	Change for Children Organization
CRIF	Collective Research Impact Framework
DDI	Data-Driven Innovation
EC	European Commission
ESA	European Space Agency
ELSA	Ethical, Legal and Social Aspects
EU	European Union
HR	Human Resources
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
PRR	Program for Recovery and Resilience
OAG	Open Anticipatory Governance
OECD	Organization for Economic Co-operation and Development

RI	Research and Innovation
R&D	Research and Development
RMIT	Royal Melbourne Institute of Technology
RRI	Responsible Research and Innovation
SDGs	Sustainable Development Goals
SGS	Société Générale de Surveillance
S&T	Science and Technology
UICN	International Union for Conservation of Nature
UN	United Nations
UNEP	United Nations Environment Program
WCED	World Commission on Environmental Development
WCS	World Conservation Strategy
WFD	Water Framework Directive

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INTRODUCTION

The overwhelming pace of transformation in water systems is giving rise to novel and increasingly weighty hazards to the community. Simultaneously, the need for water is escalating, not only for household consumption, but also across various other sectors, such as agriculture, energy, and industry. Several decades of extensive global water research have unequivocally demonstrated these patterns while also highlighting crucial challenges and possibilities (UNESCO, 2023).

The global community has been confronted with a severe water shortage, exacerbated by increasing demographic pressures, expanding urban landscapes, rising industrial development, and the impacts of climate change (UNESCO, 2019). The dearth of water resources, coupled with inadequate regulation and contamination, presents a great obstacle to sustainable growth, and carries considerable ecological, communal, and fiscal consequences (IPCC, 2019). Consequently, there is a pressing requirement for the responsible and sustainable utilization of water resources. The scarcity of water is a significant challenge, commonly linked to the responsible use of water resources. According to statistics provided by the United Nations, approximately 2.2 billion individuals do not have access to uncontaminated drinking water. The urgency of sustainability is rapidly growing when it comes to the global management of water resources (United Nations, 2018). Around the globe, a significant 85% of wetlands have been depleted, and the existing ones are under jeopardy due to numerous human activities, such as land-use modifications, pollution, and overconsumption (Ramsar Convention, 2016). The increasing apprehension about the effects of climate change[1] on water

[1] Climate change refers to changes in global weather patterns, like alterations in temperature, precipitation, and other climatic indicators. It is primarily driven by human activities, such as the burning of fossil fuels, deforestation, and other land-use changes, which lead to increased

resources is a significant issue that is being observed by water management professionals globally. The changes in precipitation and evapotranspiration patterns, as well as the increased temperatures, result in insufficiency of water availability, degraded water purity, and upsurge in water requisites (IPCC, 2018).

Ever since the 1960's until the present, several frameworks and guidelines for sustainability and sustainable development have been drawn (Caradonna, 2014). Sachs's (2017) sustainable development concept provides a framework for sustainable peace, peace education, and human rights-based global justice. This innovation enables holistic education for creating socially inclusive and environmentally sustainable society with a focus on societal cultivation of a shared global ethic.

The effective implementation of sustainable water management techniques is imperative for mitigating the impacts of climate change and worldwide wetland degradation. Cutting-edge technologies are instrumental in the adoption of sustainable protocols, improving the accessibility and purity of water, and safeguarding wetlands (UNESCO, 2021).

Renewable energy sources (solar, wind, and hydropower) have the potential to reduce carbon emissions, facilitating a shift towards a low-carbon economy (IEA, 2020). In regions where water scarcity poses a significant challenge, the implementation of sophisticated water treatment solutions, including but not limited to reverse osmosis, nanofiltration, and membrane bioreactors, can play a crucial role in water conservation and reuse (United Nations Environment Programme, 2016). Emerging digital technologies, such as sensory systems, unmanned aerial vehicles and AI-powered solutions, have shown potential to offer continuous monitoring and strategic handling of water resources, paving the way for improved water management strategies with enhanced efficiency and efficacy (WEF, 2018).

Innovation in social and organizational spheres can largely contribute towards mitigating challenges related to sustainable water management. Innovative financing tools (green bonds; water funds) present channels for sourcing funds to drive water restoration and conservation efforts (OECD, 2020). Collaborative forms of governance, including engagement with stakeholders, initiatives which marry public and private sectors, and multi-stakeholder

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concentrations of greenhouse gases (GHGs) in the atmosphere. Consequences of global warming are the rise of sea levels, alterations in precipitation trends, melting of glaciers and marine ice, and increased occurrence of intense weather events like droughts, heatwaves, and floods. Their effects carry great significance for both human societies and natural ecosystems, extending to various aspects, such as food security, water resources, infrastructure, and human health, among other areas. In addition, the impacts of climate change are greater on marginalized communities, including disadvantaged economic groups, native inhabitants, and territories with limited resources (IPCC, 2021).

platforms have the potential to enhance the efficacy and inclusivity of decision-making processes concerning water management (UNESCO, 2021).

Additionally, the intersection of water and energy is a crucial topic of interest for policymakers, scholars, and experts involved in water management, sustainable practices, and technology assessment. Water and energy have a symbiotic relationship, where the procurement and delivery of energy necessitates substantial quantities of water, and the treatment and delivery of water entail substantial quantities of energy (UN, n.d.).[2]

The implementation of innovative strategies can prove integral in tackling the obstacles posed by climate change and establishing sustainable water management practices. Incorporating innovative technologies, tools and methodologies can effectively reduce greenhouse gas emissions, enhance energy efficiency, uphold water conservation, and safeguard natural ecosystems.

1.1 The problem

Although there are recognizable initiatives and methods being applied and implemented, it is still not clear what means to be responsible, and how participation of the public is being carried out to and inclusive governance.

The prevailing notion of sustainability frequently proves inadequate in incorporating the fundamental aspects of responsibility in the use of technology for water management. Although sustainability seeks to uphold the sustained viability of water resources in the long run, it lacks capacity to sufficiently acknowledge forward-looking governance practices and involve all stakeholders in the decision-making processes. This constraint impedes the progress and assessment of technologies that have the potential to efficiently tackle issues pertaining to conscientious water consumption.

The general objective of this work is to understand the phenomenon and concept of sustainability regarding technological implementation for responsible water management, in order to create a thorough and all-encompassing structure that surpasses the current approach of sustainability and incorporates the elements of anticipatory governance and inclusivity.

The research's specific objectives can be concisely articulated as:

[2] The following link contains more information on how the governments are dealing with the interactions between water, food and energy: https://www.unwater.org/water-facts/water-food-and-energy.

a) To establish a structured system for the responsible assessment of water technology, which involves anticipatory governance and participatory decision-making mechanisms.
b) To scrutinize the facet of responsibility in innovation trough Responsible Research Innovation (RRI) and inclusivity, and its befitting link with anticipation.
c) To examine the political and economic aspects related to advancements in water technology and their impact on the social structure.
d) To elucidate extant water use technologies, delineating their operative features, and the criteria employed for their quantification and appraisal.
e) To establish a systematic approach towards technology assessment using the relational quality of the network of actors are the key element for the co-production of knowledge, science, and technology.

1.2 Methodology overview

The methodology applied is exploratory, descriptive, and qualitative, using a simulation embodying a framework. This research adopts a multidisciplinary framework that integrates components derived from the domains of sustainability science, innovation studies, political economy, and water resource management. The investigation employs an integration of qualitative and quantitative research techniques to attain a comprehensive understanding of the intricate interdependencies among sustainability, accountable innovation, and water technology. Appendix A shows the work plan for this research, including general and specific goals, and deliverables.

It was employed a structured approach to steer my research, guaranteeing concentration on the objective and its questions defined previously throughout the entirety of the undertaking. The initial phase consisted of formulating an extensive research strategy, which constituted the basis for the research. This plan delineated the extent of the investigation and instituted the structure within which I carried out my research.

In order to enhance the focus of the study, I developed precise research goals. These objectives offered a lucid and succinct synopsis of the outcome I sought to attain through this study. Each objective was formulated with the intention of addressing a unique facet of the overarching research subject matter, thereby guaranteeing an ordered and methodical investigation.

Having established my research objectives, the following step was proceeding to devise research questions that were in keeping with each respective objective. These inquiries were meticulously formulated to steer my literary examination and data compilation endeavors, guaranteeing that I centered on pivotal facets pertinent to the study. Every research question presented a focused inquiry with the objective of enhancing my comprehension of the areas being examined.

In order to validate and strengthen the reliability of my research findings, I undertook a comprehensive examination of relevant scholarly literature. This entailed a methodical exploration of pertinent scholarly articles and studies, which furnished valuable perspectives and empirical substantiation to underpin my research inquiries. Through alluding to these preexisting works, I ensured the establishment of a strong scholarly discourse for my study, thereby constructing it upon a sturdy bedrock of preceding research.

The data gathering mechanism used for this study entails a wide range of sources, encompassing thorough literature evaluations, an assessment of pre-existing case studies, and technology appraisal techniques. The information gathered shall yield significant comprehension regarding the theoretical aspects of sustainability, the duty of responsible innovation, and the governmental and societal influences that impact the advancement and implementation of water technology.

The data shall undergo scrutiny through a thematic analysis methodology, aimed at discerning prominent themes and patterns that pertain to sustainability, responsible innovation, and water technology.

After a meticulous examination of the current literature and conducting empirical research, an all-encompassing methodology will be formulated. This conceptual framework is designed to provide guidance for the responsible assessment of water technology, while taking into consideration the key elements of forward-looking governance and comprehensive representation. The framework is intended to furnish pragmatic instruments and directives to assess the responsibility and sustainability of water technologies in an integrated fashion.

Through meticulous planning, articulation of clearly defined research objectives, and formulation of focused research questions predicated on a thorough examination of existing scholarly literature, my intention was to make a substantive and valuable contribution to the academic conversation. This method facilitated a systematic investigation of the research subject, enabling the derivation of profound insights and the provision of a significant contribution.

1.3 Limitations

It is imperative to take into consideration the constraints and boundaries of this investigation. The study might not comprehensively embody the variety of outlooks and customs in disparate regions or cultural circumstances, as it tries to touch multiple interfaces related to the main topic of water. In the further future research are presented some steps that should be followed in a larger timeframe of research, including detailing the scope, in terms of geography and specific water functions and technology. Nevertheless, the approach formulated in this investigation serves as an initial step, materialized in a simulation, and it might necessitate additional investment and a larger timeframe for implementation. The scoping on the topic of water, will need to be accomplished by doing a systematic literature review for the specific function and technology, in a specific geography and crossing with case abroad.

The primary objective of this research is to make a significant contribution to the progress of responsible assessment of water technology and impart valuable knowledge to policymakers, practitioners, and all societal actors.

1.4 Structure

In order to deliver to the proposed objectives, this study is divided in five main chapters.

1.4.1 Introduction

The present opening chapter delineates the primary research aims and hypotheses that undergird the thesis. It further aligns the goals and conjectures of the dissertation with the broader parameters of the academic domains with which they are implicated, aiming to provide a pertinent and/or novel contribution. This study's main objective is to chart the challenges related to the responsible use of water, with a specific emphasis on the insufficiency of water resources and the impact of climatic changes. In addition, the present study aims to establish a clearly defined overarching goal, hypothesis, and subordinate objectives that will serve as guidelines for the work.

This path should lead to the development of a Technology Assessment Framework based on anticipatory governance, where sustainability takes a responsibility part in the water use, in this case a simulation.

In order to accomplish the research goal and substantiate the hypothesis, five distinct objectives should be addressed. Each individual objective is aligned with one of the previously identified research challenges.

The general aim of this work is to put forward a comprehensive structure for the responsible and sustainable use of water, grounded in the principles of Responsible Research and Innovation (RRI). The suggested paradigm shall encompass the diverse aspects of water use, including social, economic, and environmental elements. It shall also involve a broad spectrum of societal actors, and not only stakeholders[3], such as policymakers, water consumers, researchers, and civil society organizations. The objective is to formulate a thorough and all-encompassing strategy for water governance that can make a valuable contribution towards attaining the water-related Sustainable Development Goals, moving from management to governance.

The fundamental conjecture of this investigation posits that the implementation of RRI-centered governance shall yield an upshot of enhanced responsible and sustainable use of water resources. The conjecture is predicated on the presupposition that RRI has the potential to offer a comprehensive and inclusive means of water governance, as it considers the interdependencies among social, economic, and environmental facets, and engages a diverse array of stakeholders in the process of decision-making. An RRI-centered approach to governance has the potential for effectively detecting and mitigating potential hazards and uncertainties that may arise from water consumption, while promoting an equitable and fair allocation of water resources and promoting technological and managerial innovations in the field of water management.

Our research will adopt a theoretical-empirical methodology. The theoretical aspect shall encompass a comprehensive evaluation of the pertinent literature pertaining to water governance, technologies used for water management, Frameworks, Responsible Research and

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[3] Societal Actors and Stakeholders represent different entities in the context of this work, in terms of their position and contribution to the process. In the context of this work:

- Stakeholder is who (person, entity, group, organizations) is involved in or affected by a course of action. They are a part of the innovation ecosystem, as persons or publics concerned and involved.
- Societal actor is the one directly or indirectly involved in the program or policy, owning their own values and demands. They are societal actors not necessarily 'representatives' of the innovation system, but more generally. Actors are any societal publics, whether they are engaged (within the innovation ecosystem) or external to it.

Innovation (RRI), and sustainability. The empirical aspect of the research will encompass conducting a simulation to define and present the envisioned framework.

1.4.2 Chapter 2 - Water: responsibility and sustainability

This chapter aims to make an in-depth presentation of the state of the art in responsible water use management.

It begins by presenting the problem of water scarcity. The current concepts of sustainability, linked to a responsible use of water, are presented, and critically analyzed. This part is followed by a characterization of what would be the key points to develop a new approach to the concept of sustainability. Then, what would be a good concept of sustainable use is characterized from the synthesis of current pre-RRI concepts.

By exploring the legal aspects of water use, we seek to unravel the intricate web of regulations, policies, and governance mechanisms that underpin the management of this vital resource. Our objective is to provide an in-depth analysis of the legal and regulatory framework, as well as policies in place, in order to elucidate the approaches adopted to effectively manage conflicting priorities, tackle issues of water scarcity, and promote sustainable water management practices. Furthermore, we will examine how international accords, regional undertakings and local statutes impact the legal framework of water governance.

1.4.3 Chapter 3 - The role of technology and sociotechnical systems

Following the previous methodology, this chapter centers on analyzing multiple existing technologies and their potential impact on the effective management of water resources in a sustainable manner. The chapter provides an overview of the respective technological approaches, exploring the strengths and limitations of each socio-technical system in the context of their compatibility with sustainable principles of water use.

In order to develop a thorough comprehension of the current situation at hand, it is imperative to explore the historical background of technology related to water management. An analysis of the historical progression of water-related technologies has the potential to offer valuable insights into the underlying factors that have catalyzed the transformational innovations responsible for enhancing the optimization, distribution, and conservation of water resources. The consideration of this historical context enables us to acknowledge the evolution from conventional approaches towards the advanced techniques that are presently use. The characterization centers upon the evolution of digital technologies that enable enhanced water management practices. Within the scope of this framework, we present an array of digital solutions and technologies applied in the field of water management. These encompass remote sensing, Internet of Things (IoT) devices, real-time data analysis, and predictive modeling.

This technology findings, while operating under a pre-RRI perspective on sustainability, can serve the purpose of establishing that the research undertaken in this thesis signifies a progress beyond the existing comprehension of effective water management for sustainability.

Our examination aims to clarify the potential of digital solutions for efficiently addressing the complex concerns related to water management.

1.4.4 Chapter 4 - Responsibility path through innovation: frameworks and new approaches

This chapter's objective is to provide a more comprehensive understanding of responsibility, particularly Responsibility-RRI (Responsible Research and Innovation). The present study aligns with the proposed conceptual framework and further enriches the understanding of sustainable water management by providing significant insights.

We aim to establish the premise of Responsibility-RRI by presenting the fundamental pillars of Responsible Research and Innovation, such as inclusiveness and anticipation, among other critical foundation points. By adopting a historical lens, this section can provide valuable insights into the evolution of RRI and facilitate vision of the shift from a pre-RRI notion of responsibility to the present RRI construct of responsibility.

The main objective of this section is to examine and evaluate the distinctions between pre-Responsible Research and Innovation (pre-RRI) responsibility and RRI-based responsibility. By means of a comprehensive appraisal process, the section endeavors to furnish substantiated rationale that clarifies the RRI paradigm of responsibility in comparison to its previous variant, regarding the issue of responsible management of water use for sustainability.

Through an analysis of the two perspectives, the section underscores the imperative of implementing a sturdy and all-encompassing initiative towards responsibility regarding water consumption. The framework of Responsibility Research and Innovation (RRI) provides a comprehensive perception of responsible conduct that considers diverse facets, including but not limited to societal participation, stakeholder participation, moral considerations, and the anticipation of potential outcomes. This broader approach acknowledges the multifaceted nature of water use governance while endeavors to tackle the related difficulties through a more comprehensive and forward-thinking framework.

By delving into the concept of responsibility-RRI along with its underlying pillars, this chapter establishes a solid foundation for forthcoming deliberations and evidence-based studies that will aid in formulating a sustainable framework for water use management. The research carried out in this thesis endeavors to enhance the comprehension and application of responsible technology and innovation in the realm of water use management, by incorporating judicious and forward-thinking aspects into the decision-making mechanisms.

1.4.5 Chapter 5 - Operationalization of technology assessment: an anticipatory governance model

In the contemporary and versatile global scenario, innovation bears significant importance in molding the evolution of civilizations. Nevertheless, gaining an in-depth comprehension of the complexities of innovation requires a nuanced and context-dependent understanding of its process. This chapter aims to explore the rationale behind conducting empirical experiments to obtain a comprehensive understanding of the collaborative process of knowledge generation and innovation. We shall delve into the obstacles and objections posed by this method, whilst offering an alternative paradigm of responsible technology and innovation founded upon open foresightful administration.

The first section of this chapter highlights the significance of conducting empirical research to comprehend the concept of innovation. The process of innovation is not necessarily sequential, but it is rather influenced by a variety of factors, making it a contingent matter. Through the application of a contextualized viewpoint, we can gain a comprehensive understanding of the intricate nature of innovation and the collaborative involvement of diverse societal actors in its development. By adopting this viewpoint, we can examine the co-creation of knowledge and improvement in connection with the expectations and requirements of society, particularly those dictated by established publics. We acknowledge the significance of bolstering listening protocols and augmenting the oversight of collaborative decision-making as key facilitators of co-creation.

In addition, a comprehensive analysis of the assessment of prospective and conscientious scientific and technical practices is conducted. Assessment tools have been commonly developed beforehand by analysts, instead of the innovators themselves. Our emphasis is on the methodology and framework presented by Zaratin et al. (2022), with particular attention drawn to their inherent rigidity and predefined nature (mission-oriented). The establishment of predefined evaluation dimensions, indicators and other factors in advance curtails the anticipatory governance's potential, impeding its capacity to factor in newly unearthed elements.

Expanding upon the deliberations, we will present our vision of a responsible approach to technological advancements and breakthroughs founded upon transparent foresightful governing practices, which we term as responsible technology and innovation. Our research aims to showcase a mechanism for fostering responsibility that focuses on enhancing the cognitive ability of the knowledge bearer. Considering the aforementioned circumstances, we recognize the notion of sustainable and responsible technology, in which sustainability is linked to meeting the requirements, anticipations, demands, and principles of diverse societal actors.

This doctoral thesis entails the hypothesis that the process of knowledge and innovation co-production is interconnected with the co-constitution of the subject individual engaged in this collaborative effort. In contrast to the conventional model of subject-actor-audience, the emergence of the epistemic subject is facilitated by the relational aspect cultivated during the co-production process. Our assertion is that an elevated level of relational quality amplifies the capacity for thoughtful consideration, allowing for the recognition and assessment of requisites, prospects, and additional factors, culminating in more conscientious joint development of groundbreaking ideas.

Proceeding to the roadmap for the implementation of the experiment, based on the concept of co-creation of epistemic networks, we introduce its two distinct phases: the initial exploratory phase and subsequent operational phase. We have reasoned the use of simulation over a concrete experiment, as the former entails intricate processes and technicalities that make this approach more suitable for our purposes. The exploratory phase aims to gather information for designing the operational phase. The project encompasses carrying out interviews, analyzing reports on the innovation ecosystem concerning water management, and investigating the participatory culture prevalent in the ecosystem. The supplementary materials encompass relevant documentation such as the interview guide, invitation materials, and informed consent forms, meticulously tailored to suit the parameters of the simulated study.

Throughout the chapter, we uphold an inclusive stance towards the configuration and mechanisms of the experiment. Our anticipatory governance exercise is designed to foster adaptability and flexibility through its open structure, enabling ongoing enhancements. We recognize the prospective assimilation of a digital platform as a deliberation space.

The simulation outlined in this chapter achieves two key aims: first, it facilitates the development of a comprehensive understanding of responsible and sustainable water use management (knowledge base); secondly, it creates a tool for assessing technology by using a learning tool that improves the interconnectivity and collaborative capacity of the network of stakeholders involved in water management.

2

WATER: RESPONSIBILITY AND SUSTAINABILITY

2.1 Introduction

In the last century, several normative frameworks emerged, focusing on sustainability and namely in water management (Caradonna, 2014).

The concepts of water management and sustainability furnish an all-encompassing structure for understanding the obstacles and perspectives of water management, as well as the ability to integrate other frameworks and technologies to address these obstacles.

This chapter will emphasize two fundamental aspects: the mapping of the water management issue, and the contribution of sustainability for establishing responsibility in water use.

The chosen topics are backed by research, highlighting the significance of social, economic, and political factors in the management of water resources, as well as the necessity of forward-thinking governance for sustainability amidst technological innovation.

This chapter aims to provide an in-depth presentation of the state of the art in responsible water use management. It begins by presenting the current drama of water use. Then, it presents the urgency for a sustainable use of water from current approaches. It will also present the current concepts of sustainability and its progression, and analyze those concepts related to the responsible use of water. In this research, water resources will be a driver to find how sustainability, governance, and technology can be connected in order to propose a framework for a responsible future.

2.2 Water management: challenges and movements

The International Union for Conservation of Nature (IUCN) stresses that "only 3% of the Earth's water is freshwater; about two-thirds of it is frozen in glaciers and polar ice caps and we have long over-stretched this precious resource". The demand of water for people will increase 50% and there was a decline of 80% in fresh water since 1970; on the other hand, 90% of natural disasters are water-related (IUCN, 2022). As the IUCN reports, water is a resource that faces scarcity, and it does affect every single human and business in the planet. This section starts with gathering the state of the art in water conservation in the world and the goals for its development, bringing up the most discussed problems and concerns of our century.

The IUCN (2022) also acknowledges an urge for water governance "that integrates the needs of people and nature, the implementation of sustainable water resource management to secure water-related ecosystem services and conserve freshwater biodiversity and support increased investment in ecosystems as natural water infrastructure".

The primary objective of water management is to facilitate the provision of sufficient quantities of water, which conforms to the prescribed standards, to cater to diverse water-based needs. Especially in advanced societies, water systems have been adapted or educated to meet the requirements of the water utilities over an extended period. The malfunction of the water system — such as during calamitous inundations, water scarcity, or grave environmental contamination — has resulted in the modification of the water system in multiple instances (Haasnoot et al., 2011).

The management of water resources is developed in deep by the United Nations Environment Programme through Integrated Water Resources Management (IWRM), which is "based on the understanding that water resources are an integral component of the ecosystem, a natural resource and a social and economic good" (United Nations Environment Program, 2011).

The United Nations stress that

> Water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. However, water is only one of a number of vital natural resources and it is imperative that water issues are not considered in isolation. (UN, 2014)

The IWRM approach (Figure 1) is now internationally accepted and seen as the way forward for efficient, equitable and sustainable development. It is also viewed as the most effective way to manage the world's limited water resources and to cope with conflicting demands (UN, 2008).

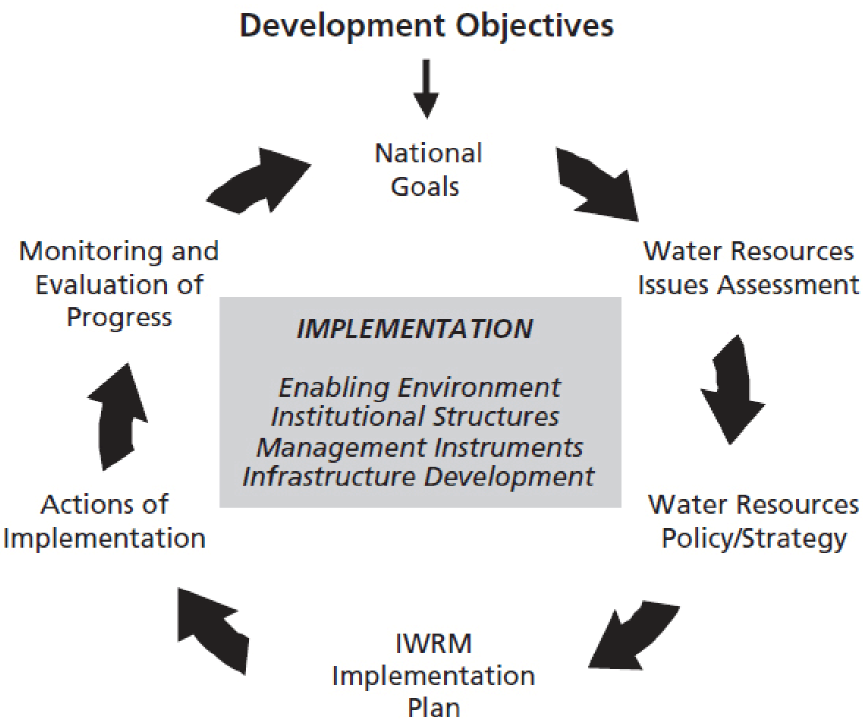

Figure 1 - Stages in IWRM planning and implementation (UN, 2014).

The distribution of water uses can vary across the globe depending on a multiplicity of factors, such as climate, geography, population density, economic development, and government policies (Shiklomanov, 2000). Nevertheless, the use of water can be determined by factors such as:

Water Availability: Regions with limited water resources, such as arid or semi-arid regions, tend to use it more sparingly and more efficiently than abundant areas. For instance, countries like Israel or Jordan, where scarcity of freshwater is an acute problem, often recycle and reuse their used water for agriculture or other purposes (FAO, 2021).

Economic Development: As countries progress economically, their water use tends to rise due to increased industrialization, urbanization, and consumption. Over the last few decades, countries like China and India have experienced rapid economic growth, which has resulted in greater water use for industrial and agricultural purposes (World Bank, 2021).

Agriculture Strategy: Water use in agriculture varies drastically around the world, depending on crop types, irrigation methods, and farm size. In many developing countries, small-scale farmers still rely on traditional irrigation techniques, like flooding or furrow irrigation, which are inefficient and wasteful. On the contrary, large-scale commercial agriculture in developed nations typically uses more efficient systems, like drip irrigation or center pivot irrigation (FAO, 2021).

Government Policies: Government policies have the potential for major influence on water use, particularly through pricing, regulation, and management measures. For instance, some countries have implemented initiatives designed to promote conservation and efficiency through water pricing schemes that charge higher rates for excessive consumption (OECD, 2021).

Social and Cultural Dimensions: Water use can be affected by cultural and social factors like lifestyle, eating habits, and traditional water management practices. For instance, in some regions around the world, water is seen as a sacred resource that must be managed according to traditional ways that prioritize communal use and conservation (UNESCO, 2021).

Although the actual use of water may vary depending on multiple factors, as mentioned before, it is feasible to identify the prevailing and most prominent water consumers in a global level.

The top water consumer is Agriculture, that accounts for 70 percent of global water withdrawal (FAO, 2021), including water used for crop irrigation, livestock watering, and other agricultural practices. It is followed by energy production, where water plays significant roles, from cooling in thermal power plants to rotating turbines at hydroelectric plants and steam generation at nuclear power plants (IEA, 2021). Furthermore, it helps in the extraction of fossil fuels, like coal, oil and natural gas for energy generation (USGS, 2021). Industries also need water for multiple purposes, such as manufacturing, processing and cleaning. For example, the World Wildlife Fund (WWF) states that the textile industry spends around 2,700 liters of water to manufacture one cotton T-shirt (WWF, 2021). Also, municipalities play a determinant role in water use: city water can be used for drinking, sanitation, and fire protection (WHO, 2019). This includes domestic use as well as the water used in parks, gardens, and swimming pools (WHO, 2019).

In this context, it is necessary to understand the relationships between people, the spatial distribution of their activities, their access to services and the efficient use of resources as important elements for urban sustainability (Cortese et al., 2019). Regarding urban water management it ranges functions from urban hygiene, drinking water and personal hygiene, draining and prevention of flooding, urban agriculture, and pleasure and recreation (Larsen & Gujer, 1997).

The aforementioned topic of energy production is intrinsically related to water use, and this relation has been namely studied as the concept of water-energy nexus. The interrelation between water and energy is a pivotal area of interest for policymakers, academics and experts engaged in managing water resources, maintaining sustainability, and evaluating technological innovations. Water and energy present an intrinsic connection, as the generation and dispersion of energy mandates substantial water consumption, while the refinement and circulation of water demand consequential energy outlays (UNEP, 2016, p. 1).

The interdependence between water and energy manifests in a nuanced and multifaceted manner. It pertains to the use of water for energy generation in various applications, including hydropower, thermal and nuclear power plants, as well as the employment of energy in water treatment and distribution, by means of pumping and desalination (Zhang et al., 2020, p. 2). In fact, we can add that the cost of energy is the most significant controllable expenditure incurred in providing wastewater services to the public water resource recovery facilities (WRRF). This is particularly true in the case of large WRRFs, where a considerable amount of energy is required during biological treatment, especially when the treatment method is based on conventional activated sludge (Póvoa et al., 2017).

In this context, it is imperative to adopt a comprehensive approach that encompasses water governance, sustainability, and technology assessment (Ishizawa et al., 2018, p. 13). Conversely, inadequate management of water resources can adversely affect energy production and supply. Similarly, suboptimal management of energy resources can cause adverse effects on water quality and accessibility (Hou et al., 2021, p. 2).

It is imperative to incorporate water and energy factors into policies and decision-making procedures concerning water management, sustainability, and technological assessment. The implementation of comprehensive approaches to water and energy management may encompass constructing integrated strategies, advocating for technologies that conserve water and energy, and enforcing policies and regulations that ensure the responsible use of such resources (Hernandez-Escampa et al., 2020, p. 3).

Furthermore, the retrieval of fossil fuels, as well as the mining of minerals utilized in sustainable energy solutions, may result in notable effects on water resources (World Bank, 2020, p. 11).

Although the relationship between water and energy may not comprehensively incorporate the social and environmental aspects of sustainability, the use of hydropower and bioenergy, if not adequately regulated, may result in adverse effects on water resources and biodiversity (UNEP, 2016, p. 3). Likewise, the use of fossil fuels and nuclear power can potentially result in adverse consequences for water and energy resources, as well as to public health and safety (EASAC, 2020).

2.3 Economic, political, and social ecosystems for water

The hydrological cycle is a complex system that embodies inherent intricacy, variability and ambiguity due to the interconnectedness amongst social, natural and engineered subsystems (Makropoulos & Savic, 2019).

This section presents an economic, social and political landscape related to water management and sustainability. First it will provide a subsection with an high-level understanding of the economic dimension and how the funds are drawing the paths and decision-making; followed by a presentation of the political ecosystems, aiming to understand how governments and nations are approaching the subject; in the next subsection, the social factors of water management are visited.

2.3.1 Economic dimension

The United Nations Water (UN-Water, 2023) stated that, in order to stimulate investment, promote employment, and enable governments to achieve their water and climate objectives, novel financing approaches for water resource management are indispensable.

Climate financing mechanisms have been instituted to fund initiatives designed to mitigate greenhouse gas emissions and enhance resilience to the impacts of climate change (Green Climate Fund, 2023, n.d.). In an analogous vision, innovation funds facilitate the preliminary exploration and establishment of novel sustainable technologies and merchandise (US Department of Energy, 2023, n.d.). Governments incentivize investments in renewable energy or energy-efficient technologies through the provision of tax incentives, including tax credits (American Council on Renewable Energy, 2019, n.d.).

1. **Green bonds:** Fixed-income securities are offered by governments, corporations, or other entities for the purpose of raising funds to finance environmental initiatives. Possible initiatives encompassed by these projects are renewable energy installations, enhancements in energy efficiency, effective practices in water conservation, among others. Green bonds generate funds that are exclusively designated for sustainable ventures, thereby drawing the interest of individuals seeking to back eco-conscious endeavors. The market for green bonds has experienced substantial growth in recent years, culminating in a historic high of $305 billion in global issuance during 2020, according to the Climate Bonds Initiative (2021).
2. **Funds for climate:** The funds allocated for minimizing greenhouse gas emissions and adjusting to climate change impacts are intended to support pertinent projects. Funds allocated for climate change adaptation and mitigation projects can be established

either nationally or internationally. An instance of a global climate fund is the Green Climate Fund, founded in 2010 by the United Nations Framework Convention on Climate Change (UNFCCC). The Green Climate Fund has set a goal of generating $100 billion per year, by 2020, to bolster developing nations in their efforts to counter and manage the effects of climate change (Green Climate Fund, 2023).

3. **Innovation funding:** These funds facilitate the financing of nascent research and development initiatives for novel technologies and goods that may prove conducive to the advancement of sustainability. Under the administration of governments or private institutions, such funds are allocated to foster innovative ventures that might not receive financial backing via conventional means. An instance of innovation fund can be seen in the Advanced Research Projects Agency-Energy (ARPA-E), in the United States. ARPA-E supports innovative research initiatives with significant potential for achieving breakthroughs in energy technology development towards reducing greenhouse gas emissions and enhancing energy efficiency (US Department of Energy, 2023).
4. **Fiscal advantages:** Certain governments offer fiscal advantages as a means to stimulate investments in sustainable innovation. The US government provides tax incentives for corporations that opt to invest in energy-efficient technologies or renewable energy. Tax deductions can mitigate the expenses associated with sustainable innovation investment and alleviate the financial vulnerability of companies. Tax incentives may serve as a motivating factor for individuals to invest in sustainable technologies such as solar panels for their residences, by providing them with lucrative tax credits or other financial benefits (American Council on Renewable Energy, 2019).

As outlined by the United Nations Environment Programme (UNEP), sustainable innovation heavily relies on financing mechanisms that provide the requisite funds, expertise and support to introduce new concepts into the market while mitigating any financial risk or uncertainty. Lack of proper mechanisms may impede the progress of numerous sustainable innovations, hindering their advancement beyond the preliminary phases of development (UNEP, 2019, p. 13).

In recent times, sustainable innovation has been majorly funded by private financing entities, such as venture capital and private equity, which has proven to be greatly consequential. A publication from the Global Innovation Lab for Climate Finance reveals that private sector's investments in sustainable innovation have surged remarkably in the last ten years, resulting in a cumulative investment of $1.1 trillion between 2007 and 2018. According to the report, private investors exhibit greater levels of flexibility in comparison to public funders and are capable of offering financial resources throughout the various stages of the innovation cycle (Global Innovation Lab for Climate Finance, 2020, p. 10).

A comprehensive report by the Organization for Economic Cooperation and Development (OECD) suggests the need for a measured and equitable approach to ensure the appropriate funding of sustainable innovation initiatives through public and private fund allocation. The report highlights the crucial function of public funding in bolstering nascent innovation and mitigating financial uncertainties linked to sustainable initiatives. Notwithstanding, the report underscores the indispensable role of private investments in the amplification of innovation and dissemination of novel technologies in the market (OECD, 2021, p. 15-16).

2.3.2 Political ecosystem

This subsection aims to gather a holistic comprehension of the management and mitigation strategies for water use and sustainability as they are tackled through policies, with a specific focus on legal aspects. Governments and institutions have acknowledged the importance of water management and have consequently established a variety of regulatory structures to guarantee its proper use and perpetual viability.

The concept of Sustainable Development was introduced in the World Conservation Strategy (WCS) of the IUCN, in 1970. After that, the World Commission on Environment and Development (WCED) published, in 1987, the Brundtland Report, also known as "Our Common Future". This was followed by other initiatives, such as "Caring for the Earth", in 1991, and then the Rio Conference that took place in 1992. In the Earth Summit, in 2002, sustainable development was the centerpiece of all debates.

The principles of "Caring for the Earth" (IUCN, 1991) were:

1. To respect and care for the community of life.
2. To improve the quality of human life.
3. To conserve the Earth’s vitality and diversity.
4. To minimize the depletion of non-renewable resources.
5. To keep within the Earth’s carrying capacity.
6. To change personal attitudes and practices.
7. To enable communities to care for their own environment.
8. To provide a national framework for integrating development and conservation.
9. To forge a global alliance.

When compared to previous developed frameworks, such as the WCS, this strategy adds up the concept of community care, bringing a strong view of "sustainable society" and integrated development when speaking about national framework, with the recognized "need to understand and accept the consequences of being part of the great community of life and to become more conscious of the effects of our decisions on other societies, future generations and other species" (World Conservation Union, 2013, p. 5).

While the Brundtland Report focused on the economic and political context, the "Caring for the Earth" introduced a global and social vision to sustainable development strategies, followed by the Rio Conference results.

The Rio Declaration on Environment and Development, commonly referred to as the Rio Declaration, comprises a corpus of 27 essential principles that had their genesis at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in 1992, under the auspices of the United Nations (UN, 1992).

The tenets enshrined in the Rio Declaration encompass an extensive array of matters pertaining to the safeguarding of the environment and the advancement of sustainable growth. Its standards encompass several elements, namely the imperative of incorporating environmental factors into the decision-making framework, the significance of adopting measures of caution, the principle of apportioning shared yet distinctive responsibilities, and the acknowledgement of the rights of indigenous communities (UN, 1992).

By the year of 2020, the European Union enacted the Water Framework Directive (WFD). The aim of the WRD is to safeguard and enrich the quality of water resources throughout the European Union while facilitating their sustainable use to advance the welfare of individuals and the environment (European Commission, 2000). The WFD entails the implementation of novel and groundbreaking mechanisms of responsibility among the EU Member States (Petersen, Klauer & Manstetten, 2009). Through the implementation of a comprehensive water management strategy, this approach upholds the preservation of ecosystem integrity by governing the regulation of discrete pollutants and establishing corresponding standards in compliance with regulatory requirements (European Commission, 2023).

The framework mandates member states to formulate river basin management plans with the goal of attaining a good ecological and chemical state of all water bodies — which encompasses rivers, lakes, and groundwater — as it serves as a framework for water management. It is imperative for the member states to carry out ongoing surveillance and evaluation of their water resources, while creating comprehensive action plans to resolve any issues highlighted during the assessment process. WFD mandates the involvement of the public in the formulation and execution of river basin management blueprints. Meanwhile, one should note that WFD played a significant role in advancing the cause of integrated water resources management and has resulted in notable enhancements in water quality and ecosystem vitality throughout the European Union. The initiative has furthermore fostered intergovernmental collaboration concerning cross-border water matters while promoting the advancement of inventive methodologies for water resource management (European Commission, 2000).

Since WFD emerged, numerous strategies have been defined to structure action regarding water policies for the EU Member States. One of them was public participation (public consultation and public access to information), which is believed to have a leading role in watershed management. Ideally, this policy would ensure not only those solutions are proposed according to the requirements of each specific location, but also that decisions are made as close as possible to where the water is used and affected. The objective is for Member States to adapt their programs to local and regional conditions, so that water use is more sustainable, rational and fair (Vasconcelos, 2004). The latest revision was presented in 2019, with the purpose to enhance the implementation of the WFD by fortifying its emphasis on water quantity, mitigating the effects of climate change and amplifying the harmonization between water and environmental policies. In October 2022, the Commission endorsed a proposal to modify the inventories of contaminants found in surface water and groundwater (European Commission, 2023).[4]

Access to safe drinking water and sanitation is a basic human right, essential for the full enjoyment of life and all human rights. On July 28, 2010, the United Nations General Assembly passed a landmark resolution acknowledging this right (UN-GA 2010). In this work we explore its significance, as well as any eventual implications for sustainability, by drawing upon additional sources for discussion.

The UNGA resolution that declared access to clean drinking water and sanitation as a basic human right was an important milestone in global efforts to expand access to these essential necessities. It signaled a growing recognition that access to clean water is crucial for poverty reduction, economic development, and sustainable development (Gleick 2010).

As well as its symbolic importance, the UNGA resolution has had real world impacts for policy and practice. It has provided a basis for advocacy and action to increase access to clean

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[4] For an up-to-date version of the Water Framework Directive, see https://environment.ec.europa.eu/topics/water/water-framework-directive_en.

water and sanitation while mobilizing resources and support for this critical cause (Bartram & Cairncross 2010).

Hofmann and Bartram (2016) highlight that the UNGA resolution contains several provisions emphasizing access to clean water and sanitation as an inalienable human right and require international cooperation to increase access. According to Hofmann and Bartram (2016), some key provisions include:

- Recognizing and affirming access to safe drinking water and sanitation as human rights.
- Acknowledging its significance for life itself, as well as all human rights.
- Recognizing that lack of access to clean water and sanitation disproportionately impacts vulnerable groups.
- Affirming the significance of international cooperation and assistance as ways of helping countries enhance access to safe drinking water and sanitation.
- Requesting that the United Nations provide support and technical assistance to countries that require assistance, to improve access to clean water and sanitation (UNGA, 2010).

Gleick (2010) noted the significant ramifications of the UNGA resolution on access to safe drinking water and sanitation are instrumental to sustainability, specifically SDG 6, which addresses availability and sustainable management of water for all.

The Sustainable Development Goals (SDGs)[5] represent a universal invitation to tackle poverty eradication, environmental safeguarding, and inclusive growth on a global scale. Comprising a network of 17 mutually dependent objectives, the SDGs were devised by the United Nations in 2015 to tackle the most pressing global issues. This document offers a succinct summary of the Sustainable Development Goals, focusing on their importance, goals and advancements towards their accomplishment (UN, 2020).

Furthermore, the SDGs aspire to encompass a wider spectrum of sustainable development, materializing as a direct result of the pressing need for a comprehensive and all-

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[5] The 17 SDGs are the following: 1.No Poverty; 2 Zero Hunger; 3. Good Health and Well-being; 4. Quality Education; 5. Gender Equality; 6. Clean Water and Sanitation; 7.Affordable and Clean Energy; 8. Decent Work and Economic Growth; 9.Industry, Innovation, and Infrastructure; 10. Reduced Inequality; 11. Sustainable Cities and Communities: 12. Responsible Consumption and Production; 13.Climate Action; 14. Life Below Water; 15. Life on Land; 16. Peace, Justice, and Strong Institutions; 17. Partnerships to Achieve the Goal . Full details available at: https://unstats.un.org/sdgs/report/2020.

encompassing structure to effectively tackle multifaceted concerns such as poverty, inequality, climate change, and environmental degradation (UN, 2015). The SDGs, through the implementation of a comprehensive framework that incorporates elements of the economic, social, and environmental spheres, offer a plan of action that lays the foundation for ensuring a sustainable future for all countries (UN, 2020). The SDGs consist of 17 goals, each with specific targets and indicators that guide policy formulation, implementation, and monitoring. These goals encompass a wide range of thematic areas, including poverty eradication, quality education, clean energy, gender equality, sustainable cities, climate action, and responsible consumption (UN, 2023).[6]

To expedite the advancement towards the Sustainable Development Goals, decision-makers and concerned parties must prioritize harmonization, cooperation, and ingenuity. It is imperative for national governments to synchronize their policies and development strategies with the Sustainable Development Goals (SDGs), incorporating them into their budgetary and decision-making mechanisms (UN, 2023).

Among the 17 goals, we should take a closer look at the SGS6 , which relates to "Ensure availability and sustainable management of water and sanitation for all" —, which entails the following objectives:

> 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
> 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
> 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
> 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
> 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
> 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
> 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
> 6.b Support and strengthen the participation of local communities in improving water and sanitation management. (European Commission, 2023)

[6] See https://sdgs.un.org/2030agenda.

Even though there are initiatives in place, “at current rates, progress towards all the targets of SDG 6 is off-track” (WWDR, 2023). According to UNESCO, “governments will need to work four times faster, on average, to meet their SDG 6 targets by 2030. However, they cannot solve this conundrum on their own. Water affects everyone, so everyone needs to take action.”

Furthermore, the resolution's call for international cooperation and assistance to improve access to clean water and sanitation underscores the need for global action on sustainability issues. As noted by Hofmann and Bartram (2016), sustainable development requires coordinated efforts from governments, international organizations, civil society, and businesses working collectively — which requires action by all the stakeholders involved, such as governments, international organizations, civil society organizations, private firms, as well as individual citizens.

On its turn, The General Assembly's resolution on the right to safe and clean drinking water and sanitation, adopted by the United Nations, underscores the crucial role of these fundamental necessities in securing comprehensive human rights and an optimal quality of life (UN, 2010). The resolution specifies that a minimum of 50 liters of water per person per day is required for personal and household use (UN, 2010). Furthermore, the resolution acknowledges the crucial role of affordability in facilitating access to secure water and sanitation. According to the United Nations (2010), it is recommended that the expenditure on water and sanitation services must not surpass 3% of an individual's household income. This premise rests upon the belief that every individual has an inherent entitlement to access reliable water and hygienic facilities, and any financial impediments to this access must be eliminated.

Ensuring accessibility of safe and clean drinking water and sanitation is a paramount concern. As stipulated in the resolution, the proximity of the water source must not exceed 1,000 meters, and the duration of the round-trip to collect water must not surpass 30 minutes (UN, 2010). This acknowledges that access to reliable water and sanitation facilities is not solely reliant on the existence of infrastructure, but also on individuals' capacity to attain and utilize those amenities.

From an economic standpoint, providing access to potable and hygienic water and to sanitation facilities is crucial, not only to uphold fundamental human rights, but also to bolster sustainable growth and development. The United Nations deemed the attainment of Sustainable Development Goal 6, which pertains to universal access to clean water and sanitation, imperative for the achievement of other interrelated goals, including but not limited to poverty and hunger reduction, enhancement of health and well-being, and advancement of economic growth and innovation (UN, 2018).

Efficient deployment can be achieved by exploring novel financial mechanisms as a prospective resolution. According to Pape et al. (2019), the implementation of innovative financing mechanisms like social impact bonds and blended finance may facilitate the mobilization of private sector funds and enhance accessibility to water and sanitation amenities in Senegal. Bruns and Ringler (2016) state that development cooperation has the potential to initiate a positive transformation in governance, thereby facilitating reforms that would enhance the management of water resources and augment accessibility to water and sanitation provisions.

Following that, innovations for a more sustainable future are being proposed all over the world. Such innovations always come with associated politics and goals to be delivered. "The extent to which they can be implemented is subject to complex politics and powerful coalitions across multi-level governance systems and scales of interest" (Daniell et al., 2014, p. 2145).

It is relevant, in this context, to consider one of the results of Vasconcelos (2004) research. The author states there is a democratic deficit: decision-makers say the public doesn't want to participate or that it is for bigger interests, while the population thinks their participation is just an aesthetic issue, as the Government will not implement the suggested changes. This situation results in the absence of adequate, phased, and structured participation mechanisms.

Towards ensuring the availability and sustainable management of water and sanitation for all, the Sustainable Development Goal 6 (SDG 6) was included in the 2030 Agenda for Sustainable Development in 2015 by the UN (UN, 2015). There are seven goals outlined under SDG 6 that aim to provide universal and equitable access to safe and affordable drinking water, adequate sanitation and hygiene, water quality improvement, water efficiency, integrated management of water resources, protection, and restoration of water-related ecosystems, as well as international cooperation and capacity-building support (UN, 2015).

To successfully operationalize SDG 6, the convergence of efforts between governments, international bodies, civic groups, and the commercial sector is essential. This entails significant investments in infrastructure and technology, as well as cooperative measures to enhance water resource management holistically (Bruns and Ringler, 2016). Multiple instances of successful SDG 6 implementation in varying circumstances have been implemented through case studies. In Senegal there is a governmental initiative, backed by various international entities and indigenous populations, that endeavors to offer reasonably priced avenues for obtaining potable water and hygienic facilities in rural locations (Pape et al., 2019). According to Pape et al. (2019), the initiative has brought about considerable advancements in the health, gender parity, and economic progress of the communities it aimed to cater to.

Likewise, the Indian government has initiated the Swachh Bharat Mission (Clean India Mission) with the aim of attaining comprehensive sanitation coverage through the construction of numerous toilets and fostering behavioral transformations through community mobilization initiatives (Coffey et al., 2017). The initiative has yielded positive results, as evidenced by a decrease in open defecation rates and an enhancement of sanitation and hygiene behavior, particularly among marginalized groups (Coffey et al., 2017).

As an example of water management policy, in Portugal, the Portuguese Environment Agency (APA) is the entity responsible for the water governance strategy. It represents the national water authority, thus having the responsibility to define policies and manage instruments that ensure the application of its principles.

The APA develops a wide range of activities that include the definition and implementation of national water resources policy, the planning of these resources and the associated territory, the licensing of their use and their supervision, the promotion of efficient water use, the implementation of monitoring programs, and the implementation of the water resource rate (APA, 2022).

The APA also manages an Innovation Fund, in Portugal, which aims to

> provide financial support for innovative technology projects in renewable energy, energy storage, geological capture and storage of CO2, capture and use of CO2 and innovative low-carbon technologies and processes in energy-intensive industries. (APA, 2022)

These frameworks and mechanisms unveil a growing awareness to the democratic deficit and the necessity to level up the complexity of the decision-making process as a multi-level governance system. Also, in the published role of APA, there is no regard to social interface with the decision and the policies defined by them.

If we look at the information level browsing through APA's website,[7] there is no digital tool to contact or to find answers, there is only a phone number (by June 2022).

Looking further at Portugal's model, a close connection between the legal mechanisms and financial incentives can also be found. For example, under the Regional Water Efficiency Plan of the Algarve, which defines the objectives to promote water efficiency, it refers to installing and managing associated equipment/technologies that promote the increase in

[7] This refers to the contact session on APA website, available at https://apambiente.pt/apa/contactos-e-atendimento in June 2022.

efficiency and sustainability of agricultural practices, like the collection of weather data, soil moisture probe, hardware and management software for irrigation plot and water use (APA, 2020).[8]

Higher governance levels can play an important role in facilitating the passage of certain types of innovations that may compete with currently entrenched systems of water management. Due to a range of natural biases, experts on certain innovations and disciplines may form part of supporting or blocking coalitions, but their evaluations of worth for water system sustainability and security are likely to be subject to competing claims based on different values and expertise, so they may not necessarily be of use in resolving questions of ''best courses of action''. This remains a political values-based decision to be negotiated through the receiving multi-level water governance system (Daniell et al., 2014, p. 2415).

On the other hand, there are the certifications of compliance, which provide the assurance of compliance with certain parameters and rules by an organization — for instance, a company that develops technology for water management.

"With increasing commitments to corporate responsibility, many companies have adopted global environmental management system standards such as ISO 14001 (ISO, 2004), which specify performance indicators as a required element" (Fiksel et al., 2012). Some of those certifications are related to security and sustainability practices. To mention some that relate to sustainability, water and technology, we can take a look at:

- **ISO 14001:** Demonstrates the company's commitment to the protection of the environment, strengthening its institutional image and following the constant evolution of the market. With requirements of effective management of the environmental aspects of business activities, considering environmental protection, pollution prevention, legal compliance, and socio-economic needs (Société Générale de Surveillance [SGS], 2022).[9]
- **ISO 27001:** Validates the company's integrity of data and systems, as well as the commitment to information security (SGS, 2022).[10]

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[8] APA has published a report about the water scarcity and a management plan for hydric efficiency in the Algarve region. It can be accessed in full at https://apambiente.pt/sites/default/files/_SNIAMB_Agua/DRH/PlaneamentoOrdenamento/PlanosGestaoSecaEscassez/PlanosRegionaisEficienciaHidrica/PREH_Algarve_2020_VOL_I_Relatorio.pdf.

[9] For more details on how the certification entities are working with quality, health and safety of the environment, see https://www.sgs.com/pt-pt/services/iso-14001-sistema-de-gestao-ambiental.

[10] To know more on how the certification entities are working with quality, health and safety of the environment, see https://www.sgs.com/pt-pt/services/iso-iec-27001-2013-sistemas-de-gestao-de-seguranca-da-informacao.

In the Portuguese Decree-Law 114/2021 of December 15,[11] an amendment to the Environmental Fund and the organic fund of the General Secretariat of the Ministry of the Environment was published. It states the following:

> Portugal has made a commitment to achieve carbon neutrality by 2050, which entails a transformational challenge, transversal to society, to ensure the energy transition and create a more circular, resource-efficient and carbon-neutral economy, ensuring a fair and cohesive transition.

Valuing the territory and its habitats, betting on the forest and ensuring the quality of the environment are also objectives to be pursued, so that a strong and fully aligned response must be mobilized with the objectives to which Portugal has set itself in the framework of the Paris Agreement and the 2030 Sustainable Development Goals.

This commitment to sustainability was based on the XXII Constitutional Government Program, which inscribed the fight against climate change and the guarantee of a fair transition as one of the four strategic challenges for government action.

Nevertheless, we should acknowledge that the Decree-Law 114/2021 sets goals for carbon emissions and environment, but it does not push up the digital as a vehicle to accomplish those goals; in fact, there is no mention of that.

2.3.3 Social ecosystem

The factors that affect economic expansion include global transformations, such as urbanization and hydrological-climatic modifications, as well as the realms of politics, history, and culture. Notwithstanding commendable endeavors to foster comprehensive methodologies to scrutinize water-related predicaments, the study of the inter-relation between human and aquatic systems continues to pose a significant obstacle to scholars and policymakers, owing to the escalating intricacies involved (Evers et al., 2018).

The fundamental principle underlying SDG 6 lies in recognizing the intrinsic value of water. Handling water resources with the utmost attention to ensure its adequate availability is imperative to uphold the welfare of humanity and bolster commercial ventures such as agriculture.

Statistics brought by Leal Filho et al. (2022) to reinforce the urgency of SDG 6 stress that 1) approximately 892 million individuals worldwide do not have access to proper sanitation facilities; 2) clean access to sanitation remains inaccessible to approximately 1.1 billion

[11] The Decree-Law is available online for further information. See the complete document at https://dre.pt/dre/detalhe/decreto-lei/114-2021-175923959.

individuals worldwide drinking water; 3) diarrheal diseases caused by inadequate sanitation and hygiene result in the tragic loss of nearly 1,000 children daily; and 4) approximately 11% of the global population lacks access to an enhanced water supply (Leal Filho et al., 2022).

According to the UN (2023),[12] nations should strengthen strategic approaches, namely providing assistance to vulnerable communities who are at risk of facing economic disruptions during periods of change. This highlights the significance of implementing comprehensive social security systems, along with customized aid, education and associated programs, and a particular emphasis on remote regions, which are home to a large number of impoverished individuals.

While extant theories attempt to converge the social and water dimensions, they traditionally begin with and uphold disciplinary viewpoints, thereby impeding genuine integration in research pertaining to the interrelationship between humans and water (Evers et al., 2017). The authors proposed a new conceptual model for understanding human-water research (Table 1 and Table 2). They state that would provide scholars and decision makers with an enhanced understanding where an in-depth comprehension of the historical and current operational mechanisms of the system may serve as a firm groundwork for prospective strategizing or mitigation efforts. The model is named Pluralistic Water Research (PWR), which

> integrates physical and socially constructed space and the arena of actors and entities interacting. It also looks at the processes to better understand the co-production (human-hydro-scapes) of the system and is defined by reciprocal boundary conditions which enable the integration of knowledge from both the natural and social sciences by acknowledging their different epistemologies, concepts and methods. (Evers et al., 2017, p. 10)

The PWR paradigm facilitates the endeavor of human-water research as it discerns crucial constituents and susceptibility within the structure by scrutinizing interfaces and reciprocal causal chains of the system units across varying spatiotemporal contexts (Evers et al., 2017).

[12] Report of the Inter-agency Task Force on Financing for Development: this is a full report on financing sustainable transformations, available at https://financing.desa.un.org/iatf/report/financing-sustainable-development-report-2023 for more details.

Table 1 - Human-water concepts and their perspective on humans, water, and interactions between the two.

	IWRM	Socio-Hydrology	Political Ecology / Waterscapes	PWR
Perspective on HUMANS	- Anthropocentric approach - Sees humans as users who want to maximize economic and social welfare	- Water-related human outcomes (well-being) influenced by norms and values in using and understanding the water source	- Social aspects and human dimension are central to the study perspective - Social interactions and power relations are key issues	- Humans are water users who are embedded in a human-hydro-scape which is influenced by human and physical boundary conditions
Perspective on WATER	- Water is a resource which should be managed for the needs of human beings with respect to environmental conditions and sustainability	- Human-modified multi-scale structures and dynamics - Water Use and management are influenced by the user's culture, norms and values	- Unequal power relations and inequalities are mirrored within the hydrologic system	- Water is a source embedded in a human-hydro-scape. Its quantity, quality, availability and accessibility and re-shaped and influenced by human and physical boundary conditions
Perspective on INTERACTION	- Focused on sustainable interaction between different users (people, agriculture, naturel, industry) and their water demands - Promotes a coordinated development and management of resources by enabling environment, institutionalizing, and implementing management instruments - The integration of interacting sectors is a key factor - Interaction builds on ecology, efficiency, and equity	- Explains and understands the co-evolution (the two-way feedback) of the human and water systems with their observable feedback, relationships and driving mechanism in the past, present and future - Models the interaction by using mathematical and optimization models	- Strong focus on how power asymmetries, discourse, perception and knowledge of water and/or human-water processes constitute practices and foster de- and re-construction of practices - Reflection on the process of co-production of social "content" and physical-environmental qualities rather than impact study on how social aspects affect physical environment and vice versa	- Space, time and feedback loops are key factors to understand interactions - Analysis of interactions, feedbacks and external influencing factors between and withing the physical space and the human system with its area of interacting actors and entities - Reciprocal acknowledgement of human and physical boundary conditions allows integration of knowledge, epistemologies and concepts from natural and social sciences

Adapted from Evers et al., 2018, p. 8.

Table 2 - Possible guiding research questions for a fictive project on the impact of changes on water availability

Concept	Possible questions
IWRM	- How can management and governance structure be adapted to decreased water availability? - How can vertical and horizontal integration be realized to optimize water management and meet the goal of x liter/day of water supply? - What should be integrated, why and how? - What indicators are suitable to evaluate current state/measures/success?
Socio-Hydrology	- What are the most important driving mechanisms of human-water interactions that could impact the future trajectory of the system? - How could the human-water-interaction be optimized to human behavior to meet a certain level of distributed water/water availability?
Political Ecology/Waterscape	- Which social aspects, agents and knowledge are mirrored in current management practices and the state of the physical system? - How are practices constituted? - What factors influence and (re)shape the co-production of social "content" and hydrological system? - How did the power asymmetries changed in time in response to decreasing water availability?
PWR	- How is the human-hydro-scape constructed by reciprocal boundary conditions? - Which values and norms or mechanism or group of agents are relevant? - What are key system elements sensitive control variables and feedback loops?

Adapted from Evers et al., 2018, p. 8.

2.3.4 Typologies of water management and stakeholders

In an exercise for mapping stakeholders related to water at multiple levels, the Organization for Economic Cooperation and Development Report (OECD, 2015) prepared a list of typologies of water management functions and a view on that in relation to roles and responsibilities, as it follows.

In this report, the typologies of water management functions that have been described are: a) Drinking water supply; b) Sewerage collection; c) Wastewater treatment; d) Water quality; e) Drainage; f) Risk management.

This 2015 report from OECD presents water management functions as it follows:

a) The **drinking water supply** regards to the provision of potable water, entailing the assurance of access to adequate and uncontaminated drinking water for human utilization. This functionality assumes paramount significance in geographical areas characterized by limited or impure water reserves, given that the availability of potable water constitutes a crucial factor in safeguarding public health and welfare (UN, 2010).

b) The **sewerage collection** materializes the second function of water management, encompassing the retrieval and conveyance of effluent and precipitation run-off originating from residential and commercial establishments to designated treatment plants. Efficient and proper sewage collection systems play a crucial role in mitigating pollution levels and minimizing the health hazards related to waterborne ailments (OECD, 2015).

c) The effective management of water involves the imperative task of **wastewater treatment** as its third function, which pertains to the process of treating and eliminating harmful pollutants present in wastewater with the objective of averting the contamination of water resources. The implementation of efficient wastewater management measures is a crucial aspect in safeguarding the well-being of the general populace and promoting the longevity of water resources, as stated by the World Health Organization (2011).

d) The **management of water quality** constitutes the fourth function of water management, encompassing the activities of monitoring and overseeing the quality of water resources, with the ultimate objective of averting contamination and promoting the sustainable use of this vital resource. This function holds significant importance in areas where water resources are limited or susceptible to contamination (UN, 2018).

e) The fifth function of water management is **drainage,** entailing the skillful management and regulation of surface water movements to avert the occurrence of flooding and erosion. Efficient hydrological systems hold a pivotal role in mitigating the likelihood of water-induced calamities whilst safeguarding the physical and human settlements (OECD, 2015).

These typologies are intimately related to the roles of responsibilities (OECD, 2015) such as: I) policy goals and priorities; II) strategic planning; III) service delivery; IV) water allocation; V) tariff setting; VI) definition and enforcement of quality, quantity and industry standards; VII) information and data gathering; VIII) monitoring and supervision of the performance contracts and water managers; IX) stakeholders' engagement; and X) conflict resolution.

Among the roles and responsibilities presented by the OECD (2015), sustainable management of the water cycle constitutes a crucial policy objective and a top priority for water resource governance. The process entails formulating and implementing a strategic scheme to optimize the utilization and productivity of water resources while preserving the natural mechanisms of the hydrologic cycle. Service providers and water utilities play a pivotal role in ensuring the seamless delivery of safe and dependable water services to local communities. To effectively manage water sustainability, it is crucial to adopt a well-rounded approach that considers the ecological, social, and economic implications of water use. Effective stakeholder engagement and conflict resolution are essential for determining the diverse needs of various groups and facilitating fair resolutions for any conflicts that may arise (OECD, 2015).

These functions and responsibilities form an ecosystem that may have greater or lesser complexity. For example, the type of government system will determine how water management functions are managed between national and regional authorities, and which formal and informal actors are involved in this process. The territorial dimension also has an impact in determining the involvement of different actors (OECD, 2015).

The OECD Report from 2015 presents an exercise regarding stakeholder engagement[13] for inclusive water governance. A series of interviews were conducted to identify stakeholders for water governance, and they were organized in groups as it follows:

- **Governments**: governmental ecosystems such as national, regional, and local power, who have an effective decision-making instrument to carry.
- **Service providers:** from public to private, this group includes public utilities, network and service providers, public-private partnerships, and private investors.
- **Watershed institutions:** there are many institutions related to water, such as river basin organization, formal networks of watershed institutions and regional water authorities.
- **Regulators:** entities responsible for the regulation of economic and environmental factors.
- **Businesses:** this is a wide range, as it includes businesses using water in their production and/or in their supply chain, the network of businesses.

[13] As an example of the application of stakeholder's involvement promoted by the government in the decision-making process, we can take a closer look at the Japanese model. The Japan Water Agency Law, revised in 2005, requires that, in all cases, the project proposals and management plans must be reviewed by prefectural governors and water users related to the specific region. Then the Governors themselves are asked to consult their prefectural assemblies to secure their approval over the projects. Once an agreement is reached with regional stakeholders, the Japan Water Agency seeks the approval of the national government that oversees its activities. Consultations are therefore carried out with the concerned ministries on the proposed projects. The Japan Water Agency Law also requires the agency to carry out stakeholder mapping as part of any project plan, as well as engagement processes (e.g., daily communication, information sharing and collaboration activities) to take their views into account (OECD, 2015, p. 62).

- **Civil society**: this group includes non-governmental organizations, member-based organizations, community-based organizations, and social movements.
- **Financial actors**: donor agencies and financial institutions.
- **Advisors:** include engineering and consulting firms.
- **Others:** the media, network of agricultural actors, parliamentarians, and trade unions can be included in this group.

The United Nations report that SDG 6 plays a crucial role in promoting sustainable development and accomplishing all other sustainable development goals, as it is vital to ensure access to clean water and sanitation to improve human health, alleviate poverty, and stimulate economic growth (UN, 2018). In addition, enhancing access to safe water and sanitation carries great ecological advantages, which entail mitigating environmental pollution and safeguarding vital ecosystems (UN, 2018).

The acknowledgement of the entitlement of safe and hygienic drinking water and sanitation as a fundamental human right is a significant stride towards attaining enduring progress (UN General Assembly, 2010). It is crucial to prioritize accessibility, affordability, and availability of fundamental services, as it contributes to enhancing public health (Prüss-Ustün et al., 2019, p. 231), alleviating poverty (United Nations Development Programme, 2016, p. 48), and advancing sustainable economic progress (United Nations General Assembly, 2010).

According to Vasconcelos (2004), stakeholder engagement methodologies have a large set of criteria. Its key rules include the following:

- Involvement in the early stages of the process, ensuring time for participants to understand the process and information and space for debate, with the aim of gradually learning and contributing with their suggestions.
- Involvement of all participants in creating the conditions to include all values and interests from the beginning of the process, adjusting when necessary.
- Placing greater emphasis on interests rather than positions, facilitating the emergence of innovative and appropriate responses to interests.

The participation of societal actors and their interactive participation is crucial for democracy (strengthens commitments), decisions (more robust and less contested), the scope (integration of the excluded), knowledge (integration of various types), and project/study/plan (adjustments throughout the process) (Vasconcelos, 2004).

2.4 Exploring the concept of sustainability: a critical assessment

"As hard it might be to believe, the world once made do without the words 'sustainable' and 'sustainability'. Today they're nearly ubiquitous." (Caradonna, p. 1)

This section seeks to create a comprehensive view on how the existing concepts of sustainability were formulated and assess their role in their dimensions, followed by the presentation of the concept of sustainability from its roots to the present day, with the goal of examining its fundamentals within its multiple spheres, emphasizing their distinct roles in accomplishing sustainable development, showing its main goal and how it introduces responsibility to the processes, showing their weaknesses from a social responsibility view.

On the next paragraphs, we start by problematizing the perspectives on sustainability concepts and its dimensions, followed by a comment on a few authors' views on the concept of sustainability.

The following subsections will present an understanding on diverse perspectives articulated by scholars regarding the subject of sustainability. This analysis will encompass a comprehensive exploration of diverse sustainability strategies and their potential ramifications for policy formulation and practical implementation.

2.4.1 Sustainability

There is considerable evidence that highlights the widespread incorporation of sustainability principles across diverse fields and industries. In 2012, Caradonna (2014, p. 7) did an exercise with Google search engine, which returned 150 million hits for the term "sustainability". By the beginning of 2023, using the same method as Caradonna in 2014, we retrieved 2.35 billion results in a search for the term "sustainability".

This fact caught the attention of some authors with a critical point of view, like Purvis and Robinson (2019, p. 681), who stated that various studies about sustainability have been published in the last 20 years and it still "remains an open concept with myriad interpretations and context-specific understanding". The authors also stress that "despite the importance of global efforts such as the Rio Declaration[14] and Brundtland Report[15] in bringing 'sustainability' into the mainstream policy discourse, the consensus building through compromise approach taken has been criticized" (Purvis & Robinson, 2019, p. 684). Adger and Jordan (2009) go even further and argue that attempting to find a precise definition of sustainability is pointless.

One should acknowledge that the historical roots of sustainability go back to the eighteenth century, related to forest conservation, when European countries acknowledged the significance of forests as a valuable natural resource, specifically regarding timber, which played a vital role in construction, shipbuilding, and fuel provision. The escalating need for timber has raised the apprehension about deforestation and depletion of forest resources. In reaction to this, a silvicultural methodologies and policies started to being developed (Caradonna, 2014).

Later, the conceptualization of sustainability moves further with the UNESCO conference called "Man and His Environment: A View Towards Survival", that took place in 1969 in San Francisco; known as the National Environmental Policy Act of 1969, the event brought to attention the interconnection between humans and the environment (Caradonna, 2014; Fiksel et al., 2012). Caradonna (2014) states that the first uses of the word, from 1970 to 1980, referred to an ideal for social, environment and economy. From 1969 to the present, several conferences have taken place around the globe and ended up leading to the design of frameworks and directives regarding sustainability (Caradonna, 2014).

Meanwhile, throughout the last 50 years, the concept of sustainability has been widely reproduced. Following history, we can take a look at the 1980s and the Brundtland Report, which states that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). According to Caradonna (2014, p. 144), "the report also deserves recognition for its pitchy and widely reproduced definition of sustainable development (...) countless organizations and scholars have adopted".

[14] The Rio Declaration is a United Nations proposition to promote sustainable development, approved on July 14, 1992, in Rio de Janeiro (UN, 1992). It was adopted in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, being recognized as a turning point in international efforts to promote sustainable development.

[15] The Brundtland Report, formally known as "Our Common Future", is a landmark sustainable development report published in 1987 by the World Commission on Environment and Development. The Brundtland Report is the published result of a commission created in 1984 to help direct the nations of the world towards the gold of sustainable development, and operated until 1987 (Brundtland, 1987).

The concept presented in the Brundtland Report is a malleable, open, and dynamic concept that allows adaptation to various contexts, but it might become too closed when it individualizes each country with their specific policies, referring that "Each nation will have to work out its own concrete policy implications" (WCED, 1987, p. 15).

The report recognizes that economic development, environmental protection, and social justice are interconnected and mutually reinforcing. The report argues that sustainable development requires a balance between these three dimensions, often referred to as the "three pillars of sustainable development" (Brundtland, 1987, p. 8).

According to the Brundtland Report, these three pillars are summarized as:

- **Economic sustainability:** Involves creating efficient, innovative, and inclusive economic systems that meet the basic needs of all people and do not deplete natural resources or harm the environment. This requires reducing waste, promoting renewable resources, and investing in sustainable technologies and infrastructure (WCED, 1987, p. 43).
- **Environmental sustainability:** Includes protecting and restoring natural resources and ecosystems, reducing pollution and mitigating climate change. This includes promoting sustainable practices in agriculture, forestry, energy production and other sectors, as well as protecting biodiversity and natural habitats (WCED, 1987, p. 43).
- **Social sustainability:** Involves promoting social justice, reducing poverty and inequality, and empowering marginalized communities. This includes access to basic needs such as food, shelter, and health care, as well as the promotion of education, human rights and social and cultural diversity (WCED, 1987, p. 43).

The Brundtland Report brought the concept of pillars in sustainability, although in literature we can find references to more pillars than the original and in a wider concept.

In this constitution of sustainability, we can find scholars that adapted and added up more pillars to the original Brundtland concept of sustainability (Serrão et al., 2020; Broniatowski & Weigel, 2006; Goodland, 2002; Royal Melbourne Institute of Technology [RMIT], 2017). The following point represent the six pillars that can also entail sustainability.

2.4.1.1 Social sustainability

This concept is concerned with ensuring that the benefits of economic development and environmental protection are equitably distributed among all members of society. It emphasizes the need to promote social justice, reduce poverty and inequality, and empower marginalized groups. It seeks to achieve social equality, fair wages, jobs with better living conditions, gender equality, full integration of women into society, and universalization of rights. It aims to develop a society based on equal rights for all, reducing social inequalities for the present and future generations (Serrão et al., 2020).

Social sustainability can be easily defined as the maintenance of social capital through investments and services that conceive the basic framework for society. It focuses not only on maintaining but also improving social quality, in light of concepts like cohesion, honesty and reciprocity, and never forgetting the idea that relationships amongst people are very important. Social sustainability can be encouraged and supported by laws, shared ideas and/or information about equality and rights (Goodland, 2002; RMIT, 2017).

To Boyer et al. (2016, p. 1), "sustainability is often conceived of as an attempt to balance competing economic, environmental and social priorities. Over the course of three decades of scholarship, however, the meaning and appropriate application of the 'social pillar' continues to inspire confusion."

One might begin to recognize that the social sustainability can take multiple forms, as highlighted by Boyer et al. (2016):

- The establishment of an underlying framework for prioritizing sustainability initiatives is integral to ensure both environmental and economic sustainability.
- The possession of social capital that serves as a prerequisite for the promotion of economic and environmental well-being.
- The other sustainability pillars are constrained by a three-dimensional framework. A case in point regarding the utilization of this methodology is the Sustainability Footprint, which gauges the pace of alteration in a particular quality-of-life gauge in terms of ecological and resource consumption gauges.
- The underlying mechanism for effecting change in the remaining sustainability domains can be comprehended as the impetus for, instead of merely a prerequisite to, environmental and economic change. This is because environmental tribulations at their core are not technological but social predicaments, and any technological amendments are inherently interdependent with social transformations.
- This concept could be described as a site-specific, procedural, and comprehensively cohesive approach, akin to a convergence point in the context of the individual.
- Efforts toward sustainability through place-based and process-oriented measures employ innovative techniques of governance that foster the convergence of diverse viewpoints and promote local origination of ideas and processes.

2.4.1.2 Political sustainability

The political pillar of sustainability aims to build a participatory democracy, balance rural and urban environments, overcome inequalities, and promote a universal appropriation of human rights. It seeks to promote active citizenship, which is defined as a set of rights and freedoms at political, social, and economic levels, through the strengthening of democratic institutions (Serrão et al., 2020).

Political sustainability is the possibility to fulfill the "political goals and resource needs without compromising future goals and needs", as "politically sustainable actions simultaneously build support for, and advance, an item on the political agenda. Actions that are not politically sustainable advance a current agenda item at the expense of future support" (Broniatowski & Weigel, 2006, p. 2).

2.4.1.3 Cultural sustainability

The conservation of cultural diversity entails reverence for customary practices and exploration of technological advancements, while also acknowledging the unique traits of diverse ecosystems, societies, and regions. The primary objective is to develop a comprehensive nationwide program rooted in communal social structure, safeguarding traditional customs, principles and emblems while simultaneously advocating for the constitutional privileges of marginalized communities (Serrão et al., 2020).

2.4.1.4 Economic sustainability

The search for local development through the efficient management of economic and natural resources, the results of which should benefit a large group of people and not just a few. Its goals are balanced economic development between different regions and different economic sectors, food security (which should be safe, healthy, and accessible), continuous modernization of production instruments, and solidarity economy, through the strength of producing social networks (Serrão et al., 2020). It mainly aims to improve the standard of living. In business contexts, it refers to maintaining the company profitability over time using efficient assets to that end (RMIT, 2017). Economic sustainability is focused on promoting economic growth and development while minimizing the negative impacts on the environment and society.

2.4.1.5 Human sustainability

Human sustainability includes improving areas like health, education, services, nutrition, knowledge, skills, and leadership. The aim is to improve and maintain capital in society, as the human lifespan is, unlike institutions, relatively short and finite, thus creating the need to invest in a person throughout their lifetime (Goodland, 2002; RMIT, 2017).

2.4.1.6 Environmental sustainability

Environmental sustainability relates to conservation of services and resources of present and future generations without affecting the health of the ecosystems that provide them. This includes five principles: conservation of biodiversity; social needs; capacity of regeneration; reuse and recycling; limitations of waste generation; and nonrenewable resources. These principles are all about preservation (biodiversity and energy), availability (basic need, services, jobs, raw materials), support (reuse and recycling processes), protection (of the regenerative capacity, harvesting rates), and improvement (limitations of nonrenewable energy and waste generation, prioritizing low-impact transportation, environmental quality) (Khan et al., 2021).

The environmental sustainability has a wide range, since it can be connected to local issues, like soil erosion or quality, air or water pollution, and water management in a specific location, or it can relate to global issues, like renewable energies or climate change (Ghosh, Westhoff & Debnath, 2019).

In this dimension, a more focused ecological view of sustainability, that proposes the use of the available ecosystems, can also be included, focusing on the least possible destruction, thus allowing nature to regain its balance according to the changes that are made. To make that possible, the preservation of energy and natural resources is essential, and it implies major changes in the way society consumes and produces. This type of sustainability aims at a safe development of ecological areas that are considered fragile, production respecting the natural cycles of ecosystems, as well as their ability to do so, and a special care in the use of non-renewable energy resources (Serrão et al., 2020). This dimension is all about the conservation and protection of natural resources and it's focused on reducing waste, pollution, carbon emissions, and promoting sustainable practices.

2.4.2 From the Brundtland Report to the United States Environmental Protection Agency (EPA) concepts of sustainability

The sustainability concept developed in the Brundtland Report has been influencing debate and policymaking globally over the years, as stated by Kates et al. (2005, p. 10). This concept emphasizes the interconnections between economic, environmental, and social issues, and calls for a holistic approach on sustainable development that incorporates all three dimensions. Furthermore, it stresses the necessity of equity and accountability between generations to attain sustainability.

On the other hand, sustainable development should be seen as a global goal, which does not seem to be compatible with the individualization of each country being able to create specific policies. Kates et al. (2005, p. 19) state that "much of what is described as sustainable development are negotiations in which workable compromises are found that address objectives of competing interest groups".

The Brundtland concept of sustainability, despite being recognized as one of the oldest and most robust, could be enriched with an inclusive and cross-cutting vision of policies, not just expecting it to be global. By promoting an almost nationalist concept of sustainability, one loses in responsibility and in knowledge. The production of heterogenous knowledge can difficult the attempts to its globalization later.

> Sustainable development thus requires the participation of diverse stakeholders and perspectives with the ideal of reconciling different and sometimes opposing values and goals toward a new synthesis and subsequent coordination of mutual action to achieve multiple values simultaneously and even synergistically. (Kates et al., 2005, p. 20)

Later, in 1992, the Rio Declaration followed the same structure, where we can read that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UNCED, 1992).

On one hand, the Brundtland Report places greater emphasis on the notion of sustainable development and underscores the requisite for international collaboration. On the other hand, the Rio Declaration articulates particular tenets to facilitate the accomplishment of sustainable development goals, placing a significant accent on the individual responsibility of each country in advancing sustainable development. "In many aspects, the Rio Declaration falls short of the highest standards set by predecessor instruments, and a number of well-accepted doctrines were lost or watered down" (Wirth, 1995, p. 599).

Furthermore, it is noteworthy that the Rio Declaration encompasses tenets pertaining to particular concerns, including but not limited to the promotion of transparency and citizen engagement, which are not addressed in the Brundtland Report.

Whilst the definition of sustainability provided by the Brundtland Commission is concise and clear, it may be considered overly theoretical when seeking to develop sustainable program initiatives and operational management strategies. Several entities have formulated operational characterizations that are compatible with their distinct objectives and principles. Frequently, these are founded on the principle of the "triple bottom line" of sustainability, encompassing the environmental, economic, and social dimensions, with varying degrees of significance attributed to each of them (Fiksel et al., 2012).

Funtowicz and Ravetz (2003) stress that the definition of sustainability provided by Brundtland lacks the nuance and comprehensiveness required to fully address the complex issues posed by sustainable development. In their words, "notwithstanding its numerous strengths, the Brundtland Report falls short as a theoretical and practical reference for sustainable development" (Funtowicz & Ravetz, 2003, p. 9).

In the scope of this work, the sustainability of the Brundtland Report lacks integrating the cultural, social and human mechanisms that allow in a structured and informed way to anticipate. This concept individualizes stakeholders (in this case, the countries) while expecting a global implementation of the sustainable development goal.

In the United States, the Environmental Protection Agency (EPA) approaches the concept of sustainability as "the ability to maintain or improve human well-being and ecosystem health over the long term". This definition emphasizes the interconnectedness of human well-being and ecosystem health, highlighting the need for sustainable practices that balance economic, environmental, and social considerations (EPA, 2022).

The Environmental Protection Agency of the United States presents in their website:

> Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations. (EPA, 2022)

According to Redclift (2005), EPA's definition of sustainability is excessively imprecise and all-encompassing, rendering it impractical, and neglects to tackle the fundamental social and economic factors that are vital for the foundation of sustainable development. The author posits that a paradigm shift towards a more rigorous and evaluative methodology is required to comprehensively comprehend the concept of sustainability.

On the other hand, it already encompasses an idea of anticipation which calls for a different responsibility, but it is quite limited when it is restricted to the planet (as a place and resource, not as everything it sustains, namely the economic, social, human components, etc.), that is, the actors who are part of it are missing.

Some authors argue that social sustainability is a stand-alone pillar that is built independently (Boyer et al., 2016, p. 1), arguing that it is even a precondition, thus it does not only reduce too much and circumscribes sustainability to the social component, but also assumes the social as a basis that already exists, and not as a process that is built throughout the process.

In the case of EPA's concept, we can observe that it lacks an integrative philosophy of actors and stakeholders and responsibility in the social sphere. It is too closed a concept because it indexes survival and well-being to the natural environment and how the Human-Nature ecosystem can exist together. In fact, one of the main strengths of EPA's definition of sustainability is its focus on the long term. While emphasizing the need for practices that maintain or improve long-term well-being and ecosystem health, the definition helps to ensure that sustainability is seen as a dynamic and ongoing process, rather than a static one. This long-term perspective is essential to ensure that sustainable development efforts are sustainable in themselves and not limited to short-term gains that may have negative long-term consequences. However, this definition does not sufficiently recognize the historical and structural factors that lead to unsustainable practices, such as economic inequality and social injustice, and it is too open to interpretation. Nevertheless, it is a useful starting point for understanding the complex and interconnected nature of sustainable practices.

Sustainability is a concept based on a group of tactics and actions that are intended to maintain the Planet Earth’s vitality and integrity through the preservation of its materials, with all the physical, chemical and ecological elements that make possible the existence and reproduction of life. Sustainability also includes meeting the needs of present and future generations while continuing the expansion of the human civilization’s potentialities (Boff, 2017).

One should acknowledge that this concept emerged in Biology, with its primary definition being the quantity of changes that the environment can undergo without being totally destroyed. It was later lent to other sciences, such as Sociology, without neglecting the environmental concern, starting to be considered as the ability that a society must respond to its needs, without exceeding the capacity of the environment (Serrão, Almeida & Carestiato, 2020).

Following that view, it's said that sustainability matters in social and economic, political and legal changes, in which they need to act in the search for balance and preservation of the environment. On the other side, the growing awareness of responsible citizenship regarding rights and duties goes beyond individual interests, when thinking about the duty of each one in the construction of a less consumerist collectivity, solidified in the standards of sustainable and balanced development (Cansi & Sobrinho, 2019).

Nevertheless, nowadays, the term sustainability is also widely used to define responsible strategies, and that is an emerging discussion on this topic and its different concepts and dimensions studied by various authors and committees, bringing different and even extreme positions (Daedlow et al., 2016; Goodland, 2002).

In parallel, sustainable development is based on the articulation between three axes: economic growth, nature preservation, and social justice. The economic model that is currently used and that leads to the depletion of natural and economic resources of the environment does not agree with the sustainability concept (Pluvis & Robinson, 2009; Serrão et al., 2020).

Goodland (2002) reinforces the importance of being specific about what type of sustainability one is referring to. The author identified four types of sustainability (Human, Social, Economic and Environmental), which he considers to be totally different and not to be merged, although, in some cases, they overlap.

On the other hand, according to Kates at al. (2005), cited in Adger & Jordan (2009, p. 9), the malleability of the Brundtland Report's sustainability concept

> Allows it to remain an open, dynamic and evolving idea that can be adapted to fit (...) very different situations and contexts across space and time (...) its openness to interpretation enables participants at multiple levels (...) within and across activity sectors (...) to redefine and re-interpret its meaning to fit their own situation.

One of the first references to three of the axis/pillars of sustainability already mentioned (economic, environmental and social) comes from the Brundtland Report, where we can read that

> No single blueprint of sustainability will be found, as economic and social systems and ecological conditions differ widely among countries. Each nation will have to work out its own concrete policy implications. Yet irrespective of these differences, sustainable development should be seen as a global objective. (WCED, 1987, p. 39)

Also, Boyer et al. (2016, p. 15) state that the "value of an integrated vision of sustainability that does not exclude certain experiences or domains from what is ultimately a holist and systemic concern". One can see "a major shift in international commitments to both sustainability and development" since 2015, when the "world committed to 17 sustainable development goals (SDGs), and a historic new agreement on climate change was signed" (Scoones, 2016, p. 294).

A more integrated view on sustainability can be found in research by Daedlow et al. (2016, p. 1), who affirm that "assessing the manner in which research is conducted is a key mechanism for leveraging a transformation in sustainability (...) the research process itself merits a full consideration of its responsibility towards societal goals and values". Knowing that there is a functional relationship between sustainability and justice, it's important to participate in the discussion about how this relationship is structured, and the way it affects the strategies and priorities that follow the concept of sustainable development, like research (Langhelle, 2000).

Either it’s sustainability itself, its domains, the relation with governance, or how it can be affected by the research process, "sustainability is a necessary condition for most things in the future" (Langhelle, 2000, p. 297). There is no mystery that underlies sustainability. It can be better explained as "a state whereby what is to be sustained". For example, human development "is genuinely sustainable in the long term. The issue becomes more controversial when we ask: precisely what should be sustained?" (Adger & Jordan, 2009, p. 4).

Sustainability is a broad concept that can be interpreted and applied in different ways depending on the context and the specific goals aimed to be achieved. In a high-level view, as we have read before in this chapter, the concept of sustainability can be described as the ability to meet the needs of the present without compromising future generations from being able to do the same. This includes the preservation of natural resources, the reduction of waste and pollution, and social and economic equity.

Multiple authors (Adger & Jordan, 2009; Serrão et al., 2010; Pluvis & Robinson, 2019) and also governmental institutions such as the EPA (2022), have discussed and applied the concepts of sustainability; nevertheless, it is urgent to improve it, integrating to its core methodologies that will allow it to improve on its own, in order to become a stronger and largely accepted concept.

These previously mentioned concepts (Brundtland, Rio Declaration, EPA) have one common structure, that is the maintenance of an element (whether social, environmental or economic) while neglecting the integration of the complete ecosystem and how to accomplish it with responsibility. It lacks a more integrative view on the development of the concept, as each definition seems too individually built.

The discourse surrounding sustainability has been accompanied by an awareness of its potential limitations in addressing responsibility adequately. A pertinent contribution to this discussion emerges from the work of Larsen and Gujer (1997, p. 9), who offer nuanced insights into the contours of future development and the imperatives of sustainable urban water management. According to the mentioned authors, it is crucial to emphasize the necessity of reevaluating the extent of services to be provided. Larsen and Gujer strongly propose a shift away from established technological norms, encouraging a deliberate transition towards novel domains of service delivery. Additionally, their request for investigation in the sphere of urban water management encourages an exploration of alternative approaches beyond the limitations of current technologies. This directive implies that the new approaches should be subject to resource constraints, based on subjective evaluations, and requiring complex political negotiations.

To proactively address the transfer of challenges across different locations and timeframes, it is important to emphasize the urgent need for broadening spatial scales and extending the temporal trajectories of relevant systems. A critical element of their storytelling revolves around the necessity for recognizable markers of sustainable development. Here, the concept of "tolerable variations in state variables" becomes significant, promoting the diligent observation of variables like biodiversity to clarify the direction of developmental initiatives Larsen and Gujer (1997, p. 9).

The shift from a reactive to proactive approach is widely recognized as a fundamental cornerstone of effective and sustainable urban water management. The writers highlight the importance of adopting proactive strategies that prioritize the efficient use of resources, aiming to reduce resource exploitation across various fields. Larsen and Gujer (1997) also emphasize the importance of strategically integrating emerging technologies into the current urban water management infrastructure. Their claim is contingent upon acknowledging the prolonged lifespan of these infrastructures and the inherent uncertainty of future developments. Therefore, the authors support transition scenarios that provide ample flexibility, enabling adaptable integration.

2.5 Conclusions

Water management for the future should be considered an even higher, as well as developing solutions to improve it, moving from reactive management to governance The achievement of sustainability proves challenging, due to the intricate interplay between the various global economic forces and the uneven distribution of political power. The global reliance on a carbon-based economy has led to unparalleled environmental impacts, as the utilization of natural resources such as water, alongside land degradation, becomes increasingly prevalent. Geopolitical instability persists, due to ramifications of the carbon economy and the depletion of oil reserves in key locations. State and government authorities have strategically utilized their influence in resource allocation, particularly in the realm of oil, to bolster the prominence of capitalist pursuits (Adger & Jordan, 2009).

The available frameworks should be able to drive to the concept of water governance, which refers to "the political, social, economic and administrative systems that affect the use and management of water" (UN-Water, 2018, p. 2). It involves a range of activities and processes, including policy development, planning, regulation, decision-making and implementation, as well as stakeholder engagement and public participation (UN-Water, 2018). It increasingly recognized as the key to solving the complex challenges of water resource management, such as ensuring access to a safe and reliable water supply, protecting the ecosystem, and adapting to climate change (Bakker et al., 2018; UNESCO, 2015).

One should acknowledge that the concepts of sustainability and governance are interrelated (Adger & Jordan, 2009). Also, water governance is a complex and multifaceted concept that encompasses a range of political, social, economic, and administrative processes and systems which affect the use and management of water resources. It involves a wide range of actors, including governments, water users, civil society organizations, private sector actors and international organizations, working together to ensure sustainable and equitable management of water resources (Bakker et al., 2018; UN-Water, 2018).

Whether working for the government or in private sectors, managers must make decisions on water allocation. These decisions can be short or large in consequences for sustainability. The demand is continuously increasing, and the portion of supplies is diminishing, due to reasons such as demographic and climatic changes, that increase the stress on water resources. A more holistic approach to water management is urgently needed, as the traditional fragmented approach is no longer viable (UN, 2014). On top of that, the correlation between water and energy systems underscores the significance of adopting a comprehensive method towards water management, sustainability, and assessment of technology (Ishizawa et al., 2018).

In addition, there are severe changes to be made when it comes to patterns of production and consumption, since they can influence sustainable development. As stressed by Fleischer and Grunwald (2007), the current generation needs to be aware that:

a) The scarcity of several natural resources, such as uncontaminated water, fossil fuels and certain minerals, underscores the significance of optimal resource management, adoption of recycling practices and substitution of non-renewable inputs with renewable alternatives.
b) The finite capacity of natural resources such as the atmosphere, groundwater, surface water, oceans, and ecosystems underscore the imperative to curtail emissions and rehabilitate impaired environments.
c) The principle of both intra and intergenerational equity is an essential component of the concept of sustainable development that necessitates the assessment of how new technologies distribute risks and benefits among individuals and across the globe.
d) The matter of sustainability regarding participation results in implications for the mechanisms involved in the formulation of viewpoints and judgments in molding technology and its interfaces with the public.

3

THE ROLE OF TECHNOLOGY AND SOCIOTECHNICAL SYSTEMS

3.1 Introduction

The implementation of technologies for water use stands to enhance the sustainability quotient and reduce water footprints, thereby reinforcing the United Nations Sustainable Development Goals (UN, 2021).

This research delves into the pivotal significance of technological innovations and sociotechnical frameworks for effectively managing water resources. Throughout history, the integration of technology and human society has been inextricable and has been a catalyst for significant change in our management and interaction with water resources. To read the present scenario, it is imperative that we investigate the past of technology. Through an examination of the historical evolution of technologies pertaining to water, valuable insights can be gained regarding the transformative innovations which have impelled the optimization, distribution, and preservation of water resources.

3.2 Technology and digital solutions update: general concepts, risks and challenges

A widely accepted interpretation of technology postulates that it comprises a repertoire of instruments, procedures, and approaches applied towards accomplishing functional objectives. Per this perspective, technology serves primarily as a tool to achieve objectives and fulfill societal requirements. This perspective on technology has gained widespread recognition among scholars, with key figures such as Lewis Mumford characterizing it as "the amplification of human capabilities" (Mumford, 1934, p. 5). Likewise, Langdon Winner posits that technology encompasses "a conglomerate of instruments, techniques, and frameworks aimed at accomplishing pragmatic objectives" (Winner, 1980, p. 122).

To set standards on the concept, we can look at the Oxford Learner's Dictionary (2022), where "technology" is defined as "scientific knowledge used in practical ways in industry, for example in designing new machines". In the Portuguese Priberam Dictionary (2022), "technology" is the "science whose purpose is the application of technical and scientific knowledge for industrial and commercial purposes" and a "set of technical terms of an art or science" (translated by the author).

Even in 2011, Misa (2011) states that he did not find a simple definition of technology that would be able to truly convey the variety of his forms or that adequately emphasizes the social and cultural interactions, as well as the consequences that are essential to the concept understanding. This was the reason that led the author to development his own concept of technology, based in the four pillars ahead:

1. **"Science and Economics":** since the age of science and systems, it is common to believe that science is essential for technology and that scientific discoveries are the main drivers of technological innovations. The notion that social changes begin with science and those technologies are based on science is a fundamental principle of modernist thought. In this vision, science is the machine that drives the modern world. The vision of the linear model science-industry-society defines technology as a desirable instrument of economic growth. In the eras of trade, industry, science and systems and globalization, technological innovations have created economic growth and structural change (Misa, 2011).
2. **"Variety and Culture":** the unappreciated variety of technology indicates that we should pay attention to the potential of technology to change society and culture. By adopting a long-term perspective, one can see that historical actors can adopt the same technologies for different purposes. Agents of change mobilize technologies to promote, strengthen or preserve certain social and cultural arrangements. Here, the term techno-politics emerges, which refers to the strategic practice of designing or using technology to constitute, incorporate or fulfill political objectives. A giant experience in the use of technologies to shape political structures and social practices has been happening in Europe for decades. Technologies are not neutral tools. The presence of a particular technique or technology can change the goals and objectives of a society, as well as the way people think (Misa, 2011).

3. **"Displacement and Change":** displacement is an important dynamic of the interaction between technology and culture, which occurs when practices around an existing or potential technology have the effect of shifting alternatives or preventing open discussion about alternatives. Technological futures are also future politicians. The examples presented demonstrate the affirmation of a distinct purpose for technology and, consequently, a desirable direction for social and cultural divisions of the world, replacing alternative purposes for technology and alternative directions for social development. Displacement is the way societies, through their technologies, are directed by certain social and cultural paths. These paths and technologies are often challenged and, quite often, societies experience unwanted consequences of technology.
4. **"Disjunctions and Divisions":** there is a source of anxiety about technology when it comes to the worrying gap or disjunction between the regulatory expectations and what can be observed and experienced in the world around us. According to the author, technology is changing rapidly because we are constantly confronted with social, cultural, and economic changes in which technology is involved. The years following 2001 witnessed the deepening of major technology-mediated divisions around the World. Global trade remains accelerated, but the optimistic vision of a peaceful world has disappeared. It should be noted that there is a wider area of disjunction in technology, which is its role in the geographical, economic and cultural divisions of the world. A concern associated with this problem is the digital divide between wealthy societies, that have immediate access to computers, telecommunications and the Internet, and poor societies, which usually do not (Misa, 2011).

The European Space Agency ([ESA], 2022), also presents, yet another definition for "technology" as "the practical application of knowledge so that something entirely new can be done, or so that something can be done in a completely new way". Or even "the single attribute that defines Homo sapiens as a species: our ability to make and use new tools".

The immensity that encompasses the concept of technology makes it complex and to obtain a definition that truly represents its spectrum of influence and has a wide acceptance.

Technology a social process, a vehicle of communication and interaction of the society and access to services. On an operational view, technology is seen as a tool for efficiency, to improve process and to create and spread knowledge. Technology has a multi-dimensional role in our current reality (Kranzberg, 1986).

Before explaining the deep connections between the social ecosystem and technology, we should briefly get an overview of the Kranzberg Laws. This legacy work from Kranzberg plays an important role in exploring how technology is interconnected with science and social responsibility (Kranzberg, 1986, in Diogo, 2019).

- **1st Law:** Technology is neither good nor bad and not neutral. Technology necessarily interacts with the civilizational complex in which it moves. However, the results of this interaction differ depending on the specific economic, social, political, cultural, demographic and time contexts.
- **2nd Law:** The invention is the mother of necessity. All inventions, to take really effective and efficient, require the development of auxiliary technologies.
- **3rd Law:** Technology develops in "packages". Mechanisms are systems, they are coherent structures composed of interactive components.
- **4th Law:** Technological policies are decided, as a priority, based on non-technical criteria. Despite the weight of technical consultancy in charge of experts, decisions on the development of a particular technology are made, mainly, based on criteria that are outside the technology itself.
- **5th Law**: The whole of history is important, but the History of Technology is the most relevant area. The characteristics of contemporary society, marked by the processes of globalization, place technology as its fundamental pillar. Knowing their mechanisms and functions therefore becomes crucial.
- **6th Law:** Technology is a human activity; the History of Technology itself is a social fact, so it must always be understood in the context of a broader civilizational "broth". Although it is possible to speak of a "technological determinism", the choices are ultimately human.

The aforementioned rules situate the work on the point of discussion the social purpose of technology and how it interlaces with "invention", development, and history of the society. To note the fact that these rules were written in 1986 and although the technology evolution was immeasurable from then to now, they are still identifiable at present and provisionally in the future. The role of history in the interpretation of the present and the future plays a fundamental role when the theme is technology.

There is a complex relationship between technology and society, according to Rosenberger and Verbeek (2015), technologies are not inherently present but are actualized through specific practices and are positioned within distinct environments. Additionally, the significance and principles attributed to technologies are not inherent to the technology per se, but rather are formed through social processes and susceptible to transformation throughout time. The intricate interplay of technology and society manifests itself in debates concerning the ethical consequences of progress in the technological sphere. As highlighted by Brey (2010) the goodness or badness of technology is not inherent, rather its outcomes may vary depending on its usage and the sociocultural setting in which it is applied. This underscores the necessity of conducting a meticulous analysis of technology and taking into account its wide-ranging socio-ethical consequences.

Mayr (1986) stressed that technology should be perceived as an outcome of not only scientific knowledge, but also a multitude of social and cultural influences, such as religion, ideology, and social stratification. Mayr sought to refute the notion that technology is a value-free, objective mechanism solely motivated by scientific advancement and rationality, by placing greater emphasis on its historical and cultural implications.

The theory of technological determinism posits that social change is primarily driven by technology, whereas social constructionism asserts that technology is molded by social and cultural factors (Bijker, Hughes, and Pinch, 1987, p. 17).

On the other hand, according to the principles of social constructionism, technology is influenced by various social and cultural elements. This viewpoint asserts that technology cannot be viewed as a neutral entity, but is rather intertwined with the cultural and social contexts in which it is utilized. According to the perspective of social constructionists, technology is not an isolated entity but is rather intricately linked to political, economic, and cultural factors, and it is common for the evolution and implementation of technology to be impacted by these very factors. Based on this viewpoint, technology does not have a predetermined outcome, but is a product of social and cultural discussion and debate (Bijker et al., 1987, p. 17).

Ramanathan and Gupta (2017) suggest that water management technologies are influenced by various elements, such as economic, social, and cultural drivers, and the interplay of these drivers with the natural surroundings. Hence, the efficacy of water management technologies lies in not just their technical prowess, but also their social and cultural suitability.

According to ESA (2022), scientific research can origin new technologies, essentially due to the revelation of new knowledge from which technologies can avail. On the other hand, recent technology can also give a "technology push", which consists of providing scientific exploration an opportunity to progress. It's very uncommon that a scientific result or an idea by an engineer can be easily or directly rendered as a product or usable idea and, in this way, it's a step-by-step process when it comes to developing the initial invention to an actual usable technology. By completing each step, the underlying ideas are validated, and a greater understanding of the process involved is gained, testing it against reality.

3.2.1 Sociotechnical systems

Sociotechnical systems are commonly defined as intricate socio-material constructs consisting of diverse assemblies of individuals, objects, infrastructures, scientific study, cultural classifications, regulations, and natural reserves (Hess and Sovacool, 2020; Urueña, 2022)

This concept of sociotechnical systems under consideration incorporates technological artefacts as constituents within the multiplicity of entities that, in a multifariously assembled manner, comprise the amalgamated socio-material environments in which our existence is structured and progresses (Urueña, 2022). Sociotechnical systems are a "social construction of technology, large technical systems, technological practices" (Hess & Sovacool, 2020, p. 4).

History of Technology

Throughout history, innovations in technology have significantly contributed to advancements in human society and the enhancement of our standard of living. The past of technology lays the groundwork for technological advancement by furnishing an abundant array of information and motivation which can be harnessed to develop fresh and enhanced technologies. (McKenna, 2018, p. 4).

Even before that, Nyer (2016, p. xi) also explained that the interplay between technological innovation and cultural values and beliefs is a two-way process, with each influencing and being influenced by the other. the author also recognizes the importance of comprehending this dynamic correlation to tackle existing social and environmental predicaments and underscores the utilization of technology in underpinning power dynamics and disproportions.

If we go way back, we will find that technology has it genesis within the communities of Homo Habilis, taking back to until 2 500 000 years ago, when it was first transformed, intentionally and with a purpose, a rock in a tool. These initial gestures followed by the Egyptian techniques of construction and writing in the Antiquity. Where we begin to see the emerging of technologies for water, the shadoof, an ancient water pumping technology originating in Egypt approximately 2000 BC, stands as one of the earliest documented methods in the field. The shadoof was a rudimentary contraption comprised of a lengthy shaft affixed with a receptacle on one terminus and a balancing mass on the other. The user can proceed to submerge the bucket onto a well or river, collect water, and subsequently activate the counterweight mechanism to elevate the filled bucket to the uppermost layer. The technology facilitated the extraction of water from deep wells, proving to be an essential solution for regions that have restricted access to surface water sources (Ferguson, 1987). By 300 BC Greece and Rome showed an early use of a water wheel that was a hydraulic device featured a substantial rotating wheel, complete with affixed paddles or buckets. The wheel was installed within a body of running water, leveraging the power of its velocity to set the wheel in motion, thus transferring water from the river to a neighboring aqueduct or irrigation channel. According to Needham (1986, p. 391), around 200 BC, the chain pump was invented in pre-modern China. The mechanism of the chain pump involved a succession of linked receptacles that were propelled by a chain driven by the force of humans or animals. The process involves the immersion of the buckets into a water source, such as a well or river, where each bucket would ascend and collect water.

After the Classical civilizations of Greece and Rome invented some mechanisms, like the watch, and more heavy mechanisms like levers, with Arquimedes math was introduced in the service of technique. In the Medieval Age there were two great types of technical evolutions: with materials (agriculture; mill as a central element of an energetic system, machines for textile and metal) and symbols (construction of cathedrals with new techniques). In the Renaissance, technology and science had a boom because science was considered important in solving technical problems and the technique was seen as a way/method of understanding and dominating the world (Diogo, 2019).

One should acknowledge that the learning process has happened since the 14th century, when the court started implementing the concept of documentation. This innovation would become responsible for the history from then on, because if it is not documented then it is not real technology. Some technology developments were lost over the history due the loss of records (Misa, 2011).

In the XVI century, with the rise of a commercial era and the navigation, innovations were made in the ship design, but the most relevant innovation was the manufacture of high-precision nautical compasses, maps, and chronometers. Moving fast to the XVIII century, with the Industrial Revolution, incising the need of human power and strength some technology innovation in tools was presented for the industry like rotary motors and the use of hydraulic pressure. By the XIX century there was transportation Revolution, whether of people, goods or even signs, with the development of railway and road lines, but also of the telegraph and telephone. This was followed by a great evolution on science with an example of the development of tar that resulted from waste of the coal industry. The concept "patent" emerged, and all evolution was accelerated due to a clear rise of competition. In the early XX century, innovations focused on perfecting the previous results and materials. After that came the World War II and a negative vision was built around the technology system, because of the impulse of the events of Hiroshima. The notion of the dichotomy between conflict and progress is also evident in this period. From 1970 to 2001 there was the rise of a global culture, the perfecting of the concept of global society, greatly boosted by the start of marketing of the World Wide Web in the 90s, which quickly began to be more than just a tool to send and receive data but also enforced the concept of network and new languages. A few years after arrives insecurities associated with the Internet, the use of technology for manipulation and hacking (Misa, 2011).

3.2.2 Digital Transformation and platforms

Before moving forward there is the necessity to distinguish two concepts: Technology and Digital Transformation.

On one hand, Digital Transformation is the introduction of technology into processes and working methods to make them faster and more efficient, by introducing a digital layer of websites and mobile applications (Ferreira, 2021). It refers to "anything from IT modernization to digital optimization, to the invention of new digital business models". This concept is "widely used in public-sector organizations to refer to modest initiatives such as putting services online or legacy modernization" (Gartner, 2022)

On the other hand, Technology refers to "the practical application of scientific knowledge, particularly in industry". Technology can be described as tools, methods and techniques that solve problems, create new products and services, or improve on existing ones. Technology includes all types of tools and techniques, including electrical, chemical, and mechanical processes (Bansal & Kumari 2016, 2016).

Digital refers to the use of digital devices such as smartphones, tablets, computers and other technologies that rely on software and computer code to function. This includes the internet, mobile apps and social media platforms. Gartner, a global research and advisory firm, defines digital as "the application of technology to create new business models and products, or enhance existing ones." (Gartner, 2022)[16]

Currently there are a great deal of emerging digital innovations covering the technology landscape, like the Internet of Things (IoT); BigData; Blockchain; Artificial Intelligence (AI). Over the last years we also watched the rise of the low code platforms (tools to facilitate coding) like

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[16] For more on Digital, see the Gartner Glossary at https://www.gartner.com/en/information-technology/glossary/digital.

Outsystems, Mendix or GeneXus. All of those bring a whole set of databases, distributed computing, cryptography, computer network, security and privacy (Truong & Sun, 2019).

A platform is a product that serves or enables other products or services. Platforms (in the context of digital business) exist at many levels. They range from high-level platforms that enable a platform business model to low-level platforms that provide a collection of business and/or technology capabilities. Platforms that enable a platform business model have associated business ecosystems. They typically expose their capabilities to members of those ecosystems via APIs. Internal platforms also typically expose their capabilities via APIs. But they may offer other mechanisms, such as direct data access, as required by the products that consume them. (Gartner, 2022)

In a more objective view, a digital platform is a

> Digital service that facilitates interactions between two or more distinct but interdependent sets of users (whether firms or individuals) who inter-act through the service via the Internet. This broad definition includes platforms of different types across different domains of application such as for example search engines, app stores, social media, gig work, marketplaces, dating, music, video sharing and so on. (Nicholson et al., 2021, p. 863)

The 2018's World Water Forum, with the theme "sharing water", was presented a platform called "Your Voice" allowed citizens to share ideas, experiences and solutions and suggestions. This shows how technological tools can be appropriated by managers for the day-to-day of administration, plans and programs and through policies, allowing public consultations, participation, open data, sharing, participation, among other actions (Cortese et al., 2019). This could have been an actual platform to give voice to citizens, development of meetings and interactions, but it was abandoned early in 2008. If we check the website, it is barely still online but the last posted information goes back to that year.

Innovation platforms' proposed value is their technological foundation for complementary innovation. Complementors, like customers or third-party developers, don't have the need to develop such foundation to create innovative products or services (Böttcher et al., 2022).

In the last 10 years, the number of digital platforms providing services increased wildly in different segments, with some great engagement and success records like LinkedIn or Airbnb. In Table 1, an overview of different types of platforms is brought here and an example for each was development in the work of Böttcher et al. (2022).

Table 3 - Example of types of platforms

Example	Definition
Airbnb	Transaction platforms serve as intermediaries for exchanges of good, services or information (Cusumano et al., 2019 in Böttcher et al., 2022)
Microsoft Azure	Innovation platforms facilitate the development of complementary products or services that add functionality or assets to the platform (Cusumano et al., 2019 in Böttcher et al., 2022)
Android	Hybrid Strategies combine intermediary function and complementary innovation to integrate transaction and innovation platforms (Cusumano et al., 2019 in Böttcher et al., 2022)
Alibaba	Subscription models capture value through lump-sum fees for market access (Armstrong, 2006 in Böttcher et al., 2022)
Groupon	Interaction-based models capture value through fixed or proportional fees per interaction (Weyl, 2010 in Böttcher et al., 2022)
Facebook	Data monetization strategies use the intangible value of that as a primary asset by selling it, converting it into other tangible benefits or avoiding cost (Najjar & Kettiger, 2014 in Böttcher et al., 2022)
Apple iOS	Coring implements elements (technology, product or service) in the platform's core that solve problems of complementors or costumers (Gawer & Cusumano, 2008 in Böttcher et al., 2022)
Uber	Tipping builds momentum by developing unique and hard-to-imitate features (Gawer & Cusumano, 2008, in Böttcher et al., 2022)
LinkedIn	Platform envelopment extends the platform’s original functionality to enter and adjacent market to bundle functionalities on one platform (Eisenmann et al., 2011, in Böttcher et al., 2022).
Quealth	Survival is defined as the persistence of the digital platform
Glase	Failure is defined as the discontinuance, bankruptcy or retrenchment of the platform

Böttcher et al., 2022.

A study by Nicholson, Nielsen and Sæbø (2021, p. 866) found that "The limitations of using categories and analytic frameworks derived from the experience of commercial platforms from the Global North for the design of systems that are intended to protect vulnerable populations often in the contexts of the Global South".

These authors underlined the United Nations High Commissioner for Refugees transition program to an open innovation platform that is focused on identification, value creating and platform governance.

Recently, the IUCN presented a platform named H2KNOW - The Water Knowledge Platform[17], with the goal of centralizing existing knowledge, tools and data, “and combine this with new approaches to build flexible, accessible, and impactful knowledge products” (IUCN, 2022).

This platform aims to follow an iterative learning strategy to identify what type, format and subject(s) for knowledge exchange and learning ‘gain ground’, and how knowledge chains have influence through networks and the broader knowledge system for water; accelerate the translation of knowledge on water resource management into action, in terms of how to implement activities, build, enhance, and learn from capacity creation actions, and how new the knowledge and communication approaches and tools can improve understanding; develop new analyses of the ’right’ knowledge to address constraints to sustainable river basin management (IUCN, 2022).

With this project, the IUCN (2022) expects that this platform will make it possible to "identify and accelerate the implementation of solutions for sustainable river basin management though adapting existing knowledge with new communication tools and approaches".

The mentioned tools and approaches are:

- "Background papers, framing existing and current knowledge for current policy debates and regional dialogues on particular challenges" (IUCN, 2022).
- "Issues briefs on the shape of things to come – what is new in global water governance discussions, and what does this mean, and how can existing knowledge be packaged to help provide experience into these new areas" (IUCN, 2022).
- "Upgrading communications: using new tools and methods that can move static knowledge products into more dynamic learning tools such as infographics, games, other media, providing information into new discussions with more diverse and broader partnerships" (IUCN, 2022)

3.2.3 Risks and challenges of digital solutions

This section will bring to the attention the most talked about risks and challenges nowadays related to the rise of technology and digital solutions, which we will find mostly related to data and security.

[17] https://www.iucn.org/theme/water/our-work/thematic-work/h2know-water-knowledge-platform

> Although our technological advances have yielded manifold benefits in increasing food supply, in providing a deluge of material goods, and in prolonging human life, people do not always appreciate technology's contributions to their lives and comfort. (...) The public's perception of technological advantages can change over time. (Kranzberg, 1986, p. 547)

Over time, technology has replaced human effort, which, while good for productivity growth and overall growth, is detrimental to workers who lose their jobs (Cansi & Sobrinho, 2019). This can be called a fear of innovation, a fear that machines will take human places and robots will take control.

This section will bring to attention three rising concerns when it comes to digital: data protection, data ownership, and cybersecurity. It the case of this research, it is important to create an awareness on this topic to make it possible to define a novelty in anticipatory governance.

3.2.3.1 Data protection and ownership

As the technology evolves, more and more devices are connected, more and more information is stored, and about almost everything, entities from all scales, users from all profiles, get deeply attached to using services that collect, store and share data. With this growing demand, the quantity of data is increasing exponentially and with that rising concerns with data protection and its actual ownership. On the other hand, as the technology evolves for the good, also evolves for the bad, and the threats to data vulnerability also grow and get more efficient.

In 2016, the European Union adopted a package of measure to be prepared to the digital with the launch of the General Data Protection Regulation. This regulation has the objective to protect "natural persons with regard to the processing of personal data and rules relating to the free movement of personal data"; "fundamental rights and freedoms of natural persons and in particular their right to the protection of personal data" and applies to "the processing of personal data wholly or partly by automated means and to the processing other than by automated means of personal data which form part of a filing system or are intended to form part of a filing system".

Data ownership is the "possession of complete control over the data and its rights including, but not limited to access, creation, generation, modification, analysis, use, sell, or deletion of the data, in addition to the right to grant rights over the data to others" (Asswad & Gómez, 2021, p. 2). This position is also shared by Penev (2019), who classifies data ownership as an oxymoron, since it can't be done an actual copyright (ownership) over facts or ideas, and for that reason it isn't under any rights and/or law.

Data owners are defined as the ones responsible and accountable for the quality of data, if seen from a data and information management point of view. "On the other hand, data ownership is defined often as the possession of complete control over the data and its rights, including the right to grant rights over the data to others" (Asswad & Gómez, 2021, p. 1).

Meanwhile, Nemzow (2022, p. 2) brings the theory of the ownership in the commons, which basically defined a shared partition of a property (inventors, users), and explains that data "isn't one thing with a single purpose since bulk data can be sliced and diced recreating existing user data or new data exposing user's habits. It lasts forever. It exists in backups. It's a time machine blurring the tangible into intangible. It's the fallow topic underlying security, privacy, anonymity, and competitive resources blurring any future in security."

In their study, Asswad & Gómez (2021) found that there are a set of characteristics as aspects that need to be assured in order to embrace the concept of data ownership. The questions to be considered are data possession; what the rights over data are; control possession; granting rights and responsibility for data; with foundations like legal aspects; ethical aspect; type of data; technical requirements and case requirements.

But these authors also speak about some kind of obscurity regarding the subject of data ownership, as it is not at all a straightforward concept. Although it has been mentioned in the literature since 1981 (Asswad & Gómez, 2021), nothing was ever done by any government to respond to the questions of data ownership, which according to Nemzow (2022) is part of the future basic needs for security.

On the other hand, there is the concept of data governance, which is "the specification of decision rights and an accountability framework to ensure the appropriate behavior in the valuation, creation, consumption and control of data and analytics" (Gartner, 2022) To this concept of data, one can add the concept of data-driven innovation (DDI), which consists on the "use of data and analytics to develop or foster new products, processes, organizational methods and markets. Data and analytics can drive both the discovery and execution of innovation, achieving new business models, products and services with a confirmed business value" (Gartner, 2022).

3.2.3.2 Cybersecurity

"Cybersecurity is the combination of people, policies, processes and technologies employed by an enterprise to protect its cyber assets". It can be optimized to various levels, defined by business leaders, "balancing the resources required with usability/manageability and the amount of risk offset. Subsets of cybersecurity include IT security, IoT security, information security and OT security" (Gartner, 2022).

3.2.4 Certification and patenting

According to the ISO/IEC/IEEE 12207 (2017)[18], a software life cycle should follow methods, procedures, and techniques to be tailored. Various methods can be used for assessing the level of maturity of a technology, including the classification of technology into distinct readiness levels and the utilization of patents to ascertain their life cycle stage (Baumann, 2017).

It is important to recognize that the correlation between patents and measures of innovative activity may exhibit variations across diverse sectors, industries, and geographical regions. The pertinence and importance of patents as a gauge for innovation may be contingent upon several variables, including the type of technology, the dynamics of the industry, the efficacy of the patent system, and the degree of patent activity within a particular geographical area (Murray, 2002).

One should keep in mind that, in order to procure a more comprehensive understanding on the notion of innovation, scholars and government officials often employ a diverse spectrum of supplementary metrics in conjunction with patents. The aforementioned measures encompass various aspects, including but not limited to expenditures incurred in research and development, publications emanating from research, citations obtained, trademarks, design registrations, investment in venture capital, as well as indicators pertaining to productivity, competitiveness, and economic performance (OECD, 2005).

On the other hand, established technologies frequently benefit from investment decisions. Particularly capital-intensive and sizable industries, like chemical, energy utilities, or automotive, can be seen as more conservative when it comes to innovation. Because fewer resources are required to make an invention marketable, less capital-intensive industries are tempted to adopt innovations more quickly (Baumann, 2017).

[18] ISO/IEC/IEEE 12207:2017 Systems and software engineering: "provides processes that can be employed for defining, controlling, and improving software life cycle processes within an organization or a project. To find more see: https://www.iso.org/standard/63712.html.

3.3 Water use technologies

As per the analysis of the United Nations (UN), the rising demand for water coupled with the exhaustion of freshwater reservoirs mandates the formulation and implementation of sustainable policies for water management (UN Water, 2021a). In light of this, multiple technological advancements have been introduced with the aim of improving water utilization and mitigating loss, encompassing drip irrigation, rainwater conservation, and intelligent irrigation frameworks. An exemplary illustration of modern irrigation systems is smart irrigation, employing advanced weather data and soil moisture sensing technologies to furnish precise amounts of water to plants and crops. The employment of such systems significantly minimizes water wastage while simultaneously augmenting plant health (UN Water, 2021b). Although the implementation and upkeep of such technologies entail considerable expenditure, they offer promising potential in terms of curbing water use and enhancing ecological viability (UN Water, 2021a). By implementing water conservation practices and enhancing operational efficiency, these technologies are in line with the United Nations' Sustainable Development Goal 6. This objective seeks to secure the accessibility and durability of water and sanitation services for all (UN, 2015).

There are multiple social challenges to be responded and it is getting clear that technology might be, if not the solution, a vehicle to get there faster. So it says the Change for Children Organization ([CCO], 2020), that "using technology for monitoring, reporting and for water rights advocacy will empower (...) citizens to engage in democratic processes and improve their access to water as a human right". The CCO has a project named "Technology for Sustainable Water Resource Governance" (Figure 2) with the goal to increase empowerment of "citizens, through the use of science and technology, to engage in democratic processes and improve access to water as a human right", "by putting technology in the hands of community water committees" (CCO, 2020).

The CCO (2020) also states that "technology can facilitate opportunity for engagement between citizen and state" and that "engagement in democratic decision-making processes will be realized through providing technology, training, and technical support to almost board members, community leaders and municipal technical personnel (responsible for sustainable water management).

Although, if we look closer at the strategy model (Figure 2), the technology insertions are related to hardware and customized apps to assist to water management and participation forums.

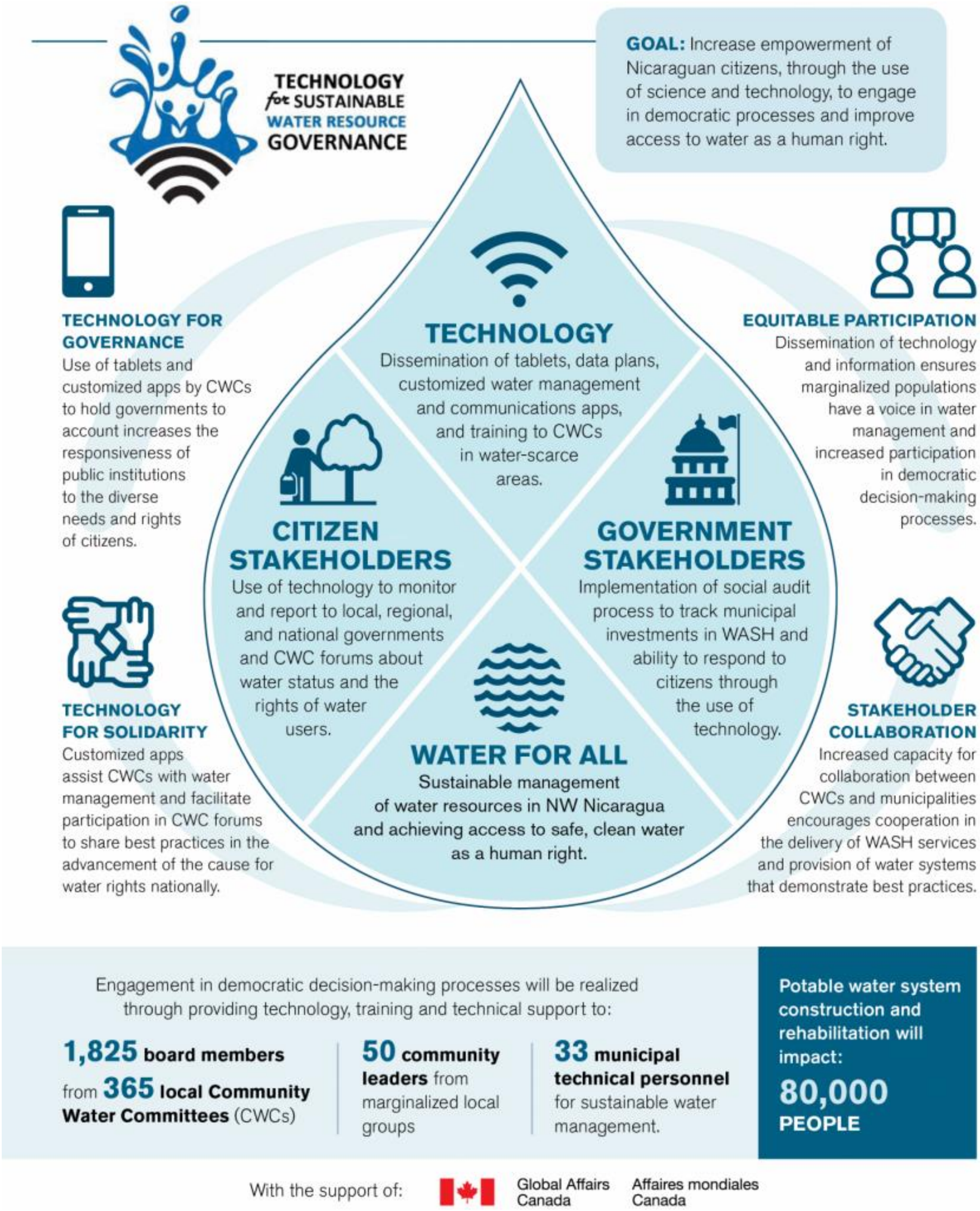

Figure 2 - Reproduction of The T Project Strategy and Technology for Sustainable Water Resource Governance of CCO (Change for Children, 2023)[19]

We can observe that CCO approach, for example, aims to empower equitable participation and to hear marginalized populations by providing hardware (like tablets) and

[19] Retrieved from https://changeforchildren.org/project/technology-for-sustainable-water-resource-governance/ in June 2023.

software (apps) to "share the best practices in the advancement of the cause for water rights nationally." (CCO, 2023)

According to Adamczyk et al. (2019, p. 2004), "a sustainable future is becoming the universal common good and ideology of the inhabitants of a digital world". This section will enlighten the relationship between technology and sustainability. The technology ecosystem will be elaborated in more detail in Chapter 5, but here in this section it's possible to find some views on how technology currently relates to sustainability and water.

Technologies are distinguished by Adamczyk et al. (2019, p. 2003) in "categories of factors designed to genuinely affect the processes of the social construction of certain narrations of sustainable development". When and if combined with sustainability, technologies could be used to benefit the environment, including answers like optimized energy system forecasting; demand-response infrastructure in transport, for example, analysis and automation for intelligent urban planning; local, national and international climate forecast; crop management; monitoring and transparency of the supply chain (Cansi & Sobrinho, 2019).

Fleischer and Grunwald (2007, p. 891) talk about the global problem that is water nowadays, mostly in developing countries, saying that "poor quality water and unsustainable supplies limit national economic development and can lead to adverse health and livelihood conditions. According to U.N. statistics for 2002, more than 2.6 billion people lack access to basic sanitation, and over 1.1 billion have no access to clean water. And in fact, "there are manifold reasons for these problems, most of them being results of the lack of political will, poor governance, institutional constraints and economic issues. But although these nontechnical issues are equally or often even more important than technical challenges, for some regions the situation can be improved by providing new technologies for water treatment and remediation".

The terms "Water 4.0", "digital water", and "smart water" may be employed interchangeably to delineate the interconnection between water resources and information and communication technologies (Alexandra et al., 2023). The recent concept of Water Management 4.0 leverages digital solutions to improve water management practices and support sustainability efforts. The World Economic Forum (2018) reports that digital transformation in water management can result in a decrease in operational costs as well as improved water quality, leak detection and maintenance efficiency.

Haasnoot et al. (2011, p. 1) stress that

> Development of sustainable water management strategies involves identification of vulnerability and adaptation possibilities, followed by an effect analysis of these adaptation strategies under different possible futures. Recent scenario studies on water management were mainly 'what-if' assessments in one or two future situations. The future is, however, more complex, and dynamic. It involves general trends and unexpected events in both the water and the social system.

IoT based solutions for water management require different types of communication technologies; in multiple cases, low-power solutions, such as Bluetooth (low-power), Lora, Narrowband IoT (NB-IoT). These communication technologies vary in range, maximum data rate, operating frequency, power consumption, and cost per device (Singh & Ahmed, 2021).

Singh and Ahmed (2021) propose the following as essential attributes for a water management system: a) low cost; b) low energy consumption; c) easy deployment and maintenance; d) water level and quality parameters; e) real-time monitoring; f) security.

3.3.1 Internet of Things (IoT)

These sensors and devices are used for collecting data on water use, quality, and availability. These tools allow us to monitor water use in real-time, detect leaks or other issues, and optimize water consumption (Sathishkumar et al., 2020). Bhaskar (2022)[20] also states that

> Most IoT systems collect data that is helpful to functional intelligence. To create an enterprise asset management system that can gather data on performance and reliability, operational efficiencies, water quality and pollutants, sensor monitoring can benefit from the use of IoT sensors.

These IoT sensors can also be used to detect hazardous chemicals, for instance in wastewater, and can be installed in equipment for management and maintenance, to "conduct data-driven remedial actions on demand using the information gathered" (Bhaskar, 2022).

Regarding its connectivity there are multiple options that are being used, for example or remote metering LPWAN (Low Power Wide Area Network); Nb IoT (Narrow Band) and LoRaWan are the most relevant. Also, 5G has a role on IoT and it "will enable enhanced communication and processing of images and sounds; the use of sensors will also evolve in the coming years, and so will integrated water cycle management" (Smart Water Magazine, 2019).[21]

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[20] Full article at Forbes.com: https://www.forbes.com/sites/theyec/2022/10/25/new-technology-trends-in-the-wastewater-management-industry/?sh=51c50b454199.

[21] https://smartwatermagazine.com/news/aqualia/new-reality-water-management-industry-40

3.3.2 Supervisory Control and Data Acquisition (SCADA)

These systems can be used to remotely monitor and control water treatment plants and distribution networks. They provide real-time data on water quality, flow rates and other parameters, so operators can quickly spot and fix problems (Khan et al., 2021). According to Schneider Electric [22](2022) these "systems monitor and control field operations across a widely dispersed infrastructure. From simple reservoir-level measurements and pipeline monitoring to emerging ERP-integrated optimization initiatives, our wired and wireless remote sites offer to help you keep up with regulations, rapid technology changes and industrial trends."

3.3.3 Artificial intelligence and machine learning (AI/ML) with predictive analysis

Using large computing capacity, it is possible to process large amounts of data and turning them into business insights. However, the process of transforming that insight into action in industrial processes is becoming more complicated due to the hyper connectivity and hyper integration of our systems. This is where AI and ML techniques can help management and decision-making evolve. Traditional analytics rely on assessment and descriptive reporting. Prescriptive and cognitive analytics are used to automate processes (Smart Water Magazine, 2019)

Predictive analytics is used to predict water demand, detect anomalies, or use water quality, and prevent major problems from developing. This allows water managers to make better decisions and improve their water management results (Vineeth et al., 2021).

3.3.4 Cloud-Based Data Management

In the cloud it can be stored and accessed a large amount of data about water quality, availability, and use by applying cloud-based data management tools. These data can be used to make better decisions and identify opportunities for efficiency and optimization (Kumar, 2021). Big data and cloud computing technologies integrated will provide "a global perspective of the integrated water cycle, with implications for overall efficiency" (Smart Water Magazine, 2019).

Technology integration, in general, can represent a crucial step toward sustainable water use. It is important to realize that technology alone will not solve the problem of water scarcity.

[22] https://www.se.com/ww/en/product-category/6000-telemetry-and-remote-scada-systems/

It is important to consider the socio-economic and political contexts within which these technologies were developed and used, as well as ensure that they are used in a way that promotes equity, justice, and environmental protection.

The above-mentioned technologies can be very promising, but they must be assessed over time to determine if they are producing the intended outcomes. Sustainable water use requires a multidisciplinary approach. This includes technological innovations, social and policy reforms, community engagement, and community engagement to create a more equitable and sustainable future.

3.3.5 Water management functions

The emergency of the governance for water has been largely recognized, even by the experience since their main goals for 2030 include "expand international cooperation and capacity-building support to developing countries in water and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies" (Table 4). Also, one of the goals was to "support and strengthen the participation of local communities in improving water and sanitation management" (UN Water, 2013).

Table 4 - Relationship between water functions and technology and its inputs/outputs

Function/Technology	Inputs	Outputs
Smart Metering	Real-time data on water consumption	Monitor and manage water use
Water Level and Quality Monitoring; Grey Water	Sensors; Data analytics	Monitoring pH; Temperature Turbidity; chemical contaminants
Predictive Analytics	Historical data; algorithms;	Forecast water demand; supply and potential issues
Water Leakage Detection	Sensors; data analytics	Locate leaks in water distribution networks
Irrigation Systems	Sensors; weather data; algorithms	Optimize irrigation practices
Warning Systems and Control Systems	Weather data, river flow monitoring, and hydrological models	Flood Forecasting and Early Warning; evacuation planning, and minimizing flood-related damages

3.3.6 Smart irrigation

Multiple water collection systems and irrigation techniques are available to source and distribute water for agricultural purposes. Nevertheless, the ultimate objective is to uniformly disperse water throughout the field, guaranteeing that every plant obtains appropriate amout of water needed. Contemporary irrigation systems have been designed to deliver water to either the crops or the root zone through direct means. These techniques optimize the utilization of water resources, ensure equal dispensation of water and conserve energy while effectively regulating irrigation (Gamal et al., 2023).

Regrettably, the practice of irrigation frequently results in water inefficiencies that could be largely decreased by effective management of irrigation systems (EPA, 2023). On the other hand, using native plants and regionally appropriate will decrease the irrigation needs and improve their own health (EPA, 2023).

Traditional irrigation technologies including flooding; furrow and manual watering are moving to more modern technique to be more efficient on water use. These new modern techniques include: Drip irrigation; Sprinkler Irrigation and Surface (Gamal et al, 2023).

To call the irrigation a "smart" system it requires the integration of inputs from the environment, soil and the crops.

Smart irrigation uses monitoring techniques that include the Soil; the plants and the Environment (Gamal et al., 2023). In the last 50 years innovations have been applied on the integration of new technologies in irrigation, namely in precision agriculture, from evapotranspiration and more recently using Machine learning, artificial intelligence and IoT (Gamal et al., 2023)

According to the Marin et al. (2017), the price of irrigation is way above what farmers can pay, so it urges to be used in the most efficient way possible.

3.3.7 Leak detection

Water transmission pipelines (usually in under-ground pipes) experience intermittent loss ranging from 20% to 30% of the water conveyed via them. These figures may further surge above 50% in aging systems, particularly those that have encountered ineffective maintenance practices. This highlights the necessity to mitigate the risk of leaks and reduce their impact by conducting comprehensive studies on leak detection technologies (El-Zahab & Zayed, 2019).

Sullivan and others (2015) state that public engagement is essential for identifying water leaks and reporting them to utilities or repair services. Public awareness campaigns and education on how to detect and report leaks can help reduce water loss as well as infrastructure damage.

3.3.8 Greywater

The wastewater from sources such as sinks, showers and washing machines is called "greywater". It can be treated and reused for non-potable purposes such as toilet flushing and irrigation. This technology combined with storing its product (greywater) can translate into a valuable resource of reuse systems (United Nations Environment Programme, 2017). Larsen et al. (2018) add that adopting these systems often requires a change of behavior and it may raise concerns about public health and safety, making this another example where public engagement and knowledge (education) can make this a beneficial solution and improve the adoption process.

3.3.9 Monitoring water quality

Multiple techniques are used to measure water level, pH, Dissolved Oxygen, Turbidity, Conductivity, Oxidation-Reduction Potential, Total Dissolved Solids, Chlorophyll, Temperature and Salinity (Singh & Ahmed, 2021).

3.4 Case studies: water management

The issue of water scarcity is a critical concern that impacts various sectors, including agriculture and urban regions, thereby underscoring the significance of urban areas as a key area of deliberation. The utilization of water as a resource has diverse applications and noteworthy sociopolitical, financial, and ecological implications. Technological advancements in governance can facilitate the effective resolution of issues pertaining to water scarcity and sustainability (UN Water, 2020).

In the next lines, we will look at examples from two of the most water-stressed regions in the world: Israel and Singapore (Marin et al., 2017; Octastefani & Kusuma, 2016).

Prior to the 1930s, irrigation practices in Israel and Palestine were predominantly reliant on community-managed local water sources, which were use by both Jewish and Arab populations (Feitelson & Fischhendler, 2016).

According to the report published by the World Bank (Marin et al., 2017), in order to ensure adequate and dependable water supply for its flourishing economy and attain water stability, a systematic approach has been adopted, encompassing institutional and regulatory modifications, as well as significant investment in water infrastructure, in accordance with the following framework:

- Strong demand management.
- Using aquifers as reservoirs.
- Reuse of treated wastewater for irrigation.
- Large-scale desalination of seawater.
- A national bulk water conveyance system.
- Major legal and institutional reforms.

Amidst a challenging condition of water scarcity, the adoption of a policy aimed towards sustainable water management has enabled Israel to attain water self-sufficiency, alongside significantly curbing the overexploitation of aquifers (Table 5). Significant progress has been made by means of a substantial improvement in the manufacture of non-traditional water sources, namely wastewater reclamation (since 1998) and seawater desalination (since 2006), in conjunction with the implementation of mandatory meter readings and a comprehensive legal system that enforces the government's authority over water resources (World Bank, 2017).

Table 5 - Water Innovations in Israel

#	Innovation	Results
1	National Water System to Connect all Water Infrastructure	Nationwide water transmission system responsible for delivering about 95% of the country's safe and usable water sources including surface water, groundwater, and desalinated water to regional distributors
2	Large-Scale Reuse of Treated Wastewater for Irrigation	The use of reclaimed wastewater has a great significance for farmers, as it currently stands as a primary water source, catering to over 40% of the country's irrigation needs. The reuse of wastewater accounts for more than 87% of the total amount being recycled.
3	Large-Scale Desalination PPP for Potable Water Independence	15 years after the implementation, the urban domestic sector accounts for 85 percent of

#	Innovation	Results
		national urban water consumption and contributes to 40 percent of the country's overall consumption with desalinated water.
4	Using Aquifers as Reservoirs	The aquifers function as reserve providers that mitigate potential evaporation losses which could have arisen if the water was contained within unsealed reservoirs.
5	Interception of Surface Water Run-Offs	The natural replenishment amounts to approximately 8% (estimated).
6	Promoting Crop Selectivity and Imports of Virtual Water	Increased the nation's food imports and decreased its dependency on domestic harvests.
7	Efficient Irrigation Technologies	Already in 1950s, Israeli enterprises played a pioneering role in conceiving and establishing efficient low-volume irrigation solutions, such as drip irrigation and mini sprinklers.
8	Demand Management and the Successful 2008 Campaign	All the public buildings and 55 percent of the houses were equipped with water-saving devices.
9	Creating a Supporting Environment for Water Innovation	Establishment of an industry-utility-university with water utility providers, private entrepreneurs, and government.

Adapted from Marin et al, 2017.

In conclusion, the Israel case shows that efficient water management under conditions of scarcity hinges on several key factors, including fostering public appreciation for the importance of water, implementing demand management techniques, and transitioning towards a pricing model that reflects the true cost of water. On the other hand, a robust enforcement mechanism, coupled with proactive measures to monitor and regulate the usage of aquifers, is considered a valuable tool for efficient water resource management. And efficient integrated management of water under scarcity conditions requires comprehensive, probabilistic, and timely data.

Singapore, also one of the top water-stressed regions in the world, was challenged to be self-sufficient in generating clean water and reducing dependence on external sources for water supply and has later earned a prominent international stature in water management and governance, thanks to its groundbreaking and cohesive strategies centered on tackling water scarcity while advancing the agenda of sustainability (Octastefani & Kusuma, 2016).

Singapore drew an all-encompassing approach towards water management, which entailed safeguarding and increasing their water sources, treating wastewater for reuse, using desalination methods, regulating water consumption, and carrying out public outreach and sensitization initiatives. They have successfully implemented a comprehensive water management strategy, leveraging a holistic approach. This has led to sustainable and self-sufficient water management, serving as a prominent exemplar for innovative and effective water management programs globally (Octastefani & Kusuma, 2016).

The Singaporean approach (Figure 3) involves several foundational tenets, such as efficient water ue, water recycling, desalination, NEWater, holistic water management, and ongoing research and development (Singapore Public Utilities Board, 2016).

Singapore is internationally recognized as a leading hub for business opportunities and knowledge in the field of water technologies, with an ecosystem of 180 water companies and more than 20 water research centers, as well as the Global Hydrohub and a model city for integrated water management. The Singapore government has spent 670 million USD in research and development to foster technologies in water management (SNWA, 2023).

The Singapore government framework for water management was developed over three key strategies, according to SNWA (2023):

- collect every drop of water.
- reuse water endlessly.
- desalinate seawater.

The key milestones and strategies that define the Singapore water story include (SNWA, 2023):

- diversification of water sources.
- water conservation and efficiency.
- NEWater.
- desalination.
- efficient drainage and flood management.
- research and innovation.

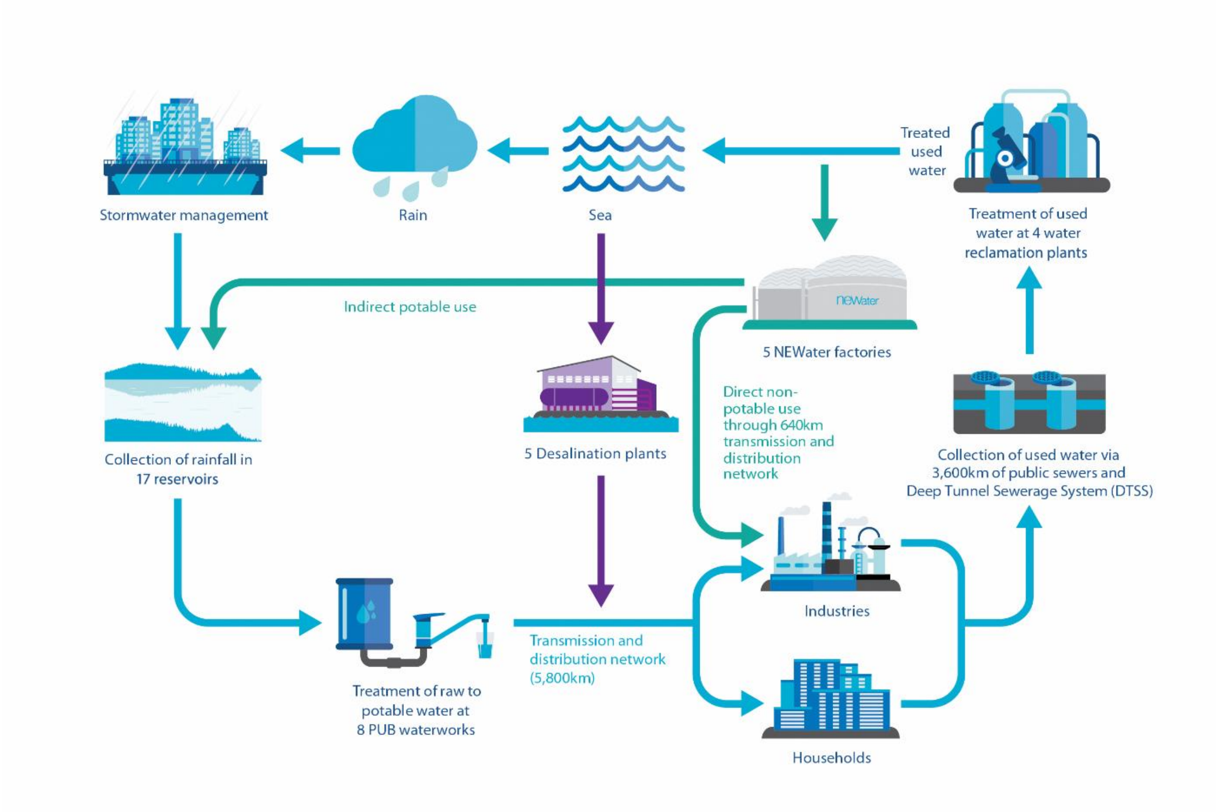

Figure 3 - Singapore Water Management Ecosystem (Singapore Water Story, 2023)[23]

Singapore has acknowledged the imperative to establish the diversification of water resources with the purpose of mitigating dependence on imported water. The nation has adopted a comprehensive strategy that incorporates four key elements, namely: domestic catchment water, externally sourced water, first-rate recycled water (NEWater), and desalinated water. The implementation of varied water sourcing methods has resulted in the development of a robust and enduring water supply infrastructure (SNWA, 2023).

On the other hand, it has incorporated water conservation and optimization of water use as paramount components in its overall water management strategy. The successful implementation of public education campaigns, pricing reforms, and state-of-the-art water conservation technologies and practices have collectively contributed towards a remarkable reduction in per capita water consumption. According to the data provided by the SNWA (2023), the daily household water consumption per person in Singapore has already decreased from 165 liters in 2000 to 141 liters in 2018. By 2030, the country intends to have it reduced to 130 liters.

[23] Retrieved from https://www.pub.gov.sg/PublishingImages/water_loop_updated_26012023.png in June 2023.

In the NEWater factories, the wastewater is subject to advanced purification techniques, such as microfiltration, reverse osmosis, and ultraviolet disinfection, to obtain ultra-pure, premium quality reclaimed water. The factories represent a vital source for several industrial applications and cooling systems, while also being suitably integrated with reservoir water to meet non-potable purposes (SNWA, 2023).

On its turn, for desalination, Singapore has built modern facilities that employ cutting-edge reverse osmosis methods to transform ocean water into safe drinking water. A substantial proportion of Singapore's water supply is met through desalination, thereby minimizing its reliance on externally sourced water (SNWA, 2023).

Following their moto "every drop count", Singapore has implemented effective drainage and flood management, incorporating sustainable urban drainage systems, extensive canal networks, and the utilization of underground storage tanks to ensure sustainable and efficient water management. This strategy aids in mitigating the risk of flooding during intense precipitation events and guarantees effective conveyance of rainwater to designated reservoirs (SNWA, 2023).

Octastefani and Kusuma (2016, p. 1) acknowledge that Singapore "is one of the best examples for innovative water management in the world".

3.5 Conclusions

Technology assumes a critical function in the society by providing a methodology to achieve functional goals and meet public needs. Academics and specialists have acknowledged that technology is a mechanism that enhances the potential of humans (Mumford, 1934), while encompassing an array of tools, methodologies, and techniques. Across the annals of time, technological breakthroughs have exerted a momentous influence on human progress, augmenting the quality of our social fabric (Misa, 2011).

Throughout the course of human history, a diverse range of technological innovations - from the water pumping mechanisms utilized in ancient Egypt to the various inventions of Greece, Rome, and China (Misa, 2011) have contributed to the evolution and transformation of countless facets of human existence.

Nevertheless, the expeditious proliferation of digital innovations has led to fresh hazards and complexities (Kranzberg, 1986). The preservation of data, the rightful possession of data, and the safeguarding of networked systems against malicious activities have emerged as significant apprehensions in the contemporary age of technology (Gartner, 2022). With the ever-increasing volume of connected devices and data being generated, it has become imperative to address concerns underlying data vulnerability, privacy, and ownership in an in-depth and comprehensive manner.

The processes of certification and patent acquisition hold significant relevance in the technological sphere. The software development process adheres to predetermined methodologies, protocols, and approaches as delineated in recognized benchmarks such as ISO/IEC/IEEE 12207. Patents are frequently employed as a metric of innovative endeavors; notwithstanding, their pertinence may fluctuate depending on the diverse industrial segments and geographic locations.

Within the domain of water management, technology has played a pivotal role in enhancing operational effectiveness and promoting ecological conservation. Sophisticated irrigation systems, like intelligent irrigation, incorporate meteorological information and soil moisture detection technologies to reduce water use and optimize plant growth. The utilization of digital solutions, namely Water 4.0 (Alexandra et al., 2023), presents prospects for the conversion of water management practices, resulting in reduced expenses, ameliorated water quality, and augmented efficiency.

The advent of the Internet of Things (IoT) has paved the way for acquiring real-time information pertaining to water consumption, quality, and accessibility (Smart Water Magazine, 2019). The acquisition of this dataset facilitates enhanced surveillance, identification of leakages, and refinement of water usage. When confronting the obstacles and fostering the opportunities presented by technology, it is crucial to take into account the ever-changing relationship among technology, culture, and ecology. Comprehending the correlation and instituting fitting countermeasures hold significant import in managing social and environmental concerns. By means of conscientious and foresighted administration, technology can function as a conduit for favorable transformation, bestowing autonomy to civilians, and enhancing availability of essential commodities such as water.

In the face of the intricate nature of the digital era, it becomes imperative to attain a harmonious equilibrium between leveraging the capacities of technology and mitigating its correlated hazards.

The adoption of these technological solutions holds the potential to augment sustainability and diminish water footprints, consequently bolstering the objectives of the United Nations Sustainable Development Goals (UN, 2021). Technology as process of co-creating knowledge and innovation since documentation was introduced (Ullman, 2017) and water management can leverage that.

Examples like Israel and Singapore show that is possible to integrate the management of resources, integrating multiple technologies. Those evolved from the problem, to designing a methodology to mitigate it, and to have at this point measurable solutions and results.

Upon conducting a critical assessment of prevailing methodologies for the maintenance of sustainability in water handling, it has become apparent that a fundamental change in perspective is indispensable to guarantee a conscientious and sustainable utilization of water resources. The synthesis of antecedent notions regarding Responsible Research and Innovation has illuminated the fundamental constituents that embody a commendable proposition of sustainable water utilization. This entails contemplating efficiency, equity, safeguards for the ecosystem, participation of stakeholders, and long-range strategizing.

4

RESPONSIBILITY PATHS THROUGH INNOVATION: FRAMEWORKS AND NEW APPROACHES

The scientific and technological innovation paradigms in the industrialized world have typically been built upon several fundamental premises. Among the factors to be considered are a distinct delineation of responsibilities among the key players in the process of innovation, prioritization of innovation in line with overarching macroeconomic imperatives, and unequivocal association of innovation with advancement and prosperity as a matter of course (OECD, 1972; Sarewitz, 1996; Eizagirre, et. al, 2017).

Over the past few years, there has been a notable uptick in the utilization of the following concepts: responsible development, responsible research, and responsible innovation. These terms demonstrate significant integration as they address a range of critical concerns in the fields of engineering ethics, participatory decision-making, technology assessment, anticipatory governance, and scientific ethics (Grunwald, 2011). The quest for responsible innovation in institutional settings has predominantly centered on managing and mitigating the adverse effects and hazards associated with scientific and technological advancements. Consequently, the dynamics of science and technology have often been regarded as a self-governing entity, that is resistant to thorough examination and evaluation. Notwithstanding, contemporary science policy endeavors of the European Union, namely Responsible Research and Innovation (RRI) and Open Science, assert to promote the notion that the science and innovation procedures themselves, encompassing the underlying preferences and expectations, should be deliberated upon inclusively (Rodríguez, 2022).

The contemporary Responsible Research and Innovation (RRI) methodology implemented in the European Union requires complete transparency of the entire innovation process (including values and motivations) and seeks collective decision-making approach, making responsible innovation synonymous with inclusive innovation (Eizagirre et al., 2017).

The aim of this chapter is to show a more robust concept of responsibility, that of RRI. A historical perspective is taken on the emergence of RRI to understand how to move from a pre-RRI concept of responsibility to an RRI concept of responsibility, how the responsibility concept evolved from pre-RRI to RRI framework: historical perspective and key differences with the goal to identify and assess the differences between the two responsibilities pre-RRI and RRI. Will follow an in-deep presentation of the RRI pillars and dimensions, as well as associated tools. RRI will be discussed as an advance in the concept of responsible technology from earlier developments of responsibility science and technology.

4.1 From defensive pre-RRI responsibility to RRI radical responsibility: historical perspective and key differences

It is imperative to comprehend the development and extent of policies related to responsible innovation as efforts to regulate the interplay or compromises between factors that prioritize economic competitiveness — a fundamental parameter of any research policy — and those that aim at enhanced transparency or ambiguity in the process of innovation (Rodríguez, Eizagirre & Ibarra, 2019). In order to contemplate the conceptual foundation of responsible innovation, it is imperative to recognize that the responsibility linked with innovation inherently implicates responsibility for the future it facilitates (Grinbaum & Groves, 2013).

This section will begin by laying out standardized concepts of responsibility, then it will explore the historical evolution of the understanding of responsibility, from pre-RRI to RRI framework, in the research and innovation ecosystem.

"Responsibility" is described by the Oxford Dictionary as the "duty to deal with or take care of somebody/something, so that you may be blamed if something goes wrong". The Cambridge Dictionary adds that to be responsible is "to have control and authority over someone or something and the duty to take care of them". These definitions are based on caring, controlling, and authority, and both lead to accountability.

The period spanning from Greek antiquity to scholasticism marks the genesis of imputability and accountability, two pivotal facets for understanding the notion of responsibility (Grinbaum & Groves, 2013).

Hans Jonas describes "responsibility" as a way to "act so that the effects of your action are compatible with the permanence of genuine human life" (Jonas, 1984, p. 11). This definition of responsibility also calls for care and accountability. The author highlights three significant aspects of modern technology: the vulnerability of nature; the role of knowledge in morality; and the potential moral claims of extra human nature. In the same chapter, he also stresses that the advent of contemporary technology has broadened the scope and implications of human activities, necessitating an augmented level of responsibility. The impact of human interventions on the environment, coupled with their cumulative effects, necessitates a reassessment of ethical considerations. This underscores the imperative need for a comprehensive understanding of our responsibilities and entitlements, coupled with the acknowledgment of the ethical importance of safeguarding the integrity of the natural world (Jonas, 1984, p. 6). This fact makes it necessary that we consider our ethical responsibilities, not just within interpersonal dealings, but also in communal undertakings that have an effect on the biosphere.

Grunwald (2011, p. 11) characterizes responsibility in three dimensions: Governance; Moral and Epistemic. The aspect of responsibility pertaining to governance reflects the reality that assigning responsibility is a deliberate action, carried out by designated individuals, and it has consequences for those involved. When assigning responsibilities, it is important to consider the extent to which actors can affect actions and decisions within their respective domains. The moral dimension of responsibility is considered by inquiring whether actions and decisions must be deemed accountable before entity of rules to the extent that normative ambiguities come to the surface. The epistemic aspect pertains to the caliber of understanding regarding the matter of accountability. These subject holds significance in discussions regarding scientific responsibility as assertions pertaining to influence and consequences are often the ramifications of scientific advancements and emergent technologies manifest a significant level of unpredictability, as noted by Von Schomberg in 2005 (Grundwald, 2011).

On a nonacademic level and "within a multistakeholder platform", the model of ISO 26000[24] standard was developed (Rocha, Antunes & Partidário, 2019, p. 9). The acquired

[24] The International Organization for Standardization (ISO) has formulated a global standard, labeled ISO 26000, that offers recommendations regarding social responsibility for enterprises of diverse

standard showcases the means to accurately identify and engage stakeholders, execute a sound evaluation of social responsibility, and formulate and apply effective strategies and actions for enhancing social performance (ISO, 2010). In this context, responsibility progressively transforms into a futuristic attribute or merit that may or may not be exemplified by one's conduct. Assuming responsibility mandates that moral individuals display prudence by anticipating the potential outcomes of their actions, and actively strive to expand their understanding of the complex world and the ways in which their conduct can potentially influence and amend it (Griunbaum & Groves, 2013).

The concept of social responsibility pertains to both the routine functioning and prospective determinations of an organization, encompassing its novel projects, associations, merchandise, services, and commercial arrangements. According to the guidelines set forth by ISO 26000, it is suggested that the most probable economic, environmental, and social consequences of organizations be considered. The norm encompasses seven fundamental subjects: a) Organizational governance; b) Human rights; c) Labour practices; d) The environment; e) Fair operating practices; f) Consumer concerns and g) Promotion of community engagement and progress (Rocha, Antunes and Partidário, 2019; ISO, 2010).

On one hand, Stilgoe, Owen and Macnaghten (2013, p. 1568) stated that "responsible innovation is an idea that is both old and new. Responsibility has always been an important theme of research and innovation practice, although how it has been framed has varied with time and place". On the other hand, they add that policy makers commonly utilize the power of science to facilitate emancipatory measures. This situation has granted scientists and innovators significant liberty in terms of being exempt from political responsibility. Considering this perspective, there seems to be a potential conflict between the responsibilities of scientists to generate trustworthy information and their ethical responsibilities towards society as a whole (Stilgoe et al., 2013).

The responsibility concept presents ethical considerations pertaining to the validity of choices made within the field of science. The integration of technology into the actions and decisions of individuals and groups gives rise to corresponding responsibilities and

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scales and operations (International Organization for Standardization [ISO], 2010). It presents a structure that enables the incorporation of social responsibility within an organization's practices and operations, irrespective of its sector or geographic vicinity (ISO, 2010). Distinguished from customary ISO regulations, ISO 26000 is designed to provide aid to organizations in comprehending and dealing with their social obligations, rather than serving as a certification mechanism (ISO, 2010). For more details, see ISO 26000:2010 - Guidance on social responsibility, available at https://www.iso.org/standard/42546.html.

accountabilities, and such integration encounters difficulties due to the presence of unknown variables familiarity with the implications resulting from said decisions (Grundwald, 2011).

One should acknowledge that European Community's research and technological development endeavors have been effectively outlined and executed through a sequence of multi-year Framework Programmes, initiating from 1984. These include the 4th RTD FP (1994-1998), the 5th FP (1998-2002), the 6th FP (2002-2006), the 7th FP (2007-2013), followed by the 8th FP - Horizon 2020 Programme spanning from 2014 to 2020 (CROS/EC, 2023).[25] Currently, the 9th Programme (2021-2027), called Horizon Europe, is in place (EC, 2023).[26] It is also important to note that the European Commission investment allocated to each framework program has been largely increasing one after the other (EC, 2015; EC, 2023).

During the mid-20th century, linear models of innovation relied on a clearly defined allocation of roles among various innovation actors and strategies that were chiefly driven by economic considerations. In the subsequent decades, policies on innovation demonstrated a gradual acknowledgment of the intricate and multifaceted aspects of innovation, and the necessity of implementing modifications, albeit with the explicit objective of fulfilling the competitiveness mandate (Eizagirre et al., 2017).

The deterministic presumptions that constitute the linear perspective of innovation faced scrutiny, particularly in the latter part of the 1960s and the 1970s, as the multifaceted character of innovation was gaining recognition along with OECD reports. Subsequently, it was perceived as encompassing contextual and institutional components, such as sector-specific actualities (governmental, academic, commercial, non-profit entities), economic and monetary milieu, or the global sphere (Eizagirre et al., 2017). The assessment of social aspects pertaining to science and technology frequently encompasses a diverse range of external stakeholders beyond the scientific community. Over the course of the last few decades, a diverse range of stakeholders including legal and ethical experts, non-governmental organizations, policy makers, and various members of the public have been engaged in the matter. Over the past few years, there has been a growing recognition of the potential benefits of engaging in collaborative interactions with stakeholders, in contrast to relying solely on the "expert" model (Zwart et al., 2014). Despite this, another set of forces that emphasized the obligation of science for generating economic benefits, began gaining significance since the 1980s. The Technical

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[25] https://cros-legacy.ec.europa.eu/content/research-projects-under-framework-programmes-0_en. For more detail on the framework programmes go to: https://cordis.europa.eu/.

[26] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/how-horizon-europe-was-developed_en

Change and Economic Policy report (1980) by the Organization for Economic Co-operation and Development (OECD) sounded a warning bell regarding the urgent requirement to undertake measures to synchronize economic and technology policies (Rodríguez et al., 2019).

To go back in time, since the early 1990s, the European Union has been actively encouraging research in the ethical, legal, and social aspects (ELSA)[27] that was linked to the advancements made in life sciences. This initiative was launched in line with the Second Framework Programme for Research and Technological Development (1987–1991), under the guidance of an ethics committee established exclusively for this purpose. Over time, the formulation and implementation of the socio-technical conjunction has become increasingly progressive, with consideration given to various variables such as the impacted knowledge areas, relevant problems, involved actors, and the influence of the interplay between social and technological factors on knowledge and innovation processes (Rodríguez et al., 2019). In the late 1990s, the prevailing attitudes towards philosophical, bioethical, and technology assessment methodologies with regards to the field of science and technology began to shift, as many began to perceive these practices as inadequate. While philosophy was previously perceived as a peripheral and esoteric discipline, bioethics was commonly viewed as a utilitarian resource for the scientific community, and TA was predominantly recognized as a specialized area. Conversely, the aspect of public engagement appeared vulnerable to subjective perspectives, unvalidated sentiments and selective political agendas (Zwart et al., 2014).

In the contemporary era, there has been a notable shift away from the notion of innovation solely relying on structure, towards a more fluid and process-oriented approach. As we progress into the 21st century, the selection environment for innovation is no longer limited to the confines of the productive environment. The innovation system diversifies its stakeholders and broadens its scope to encompass various practices, such as design, knowledge dissemination, marketing, patent administration, financial partnerships, and more (OECD, 1999; Eizagirre et al., 2017).

Although the ELSA (Ethical, Legal and Social Aspect) framework appeared in the 4th EU Framework Programme, in the year of 1994, only in the period between 2002 and 2012 was its "golden years". This term was coined to signify the initiation of initiatives aimed at fostering and financing investigations concerning the moral, legal and communal implications of nascent sciences and technologies (Zwart et al., 2014, p. 11).

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[27] ELSA in Europe; ELSI in the US.

The committees that provide guidance on ethical matters were commonly perceived as operating within predetermined protocols and objectives, aimed at achieving agreement and resolving complex concerns. This rendered them susceptible to the allegation that they had removed contentious items or resolved disputes related to more extensive or profound matters, as observed earlier (Zwart et al., 2014). The term "Responsible Research and Innovation (RRI)" has gained significant prominence in policy discourses, particularly in Europe. The concept will be a pivotal concern in the potential EU Framework Programme for Research and Innovation "Horizon 2020" as a cross-disciplinary matter (Von Schomberg, 2013).

The Water Framework Directive (WFD) mentioned earlier, entails another notion of responsibility, as while " imposes a strong obligation on EU Member States to achieve good water status." (Petersen, Klauer & Manstetten, 2009, p. 2062). The fulfilment of fundamental environmental policy objectives necessitates the ultimate responsibility of the state. As the assumption of ultimate responsibility regarding environmental issues is contingent upon the exercise of sovereign power by the state, it follows that state sovereignty is an imperative for the effective implementation of environmental policies. Nonetheless, it should be noted that the exclusion of political processes, commonly encompassed within the concept of "governance", should not be regarded as superfluous (EC, 2023, Petersen, Klauer & Manstetten, 2009).

The underlying premise from pre-RRI frameworks was that scientific knowledge alone may not adequately ensure the ethical and social validity of the implementation and advancements of emerging technologies (Zwart et al., 2014). And "RRI initiatives propose to move agenda-setting processes in the direction of societal responsibility" (Zwart et al., 2014, p. 12).

To go back in time, the concept of Responsible Research and Innovation (RRI) has its roots in a workshop on Science in Society organized by the European Commission in Brussels, in 2011. The objective of the workshop was to establish a comprehensive view of RRI by incorporating insights from both academic and policy experts, intended to serve as a basis for informing targeted policy recommendations to be executed across the European Union (Gardner & Williams, 2015). This RRI Framework assumes the concept of responsibility according to which innovation processes are conceived as radically open and debatable processes, even with regard to the preferences and expectations underlying them (EC, 2013; Rodríguez, 2022).

During the latter half of the 1990s, Science and Technology Studies (STS) underwent noteworthy advancements. Increasing attention was directed towards anthropological and cultural methodologies, with specific emphasis on the themes of race, gender, colonialism, multiculturalism, and postcolonial perspectives. The domain has also broadened its inquiry into policy, proficiency in policy formulation, and the societal framing of potential hazards. The Actor-network theory has progressed further, with a greater emphasis placed on the concurrence linking scientific understanding and the external realm. Furthermore, there emerged a heightened emphasis on enhancing public comprehension, questioning the deficit-oriented paradigm, and amplifying the consideration for sociotechnical systems and user participation. These advancements have broadened and enhanced views within STS in social science studies pertaining to energy (Hess & Sovacool, 2020).

The pre-RRI approaches are focused on the issue regarding whether the development has "undesired effects" (Von Schomberg, 2012; Zwart et al., 2014). Responsible innovation pertains to the conscientious approach adopted in the development and implementation of novel technologies and solutions, with due consideration of their prospective ramifications on societal, economic, and environmental facets (Von Schomberg, 2013). It underscores the imperative for ethical deliberations, sustainability, and the welfare of individuals and communities impacted by innovations in technology. Responsible innovation requires the essential incorporation of ethical considerations, as stated by Guston (2014). The evaluation of potential risks and benefits, guaranteeing the safeguarding of privacy and data, and upholding the principles of human rights are fundamental elements of conscientious innovation, as posited by Owen, Bessant, and Heintz (2013). Moreover, responsible innovation accentuates ecological stability by mitigating the detrimental ecological ramifications of novel technologies through the prudent use of resources, the reduction of waste, and the deployment of sustainable energy resources (Owen et al., 2013).

Assuming responsibility of this nature, demonstrated through modes of governing, is a crucial constituent of the ethical and morally upright approach to innovation (Owen et al., 2013). However, it is pertinent to acknowledge that this approach has its own inherent constraints and limitations. It lacks the necessary equipment to effectively oversee domains pertaining to emergent science and technology, characterized by an elevated level of uncertainty in terms of both present and future ramifications, or those which, owing to their innovative nature, lack any historical antecedents (Owen et al., 2013).

Responsible Research and Innovation strategy of the European Union (EU) seeks to open the entire innovation process (expressed in terms of demands, values, and motivations) to collective decision, creating a vision of responsible innovation as inclusive innovation. In this case, "inclusive" refers to the ability to bring together and consider all societal actors, their positions and demands, whether they are interested in the technology in question or not, which translates into an extreme plurality of visions, demands, expectations and values (Eizagirre, Rodríguez & Ibarra, 2017).

Since it was presented, scholars and politicians moved on with research on this topic, like Von Schomberg, who proposes the following definition for RRI:

> Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society). (Von Schomberg, 2012, p. 50)

The European Commission (EC) proposes another definition of RRI, although it has a similar view:

> An approach that anticipates and evaluates the possible consequences and expectations of society with regard to research and innovation, in order to encourage the design of inclusive and sustainable research and innovation". To achieve this objective of designing research and innovation in an inclusive manner, such Commission suggests that "the agents of society (researchers, citizens, policy makers, companies, third sector organizations, and so on) work together throughout the research and innovation process in order to better align both the process and its results with the values, needs and expectations of society. (EC, 2013)

On the other side, there was a rise of a concept called "irresponsible innovation", mentioned by Von Schomberg (2015, p. 10), as the author stresses that "as many actors are involved in innovation processes, "irresponsible" outcomes are seldom the result of one single irresponsible actor. More typically, irresponsible innovation is reflected in practices where stakeholders were unaware of the importance of societal context, or where stakeholder interactions were unproductive in the resolutions of conflicts".

The same author identifies four types of irresponsible innovation: technology push, negligence of fundamental ethical principles, policy pull and lack of precautionary measures and technology foresight (Von Schomber, 2015).

In addition to that, Grunwald (2011, p. 9) states:

> However, what "responsible" in a specific context means and what distinguishes "responsible" from "irresponsible" or less responsible innovation is difficult to identify. The distinction will strongly depend on values, rules, customs but also on the knowledge available and its validity and will vary according to different context and actor conditions.

Aligned with this vision and motivated specifically by the recognition of the limited success of responsible science and technology policy in relation to the somewhat unpredictable societal and political reception of transgenic plants within EU borders, it appears that European institutions have recognized the necessity of adopting a more comprehensive and intricate approach to responsibility. This approach is not solely focused on the regulation of technological advancements based on objectively determined risks and challenges, and a set of presumptions about competitiveness, prosperity, and advancement, which are upheld without being subjected to scrutiny (Von Schomberg, 2015; Rodríguez et al., 2019).

One can say that RRI articulates responsible innovation practices in four fundamental dimensions (Von Schomberg, 2012) which are materialized as inclusiveness; reflexivity; responsiveness and anticipation, as it follows:

- **Inclusiveness:** diversity of actors and inclusion of their demands and expectations. Uses approaches like consensus conferences; citizen juries and panels; focus groups; science shops; deliberative mapping and polling; exercise lay membership of expert bodies; user design; open innovation. There are many factors that can affect the implementation of this exercises, such as questionable legitimacy of deliverable exercises; need for clarity about purposes of motivation for dialoged; deliberation of framing assumptions; ability to consider power imbalances; ability to interrogate the social and ethical stakes associated with new science and technology; quality of dialogue as a learning (Stilgoe et al., 2013). The concept of responsibility is seen mostly as a quality inhered to the degree of inclusion of a plurality of actors and perspectives (Eizagirre et al., 2017; Owen et al., 2013; Owen & Pansera, 2019; Rodríguez et al., 2019; Tancoigne, Randles & Joly, 2016). This dimension tries to broaden the visions, purposes and dilemmas of innovation for a collective deliberation that invites and tries to listen to the broad and diverse perspectives of social actors. This dimension ensures the inclusion of a vast heterogeneity of perspectives gathered in each innovation process, demands, values, expectations, that emerge in the face of all innovation (Owen et al., 2013).
- **Reflexivity (openness):** openness of alternatives and transparency of its approach. This dimension uses multidisciplinary collaboration and training; embedded social scientists and ethicists in laboratories responsibilities; ethical technology assessment; codes of conduct; governance moratoriums. The implementation of these methods can be affected by rethink moral division of labor; Enlarging or redefining role (Stilgoe et al., 2013). This dimension of responsible practice appeals to reflection on known and unknown issues, motivations, and potential impacts of innovation processes, incorporating into scrutiny and analysis the risk and uncertainty associated with such processes (Owen et al., 2013).
- **Responsiveness**: responsiveness and adaptation to the context of demands. It refers to the required "capacity to change shape or direction in response to stakeholder and public values and changing circumstances" (Stilgoe et al., 2013, p. 1572). This

dimension uses methods like open access and other mechanisms of transparency; value-sensitive design; alternative intellectual property regimes; standards; constitution of grand challenges and thematic research programs; roadmaps' regulation. Even then, there are some factors that can affect this implementation, such as: strategic policies and technology; science-policy culture; institutional structure; prevailing policy discourses; institutional cultures; institutional leadership; openness and transparency; intellectual property regimes and technological standards (Stilgoe et al., 2013).

- **Anticipation:** acts by creating future scenarios to guide the present and increase the ability to reflect on future practices (Rodríguez et al., 2019). This dimension uses methods like foresight, technology assessment; horizon scanning; scenarios; vision assessment and anticipate socio-literary techniques. The implementation of these techniques can also be affected by many factors such as engaging with existing imaginaries; participation rather than prediction; plausibility; investment in scenario-building; scientific autonomy and reluctance to anticipate socio-literary techniques (Stilgoe et al., 2013). Anticipation calls for an early detection and mitigation of potential research and innovation impacts and outcomes. It seeks the description and analysis of the potential and intentional future impacts of innovation processes in the economic, social, political, environmental fields and others. To this end, it promotes the application of "forecasting" methodologies, constructive evaluation of technology, elaboration of possible scenarios, etc. It seeks to integrate the various visions of the future into the present to "build the future from the present", thus distinguishing itself from strategies of mere forecasting of the future (Owen et al., 2013).

This conception of RRI-responsible practices in innovation differs from another orientation – more dominant in the policies currently existing in the EU – of RRI in a more substantive nature that captures the concept of RRI as the combination of six essential dimensions: gender equality, free access, citizen participation, scientific education, ethics, and governance. This contribution will make use of the conception of RRI proposed in Owen et al. (2013), more linked to the idea of RRI as a principle of action of responsible practices in innovation processes, not reducible to the dimensions just mentioned (Rodríguez et al., 2019).

With this approach to innovation thus understood, the EC reflects the need for dynamic innovation that responds constructively to a plurality of social demands, expressed by a wide heterogeneity of social actors involved in all innovative processes. The ultimate goal is the integration of such processes into the needs expressed in society (Eizagirre et al., 2017).

In fact, the aims of innovation must be governed by such demands and their impacts on them and not, as in the trajectory followed by public policies of innovation and development, by the reduction of the risks and the negative consequences of innovative processes.

As has been said, in this contribution one will understand the concept of RRI-responsibility in the terms expressed in Owen et al. (2013): responsible innovation implies a collective commitment to take care of the future by managing science and innovation in the present, opening new opportunities to create value in society through science and technology. In this consideration, openness to the future of societies plays a critical role that must be understood and operationalized.

One should note the conclusions from Zwart et al. (2014), that present that "the newness of RRI does not reside in its interactive and anticipatory orientation, as is suggested by authors who introduced the term, but rather in its emphases on social-economic impacts (valorization, employment and competitiveness)."

According to Von Schomberg (2011), RRI brings ethics as an opportunity in a more positive view than ELSA. Additionally, this pre-RRI framework focuses on the end stage of innovation, guiding it on the negative consequences and functions as a limitation (Zwart et al., 2014).

Jakobsen et al. (2019), having analyzed the current literature on RRI, identified two shortcomings: "The first concerns the types of innovation processes investigated. The second is the limited investigation of the broader societal impacts of innovations."

One will dwell a little more about the four dimensions suggested by Owen et al. (2013) that have been introduced above: the practice of responsible innovation must be anticipatory, reflective, deliberative, and co-responsible ("responsive"). Responsible innovation practices integrate visions of the future, promoting reflection and deliberation about them and the uncertainties involved to define an innovation trajectory, which aims to be iterative and dynamic. This type of practices can be anticipatory, reflective, deliberative, and co-responsible.

The EC's interpretation of RRI defines basic pillars that should guide the investigation and innovation in Europe: gender equality, public participation, open access to the investigation, scientific education, and ethical dimension (EC, 2013).

Innovation is conceived as an interactive and collective process in which actors appeal to respond to each other in their demands regarding the innovation in question. This dynamic allows to define the direction and influence the subsequent trajectory and pace of innovation, based on participatory and anticipatory governance models. It should be a fully dynamic process: iterative, inclusive, and open to adaptive learning.

As one can learn, the RRI innovation model adopted in the EU is constituted as a dynamic process regulated by an iterative, inclusive governance system, open to adaptive learning. RRI practices articulate forms of governance of interaction that include maximally societal actors and guarantee spaces for the clarification and reflection of ideas oriented to the joint deliberation of a dynamic innovation strategy, which must be prepared to be adjusted or modified whenever necessary.

Responsible Research and Innovation (RRI) encompasses a comprehensive and elevated level of responsibility that strives to mold, enhance, facilitate, synchronize, and harmonize both traditional and new research and innovation-related procedures, participants, and responsibilities, with the purpose of guaranteeing satisfactory and suitable research results. It is imperative to take into account the various facets and elements of established research governance in order to conduct a comprehensive analysis of the current research landscape in ICT (ORBIT, 2023).[28]

The rising concern regarding effective approaches to address complex societal problems has brought significant attention to the RRI literature, particularly within the realm of policymaking (Jakobsen et al., 2019).

4.2 Anticipation

Materializing one of the four dimensions of RRI, anticipation will be a focal point of this work, as a key dimension for the operationalization. In this section we will present the concept and how it relates to future studies methodologies, qualitative and quantitative methods.

Reaching the Oxford Learner's Dictionary, we can find a Anticipation can be described as the integration of visions of the future into the present: "the fact of seeing that something might happen in the future and perhaps doing something about it now" (Oxford Learner's Dictionary, 2022).

Anticipation allows "the use of the future as a praxiological guide for the present" of innovation (Urueña, Rodríguez & Ibarra, 2021) and it is about "practicing, rehearsing, or exercising a capacity in a logically, spatially, or temporally prior way than it is about divining a future" (Guston, 2014, p. 226).

In the sense, the future expresses itself through scenarios of use and sociotechnical, comprehensive visions, technoeconomic expectations (potentials) and metaphorical-symbolic

[28] https://www.orbit-rri.org/about/about-rri/

expectations (Barben et al., 2007; Borup & Konrad, 2004). And like that, it's possible to affirm that RRI-responsible deliberation among societal actors is anticipatory in nature. This character should be distinguished from that of the Forecast and Foresight. As foresight is a vision of the future, based on a certain method of predicting and preparing for the future, forecast is a "statement of what is judged likely to happen in the future, especially in connection with a particular situation" (Cambridge Dictionary, 2022).

In the following sections we will delve into the nuances of two intertwined concepts, foresight and forecast, going through their similarities and key differences. Meanwhile, this section will be presenting various foresight techniques employed by researchers and practitioners to discern and anticipate emergent trends and challenges.

4.2.1 Foresight

Foresight is a "process which involves intense iterative periods of open reflection, networking, consultation and discussion, leading to the joint refining of future visions and the common ownership of strategies. It is the discovery of a common space for open thinking on the future and incubation of strategic approaches" (Popper, 2008, p. 45). A "pre-condition for foresight practices to become "instruments for" responsible innovation is to make them "subjects of" responsibility simultaneously. This involves monitoring the socio-epistemic relations whereby foresight practices are designed and executed, as well as monitoring how their emergent heuristics are translated into action" (Urueña et al., 2021, p. 1).

And not less important, is the fact that foresight is "by default" devised to promote democratic processes through inclusiveness, openness, transparency, public engagement and multistakeholder approaches "and can have a contribution on a more responsible innovation" (Amanatidou, 2017, p. 1, cited by Urueña et al., 2021, p. 2).

This foresight exercise is "commonly conceived as being able to empower and capacitate societal actors, integrate knowledge-systems, and/or even create "more whole human beings" (Ramos, 2006, p. 652, cited by Urueña et al., 2021, p. 2).

Urueña et al. (2021, p. 2) stress that "the heuristic versatility of foresight is increasingly positioning this anticipatory instrument as a key resource to promote more responsible research and innovation practices".

To go in more detail, on the technical process of foresight, the exercise can be performed in five phases/steps (that can be repeated), according to Popper (2008a): 1) Pre-Foresight; 2) Recruitment; 3) Generation; 4) Action & 5) Renewal.

Pre-foresight is the step that encompasses the establishment of the parameters and goals for the foresight endeavor. The procedure encompasses the discerning of the extents, objectives, and primary parties which partake in the aforementioned process. Antecedent foresight measures comprise an initial appraisal of prospective concerns and complexities that demand attention. The Recruitment phase is when pertinent stakeholders and specialists are identified and enlisted in the foresight initiative. Such individuals tend to possess a wide range of backgrounds, expertise, and perspectives. The objective of the recruitment procedure is to guarantee a multifaceted and comprehensive methodology to foresight, which permits the investigation of an extensive assortment of conceivable future scenarios. During the generation phase, there is a methodical gathering and evaluation of information, data, and insights that pertain to future events. Diverse methodologies, specifically trend analysis, scenario planning, and expert interviews, can be utilized to attain a holistic comprehension of potential developments, emerging patterns, and probable disturbances in the future. This stage is centered on the exploration of diverse potential scenarios for the future, along with the identification of key factors driving change. After the development of future scenarios, the subsequent phase of action necessitates the identification of strategies, policies, and actions that can be executed to effectively tackle the expected challenges and opportunities. This stage underscores the significance of translating insights derived from strategic foresight into practical recommendations and informed decisions. It entails prioritizing and devising precise strategies to sculpt the envisioned future and surmount foreseeable hurdles. The renewal step underscores the iterative and continuous character of foresight activities. The process entails a critical analysis of the results and insights derived from the prior stages, coupled with the enhancement of the strategic planning methodology to optimize future iterations. This stage acknowledges that upcoming times are dynamic and persistently changing, necessitating frequent revisions, adaptations, and assimilation of fresh perspectives and erudition (Popper, 2008a)

The construction of future scenarios can be carried out following, for example, three methodological strategies that Popper (2008) proposes for forecasting, based on the techniques used in them:

- **Qualitative**: with techniques that "attribute meaning to events and perceptions". They can be interviews; panel discussions; literature review; SWOT analysis; brainstorming; conferences/workshops; essays/scenario writing; back casting; surveys; citizen panels; science functioning; weak signals/wild cards; brainstorming;

expert panels; interviews; morphological analyses; relevance trees/logic charts; with "subjectivity or creativity" (Popper, 2008, p. 54).

- **Quantitative**: with techniques that "measure variables and apply statistical analysis". Examples of these techniques are indicators/series of temporal analysis; bibliometrics; modeling; patent analysis; trend extrapolation and benchmarking (Popper, 2008, p. 54).
- **Semi-qualitative**: with techniques that "apply mathematical principles to quantify subjectivity, rational judgments and the points of view of experts and specialists". Examples of these techniques are: cross-impact/structural analysis; Delphi; stakeholder analysis; voting; Road mapping; key/critical technologies; multi-criteria analysis; polling/voting; quantitative scenarios (Popper, 2008, p. 54).

Considering the topics on spotlight in this research, we will focus on qualitative methods such as surveys; back casting; expert panels; conferences/workshops; citizen panels; interviews; SWOT Analysis; Scenario/Scenario Workshops and also in semi-quantitative methods namely Delphi; Key/Critical Technologies; Pooling/Voting; Road mapping; Stakeholder Analysis; Forecast and quantitative methods such as Benchmarking; bibliometrics; indicators; pattern analysis.

4.2.1.1 Qualitative methods

- **Surveys:** "a tool for social research" in the form of questionnaire "distributed or made available online, and responses drawn from what is usually hoped to be a large pool of respondents" (Popper, 2008, p. 55).
- **Back casting:** " an approach that involves working back from an imagined future, to establish what path might takes us there from the present" (Popper, 2008, p. 55).
- **Expert panels:** "groups of people dedicated to analyzing and combining their knowledge concerning a given area of interest." They can be local, regional, national or international (Popper, 2008, p. 55).
- **Conferences/workshops**: "events or meetings lasting from a few hours to a few days, in which there is typically a mix of talks, presentations, discussions and debates on a particular subject" (Popper, 2008, p. 55).
- **Citizen panels:** "groups of citizens (members of polity and/or residents of a particular geographic area) dedicated to providing views on relevant issues, often for a regional or national government"(Popper, 2008, p. 55).
- **Interviews:** "structured conversations" that are a fundamental tool of social research" and are used as "formal consultation instruments, intended to gather knowledge that is distributed across the range of interviewees" (Popper, 2008, p. 55).

- **SWOT analysis:** an exercise which starts by identifying "factors internal to the organization or geopolitical unit in question (resources, capabilities, etc.) and classifies them in terms of Strengths and Weaknesses" (Popper, 2008, p. 55).
- **Scenarios/scenario workshops:** "approaches involving the construction and use of scenarios, more or less systematic and internally consistent visions of plausible future states of affairs", that might include various features of the object of the experiment (Popper, 2008, p. 56).

    Going a little further about this method, there can also be mentioned the socio-technical scenarios that are created and makes us "acknowledge the inherent uncertainty and contingency of the future by thinking in terms of multiple possible futures, and by highlighting the role of complex interlocking events and coincidence" (Boenink, 2013, p. 152). Socio-technical scenarios bring plausibility to the equation "by using insights in historical patterns and in mechanisms of socio-technical change, and by including a multi-level perspective on transition processes, they aim to construct plausible stories about how we might evolve from the present situation to a very different one – even if the end state itself is arbitrary (Popper, 2008, p. 56).

Anticipating the future through scenario building is a frequently employed methodology to predict forthcoming events. This methodology involves scrutinizing several potential future scenarios to facilitate informed decision-making processes (Schoemaker, 1995). The process of constructing scenarios can assume diverse forms, encompassing both quantitative and qualitative methodologies, and may be suitably employed within different spheres, ranging from climate change adaption to technological advancement and healthcare developments (van der Heijden, 1996). An instance of scenario building is the method of back casting, which commences with a desirable future scenario and retrospectively constructs the required steps to achieve it (Robinson, 2003).

4.2.1.2 Quantitative methods

The qualitative methods are tools that create evidence for future thinking. Some tools identified by Popper (2008) follow, since they are very worthy to mention in this line of work.

- **Benchmarking:** "marketing and business strategy planning", mostly based in comparations between similar parts (Popper, 2008, p. 57).
- **Bibliometrics:** "quantitative and statistical analysis of publications". For example, counting the number of publications on a specific subject to identify an emerging area (Popper, 2008, p. 57).

- **Indicators:** "identification of figures to measure changes over time". Usually based in statistical data to describe, monitor and measure the current state of evolution of factors related to the object of the experiment (Popper, 2008, p. 57).
- **Pattern analysis:** close to the bibliometrics tool, but uses patterns, providing "strategic intelligence on technologies" (Popper, 2008, p. 58).

4.2.1.3 Semi-quantitative methods

- **Delphi**: it's a "technique that involves repeated polling of the same individuals, feeding back (sometimes) anonymized responses from earlier rounds of polling, with the idea that this will allow for better judgements to be made without undue influence from forceful or high-status advocates" (Popper, 2008, p. 58).
- **Key/critical technologies**: "methods that involve the elaboration of a list of key technologies for a specific industrial sector, country or region." A technology is said to be "key" if it contributes to wealth creation or if it helps to increase quality of life of citizens, is critical to corporate competitiveness, or is an underpinning technology that influences many other technologies. To be implement, this method needs expert panels or surveys and voting to prioritize the process (Popper, 2008, p. 58).
- **Polling/voting:** used "to gain an assessment of the strength of views about a particular topic among a set of participants" and it consists basically in voting and surveying methods. Usually the polling/voting is done during workshops or even in a computer system. The voting results are supposed to represent "how probable, uncertain or important they consider events to be, which actions are priorities, how feasible alternatives are and so on" (Popper, 2008, p. 58).
- **Road mapping:** a technique that "outlines the future of a field of technology, generating a timeline for development of various interrelated technologies and (sometimes) including factors like regulatory and market structures" (Popper, 2008, p. 58). Inside the community of high-tech industry, road mapping has been widely used and serving "as a tool for communication, exchange and development of shared visions, and as a way of communicating expectations about the future to other parties (example [e.g.] sponsors)" (Popper, 2008, p. 58).
- **Stakeholder analysis**: strategic planning techniques that take into account "interests and strengths of different stakeholders, in order to identify key objectives in a system and recognize potential alliances, conflicts and strategies. These methods are quite common in business and political affairs" (Popper, 2008, p. 58).

Considering what has been presented before, Urueña et al., (2021) call into question the way that foresight is taken for granted in the exercises of anticipation. These authors found the need to understand how the exercise of forecast is dependent of the dynamics of how its conducted, considering that foresight has a degree of openness and closure that is defined by its constitutive dynamics. The degree of openness and closure is determined by sociotechnical constraints (also called hampering factors) that modulate it. In that sense, the authors suggest that foresight can be a "subject of responsibility" and the socio-epistemic relations should be monitored throughout the entire process, "throughout the ex-ante, ex-dure and ex-post foresight operationalization phases" (Urueña et al., 2021, p. 2).

On the other hand, Amanatidou (2017), states that foresight contributes to develop more participatory societies and it has been under-explored, because it can add more to societies that what was its purpose

In their turn, Urueña et al. (2021, p. 1) say that,

> By acknowledging the existence of more "open" or "closed" forms of foresight (which in turn can articulate more "open" or "closed" anticipations), the article argues that the degree of "openness/ closure" of foresight activities is constituted during the ex-ante, ex-dure and ex-post processes and according to the relations underlying their constructive dynamics. The main conclusion reached is that a pre-condition for foresight practices to become "instruments."

4.2.2 Forecast

Forecasting is a model based in fundamental assumptions that define their validity. These assumptions are created based on behavior of variables that are key in the definition of a certain field (Poli, 2019).

Poli (2019) makes a distinction between two situations where forecast entails different time scale: the climate changes forecast and the econometric forecast. He even creates a concept window for 'Short', from 0 to 5 years; 'Intermediate', from 10 to 50 years and 'Long', that is from 100 years on;

> "Forecast activities can be conceived as subtle reification mechanisms of existing knowledge co-production patterns and their guiding purposes." and keep "certain outcomes, purposes and processes of innovation safe from socio -political problematization. The effectiveness of the forecast exercises can vary depending on the context of their application (Urueña et al., 2019, p. 4)

Forecast is a multidimensional tool, as it entails a timeframe that defines the way it's done and what variables and assumptions to use based on that.

Anticipation is a **construction of the future, based on certain methods that allow to evaluate or determine, in real time,** the adequacy of decisions relating to the process of technological creation. Anticipation is a way of integrating into the present the visions of the future of all possible societal actors. This makes it possible to conceive the responsible assessment of innovation as a problem of anticipatory governance (Guston & Sarewitz, 2002).

It is crucial to keep in mind a conceptual distinction between forecast and foresight although they are both approaches to the future. While Forecast is empirical-predictivist, foresight is non-predictivist and it's able to "empower and capacitate societal actors" (Urueña et al., 2021, p. 2). Foresight can "provide valuable anticipatory heuristics for responsible innovation" and acquire different degrees of openness or closure (Urueña et al., 2021, p. 2). Overall, foresight can be a very dynamic tool that integrates anticipatory governance, being able to open it up, while forecast is a morel empirical tool of prediction of a certain closed scenario.

The concepts of anticipation, foresight, and forecasting are interrelated and employed to signify distinct methodologies for comprehending and anticipating future events.

4.3 Inclusiveness

To go deeper on the inclusiveness dimension of RRI, this section opens the problematization of the inclusivity of the society in the governance process.

Inclusiveness is the dimension that makes possible integrating a diversity of actors and include their demands and expectations in the decision-making process. It can be said that it involucrate a layer of "citizenship" because its tools are based in the societal actors.

Some authors, such as Keulen and Est (2018), have coined terms like "digital citizenship" or "technological citizenship" to contribute to a better understanding of the operationalization of the inclusivity of actors, as well as their demands and expectations, in innovation processes. The current development of the integration of big data instruments with artificial intelligence, combined with the rapid evolution of the Internet of Things (IoT) provides societal actors with new perspectives. According to the mentioned authors "it is important that citizens have the option to participate in the decision-making process regarding technology at all stages of development, from research to application. Technological citizenship emancipates the ordinary citizen in relation to technology experts and developers". Technological citizenship or "digital citizenship" makes it possible to include a whole heterogeneity of actors in innovation processes (Keulen & Est, 2018).

As Urueña (2021, p. 2) said, regarding Anticipatory Governance (AG) and Research & Innovation (RI):

> Through an inclusive engagement (in terms of knowledges and actors) with representations of 'the future', AG and RI aim to enable a range of capacities to the constellation of social actors that constitute the innovation co-production network, and thereby facilitate more self-reflexive and responsive ongoing research and development (R&D) practices. However, this incipient call for anticipation has not been accompanied by a specific and systematic conceptual development of this socio-epistemic practice within AG and RI literature.

In this sense, **inclusivity** does not refer to the mere participation of diverse societal actors, but to the **inclusion of their perspectives and demands in the process of development and innovation**. Inclusivity thus imposes a clear political challenge: the construction of a space in which all societal actors can participate, not only the most concerned or stakeholders, to propose their demands with the intention that they are heard by the other actors and can be deliberated on (Eizagirre et al., 2017).

For this to happen, it's necessary to involve the population, the possibility of deliberation and opportunities to form partnerships that think and ensure the implementation of joint solutions. An example of a strategy for this purpose are participatory workshops, very effective to make the usual planning activity more flexible and adapting, creating a symbiosis between the "bottom-up" hierarchical model (common sense knowledge) and "top-down" hierarchical models low" (science-based knowledge) (Vasconcelos, 2004).

In order to promote effective development and innovation, it is imperative to acknowledge and appreciate the varied experiences and knowledge that various groups offer. This requires a conscious undertaking to incorporate these viewpoints into the development and innovation process. The objective of inclusivity is to guarantee that the results of these procedures are fair, maintainable, and adaptable to meet the requirements of all individuals in the community (Stilgoe et al., 2013).

The interactive participation will help build up the democracy, with a more robust and less questionable decision process, also gathering a strong eternity of knowledge co-created in the process. But this process should be understood as a mutable system, that can evolve through itself and change as many times as needed to arrive to the solution on the decision making. In the contemporary times, there has been a noticeable surge in the inclination towards participative decision-making and collaborative creation as viable methods for fostering a stronger democracy. These methodologies endeavor to involve individuals and entities who have a vested interest in a given matter, in order to increase the authenticity and efficacy of resultant policies. The present discourse aims to investigate the advantages of involving stakeholders in decision-making and co-creation processes, by referencing seminal works of scholars such as Arnstein (1969), Fung and Wright (2015), and Jenkins (2006).

It was posited by Arnstein (1969) that attaining significant citizen engagement necessitates more than merely offering input or feedback. As an alternative, she has put forth a graded system of involvement, coined as the "ladder" of participation, which encompasses varying levels of engagement ranging from "manipulation" and "therapy" to "citizen control". At the pinnacle of the hierarchy, individuals possess the authority to determine and influence the result of the course of action. The term frequently employed to designate this particular approach is "empowered participatory governance," as posited by Fung and Wright (2015).

Participatory decision-making and co-creation offer a prime advantage in that they have the potential to result in decisions that are better informed and more legitimate. By engaging a variety of stakeholders and subject matter experts, policymakers can glean a more comprehensive pool of viewpoints and expertise. This approach can facilitate the recognition of prospective trade-offs and inadvertent repercussions of policy determinations, and guarantee that the decisions align with the requirements and principles of the impacted individuals.

The practice of involving stakeholders in decision-making and collaborative creation can cultivate an environment of collective cultural knowledge enhancement. According to Jenkins (2006), the cultivation of participatory culture and co-creation is crucial to foster the growth of innovation and creativity. Through engaging citizens and stakeholders in the formulation of policies and initiatives, governments can leverage a vast array of expertise and viewpoints and facilitate the cultivation of mutual cultural awareness.

The notion of stakeholders is intertwined with the wider idea of societal agents, as they both pertain to factions or persons who are impacted by, or have a vested interest in, a specific matter or verdict. Stakeholders are commonly designated as individuals or groups that possess the capacity to influence or be influenced by the actions or decisions undertaken by an organization. Stakeholder is who have a stake in the business (Freeman & Mcvea, 2001). In the context of this work, stakeholders are who provides the representation of the ecosystem.

On the contrary, societal actors represent the heterogeneous spectrum of persons and collectives constituting a given community. These entities may consist of persons, households, municipalities, advocacy groups, and non-governmental organizations (Castells, 2010). The societal actors, as seen in this work, are the publics of society who has something to say about the problem.

Within the sphere of participatory decision-making and collaborative innovation, it is widely acknowledged that stakeholders hold a pivotal role as indispensable collaborators in the decision-making process. In view of their ability to offer invaluable insights and diverse perspectives on the issues at hand, stakeholders are regarded as significant allies in this regard (Arnstein, 1969); Fung, & Wright, 2015). In contrast, societal stakeholders pertain to the heterogeneous array of persons and organizations comprising a given community. This encompasses a diverse range of constituents, comprising of individuals, households, localities, advocacy associations, and non-governmental entities (Castells, 2010).

Although there might be certain similarities between these ideas, stakeholders are generally regarded as a subset of societal actors, with a more precise emphasis on those individuals or groups who are directly affected by a specific decision or policy (Friedman & Miles, 2006).

In order to effectively foster both economic value creation alongside environmental solutions, it is crucial to obtain co-created knowledge regarding the initiation and monitoring of multidimensional and multi-scale innovation dynamics. social challenges. Within these procedures, it is necessary to conduct thorough assessments to validate innovative approaches the responsibility for the final deliverable (Jakobsen et al., 2023).

According to Jakobsen et al. (2023), RRI can also be divided into three great features:

1. Raises apprehension regarding the objectives of scientific endeavors and innovative pursuits; initiates discourse pertaining to the direction of research aims and innovative actions, while emphasizing the need to uphold ethical, inclusive, and democratic principles throughout the process.
2. It is imperative to establish procedures for contemplation and integration in the research and innovation procedure.
3. An essential to reconsider the interpretation of responsibility. The subject matter of RRI should not be confined solely to the research community, but ought to be of interest to individuals occupying various roles such as entrepreneurs, business leaders, policymakers, government-sanctioned entities, and organizations which allocate resources towards scientific investigation.

Looking closer at what Von Schomberg (2012, p. 36) stated:

> The formation of public opinion on new technologies is not a historically or geographically isolated process; rather, it is inevitably linked to prior (national and international) debate on similar topics. Ideally, such debates should enable a learning process – one that allows for the fact that public opinion forms within particular cultures and political systems.

One can acknowledge that participatory processes are fundamental since they can help to speed up the decision-making process with a view to sustainability. For this, a joint reflection on society at the level of social, political, and economic processes is necessary. Participation is essential in planning. However, this should not be fully controlled by participatory processes.

Although, in practice, one is not sure how citizen participation should be, the existence of shared power is sought, in which organizations and institutions must share objectives, resources and power, activities or authority, to minimize losses and achieve collective gains (Vasconcelos, 2004).

Although, like Eizagirre et al. (2017, p. 31) stressed that:

> We should continue to be aware of potential inertia, power asymmetries and fundamental priorities that might constrain the constitution of more radically responsible socio-technical realities and futures, in as much as RRI aims to open up the objectives, goals and interests of innovation to public scrutiny. These tend to have been sealed off from the social context, which grants this outlook the virtue of making it possible to conceive more alternative outlooks and futures for science and its relationship with society and nature. In any event, RRI and its mission to make innovation a more inclusively contingent process allow these dynamics and constraints to be explicated, which may be considered an important contribution in itself.

Jakobsen, Fløysand and Overton share their thoughts on the RRI approach:

> We believe a multidimensional and multi-scale approach, combined with the arts of exploring and exploiting innovation, is a fruitful new avenue for RRI. It paves the way for expanding the RRI research field beyond its current, narrow focus on practices within the scientific community to responsible innovation research that focuses on a much broader spectrum of innovation practices taking place within a multidimensional and multi-scale real-world setting. (Jakobsen, Fløysand & Overton, 2019)

4.4 Anticipatory Governance

In the previous section we delved into the concept of anticipation and inclusiveness as foundational elements of anticipatory governance.

According to Guston (2008, p. 6), anticipatory governances is a "broad-based capacity extending through society that can help individuals and institutions act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible".

The same author also wrote, in 2014 (p. 219), that anticipatory governance is "broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible:

> Anticipatory governance implies that effective action is based on more than sound analytical capacities and relevant empirical knowledge: It also emerges out of a distributed collection of social and epistemological capacities, including collective self-criticism, imagination, and the disposition to learn from trial and error. For, although action and outcomes are emergent qualities of human choice and behavior, they rarely, if ever, proceed from certainty or prediction, and neither are they based on the simple intentions of individual actors or policies.

Rather, as the concept of “anticipation” is meant to indicate, the co-evolution of science and society is distinct from the notion of predictive certainty. In addition, the anticipatory approach is distinct from the more reactionary and retrospective activities that follow the production of knowledge-based innovations—rather than emerge with them. Anticipation implies an awareness of the co-production of sociotechnical knowledge and the importance of richly imagining sociotechnical alternatives that might inspire its use (Barben et al., 2008, p. 991).

One can conclude that anticipatory governance is a framework that "comprises the ability of a variety of lay and expert stakeholders, both individually and through an array of feedback mechanisms, to collectively imagine, critique and thereby shape the issues presented by emerging technologies before they become reified in particular way" (Barben et al., 2008, p. 993). A possibility for anticipatory governance can be created by applying the principals of technological assessment and technological foresight, since they can reduce the human cost of trial and error and take advantage of a societal learning process of stakeholders and technical innovators. This should ultimately lead to products which are (more) societal robust (Von Schomberg, 2013).

4.4.1 Openness and closure

Anticipatory governance can be open or closed, depending on the extent to which stakeholders are involved in the process (Guston, 2014). Open anticipatory governance involves actively engaging stakeholders and creating a deliberative space for collective decision-making, whereas closed anticipatory governance relies on expert knowledge and centralized decision-making (Guston, 2014)

On the other hand, Guston (2014), in his study, brings three types of critiques of anticipatory governance focused on proximities:

- too close to nanotechnology;
- too close to the public;
- too close to technoscience’s.

These critiques are important (and fundamental) to think about when designing a solution for anticipatory governance that goes beyond that and uses it latter in a learning process.

According to Von Schomberg (2013, p. 13), "recent forms of technology assessment (among other 'real time technology assessment generally focus their attention on monitoring of research and innovations processes or make them more dynamic and inclusive (Schot & Rip, 1997).

4.4.2 Real Time Technology Assessment

> Technology assessment (TA) refers to the early identification and assessment of eventual impacts of technological change and applications, as a service to policy making and decision making more generally. TA can be done by (or for) business firms, or as a medical, social, or environmental impact assessment (Rip, 2001, p. 15512).

Since the 1980s, the field of public service technical assistance has undergone professionalization and the development of distinct methodologies within the domain. TA is interconnected with wider trends, including the advent of a society that is increasingly preoccupied with mitigating and managing risk.

The conventional prevalent (though not exclusive) form of Technical Assessment primarily serves as a scientific instrument that strives to conduct intricate analyses and proffer technical remedies, subsequently facilitating the process of arriving at informed decisions. Forecasting techniques played a critical part in facilitating this process (Urueña, 2022).

A more contemporaneous approach is the concept of Real-time Technology Assessment (RTA), appraising new and developing technological innovations, which is conducted as the technology progressively advances and is put into effect. The purpose of Real-time TA is to tackle the issues arising from the fast-paced development of technology since it can exert substantial influences on the community, the financial system, and the ecology (Guston & Sarewitz, 2002). Instead of postponing the evaluation of a technology until its full development, the approach of Real-time TA involves continuous observation, examination, and response to guarantee that the technology is constructed and executed in a socially accountable and long-lasting fashion.

The Real-time TA framework is based on the fundamental principles of responsible research and innovation (RRI), which prioritize stakeholder engagement, evaluation of wider societal and ethical impacts of emerging technologies, and ethical research practices (Owen et al., 2012). Including stakeholders in the evaluation process can facilitate the incorporation of diverse viewpoints and considerations, promoting the socially responsible and equitable development and utilization of technology by using Real-time TA.

The development of suitable **indicators** to evaluate the consequences of novel technologies is a significant hurdle in carrying out the Real-time TA, as stated by Guston (2007). utilizing indicators can facilitate the detection of potential hazards and advantages, as well as enable the monitoring of fluctuations in the technology's social, economic, and environmental ramifications throughout its lifecycle. Nonetheless, the creation of significant and efficient indicators necessitates the involvement of numerous stakeholders and may demand novel methods of data gathering and evaluation.

An illustration of an initiative that has employed the Real-time TA approach is the Responsible Innovation in Nanotechnology (RIN) project, which was financially supported by the Engineering and Physical Sciences Research Council (EPSRC) of the UK government. The RIN project encompassed a research endeavor lasting for a period of five years, with the primary objective of devising and evaluating a responsible innovation framework for nanotechnology. One of the notable features of the framework was the inclusion of a real-time technology assessment component (Stilgoe et al., 2013). The mentioned project encompassed a range of case studies investigating the development and utilization of nanotechnologies, coupled with stakeholder engagement initiatives and participatory technology assessment activities.

The Synthetic Biology Engineering Research Center (SynBERC), located within the United States, serves as a collaborative research hub that concentrates on advancing the frontiers of synthetic biology methodologies among disparate academic institutions. The institute has devised a systematic structure for contemporaneous evaluation of synthetic biology technologies, encompassing continuous surveillance and appraisal of the technology along with its possible ramifications (Roco et al., 2010). The framework encompasses the establishment of metrics for monitoring the societal, financial, and ecological repercussions of the technology, in conjunction with channels for engaging and obtaining feedback from stakeholders.

4.4.3 Measurement of innovation & indicators

Following the release of the Brundtland Report, which introduced the concept of sustainable development, as mentioned before, there has been a growing call for a redefined approach to innovation. Thus, in recent years, the idea of eco-innovation has garnered heightened interest from all over the world. Nations across the globe recognize its potential to effectively tackle both economic and environmental priorities. Specifically, technology is seen as the foundation of eco-innovation is considered pivotal as it has a favorable impact on the economic progress and enables a more intelligent and environmentally conscious action (Albino et. al., 2014).

According to the Oslo Manual (2018), innovation is "A new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD/Eurostat, 2018, p. 20). In only one sentence, "Innovation is the execution of new ideas that create value" (Gartner, 2021).

Innovation "involves the design, development, and implementation of new or improved products, services, processes, systems, or social practices" (European Commission, 2021, p. 15). According to the definition provided by the National Academy of Engineering (NAE) in the United States, innovation is "the process of creating and implementing new or significantly improved products, services, processes, or technologies that add value or solve problems. It involves generating new ideas and concepts, developing, and testing prototypes, and bringing the resulting products, services, or processes to market" (National Academy of Engineering, 2022, p. 1) Or, as stated by the Organization for Economic Cooperation and Development (OECD), "innovation drives growth and helps address social challenges" (OECD, 2010).

On its turn, based on Albino et al. (2014), "eco-innovation is an innovation that primarily contributes to reduce environmental impacts and opens new sustainable pathways in the market." (Albino et al., 2014, p. 3).

According to OECD, eco-innovation is "the implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which, with or without intent, lead to environmental improvements compared to relevant alternatives" (OECD/Eurostat, 2010, p. 40).

Innovation is a complex notion that holds significant importance in terms of bolstering economic prosperity, enhancing competitiveness, and promoting societal advancement (Freeman, 1995). According to Freeman (1995), the concept of innovation pertains to the introduction of novel aspects, spanning across products, processes, and organizational frameworks. OCED articulates innovation as the execution of fresh alternatives or integrated enhancements in terms of products (goods or services), processes, marketing approaches, or the organization's mode of operation, which may encompass internal and external relations (OECD, 2010).

Multiple determinants, encompassing scientific and technological breakthroughs, potential for market expansion, customer demands and inclinations, regulatory structures, as well as organizational culture and capacity, are propelling this phenomenon of innovation (Freeman, 1995).

Scholars have put forth diverse approaches to measure innovation, each possessing individual merits and drawbacks. Kesidou and Demirel (2012) present a comprehensive survey of the prevalent approaches employed to gauge innovation, encompassing input-centric, output-centric, and integrated indices. Indicators focused on inputs gauge the investment of resources in innovation, encompassing factors like R&D expenditure and the quantity of researchers. Outcome-oriented indicators measure the effectiveness of innovation, encompassing measures like patents, trademarks, and novelties brought into the market. Composite indicators amalgamate both input and output metrics to present a more exhaustive portrayal of innovation efficacy.

Furthermore, and according to Gartner (2021), it has been beneficial to consider the intricacies of innovation that contribute to varying objectives, undertakings, and endeavors. The following are five frequently utilized and valuable dimensions (Gartner, 2021):

- **Novelty:** transitioning from "unexplored territory" to "unprecedented territory worldwide.
- **Market impact:** it can be attributed to a wide range of factors, including but not limited to product/service enhancements, customer experience enhancements, new products and services, and the adoption of new business models.
- **Timing:** ranging from a brief period to realize worth (weeks or months) to a prolonged period to realize worth (years or even decades).
- **Scale:** The continuum ranges from minor, progressive adjustments to monumental, transformative endeavors.
- **Focus:** The scope of innovation encompasses both the improvement of processes and operations as well as the development of products and services, both of which have a significant bearing on the Market Impact dimension. It should be observed that this dimension should be considered more as a group of classifications rather than a mere scale.

Although Gault (2010) calls our attention to the fact that caution must be exercised in the utilization of indicators as a standalone measure does not always provide a comprehensive picture, contrary to the perception held by inexperienced policy analysts or lay users.

One of the prevalent techniques employed to quantify innovation is via patent data. Patents are official papers that confer upon innovators the sole entitlement to utilization, vending, or authorizing their creations for a specified length of time. Therefore, patents can offer valuable insights about the extent of innovative undertakings and the domains of technology in which they are transpiring. Patents may not provide an precise measure of innovation, considering that certain inventions may not meet the criteria for patentability, and certain patents may have been registered but not utilized in practicality (OECD, 2018).

Baumann et al. (2021) studied global research trends (related to battery storage, hydrogen, and bioenergy) by using comparative patent analysis, where they developed a software tool to do this analysis.

Patent documents provide knowledge about which countries are investing in certain technologies and make it possible to identify potential innovation trends (Baumann et al., 2021, p. 1) proving insights and metrics.

On the other hand, in his book, Gault (2010, p. 18) stresses that

> It is worth making the point that R&D is not innovation until it connects to the market, and neither is patenting nor publication. This immediately introduces size as an important variable for understanding innovation as it is the large fi rm that is more likely to do R&D, to patent (in some industries, as not all use patents).

In research, innovation is conceptualized as a multidimensional process and when the subjects are water and technology, there are a lot of layers to be added, because it's not only a product or a natural resource, water it's everything (Smith, 2005).

A framework comprises of economic agents, also known as actors, participating in actions that bear interconnections with fellow actors. The pursuits and associations give rise to immediate results and enduring effects. The system is delineated, signifying the existence of definite limits or parameters that exert a profound impact on the actions of the participants and the circulation of resources across interconnections (Gault, 2018).

Boavida (2017, p. 1) states that "indicators exist as a human effort to simplify understanding and governance of reality. They are conceptual instruments used to measure, evaluate and help with decisions by summarizing characteristics or highlighting what is happening in reality". According to Warhurst (2002), some indicator types can be defined for sustainable development, such as:

- **Performance:** makes a comparison between the actual situation and the targets defined.
- **Efficiency:** measures the process and product use. This applies to measuring of indicators itself like efficiency in water use or energy use.
- **Sustainable Reference Values:** measurement of target levels set for environmental quality.
- **Production:** related to engineering mostly and progress management, regarding environmental and economic aspects of the production.
- **Regulatory:** "drawn from consideration of legal compliance and typically are limited to the environmental dimension" (Warhurst, 2002, p. 35).

- **Accounting:** used for reporting, such as liability management, efficiency and cost tracking related with waste management.
- **Economic:** "used to value external environmental and social costs"; might work as an "input to any lifecycle-based assessment of environmental performance"(Warhurst, 2002, p. 35).
- **Quality:** based mostly on minimizing waste in the production.
- **Ecological:** assessment of the impacts on ecosystems.

In the scenario, eco-innovation has the potential to facilitate the progression towards a lifestyle that is focused on the environment and characterized by greater efficiency in low-carbon practices. Infrastructure in industrial sectors including transportation, power generation, waste disposal, and water purification (Albino et al., 2014)

In his studies about measuring innovation in all sectors of economy, Gault (2018) came to the conclusion that

> The objective of innovation policy is not just increasing the number of institutional units that innovate, but supporting social and economic outcomes, such as jobs and economic growth. To measure such outcomes, the definition of innovation has to be restricted so that the subset of institutional units that satisfy the restriction can be identified. In cases where the outcomes take time to appear, additional surveys are required which introduce a time difference from the innovation to the desired outcome such as inclusiveness, sustainability and change in the state of the poor. (Gault, 2018, p. 621)

On the other hand, Smith (2005) says that measurement is only possible if there is commensurability, implying the entities are qualitatively similar on some level, which allows comparisons to be made in quantitative terms. A problem urges right away, since innovation is the creation of something new, through processes of learning and building knowledge, producing qualitatively new performance outcomes that can be difficult to measure or that are intrinsically non-measurable. Some questions about "what is «new?»" must be made, which comes as a day-to-day problem to Science & Technology indicators (R&D in particular), but that does not mean that they are unsolvable.

Knowing that measuring qualitatively diverse phenomena is a serious problem for R&D data, it's very difficult to assess dissimilar ways to research, let alone the results. This problem might not be solvable but can be circumvented by specifying some aspects of the research process that can be measurable in some way. People that work for R&D data collection have been studying the research-comprising activities and then seek data on expenditure or personnel resources that must be devoted to such activities. This way of collecting indicators can be economic, but the datasets that result from it are compatible with industrial datasets and with the national accounts (Smith, 2005).

That combined with R&D that always presents a novelty element and the resolution of scientific and/or technological uncertainty, brings measurement to a complexity level that will need the need of technology itself to get results. The R&D data is always an innovation indicator since it measures an input only. It also has advantages: long period over which data is collected, detailed subclassifications that are available in many countries; and relatively good harmonization across countries. This long period that takes from data collection to an actual report or understanding of the data can be drastically decreased using technology, in this case a digital platform (Smith, 2005).

Regarding indicators, there are many approaches regarding this ecosystem, but generally the most present are emissions/carbon footprint; energy (consumption); product recycling rate and productive natural resources; biodiversity and habitat; water (footprint and reduction); saving levels due to conservation and improvement efforts and traceability (Smith, 2005). Recent years have seen attempts to create new, and better-designed indicators focused directly on innovation and surveys have been developed with a "subject" or "object" approach. These tools should be used in the topic of measuring innovation of technologies for water used, but again the large amount of data will need technology to be handled (Smith, 2005).

4.5 Future scenarios

As we consider the future, it becomes imperative to examine different scenarios that provide valuable perspectives into the potential developments of water governance. These situations serve as invaluable devices for policymakers, researchers, and interested parties to predict and get ready for upcoming issues, recognize potential hazards and prospects, and develop sustainable water management tactics. Within this segment, we will be examining crafted scenarios meant to envisage and scrutinize prospective courses of action and obstacles pertaining to the development of water management.

Scenario-building practices are a method to conceptualize plausibility of the future. According to Boenink (2013, p. 149), scenarios "help anticipate the future by imagining different possible futures, thus avoiding tunnel vision caused by 'presentism'. In addition, they are thought to promote flexibility in responding to on-going developments". In this case, the starting point is the goal set by the UN, in the matter of Sustainability Development Goal for 2030: clean water and sanitation for everyone (UN Water, 2013).

A report published by Kemira (2021)[29], built by a group of researchers in the United States of America and some organizations related to water, starts by saying that, meanwhile, the UN goal accomplishment doesn't look like it is following the expected course. Although, it also describes four possible future scenarios in water management for 2040, as it follows:

- **Scenario 1:** "water conflicts and resource games", "policymakers focus on present crises rather than looking to the future", "industry, energy producers, agriculture and consumers disagree over ownership of water" (Kemira, 2021, p. 6). The drivers here are the economic growth driven world, the strong population growth and the failure coordinating between sustainability and climate action. In this scenario, the water utilities will have its aging infrastructure renovated and expanded in population centers. There will be new investment in water recycling and wastewater treatment plants. The decentralization of systems becomes more common.
- **Scenario 2:** "cities and corporations lead on water": "the private sector pursues ownership of water and energy infrastructure" (Kemira, 2021, p. 16). Here, the drivers are strong pressure from citizens to solve climate change; circular economy driven by cooperation between corporations and large cities and strong renewable energy development. In this scenario, the water utilities will see a digitalization and reinvestment improve efficiency of aging water infrastructure. The decentralized systems become more common, and the water reuse becomes mainstream. New solutions and financing will be available to reduce waste, improve resource use and water efficiency.
- **Scenario 3:** "data-and platform-driven water": "digitalization stimulates free markets and new growth, especially in emerging economies" (Kemira, 2021, p. 20). Here, the drivers are market-driven and moderately regulated economy; information-driven society and political stabilization in emerging economies accelerates growth. In this scenario, the water utilities in large cities will have centralized systems. In growing cities and emerging economies, will prevail the hybrid models and water reuse. There will be a decentralization of water management systems and water capture systems to rural areas.
- **Scenario 4:** "circularity and regulated water": "centralized public systems become a trusted solution" (Kemira, 2021, p. 24). Here, the drivers are the multilateral agreements drive sustainable development; a strong climate activism and industrial countries commit to climate action. In this scenario, the decision making on water utilities and management will include public participation. In the Western World the

[29] Kemira Report can be found at http://pages.kemira.com/rs/784-UGU-140/images/kemira-water-management-scenarios-2040.pdf.

centralized water treatment will get more investments. The municipal water utilities become online and digitally enabled and will have data-driven quality control.

These four scenarios are enough to show us how the uncertainties in economic models, climate action, water resources, consumer values and in water utilities infrastructure can lead to new technologies and innovation in the water governance. Following the idea that the future will be data driven, the question about data protection and data ownership needs to be raised. The growing production and access to data will increase the complexity of the legal system around the technologies for water governance since data needs to be safely stored (from breaches and from permanent losses) and its owner also needs to be clear. And this is a whole new dimension to be defined.

In the short-term, a fully integrated, process-oriented, place-based sustainability privileges certain analytical methods over others. Case studies that draw from participant observation, participatory action research, and semi-structured interviews are arguably well suited to capture the peculiarities of place and to internalize the details that large-sample analytical methods overlook. In the long-term, a placed-based, process-oriented, and fully integrated understanding of sustainability challenges scholars of sustainability to explore new frontiers and identify communities that remain on the margins of political discourse. Their perspectives are likely to sharpen environmental debates and guide public policy toward resolutions to critical environmental and economic dilemmas (Boyer et al., 2016, p. 14).

Future scenarios are a tool of foresight to better understand the variables that might be involved in the future and try to create an action plan about them in the present. This is why the scenarios brought to us by Kemira's (2021) report are so relevant. On the other hand, Boyer et al. (2016) also talk about the future needs, either short-term and/or long-term, for participatory governance.

According to Schoemaker (1995) and Schwartz (1996), scenario building is a strategic approach used to effectively manage uncertainty surrounding future endeavors through the creation of a variety of conceivable future scenarios, thus facilitating informed decision-making and planning processes. It recognizes the intrinsic unpredictability of forthcoming events and favors individuals and entities in gearing up for diverse scenarios and in adapting to evolving situations.

The scenario building process can be carried out with different strategies, the following steps are proposed by Schoemaker (1995) and Schwartz (1996):

4. Initiate the process of identifying the pivotal catalysts of transformation: Commence by discerning the primary determinants that are expected to impact the forthcoming scenarios, including alterations in demographics, advances in technology, or changes in geopolitical circumstances.
5. Employ scenario building techniques to formulate a diverse collection of credible future scenarios grounded in the pivotal change-inducing factors you have ascertained. Every situation ought to display internal coherence and embody a uniform set of presumptions with regards to the future.
6. Assess the ramifications of each situation: Once a repertoire of scenarios has been established, analyze the possible ramifications of each situation for the organization or decision-making procedure. Consider the probable hazards, possibilities, and difficulties associated with each scenario, in addition to the prospective influence on significant stakeholders.
7. Identify Resilient Strategies: After conducting a thorough evaluation of each scenario, identify a variety of strategies that possess the ability to endure and adjust to a spectrum of potential scenarios. The strategies ought to be devised in a manner that would assist you in accomplishing your objectives, irrespective of the outcome that unfolds.
8. Continuously observe and adjust: Observe the developing circumstances and adjust your tactics accordingly as fresh information becomes accessible or the future evolves.

For water management there are some examples of the application of scenario building in the strategies design. In 2012, for the water management in the Netherlands, Haasnoot and Middelkoop, presented the scenario analysis employed to investigate various prospective outcomes, as the country contends with a host of formidable obstacles such as escalating sea levels, subsiding land, and intensifying weather patterns. Four scenarios were developed, with each of them representing a distinct level of collaboration and governance among the various stakeholders responsible for water management. Subsequently, the implications of each scenario for institutional arrangements and policy decisions were evaluated.

In the Nile River basin, according to Enserink and Onencan (2017), scenario building was used in 2014 for the analysis to investigate the possible effects of climate change and socio-economic advancements on the availability of water and the demand for water by 2050. Four distinct scenarios were formulated, each accounting for diverse amalgamations of impacts resulting from climate change and economic growth. The ramifications of each envisaged outcome were analyzed to ascertain their effectuality with respect to water management and environmental preservation.

The World Bank (2019)[30] adds that "the Nile countries comes together on a regular basis and have agreed to many mutual activities – although several key challenges remain."

4.6 Conclusions

The allocation of tasks and the delegation of responsibility occur within specific social and political contexts, which impact and influence identifiable individuals within distinct configurations. The revision of governance in a particular domain can prompt a shift in decision-making procedures, wherein a deliberate contemplation and ascription of responsibility can significantly impact the governance approach (Grundwald, 2011).

As presented earlier, the pre-RRI concepts of responsibility are focused on accountability (standard) and risks and effects for midterm (EU Framework Programmes eg. ELSA), while the RRI concept focuses more from the research stage (not only anticipation, but also inclusiveness). One can argue that we watched a radicalization of the concepts of responsible innovation in the last decades (Urueña. 2022). The RRI Responsibility adopts a proactive approach that integrates ethical considerations, societal values, and stakeholder engagement throughout the spectrum of research and innovation endeavors. The RRI framework underscores the importance of ensuring congruity between scientific and technological advancements and the societal requirements and aspirations, thereby fostering results that are inclusive and sustainable.

On one hand, the ELSA Framework specifically addresses the ethical, legal, and social consequences of genetic research and its ensuing practical outcomes. The ethical challenges associated with genomics demand the focused attention of researchers, policymakers, and stakeholders in fulfilling their respective obligations. The notion of responsibility as contemplated in the ELSA Framework entails the conscientious pursuit of genetic research, taking into due account its wider-ranging implications for society at large.

On the other hand, the **RRI Framework presents an extensive range and encompasses diverse scientific and technological domains.** It underscores the significance of responsibility in the domain of research and advancement more expansively, surpassing the realm of genomics. The RRI Framework mandates ethical behavior throughout all stages of research and innovation, underscoring the need to incorporate civic principles, anticipate and deliberate on

[30] For more on the Nile Basin initiative development established in 1999, see the Work Bank publication at https://www.worldbank.org/en/news/feature/2019/02/22/stronger-together-20-years-of-cooperation-around-the-nile.

prospective consequences, and involve stakeholders in determining a course of action. Both frameworks acknowledge the significance of engaging stakeholders; however, the RRI Framework places a more substantial emphasis on this aspect. Within the ambit of responsible research and innovation (RRI), responsibility entails the integral participation of diverse stakeholders, including but not limited to citizens, policymakers, industrial delegates, as well as civil society organizations, in the research and innovation continuum. The objective of this engagement is to guarantee that the results of the research and innovation endeavors are congruous with the demands and principles of society.

Although stakeholder engagement bears relevance within the ELSA Framework, its primary emphasis lies in engaging stakeholders to address the ethical, legal, and social implications that pertain specifically to the field of genetics and genomics research. The ELSA Framework typically entails a collaborative effort among scholars, experts in ethics and law, medical practitioners, advocacy organizations representing patients, and other relevant actors, to tackle the ethical, social, and legal challenges arising from genetic research.

The ELSA Framework has a strong correlation with studies in genomics and has been established as a reaction to the expeditious progressions made in this domain. This approach is frequently employed to proactively identify and tackle ethical considerations linked with emerging genetic technologies. The ELSA Framework places emphasis on the present and proximate ramifications of genetic research and its direct implementations, with respect to the notion of responsibility. The RRI Framework adopts a comprehensive and proactive stance. It fosters a culture of conscientiousness in carrying out research and advancing innovation across a multitude of areas and realms. The notion of responsibility in RRI transcends immediate ramifications and incorporates long-range effects, viability, and the broader communal influence of research and innovative undertakings.

The acquisition of scientific knowledge provides us with a standard of evidence that is well-suited for upholding a consequentialist approach to responsibility. Scientific evidence serves as a tool for evaluating an individual's ability to predict outcomes in hindsight. Furthermore, it is anticipated that individuals who make significant decisions employ this methodology. It is the duty of individuals who hold significant social positions to use this evidence as a foundation for exercising prudence (Grinbaum & Groves, 2013).

This inclusive viewpoint necessitates a concentration on the matter of socially responsible innovation in fundamentally political expressions. Effective responsibility can only be realized through the comprehensive integration, accommodation, and institutionalization of diverse values, interests and knowledge which serve to invigorate and shape innovation. The politicization of responsibility is a crucial issue that is intricately linked to our society's capacity to make collective decisions regarding the nature of innovation we aspire to achieve (Eizagirre et al., 2017)

The principles and dimensions delineated within RRI can facilitate the conscientious and sustainable development of research and innovation. Through anticipating the identification and resolution of potential impacts and consequences, RRI aids in the prevention and mitigation of adverse results. It enables researchers and innovators to consider the moral, societal and ecological ramifications of their efforts, and make well-informed judgments to guarantee conscientious and enduring results. The promotion of critical reflection (Reflexivity), particularly reflexive practices, aids researchers and stakeholders in identifying their personal biases, values, and assumptions (Von Schomberg, 2013). The possession of self-awareness allows individuals to address ethical and social hurdles effectively and sensitively, making well-informed and conscientious decisions throughout the course of their research and innovative endeavors (Stilgoe et al., 2013). Inclusivity is a fundamental aspect of RRI, whereby an array of stakeholders, encompassing members of the public, are actively engaged in the decision-making procedures. By integrating diverse viewpoints, insights, and ethical principles, RRI fosters the responsiveness of research and innovation to address the complex challenges and pressing issues of society. The practice of inclusivity promotes a participatory and responsible methodology, resulting in results that are consistent with the anticipated standards of the community. RRI advocates for a culture of transparency and openness in research and innovation endeavors, wherein knowledge, methodologies and outcomes are mutually shared among relevant stakeholders. This level of transparency facilitates meticulous examination, critical assessment, and community involvement, resulting in the establishment of confidence and responsibility regarding scientific and technological advancements. The attribute of being open further enables efficient teamwork, knowledge acquisition, and the propagation of ethical methodologies.

RRI approach fosters a structured mechanism that promotes the collaboration of researchers and innovators with stakeholders, encompassing the public, industry, policymakers, and civil society, across the entire spectrum of research and innovation endeavors. The integration of heterogeneous viewpoints fosters responsibility, amplifies the applicability of research findings, and bolsters the prospects of sustainable progress.

The operational focus of decision makers is often confined to silos, which can result in a limited range of perspectives and a gap in diversified knowledge. Such limitations can lead to biases and hinder informed decision-making (Hargreaves et al., 2019). In order to effectively tackle this matter, it is imperative to consider the notion of knowledge co-creation. Such an approach entails actively involving a variety of stakeholders in the decision-making process, drawing upon their multifarious knowledge and expertise, as posited by Pohl et al. (2010). By adopting this methodology, we guarantee that our objectives and tactics pertaining to water use and sustainability are based on a diverse pool of viewpoints. This ultimately mitigates any predispositions or oversights that may occur.

The incorporation of futures studies and scenario planning tools is crucial within the context of inclusive and forward-thinking governance, as evidenced by Dewulf et al. (2013). Through an appreciation of the diverse geography, culture, and knowledge present in a given area, those in leadership positions can surpass reliance upon external benchmarks and cultivate productive relationships with local communities. By incorporating local needs, values, and priorities into water use and sustainability policies, decision makers can enhance the relevance and acceptance of these policies among stakeholders. The process of attaining knowledge co-creation needs decision makers to establish an all-encompassing discourse platform, encompassing diverse stakeholders from various sectors and backgrounds (Cash et al., 2003).

Going from the RRI responsibility vision, it will be possible to develop useful framework for addressing the intricacies that arise in the management of water use. RRI advocates for a comprehensive and participatory approach towards water management, which involves the integration of societal values, ethical considerations, stakeholder involvement, and anticipation of potential impacts to ensure inclusivity and sustainability. It underscores the significance of taking into account not just the technical factors, but also the social, economic, and environmental facets.

The RRI approach places significant importance on incorporating societal values, engaging with stakeholders, and providing foresight into potential impacts during the entirety of the research and innovation process (Stilgoe et al., 2013). Whilst our discoveries augment the existing comprehension of water conservation, further analysis should endeavor to integrate RRI principles to augment the sustainability paradigm.

5

OPERATIONALIZATION OF TECHNOLOGY ASSESSMENT: AN ANTICIPATORY GOVERNANCE MODEL

> As technical activities have become more pervasive and complex, demand has grown for more complete and multivalent evaluations of the costs and benefits of technological progress. It is widely recognized that increased participation and interactive knowledge-making may improve responsibility and lead to more credible assessments of science and technology. (Jasanoff, 2003, p. 243)

5.1 Introduction

The purpose of this chapter is to operationalize the conceptual framework put forth in the preceding chapter, which highlighted the deeply dependent nature of responsible management of water use. The current emphasis lies on implementing contingency measures through a simulation and assessment. This task is done using an anticipatory governance framework focused on fostering inclusivity societal actors' engagement and promoting anticipation to accomplish appropriate governance consequences.

In order to conduct this experiment in an efficient manner, a simulated approach rather than a physical experimentation is implemented. Guidelines for simulation are presented to ensure the experiment's consistency and practicability. The prime focus pertains to the implementation of the anticipatory governance approach, whereby the water use governance framework and its corresponding sphere of governance are mutually established. The process of simultaneous learning refers to the intentional application of a learning tool to facilitate the constitution of the epistemic subject[31]. It is crucial to understand that governance involves more than just gathering viewpoints from stakeholders; it involves forging a body that proactively develops a foresighted governance system for managing water use. The proposed instrument will enable the simultaneous co-creation of the governance mechanism and co-constitution of the subject, that is to say, the network of actors that co-produce knowledge in a collaborative manner. Following the operational simulation of open anticipatory governance, the chapter advances through its roadmap stages. To begin with, there is a paradigm shift in the perception of water, wherein it is no longer considered as a mere resource, but rather as a "common" resource that is shared by all. The adoption of this new viewpoint carries significant weight, and the chapter provides an in-depth analysis and rationale for this transition, underscoring the responsible use of water as a collective responsibility through transparent and forward-thinking governance.

The previous chapter delves deeper into alternative perspectives of Responsible Research and Innovation (RRI) technology assessment. A primary focus will be placed on two approaches, one related to co-production of knowledge and other mission oriented, and a critical assessment is presented, emphasizing the absence of transparency in these methodologies. Underlining the importance of assessment in the context of a Technology Assessment Framework is of utmost significance, given that the thesis is presented within this framework.

The rationale for performing practical experiments lies in obtaining a contextualized comprehension of the generation of innovation. Through active participation in empirical experimentation, researchers can comprehend the intricate nuances of innovation within a

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[31] To understand the advancement of human development and cognitive abilities, it is imperative to read the Piagetian theory within an epistemological framework (Niaz, 1991). Epistemology is a field in philosophy that deals with the fundamental nature, scope, validity, and limitations of knowledge, as stated by Hookway in 2018. According to Goldman (2010), the origin of the term "epistemic" can be traced back to the Greek word "epistēmē," connoting knowledge or comprehension. It is widely utilized to denote the cognitive processes or systems that are implicated in the acquisition, retention, and application of knowledge. Additionally, it encompasses the methods and techniques utilized to develop or authenticate knowledge (Nozick, 1981). As stressed by Piaget:

The epistemic subject, insofar as it refers to the person who knows and the subject of knowledge, emphasizes the perspective of the subject and underlines the importance of individual experience (Piaget, 1971, p. 146).

The conceptualization of the epistemic subject, in contrast to the psychological subject, is a hypothetical construct. It refers to the fundamental cognitive structures shared by individuals within the same stage of cognitive development (Niaz, 1991).

Arraiza Zabalegi (2019) states that given the concept of the interdependence of the epistemic, political, and ontological spheres, the impacts of our actions carry greater weight and significance.

given context, gauge its viability and consequential effects, acquire empirical data, and facilitate a collaborative learning environment. The utilization of practical experiments serves as a significant mechanism for the meticulous evaluation and advancement of our comprehension pertaining to innovation procedures and results.

This governance process is functionally decomposed into a double functional process: (i) co-production of responsible technology for the governance of water use and (ii) co-constitution of the epistemic subject. Where (i) and (ii) are simultaneous. This double functional process is constructed in the simulation in the next sections. The milestones of this phase are the workshops as a strategy for the application of anticipatory governance.

The principles of the new model proposed here (InovPlat) are as follows:

1. The publics constitutes a network of actors.
2. Actor network theory: co-production + co-knowledge: in the mechanism of co-production of technology, not only technology is produced, but also the epistemic subject is co-constituted, translating into a unique ecosystem of knowledge.

Ultimately, the chapter concludes by designing an approach of a simulation model that employs the socio-technical framework for the purpose of promoting responsible water use. The present exercise has yielded a novel paradigm of sustainable water management, which stands as the primary aim of the doctoral dissertation. The core objective of the simulation exercise is to impart practical knowledge pertaining to responsible practices, thereby contributing towards the establishment of a reliable and viable water management framework with a sustainable outlook.

The following framework proposed can be applied to problem solving and decision making in multiple fields of science and technology, not only for water management, but for inclusive anticipatory governance as a whole for smaller to larger scale projects.

That is to say that the proposed experiment can be applied in projects from different topics, not related to water, but to applications of technology, and to distinct levels of geography, either its local/small level, or a larger/Global level.

5.2 Analysis of practical experiments: co-production vs. mission-oriented

The following sections present a critical analysis of two approaches presented by different authors: first the co-production of knowledge approach, explored by Selin (2011) and Urueña et al. (2021); then a mission-oriented approach with pre-set goals, presented by Zarantin et al. (2022) regarding the Multi-Act framework.

5.2.1 Co-production of knowledge approach

This section introduces an approach that is centered on the co-production of knowledge from a subject-actor-public pre-existing to the co-production process. Selin (2011) and Urueña et al. (2021) present this methodology where the co-production of knowledge is performed from expectations and social demands of publics already constituted, improved of listening procedures and management of deliberation as an engine of co-production.

According to Urueña et al. (2021, p. 1),

> A pre-condition for foresight practices to become "instruments for" responsible innovation is to make them "subjects of" responsibility simultaneously. This involves monitoring the socioepistemic relations whereby foresight practices are designed and executed, as well as monitoring how their emergent heuristics are translated into action.

In other words, in order to have foresight practices serve as tools for responsible innovation, it is imperative that they hold subject responsibility, entailing the surveillance of the socioepistemic connections that underlie the creation and implementation of foresight methodologies, and the monitoring of how their resultant heuristics are transformed into practical applications.

Selin (2011) seeks to demonstrate that Anticipatory Governance (AG) is a good method for technology assessment. In her work, the author explains how the Arizona State University used AG with the aim of boosting a new methodology applicable to science and technology, based on models that were already used by companies, or even applied to technology in war scenarios. This model consisted of beginning to design anticipatory governance processes and mechanisms, which served as real-time assessment mechanisms of science and technology.

In her work, Selin discusses the challenges associated with making choices about emerging technologies and the need for long-term considerations in decision making. Anticipating the outcomes of a technology is challenging before its implementation, but once implemented, it becomes problematic to manage or adjust its consequences. Additionally, it highlights the absence of responsible governance and emphasizes the importance of creating a dialogue, exploring options, and prioritizing progress in early technological advancements (Selin, 2011). Efforts to evaluate and direct technological development encounter various obstacles, such as the participation of different stakeholders with differing perspectives. The

NanoFutures Project[32] (as outlined in her research) seeks to assess its feasibility by asking for input from all sorts of stakeholders. An open-source approach is employed by the project, which seeks to collect valuable information about what different technical and non-expert experts believe are plausible. These types of discussions were designed to investigate economic, social, and political feasibility which will eventually lead to debates about whether something is desirable. Although, the author also reflects on the difficulty of having someone else's future views as something that can make them question people' "what they are doing and what they want". People may reevaluate their aspirations and conduct by considering the future and scrutinizing expectations. On the flip side, controlling future scenarios also involves limiting certain concerns and possibilities. By framing the future, the NanoFutures project aims to modify action in the present by reorienting attention.

Selin (2011) also notes the risks associated with using the future tense in research, such as neglecting the present or deflecting attention from current issues " There are additional risks in employing the future tense in research. For example, there is a risk of avoiding or downgrading the present by centering debate in the future" (Selin, 2011, p. 735). Although it is important to contemplate potential futures is to counteract long-held assumptions about technological advancements. The act of reflecting allows for a more precise evaluation of the speed of technological advancement, social acceptance or denial, and cultural transformation. The project (NanoFutures) aims to promote inclusive and reflexive decision-making processes regarding technology by introducing workshops, data analysis, and stakeholder engagement.

Through anticipatory governance we can identify factors that close or favor the co-production of the most open or more democratic technology. At least we can have elements to evaluate the technology with certain objectives. According to Selin (2011, p. 2) "Governing emerging technologies faces two main challenges: 1) insufficiently diverse and reflexive decision making; and 2) a speed of technological change uncoupled from capacity for socio-political response". The levels of uncertainty associated with these technologies are the given point in choosing how they should be governed:

> Anticipatory governance is ‘a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible’. It motivates activities designed to build capacities in foresight,

[32] The NanoFutures Project "aims to address a central question: how to deliberate the social implications of an emergent technology whose out- comes are not known." and "involves novel foresight methodologies to develop plausible visions of nanotechnology enabled futures, elucidate public preferences for various alternatives, and using such preferences, help further refine future visions for research and outreach." (Selin 2011, p. 723).

engagement, and integration – as well as through their production ensemble. (Guston, 2014, p. 218)

Three main parts make up the NanoFutures initiative (Selin, 2011). First, there is the development stage, during which scenarios for products with nanotechnology capabilities are developed. Potential uses of nanotechnology are represented by these scenarios. Secondly, to determine the technical plausibility of the suggested scenarios, a combination of research techniques and interventions are used in the vetting stage. The goal of this step is to make sure that the proposed nano-enabled products are technically feasible. And then, presenting the product scenarios to numerous stakeholders is the final step in the deliberation phase. This enables the scenarios to be expanded upon, critically analyzed, and discussed, encouraging a teamwork-based and all-inclusive approach to determining the direction of nanotechnology, in the case of Selin (2011) article.

5.2.2 Pre-set goals: Mission oriented approach

In this section we will present as an example a framework for assessment of anticipatory and responsible and technology from evaluation instruments created a priori by the analyst, not by the actors of innovation.

Under the Portfolio of the European Commission Horizon 2020 Work Programme can be found the strategic framework project called Multi-Act[33], originally designed for the health research industry. The Multi-Act uses an anticipatory governance model that aims to be innovative and participatory to help improve the impact of health care research, gathering not only the people who actually suffer from the disease but also their families and caregivers, in what they named as a Collective Research Impact Framework (CRIF). This framework aims to create an effective co-accountability of all "relevant stakeholders" (Zaratin et al., 2022). In addition to the tool basis, it would be defined as a holistic concept encompassing governance criteria, patient integration, and multidimensional impact assessment. This is a mission-oriented model[34] and enables an innovative co-accountability strategy that translates into a

[33] The Multi-Act developed in consortium by various entities such as The Italian Multiple Sclerosis Society Foundation; Università degli Studi di Trento, UNITN; ERNST & YOUNG Italy, EY; Universidad de Burgos; Tampere University; European Brain Council; INTRASOFT International S.A.; European Health Management Association; Fondation pour l'Aide à la recherche sur la Sclérose en plaques; Dane-i-Analizy.pl Sp. z o.o. and Universidade Católica Portuguesa. More information about H2020 funding project can be found at official project website at: https://www.multiact.eu/.

[34] The authors also state that to deliver transformational missions it is essential to use multi-stakeholder research initiates. "Within this strategic framework, research institutions must make themselves

new governance criterion that includes new guidelines for patient integration through health research and a new system for assessing the impacts of research across different dimensions. The aforementioned model is developed in five phases and includes a set of normative characteristics and operational procedures for carrying out the investigation (Figure 4) as the following steps:

1. Multi-stakeholder: map stakeholders and establish the scope and the mission.
2. Develop an Operative framework.
3. Co-selection of relevant Impact aspects and definition of an agenda.
4. Shared measurement system (indicators).
5. Execution and action: reporting, monitoring and assessment.

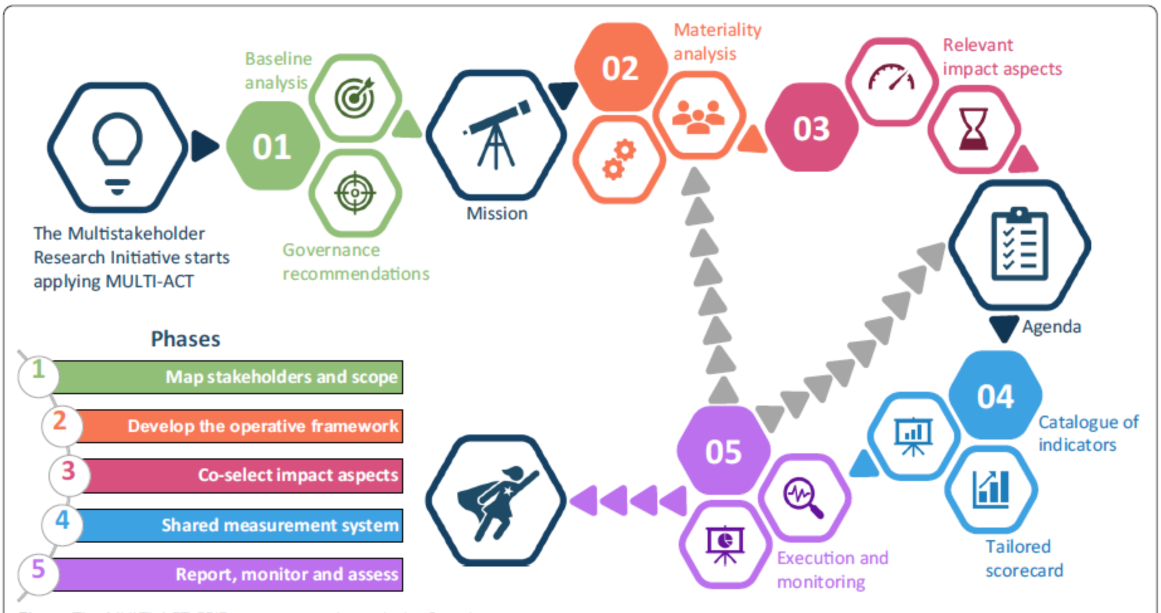

Fig. 2 The MULTI-ACT CRIF user journey through the five phases

Figure 4 - Multi-Act Model (Zaratin et al., 2022, p. 4)

Each research initiative must define its scope and mission (phase 1) and implement an operating framework for its realization (phase 2). The control of the results is entrusted to the definition of specific aspects that lead to the definition of an agenda (phase 3) and which are the basis for the selection of the related multidimensional indicators of the measurement model shared by the stakeholders involved in the initiative (phase 4) (Zaratin et al., p. 4, 2022)

Multi-Act's approach compared to other models, is distinct by incorporating the mission-related attribute as a dimension that caters to the stakeholders' interests. This feature serves

capable of rethinking their own governance and working models through an enhanced collaborative sustainable approach" (Zaratin et al., 2022, p. 2).

as an explicit catalyst for collaborative responsibility. "The framework introduces the evaluation of the efficacy of an R&I initiative interpreted as its capacity to fulfil the shared mission (along with the other impact dimensions detailed hereafter) as a pivotal element to promote research that has an impact on patients and society" (Zaratin et al., 2022, p. 2). Furthermore, it claims to be circular and flexible (Figure 5), to maximize the success of fulfilling the mission and achieving anticipatory governance through aiding institutions in applying participatory governance, so they can create knowledge-based evidence while such management is still possible" (Zaratin et al., 2022). With this, the author calls to the urgency of the "integration of RRI mission-oriented participatory and anticipatory governance" (Zaratin et al., 2022, p. 2). There is also a digital toolbox to connect with the stakeholders, as part of the framework, which is a space to get answers to interviews, called Multi-Act Toolbox[35]. In the official project website, they state that tools are to be used "by organizations willing to conduct health research with a multi-stakeholder and co-accountable approach." (Multi-Act, 2021).

Figure 5 - MultiAct Toolbox Components (available at https://toolbox.multiact.eu/multi-act-manual#_Toc70265316)

This methodology has its strengths, particularly in the way it systematizes processes and structure objectives. However, it inevitably becomes closed from the point of view of

[35] The Multi-Act Toolbox was developed as a deliverable of the funded project. The tool has a registration form, login and then a set of questionaries are available. The tool can be fund online at: https://toolbox.multiact.eu/

knowledge creation and the learning processes, by defining the departure a set of assumptions that will eventually create barriers, even if this is not the initial objective. Learning processes must be fully open in order to be able to reflect on the production of knowledge and consequently more responsible technology.

These two approaches (co-construction and mission oriented) are somehow symmetrical, on one hand the multiact has its principles and goals defined from the beginning for being mission oriented which makes it a closed process, and on the other hand, the co-production of knowledge approach is radically open and considers the epistemic subject as one individual, not seeing all connection between the network of actors that is build. The MultiAct instrument, is rather limited for its aprioristic and closed character: the a priori fixation of the dimensions, indicators, plans and analysis of the evaluation "closes" the anticipatory governance to previously established factors. By adopting an aprioristic mindset, individuals curtail their capacity to delve into novel concepts, viewpoints, and opportunities. It curtails the liberty to conduct experiments and explore innovative solutions. The closed character of the multiact can inhibit creativity (as innovation flourishes through the cultivation of imaginative thinking and a willingness to innovate beyond traditional norms). Additionally, the closing at the outset increases the inability to embrace change and progress in a dynamic and swiftly changing environment, diminishing competitiveness and responsiveness by limiting the learning and enhancement process.

The objective of the methodology presented will be to improve anticipatory governance as a heuristic instrument to open new possibilities for technology development. It is a methodological problem, in this case applied to heuristics.

If on one hand, the model presented by Selin (2011) and the model presented by Zaratin et al. (2022), the Multi-Act both turned out to be too closed, the project that gave rise to the Multi-Act methodology is a novelty that consists on the use of a digital tool, for the collection and management of information collected during the process.

This section will start by providing a view on what are the strongest methodologies that were studied and developed by researchers for operationalization of anticipatory governance and what are the initiatives that are also being developed in this area. After that it will be made a reflection and a comment on what are the strong points and the weak points of this methodologies and understand how those analyses can contribute to the definition of a new model.

There are several perspectives and visions on how to recognize the dynamic of producing scientific knowledge in elements such as the heterogeneity of the agendas and the materiality involved, their logics and values, as well as proposing changes in the institutional guidelines that govern the practices of (scientific) knowledge production (Ibarra, 2012).

The main goal of these models is to explain how the science-society dichotomy works.

We can see that, in the last 15 years, two ways of how to operationalize came up in two great conceptions - on how to conceive the anticipatory governance (public engagement learning process):

This logic is based on a more original idea by René von Schomberg (2011) and the basic concept of RRI. Here, the most emerging technologies are the most experienced and therefore have to be conducted in the most democratic way possible. An example of a methodology designed based on these assumptions is the Multi-Act, where the goal is to try to make technology more democratic space, more than in agreement with the shared values of society.

On the other hand, Urueña et al. (2021) write about the operationalization of anticipatory governance and identifies the openness and closure factors. According to the authors this model could be structured in three phases: *ex-ante*, *ex-dure* and *ex-post*. The four key points here are: co-accountability; mission-oriented research; participatory governance; and Responsible Research and Innovation (Urueña et al., 2021).

It is important to remember that Von Schomberg (2011) was one of the first to write about the mutual responsibility between science and society and the forward looking of socially desirable.

When discussing about the epistemic subject we should bringing the topic of Public Engagement. Anticipatory governance allows us to involve actors and social responsibility, the so-called "Public Engagement"– which serves to insert mechanisms of actors in the assessment of technology in order to add these actors to learning processes.

Public engagement is not (or should not be) an objective in itself, but rather the involvement of actors in the learning process. This is a concept that will make sense to introduce, learning processes, since technology assessment is a learning process in itself.

Thus, if we understand the evaluation of technology as a learning process, and, on the other hand, we understand a process of technology assessment as a process in which actors, demands, expectations, expectations more than the actors themselves, we should look for a way to integrate this into a technology.

If this is a learning process, the whole learning process, by definition, must be opened, so the opposition we always make between open and closed is justified by this axis. There is, therefore, a normative component with the condition of opening. The normative condition would be the one that binds in open processes, because anticipatory governance processes need to be more open.

What matters is the concept of openness linked to the co-production of technology. The Technology Assessment is an evaluation that is made in real time, that is, at the same time that technology is assessed, it is co-producing technology at the level of all actors in society.

The concept of openness is linked to learning, we can only learn if we use processes open to discussion and deliberation, and not closed processes that are determined *a priori,* following predefined processes that we have to accept, thus becoming conditioning. Only in this way is it possible to deliberation all possible situations, when identifying objectives.

We cannot have an assessment mechanism at the outset where the indicators are fixed beforehand, since this will restrict the process, making it more closed.

It is important to take a minute to understand what are the living labs that have been so talked about in the last 10 years. "By living labs, we mean reconstructing the interaction space. It can be any space, anywhere, suitable for collaborative design, the application of knowledge for empowerment, uplift, and development of people and communities for the use of innovation" (Leminen et al., 2012).

As mentioned in chapter 3, RRI – Responsible Research and Innovation, there has been an evolution in the understanding of the science-society relationship. Anticipation is a driver for public implication on technology assessment issues. It is instrumental, according to Barrenechea and Ibarra (2019), that we use the construction of future scenarios, to incorporate needs, values, expectations of society. Seen from this perspective, the RRI production of knowledge articulated around plural demands and expectations, co-responsibility, and social desirability, translates into collective socio-technical options of better quality (relational). That is, in continuous and collective commitments both with the purposes of knowledge production and with science-society co-responsibilities.

5.3 Responsible technology and innovation based in open anticipatory governance

This section follows with the presentation of our concept of responsible technology and innovation based on open anticipatory governance. The objective of the experiment is to show the tools and means to build this responsibility. This new responsibility most be built from the learning of the application of an instrument to improve the deliberative capacity of the epistemic subject, in other words a full network of actors.

In this context, we can now identify a comprehensive concept of sustainable responsible technology where sustainability is linked to the satisfaction of demands, expectations, desires, values, of the society (as a whole and not a set of pre-defined stakeholders).

The hypothesis of this is work is that the process of co-production of knowledge and innovation is simultaneous to the process of co-constitution of the subject of this co-production. And the higher the relational quality of the subject, the greater will be his deliberative capacity (identification of demands, expectations, etc. and their valorization) and the better conducted the process of co-production of innovation.

It is worth considering that the scientific communities, acting collectively, have placed the image of the scientific enterprise within the scope of the discussion. It is exactly this phenomenon that has put an end to the old individualism (Ibarra, 2012).

As mentioned by Ibarra (2012), the present prevailing perspective holds that the societal aspects of scientific knowledge are limited to the personal acquisition of cognitive skills at an individual level, and requires not only a modification within the prevailing paradigm, but also a transformation of the paradigm itself, which can facilitate us in evidencing that scientific knowledge, regardless of its conceptual form, encompasses its own realm, defines its purposes and objectives, and establishes its own ethical principles. Acceptance of the metaphysical principal, it should not be construed as endorsed. That is to say, the notion that the socialization of individual agents' intentions plays a significant role in defining the objectivity of scientific inquiry.

As stressed by Ibarra (2012):

> The social constitution of science is coupled with that of the psychical constitution of its members. However, these are essentially different forms of constitution created through basically different actions. The actions of the network cannot be confined to the individual actions of its members. (Ibarra, 2012, p. 73)

This vision drives to a radical "disenchantment" of the individual subject. Ideas and notions flow among individuals, undergoing modification during the process of dissemination, thereby enabling other people to establish a particular form of association that differs from their own (Ibarra, 2012). In this approach we can follow the idea of epistemic subject transformed in an epistemic network. The author brings the concept of "collective subjects" as agents of science and technology, which will be the key for the development of the framework presented in the next sections. One should consider that science and technology is a collective result of co-creation of the epistemic network.

The key of our proposal is integrating the actor-network theory on a framework that would be supported by a digital platform. By taking advantage of the use of digital tools, it should be a faster and more efficient route to accomplish the following objectives:

- Understand the dynamics of the connectivity between the actors and relational quality.
- Reduce the demarcation between science and technology, engineering, social and human sciences.
- Establish a basis for dialogue between the industry/business space and the societal space, identifying aligned objectives.
- Promote the inclusion of societal issues in the design of innovation trajectories.
- Provide a reliable participant's profile analysis.
- Promote reflection on the consequences of the applicability of certain technology in the problem area.
- Promote the identification of diversity of interests and assumptions of the actors.
- Promote reflection on the identification of domains of knowledge, uncertainty, and ignorance in relation to the scope of application of technology.
- To analyze the connectivity of the public, both current and potential
- Identify possible actors to incorporate from the analysis of potential connectivity.
- Compensate notable biases of lack of diversity (especially gender or culture, but also age).
- Identify initial hindering or facilitating elements for the anticipatory co-production of knowledge.

This strategy approach should give a guideline for its implementation to be developed in a next phase of the investigation, through a process of public involvement (including scientists and technologists) in technological co-production actions, throughout the whole process: exploration, deliberation, conceptualization, and assessment, set to a specific problem to solve, for decision making, in a geography scope. All these phases should be validated and tested in another phase of the research, which is not the aim of this work, due to the time duration imposed.

The "open anticipatory co-production" takes value here as an inclusive, multi-actor process of involvement that seeks to integrate the perspectives of the societal actors (their values, demands, expectations) throughout the research and innovation process, as reflections of societal problems. This open anticipation approach goes beyond simple stakeholder consultation or deliberation, since it is based on an interactive process that facilitates collaboration, mutual learning and a high degree of reflexivity and responsiveness among actors. As a result, the open anticipatory process of co-production of knowledge and innovation will make it possible to identify eventual positive responses (*right impacts*) to the challenges present in society - and not only to detect the potential risk derived from the application of the technologies at stake.

5.4 Simulation for operationalization of the experiment

This section presents the operational methodology of the experiment. The operationalization of the experiment will be done by means of a simulation, that will not only define a roadmap for its tasks, but also provide a specification of a platform to do it. In a previous work from Romeiro and Ibarra (2022) regarding responsible technology and innovation, with a distinct technology as case study, an experiment was conducted with interviews. This experiment to be fully tested[36] should undergo through funding mechanisms to be implemented, as it requires not only resources to gather results with actors but also a larger timeframe to assess the quality of the co-production of knowledge in the network and build the digital platform make it happen.

As stressed by Vasconcelos (2004), interactive methodologies are an asset in the decision-making process in sustainability, namely because they lead to the emergence of unexpected partnerships that bring unexpected themes to the political agenda and reformulate the old ones (social capital). In addition, they also allow the dissemination of information (intellectual capital) and the structuring of information at each stage of the process, optimizing the opportunity for everyone to be involved.

The structure of this operationalization experiment is the following:

- Single process of co-construction of knowledge functionally oriented in two directions: (i) co-production of knowledge and (ii) co-constitution of the epistemic subject (network of actors).
- The unique process is structured in two phases: exploratory and operational:
    1. The exploratory phase - with stakeholders - with defined tasks.

[36] Due to unforeseen circumstances, the PhD Program under which this research was developed was discontinued, thus having the deadline being reduced for students to be able to finish the course, having been determined by A3ES that the research work should be completed by July 30, 2022, as officially notified to the students on May 12, 2022.

2. The operational phase - with actors who constitute the subject of co-production: the network of actors - has other tasks: those expressed in (i) and (ii). The co-constitution of the subject - i.e. (ii) - is carried out using a learning tool (adapted Barrenechea and Ibarra, 2019) - to improve the relational quality of the network.

5.5 Structural and technical aspects

The following sections will explore the structure proposed for the experiment, from the definition of the roles and its responsibilities and instruments.

5.5.1 Structure of the operational group

The operational group will be given specific profiles and permissions on the platform, to be able to create workshops and questionnaires. There should be defined the following roles (it is advised to create a board to vote for the roles from volunteers):

1. Responsible for the experiment. Formulates and orchestrates the experimental protocol. Has privileges as platform admin.
2. Administrative assistant supporting the leadership team. Assists the designated party and provides assistance to the facilitator.
3. Facilitator. Enables the activation of the workshops. Possess expertise in collaborative creation endeavors and hands-on educational techniques. Accountable for the coordination and facilitation of the workshops, while non-responsible for their substance.

5.5.2 Instruments for workshops dynamics

There is a wide range of instruments available that are specifically designed to facilitate co-creation. While there may be room for further discussion, the World Café methodology has potential to serve as a viable tool for facilitating productive discussions amongst four to five stakeholders. After completing the necessary deliberation and assessment of a particular aspect, the stakeholder proceeds to engage in further discussions with relevant groups. The process is iterated.

5.5.3 Implementation of the process

The workshop program comprises a series of workshops, with varying durations. The training sessions are spread over a timeframe that will be determined along with the process from the preparation stage. The number, structure, objectives, and duration of the workshops must remain open to the deliberation and decision of the actors, in order to preserve the openness of the governance mechanism.

Prior to the workshops, a series of diverse engagement initiatives will be implemented with the aim of fostering active participation and engagement among attendees. The initial workshop is anticipated to commence with approximately 12 actors. It is anticipated that the subsequent two workshops will witness a surge, bringing the estimated count to 20. Recognizing the actors who display higher levels of engagement is crucial. However, it is imperative to refrain from granting them a dominant position to prevent any possible bias. Active participants are instrumental in upholding the overall momentum of the study.

Invitations can be extended to the participants and stakeholders of the exploratory phase for their potential involvement.

5.5.4 Location: the platform

As stressed by Werker (2021, p. 288):

> As the digital transformation of our societies including RRI systems will take off even more in coming years, more consequences might emerge in the future. In order to assess RRI in the digital age we need a system approach, because RRI emerges from the co-evolution of stakeholders, their relationships and activities as well as the supporting institutions.

Also, according to the author, "we have to acknowledge and use the opportunities and challenges emerging from the digital transformation which changes the playing field of RRI systems substantially" (Werker, 2021, p. 288).

The location of the workshops and activities should be online, in the platform designed in the next section. The digital deliberation space will provide a "location" for the experiment to take place.

The workshops should take place online using collaboration tolls[37] integrated with the following propose platform.

[37] For the workshops to take place should be implemented an integration with a tool similar to "Conceptboard" with allows the use of canvas and "post-its" to "co-create in real time" and it also

Ultimately this will allow the increase of participation and reducing gas emissions (by reducing travels to get the teams together) and removing geographical barriers. On the other hand, going digital will also allow for improvements on the traceability of the data and knowledge, with increased efficiency in synthesizing the information automatically.

5.6 Objective of the experiment

The implementation of co-production of knowledge production focused on addressing responsible technology challenges pertaining to sustainable water use will yield a model of the developed approach, along with insights into the enabling factors and hindrances to an inclusive process of anticipatory governance. This, in turn, will promote responsible technology through the ability to identify and scrutinize relevant societal issues and their beneficial effects.

The concept of open anticipatory co-production is hereby presented as a participative and pluralistic approach that seeks to incorporate the viewpoints of multiple stakeholders, including that of the public (their values, desires, and expectations), into the research and innovation process with the objective of addressing societal challenges.

This methodology transcends stakeholder consultation or deliberation by employing an iterative approach that fosters collaboration, reciprocal learning, and an elevated level of introspection and adaptability among stakeholders.

Consequently, the collaborative and proactive approach of co-generating knowledge and innovation would enable the identification of feasible affirmative outcomes (favorable effects) to address the societal hurdles - rather than solely detecting the potential hazards arising from the use of the pertinent technologies.

It must be acknowledged that the scientific community, in their collective capacity, have made strides towards placing the public perception of the scientific enterprise at the forefront of discussions, thus paving the way for a shift away from the traditional emphasis on individualism.

This proposal for anticipatory governance aims to create an all-new space, based in open experience at multiple contexts of knowledge production and innovation, that will integrate a tool to measure relation quality in the network of actors as a key point of novelty. This is a layer

allows to think visual and create visual frameworks. For more information on this example please follow: https://conceptboard.com/online-whiteboard/

of innovation on top of the concepts described before and in the following paragraphs since it moves all the process to the digital space.

The conceptual openness described here is regarding on how it really responds to societal problems and its outcomes, and how can be considered the right impacts for them. More precisely, it shows how the impacts are not conditioned by predetermined factors derived from economic imperatives (macroeconomic, industrial objectives and others), political (values prefixed as unquestionable attributes), cultural (prefixed principles related to integration, cultural identity, and others).

Here, the openness of research and innovation is linked to the development of an open anticipatory capacity of the public subject to the experience of constructing plausible futures and drawing consequences for the present from them. The operationalization exercise will make it possible to identify the factors that facilitate and hinder this open anticipatory capacity, but it will be materialized by a platform - a digital platform. Since it's digital, this platform will have its own omnipresence, as it can be made available everywhere for everyone.

Considering that openness is a function of the process of implementing the co-production of knowledge and innovation, this work will be a contribute to the validation of a community dialogue, in an open way, with associated knowledge and not only for the obvious stakeholders.

5.7 Novelty of the proposal

The objective of the endeavor is to conduct an analysis on how open innovation can be harnessed in the context of knowledge production and innovation. Unconstrained by predetermined factors stemming from macroeconomic imperatives, industrial objectives, and political or cultural values perceived as incontestable attributes, openness in this context is characterized by its responsiveness to societal issues and its ability to yield positive consequences for society.

In the current proposal, the correlation between research and innovation's openness is intertwined with the cultivation of the public's open anticipatory capability. This capability is critical in enabling the creation of realistic prospects for the future, from which consequential actions can be taken in the present. The process of operationalization will facilitate the identification of the factors that either foster or impede this open anticipatory capacity.

According to Ibarra (2012), the circulation networks [38], which are the ideas and principles that disseminated and undergo modifications as they pass from one person to another, can be considered as link agents or nodes which operate in a loosely coupled manner, rather than established systems or subsystems. Within these networks, robust and feeble ties (circulations) coexist between nodes, operating as fluid structures. The lax organizational structure of this network tends to emphasize the significance of individual agency, thereby enabling diverse methods of agent intervention that shape the network's style.

Transparency is intrinsic to the implementation of knowledge and innovation co-production, a process that necessitates openness as demonstrated by the project's intended validation and must not be constrained by pre-established dialogue communities.

> Individuals are also constituted in this process. Individuals obviously exist and create circulation processes; however, we are not referring here to the same scientific subjects which we find in the theories of the "standard view", or in the semanticist, socio historicist, or cognitive approaches in the philosophy of science, or in science and technology studies: the individual subjects of the thesis of epistemological realism (i) of the MP. (Ibarra, 2012)

It is not a mere issue of actors who participate in workshops and activities, but rather how to co-constitute the epistemic subject.

The implementation of a participatory management will bring several benefits: it allows participants to analyze, discuss and generate new information; it contributes to the co-responsibility of the participants, making them more responsible and active citizens; it creates spaces for dialogue that allow the analysis, crossing and generation of information; it articulates a large number of factors and a variety of actors with different levels of knowledge and interests ; and it operates in complex contexts of uncertainty (Vasconcelos, 2004). This vision on participatory management should be applied to this subject of responsible water resources management.

Barrenechea and Ibarra (2019) introduced a learning tool with a model to measure the quality of the network of relationships, one can see that the theory presented by the authors brings the concept of network as a network of relationships and not as a network of actors. And it is precisely on this point that the proposal presented here will be based, situated in a different way of understanding the co-constitution of the epistemic subject. As stressed by

[38] According to Ibarra (2012, p. 68), "an individual subject does not belong to a single thought collective, but rather to several of them"; the author adds that "thoughts and concepts circulate from individual to individual, being modified in the course of circulation, in such a way that other individuals make a type of association, which is distinct from them". This circulation relates to the flux of knowledge between individuals.

these authors, the relevant connectivity operationalizes the core and dynamics of relational quality of sociotechnical interactions, as it seeks to define the level of approach that aims to evaluate the current network and potential. For that, it is necessary to observe the nodes and relationships in the current configuration and dynamics. This relevant connectivity will make it possible to assess the quality of interactions and manage scientific collaboration networks. This model will be used in the present context by the subject to improve the relational quality of the network.

Barrenechea and Ibarra (2019) identified five key factors of relevant connectivity:

1. **Institutional conditions** that mean considering membership of the framework networks and the viability or not of the institutional model: a) Framework networks: the number of networks and their characterization according to the scope; b) Feasibility for cooperation: collects the perception of project coordinators and seeks to assess whether the institutional model is perceived as facilitating connectivity.
2. **Profile** is the factor that allows to analyze the current configuration of the network and follow its evolution based on the hypothesis that the greater diversity of sociotechnical networks or seeking to identify elements related to the greater or lesser permeability of the sociotechnical network in terms of relevance. This factor includes seven subfactors which are: a) Network size: total number of links; b) Institutional complexity: classification of links based on "type": number of public and private institutions.; c) Spatial complexity: classification of connections according to the area of origin of its members (permeability and territorial relevance). d) Disciplinary complexity: considers the epistemological elements of the network; e) Network Activity Profile collects qualitative estimates on the distribution of network resources and efforts based on five areas of activity: 1) certified science and knowledge, 2) education and training, 3) innovation and professional work, 4) policies and social issues, 5) internal cooperation and visibility; e) Human resources (HR): refers to the HR profile directly linked to the projects; Recruitment objectives: identifies the main objectives for which each of the project's organizations (links) have been incorporated.
3. **Content**. It is based on the identification of the type of inputs that are exchanged within the scope of the projects. It is divided into two subfactors a) Type of inputs received; b) Type of inputs offered). These inputs can be of various order, namely scientific knowledge, information, databases, financing, and many others.
4. **Dynamic**. This factor is elaborated in two subfactors which are a) Link attributes (age; type of formalization of links; type of operation of links) and b) Interaction (type of links established; type of exchanges).
5. **Potentiality**. Provides guidance to the reflexive management of the relational quality in prospective terms. It includes three subfactors: a) connection capacity: source

resources – source that gave rise to established links and ability to articulate demands from different sectors in project design; b) Network consolidation": Projection of current links and Stability (e.g. the current state of the network that expresses consolidation capacity); c) Network extension: encompasses the following dimensions: State versus size, Potential composition by sector and Expansion profile.

The key here is to improve the co-constitution of the epistemic subject, putting the focus on the quality of the relations between the networks. This would then be an instrument of the network of actors that will be used as a reflective tool for its own constitution.

5.8 Stakeholders & actors

It is critical to make a clear distinction between stakeholders (actors of the exploratory phase, representatives of the innovation ecosystem) and actors (societal subjects not necessarily "representatives" of the innovation system, but more generally) in the specific context of this work.

Stakeholders include who (person, entity, group, organizations) is involved in or affected by a course of action. They are a part of the innovation ecosystem, as persons or publics concerned and involved. In the proposed simulation should be worked with representative stakeholders.

Societal actors are the ones directly or indirectly involved in the program or policy, owning their own values and demands. They are societal actors not necessarily 'representatives' of the innovation system, but more generally. Actors are any societal publics, whether they are engaged (within the innovation ecosystem) or external to it. Societal actors are who constitute the subject of co-production: the network of actors. The term "societal actors" is more encompassing and doesn't necessarily imply a direct interest in a specific project or initiative. Instead, it highlights the various entities that collectively contribute to shaping the fabric of society and its activities.

Stakeholders are often directly involved in the project's activities or outcomes, whereas societal actors can have indirect and broader influences on the societal landscape as a whole.

The first are those involved in the exploratory phase and are representatives of different areas of application of the technology; In that sense they are "concerned" stakeholders. The latter, correspond to the operational phase, and respond to the idea of "societal actors" of RRI, whether concerned, involved or not, in technology. The important thing is to recruit them for the experiment and that they contribute their visions, demands, values, even if they are not representatives of technology. What is essential in our approach is that it is those demands, expectations, visions, those that must be representative of society, not the members involved in the experiment, as such.

The innovation process should entail a construction of capital not only social but also intellectual and political. Social, intellectual, and political capital arise when people are given the opportunity to interact, share and debate ideas, which is essential to ensure the implementation of solutions, thus contributing to long-term sustainability (Vasconcelos, 2004).

It is important to distinguish these types of capital: social capital refers to the form of trust, networks of communication and norms of behavior; intellectual capital relates to accepted and shared information; and political capital promotes the opportunity to transform decisions into effective actions (Vasconcelos, 2004). By defining on the simulation exercise not only stakeholders but being able to also include a wide range of societal actors that with their own vision and demands will increase the social, intellectual, and political capital of the research, as well as the openness of the results.

The main goal it's to articulate actors and their knowledge. For that to happen, there is a need to define a methodology for structuring and conducting their participation. The identification of societal actors can be done through an exercise of mapping, by identifying them "in relation to their involvement across the water chain" and "potential linkages to other sectors", and this includes quality, quantity, drainage, water supply, wastewater management, land use, agriculture and more (OECD, 2015).

This task of mapping societal actors should start with a literature review on the innovation ecosystem and water governance in the pre-defined geography. The literature review should provide a view on who are the more representative societal actors and what is theirs focus and with that the path to follow the experiment. In this mapping exercise, the goal is to identify the main actors that will perform as decision makers: "who is influential in the area, community or organization"; "who has the power to obstruct decisions" and "who has been involved in the issue in the past". This task should be able to find actors that detain "a formal responsibility" and "an impact on the decision-making process, as well as stakeholders with a material interest or who might be impacted" by the project/policy process or its outcomes (OECD, 2015).

5.9 Roadmap for operationalization of The InovPlat Experiment

This section will provide the guidelines on how the operationalization should be oriented throughout the process. Then it will be described two phases, exploratory and operational.

We start by drawing a roadmap that should be established sequentially, through a series of steps. One should note that in some of the steps the regime of activity will be cyclical rather than linear in character. This is a major point to consider, that the activity will be cyclical, what happens because of the process' openness and de co-production of knowledge that is systematic and constant (Ibarra, 2012).

Regarding its objective, the operationalization of the co-production of knowledge is oriented to tackle the challenges of sustainability in technology for water use with this approach. This should have a report of the developed process as a final product, with the identification of enablers and barriers for an open process of anticipatory governance (and therefore for responsible technologies in water use) that promote the capacity to identify and deliberate on societal problems and positive impacts on them.

The aim is to identify the main societal challenges to which water use technology are trying to respond, and to encourage the involvement of publics in collaborative exercises aimed at addressing these challenges. The articulating axis of the experiment is knowledge co-production on the basis of open anticipatory governance.

The fundamental axis of this experiment pertains to the mutual creation of knowledge through the framework of open anticipatory governance, integrating aspects from the mentioned mission-oriented approach, but also the co-production approach using a digital space (Figure 6). This methodology prioritizes the involvement and engagement of actors throughout the entire spectrum of technology development and implementation. Open anticipatory governance involves fostering a transparent and inclusive decision-making process that anticipates and addresses potential future challenges and uncertainties. Through collaborative knowledge co-production, societal actors can collectively anticipate the impacts of water management technologies, identify potential risks and benefits, and ensure that these technologies are in line with the societal needs, values, and sustainability objectives.

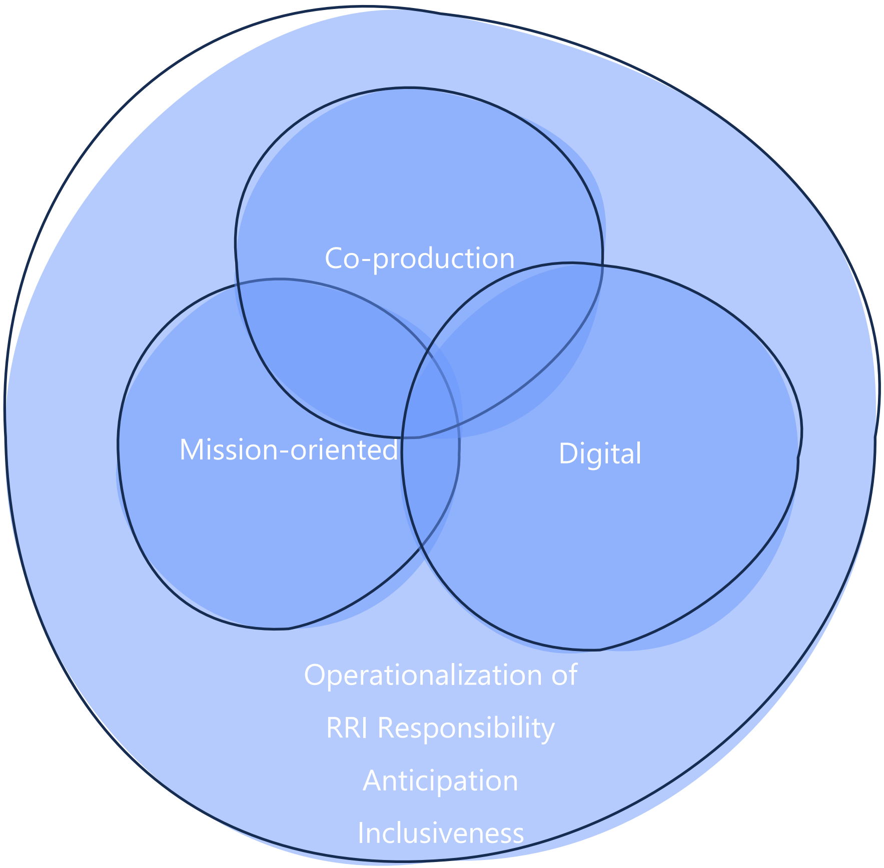

Figure 6 - Proposal integrating different approaches.

The overarching objective is to establish an all-encompassing and collaborative structure that unites interested parties in tackling water management issues of a communal nature. Through the implementation of collaborative exercises, co-production of knowledge, and anticipatory governance practices, novel solutions can be formulated and executed to effectively tackle the pressing dilemmas associated with water management in our current times. Through this approach, the collective wisdom and expertise of diverse stakeholders can be harnessed to create sustainable, equitable, and effective water use technologies.

In the following section we present an operational framework plan to figure out the tasks, issues and obstacles for the experiment. It will show a roadmap on you where to go, what to use, and when to do it (moments and proposals for instruments, resources and experiences for each of them).

The exploratory phase aims to make a diagnosis of the research and innovation ecosystem related to the problem. This task begins by working with stakeholders (representative) in order to have an accurate answer of what and the situation. To develop this phase, methods such as interviews, reports, economics should be used. This is to know the situation; through the information they offer stakeholders and complementary information from accurate reports.

An ecosystem diagnosis should be carried out and the culture of participation is known – it is a previous work of public engagement and development of social participation. This step is fundamental to understand in what cultural scenario we will operate.

At the time of diagnosis, we are already simultaneously working on the list of actor's positions once we have this information of the micro system and culture information.

It is at this point that we start working with actors (it doesn't have to be representative), more precisely we begin with people who want to get involved in the experiment. And we will be able to observe how the epistemic subject is strengthening and being increasingly solid and robust. It does not matter for this phase that the actors are represented, because that is not the goal.

From this point, it should be taken into account that it is not simply about responding to the issues that others propose in their research, analyzing values, but rather we have to work within the network to constitute this actor as we co-produce a better technology more integrated in a sociotechnical way.

This contribution to an operationalization of a research experiment for anticipatory governance should follow two main phases:

a) **Exploratory Phase (with representative stakeholders):** The exploratory phase centers on involving representative stakeholders to collect vital information and perspectives. In this stage, the project's innovation ecosystem will be determined, with particular emphasis on the technology for water use. The objective is to comprehensively understand the current technological scenario and its ability to effectively tackle challenges pertaining to water. Furthermore, the exploratory phase endeavors to ascertain the notions, dispositions, and socio-cultural orientation of the surroundings. Attaining insight into the perspectives of stakeholders concerning the environment can enable the project to devise tactics that are consistent with their principles and convictions. In addition, the current phase seeks to discern and articulate the knowledge, uncertainty, and anticipations of relevant stakeholders, furnishing crucial perceptions into their distinct requirements and apprehensions. This data will serve to guide the development of the operational phase, guaranteeing its customization to satisfy the needs and expectations of the stakeholders.
b) **Operational Phase:** The Operational phase of the project involves conducting workshops with societal actors and executing complementary initiatives. These workshops function as instrumental forums for engagement, allowing parties to

engage and make valuable contributions to the initiative. Furthermore, the operational phase comprises a trial aiming to ensure open anticipatory co-production of knowledge. In this experiment, involves the production of future scenarios that will be generated to facilitate societal actors in envisioning potential outcomes and investigating the ramifications of technology. Additionally, this phase emphasizes the co-construction of the process publics.

To be noted that at each stage of the experiment, online, should be available tools and documentation regarding the project in assessment at the time, knowledge base for related topics, documents explaining the scope and responsibilities of the team.

As a result, from every phase there should be published and available auto generated reports and information materials, like as concept boards created, drawn scenarios. All this data should be always kept and available, assuring also the traceability of all the experiment.

5.9.1 Exploratory phase

The exploratory phase should have an approximated duration of two months and be oriented by objectives and tasks defined at the beginning of the process.

The following tasks should be carried out to create the exploratory process:

1. Identification of the project's innovation ecosystem of technology for water use.
2. Elaboration of the technologies for water use, innovation ecosystem report.
3. Elaboration of the Report on the cultural environment of the experiment.
4. Interviews for the elaboration of the water use technologies innovation ecosystem for sustainability.
5. Innovation ecosystem report.

5.9.1.1 Identification of the project's innovation ecosystem of technology for water use

One should consider that:

> An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors. (Granstrand & Holgersson, 2020, p. 1)

The exploratory phase should start by identifying the innovation ecosystem of a given technology identification should provide and understating on the analysis the technological, socioeconomic, and cultural context of the project to be developed. This is done with the stakeholders.

The deliverables for this task should be at least two documents/reports containing the following information:

- Socio-technological-economic-legal ecosystem of technologies for water use.
- Cultural ecosystem of technologies for water use: related to the perception of technology, of the future in innovation, of attitudes towards participation and public engagement of the cultural environment of the ecosystem at stake.

The impacts of the technologies for sustainability in water used should be assessed by individuals whose roles are relevant in this regard. First, the stakeholders should be identified. To identify the stakeholders, an exercise of stakeholder mapping can be done in two steps. Either by identifying the stakeholders "in relation to their involvement across the water chain" or as "potential linkages to other sectors", this includes quality, quantity, drainage, water supply, wastewater management, land use, agriculture, and more (OECD, 2015).

The first phase of the mapping should allow to identify the main actors that will perform as decision makers, "who is influential in the area, community or organization"; "who has the power to obstruct decisions" and "who has been involved in the issue in the past". This task should be able to find actors that detain "a formal responsibility" and "an impact on the decision-making process, as well as stakeholders with a material interest or who might be impacted" by the project/policy process or its outcomes (OECD, 2015).

Considering that stakeholders have a fundamental role in the operationalization of the technology assessment processes. By identifying these stakeholders and grouping then according to their part in the process, but also considering their values and demands, an exercise of operationalization can be designed, after this exploratory phase.

Using as reference the exercise of the OECD (2015), where interviews were conducted to identified stakeholders for water governance and organized them in groups, as it follows:

- **Governments:** the government ecosystems such as national, regional, and local power, who have an effective decision-making Instrument to carry.
- **Service providers:** from public to private, this group includes public utilities, network and service providers, public-private partnerships, and private operators.
- **Watershed institutions:** there are a large number of institutions related to water, such as river basin organization, formal networks of watershed institutions and regional water authorities.
- **Regulators:** entities responsible for the regulation of economic and environmental factors.

- **Business:** this is a wide range because includes businesses using water in their production and or in their supply chain, the network of businesses.
- **Civil society:** in this group fits the non-governmental organizations; member-based organizations; community-based organizations; social movements.
- **Financial actors:** donor agencies and financial institutions.
- **Advisors:** this includes engineering and consulting firms
- **Others:** in this group can be included the media; network of agricultural actors; parliamentarians and trade unions.

Additionally, and considering the state of the art on water use technologies mentioned in the previous chapters, there are a few stakeholders that can be added to this previous list, which are:

- **Technology industry:** this group fits all technology companies that develop solutions for water governance, managing water, assessing water quality, creating new data and gathering environmental data.
- **Innovation ecosystem:** the entities that do research on water, environmental and technological research, to provide new solutions.

Appendix C brings the template for the stakeholder invitation letter.

To gather all the stakeholders and obtain valuable results, it should be considered that their involvement in the experiment is not easy and automatic (Arnstein, 1969) Therefore, methodologies for stakeholder engagement should take place in each step of the experiment from the start.

5.9.1.2 Elaboration of the technologies for water use, innovation ecosystem report

The methodology to start this step begins with a literature review on the innovation ecosystem in the predefined geography. This review should give the researcher a perspective on who can be the more representative stakeholders and their focus, giving the researcher a sight of the path to follow with the experiment.

With the panorama given by the literature review, one should prepare semi-structured inter-views with stakeholders that are representative of the ecosystem actors in question (10 to 14 actors) These interviews should have around 12 questions focused in getting the insights needed for the next phases.

These set of interviews should include stakeholders from business, industry, politics, media, research, citizenship, financial services, and a regulator.

There are three dimensions that should be identified for the said interviews:

- Most relevant values and principles at stake.
- Key elements for the knowledge co-production process.
- Stakeholder interests in knowledge co-production.

These dimensions defined here should work as triggers for the organization of workshops and activities (e.g., paying attention to the interests of the actors in the experiment).

5.9.1.3 Elaboration of the report on the cultural environment of the experiment

After gathering the information and answers from the previous phases on the semi-structured interviews, it should be possible to create a report on societal perceptions about science and technology in general, which will give a vision about:

- The technology at stake.
- Participatory attitudes and cultures.
- Previous participatory experiences in the environment.
- Social considerations on futures and their role in the construction of the present.
- Previous anticipatory experiences in this domain.

After gathering information on these main topics, it should be carried out an identification of relevant reports in the literature concerning the above-mentioned topics to validate and improve the quality of the following task.

5.9.1.4 Interviews for the elaboration of the water use technologies innovation ecosystem for sustainability

The interviews should be the main piece to design the operation phase, it should gather approaches and opinions of representatives of stakeholder groups representing:

- Industry (companies from all moments: developers, manufacturers)
- Research (university, technology centers, public and private R&I organizations, innovation clusters)
- Business and trade (sectoral and industrial associations; trade; professional end-users)
- Promotion entities (public innovation agencies -local, regional-, funding bodies -public, private-, insurance companies)
- Political agency (government departments and agencies -local and regional-, regulatory and standardization bodies, ethics committees)
- Society (citizens, non-government organizations, trade unions, consumer organizations, media).

The choice of the stakeholders to involve in the process should be carefully thought and follow some criteria. It is of great importance to pay attention to gender equality in this and the other phases of the process. Also, should be considered that not all of the invited stakeholders will accept to be part of the process. One should distinguish three concentric spaces, according to the relevance of the actors in the development of research and innovation:

- Primary innovation stakeholders, which include researchers, developers, producing companies.
- Secondary stakeholders, which are Regulators, investors, authorities, end-user citizens.
- Third environment stakeholders: profiles not included in the previous environments.

Primary stakeholders, including scholars, corporate and development, and governmental bodies, assume an immediate and participatory function in the process of innovation. Academics offer significant expertise and knowledge, whereas commercial and industrial representatives bring forth pragmatic viewpoints and resources. Governmental entities exert a significant impact on the regulatory framework and policies that pertain to pioneering initiatives. Furthermore, it is imperative to take into account the perspectives of key secondary stakeholders such as the wider community, consumers, non-governmental organizations, and the media, when addressing the broader societal and environmental ramifications of the matter at hand.

The interviews should include 10 to 14 stakeholders. They should be performed individually or as a group. Appendix C shows a template for the interview script, which materializes a semi-structured interview instrument with 12 questions.

The contents of the interviews can be stored in two formats. if the questionnaire is answered in written form, it will be digitally filled and store; and if it is a spoken interview, it is automatically recorded and converted into text using an audio transcription tool.[39]

5.9.1.5 Innovation Ecosystem Report

As a result of the previous phases, an innovation ecosystem report should be developed with two purposes:

- Identification of the problem field in question and the possible technologies potentially involved in the possible application scenarios.

[39] In order to record the interviews and transcribe speech to text, there are multiple tools available for integration to the larger platform — e.g., Microsoft's transcription tool or similar.

- Description of a water technology ecosystem based on: (1) the values and principles that inspire innovation; (2) the market; (3) political and regulatory aspects; and (4) experiences of co-production and/or public citizen involvement and/or anticipatory governance.

The aim is to link ethical and social aspects with the technologies under analysis, as well as to identify the interest (or lack of interest) of the stakeholders interviewed.

For the water management innovation ecosystem report, the methodology should follow both:

c) Study of ecosystem reports and cultural studies.
d) Analysis of interviews.

Activities to be carried out:

- Identification and analysis of the above-mentioned reports.
- Design, implementation, and analysis of interviews.

The goal is to obtain information for the design of the operational phase: interviews, reports on the innovation ecosystem in water management, reports on the participatory culture in the ecosystem (attitudes and perceptions about science and technology, about water, about participation in S&T issues, etc.).

As an attachment will be found templates for semi-interview script: the invitation document "Invitation to Interview" (Appendix C) that should be integrated in the platform in HTLM, as well as the documents of "situation" of the interviews: "Interview Consent Form" (Appendix B).

5.9.2 Operational phase

The operational phase marks the pivotal stage in executing the open-ended anticipatory co-production experiment of water use technology aimed at confronting the predicaments presented by responsible sustainability challenges. Outlined herewith is the operationalization plan to be implemented. The milestones of this phase are the workshops: strategy for the application of anticipatory governance.

One should consider that this phase should have the two following outputs:

1. construction of socio-technical scenarios for the future.
2. deliberation on scenarios for the identification of demands, values, desires... of the public.

The key objective of anticipatory governance is to identify the "right impacts" of research and innovation - not only the aspects of risk and uncertainty as in the regulatory actions of public policies in S&T but also the positive impacts of the development of S&T; Anticipatory governance allows us to know these right impacts.

This phase should be based in workshops, which should be at least three of them, as mentioned in the previous section. These workshops should gather societal actors and complementary activities between the workshops. Reminding that societal actors are any group of the society with a relation or a contribution to the subject.

These workshops will be the key to materialize an open anticipatory co-production of knowledge in water management technologies and sustainability experiment.

This operationalization should lead to an anticipatory governance model based in RRI.

First, we need to look back at Chapter 3, were we found that RRI

> Is a transparent, interactive process by the societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products in order to allow a proper embedding of scientific and technological advances in our society. (Von Schomberg, 2011, p. 50)

This concept relates to anticipatory governance since RRI is conceived as the starting point for the development of research and innovation actions aimed at solving the major deficits of the current research and innovation system. They are basically linked to a certain conception of how one can manage research and innovation. The dominant conception is that this management can only be carried out through indirect governance of technologies, orienting it towards risk management. Thus, the institutions in charge of the governance of these technologies are only able to respond throughout the research and innovation processes when unanticipated risks materialize.

The RRI approach introduces greater complexity into the idea of governance of these processes, also establishing the capacity to identify socially desirable outcomes of research for institutions. This can be done by incorporating methodologies and perspectives that favor the anticipatory identification of "right impacts". Anticipation can contribute to assess different plausible and desirable alternative futures, linked to different technological courses, and deliberate on them in the present in spaces of public citizen involvement in which actors and publics identify and promote values and expectations for the co-production of technology. These values, social demands and public expectations identify the right impacts that research and innovation should pursue to be responsible.

Second, this Anticipatory Governance (AG) can only be efficient if actually open. One can see that nowadays it's common to interpret 'open' in the sense of 'open science', 'open research' and others (as a normative direction oriented to share knowledge and all its related aspects like data, methodologies, instruments) as early as possible in the processes of its production.

Although it can be related to that aspect, in anticipatory governance, 'open' means that the task of anticipatory governance identified in the previous paragraph is only successfully deployed if it is implemented in an unrestricted open framework in which it is possible to deliberate on any determinations (values, demands, desires, ...) raised by the actors, in this case Open Anticipatory Governance.

It is therefore crucial to identify the factors that favor - or hinder - this openness of anticipatory governance, making it a heuristically useful tool for the proper identification of right impacts for research. These factors are linked above all to the way in which anticipatory governance itself is constructed in a process of public deliberation. The aim of this experiment is to focus on the moments in the construction of these processes and to identify the factors that increase or reduce heuristic power.

In fact, several scholars have endorsed the notion that the efficacy of anticipatory governance greatly hinges on its degree of openness. According to Sengers and Wieczorek (2019), the adoption of anticipatory governance can facilitate the development of robustness and foster sustainability. According to the proposal put forth by Guston (2014), an effective framework for anticipatory governance must facilitate increased and diverse involvement, thoughtful discussion, and concerted cooperation among all relevant parties. According to Robinson's (2012) proposal, an anticipatory governance strategy that prioritizes social-ecological resilience and demands transparency is crucial for achieving success. Owen, Macnaghten and Stilgoe (2012) suggest adopting a responsible research and innovation approach which entails active collaboration with society and promoting transparency to preempt and address potential issues.

Therefore, it's crucial to identify the factors that favor - or hinder - this openness of anticipatory governance, making it a heuristically useful tool for the proper identification of right impacts for research. Above all, these factors are linked to the way in which anticipatory governance itself is constructed in a process of public deliberation. The aim of this experiment is to focus on the moments in the construction of these processes and to identify the factors that increase or reduce heuristic power.

5.9.2.1 Preparation of the experiment

To start the experiment the first step should be the formation and pooling of the team responsible for the experiment. This task should be done through several meetings (online) before starting the operationalization. Issues to be discussed in the launch of the first online team meetings:

(0) Knowledge on water use technologies

(i) Open anticipatory governance, what is it?

(ii) Methodology of "experimentation" -living labs, citizen labs, ...

(iii) Purpose and flow of the workshops

(iv) Timeline of the process

(v) Strategy for the recruitment of participants

About (i). Governance as societal engagement: science and innovation are conceived as open to the priorities, desires of the publics, making them "socially more robust" (Nowotny, Gibbons & Scott, 2015; Jasanoff, 2003) and trustworthy.

One should acknowledge that "The question confronting the governance of science is how to bring knowledgeable publics into the front-end of scientific and technological production - a place from which they have historically been strictly excluded" (Jasanoff, 2003, p. 235). Nowotny et al. (2015) also expound on the influence of intricacy and ambiguity on the processes of scientific inquiry and advancement. Their contention is that with the emergence of intricate societal issues and swiftly evolving technologies, conventional linear frameworks for generating knowledge have become inadequate., underscoring the significance of acknowledging and incorporating uncertain factors, reflexivity, and a variety of knowledge sources in decision-making protocols (Nowotny et al., 2015).

"The process of contextualization moves science beyond merely reliable knowledge to the production of socially more robust knowledge" (Jasanoff, 2003, p. 246).

The concept of co-production in experimentation is originally meant the participation of end users in product development by contributing their expertise and adding value to the product (von Hippel, 1986). In the present proposal, "co-production" is understood in another sense: that of engaging the public as an active stakeholder in the development of the innovation trajectory, setting priorities, expectations and desires for the trajectory.

About (ii). Methodology of the co-production experimentation space. Build a space for deliberation in which different publics can present their concerns, experience, knowledge, desires. To address complex problems. In this process, solutions are proposed that can be tested and evaluated, so that, even if the problems raised are not solved, the result contributes to an increase in collective learning capabilities.

5.9.2.2 Additional recommendations for designing the experiment

This section provides guidelines for the efficient execution of a collaborative innovation process in water utilization technology research. The process of co-creation entails the active engagement of publics across varied sectors in collaborative initiatives aimed at tackling water management issues that have significant societal implications. The proposed guidelines prioritize fundamental actions that enable smooth collaborative creation experiences. These actions involve identifying requirements and opportunities, assessing the landscape of innovation, emphasizing advantages, executing a systematic process, harmonizing objectives, confirming shared comprehension, and restructuring the atmosphere to establish a collaborative culture. Furthermore, it underscores the significance of factoring in cultural contingencies, such as variances in age groups and gender, and proactively tackling any potential hazards and obstacles while devising the co-production trial.

Adopting a co-creation methodology is imperative in effectively tackling the intricate issues linked with the deployment of water-use technologies. The present work offers evidence-based guidance and insights derived from in-depth investigation and scrutiny to aid investigators and interested parties in proficiently carrying out co-creation initiatives. The objective is to optimize the advantages of working together, promote originality, and uphold the harmony of water management techniques with the societal requirements and principles.

5.9.2.3 Recommendations (adapted from GoNano)[40]

- Conduct an analysis to identify potential areas for co-creation by assessing the challenges and opportunities where collaborative creation can bring significant improvements. The methodology requires actively involving pertinent stakeholders to comprehend their viewpoints and preferences.
- Conduct an in-depth analysis of the innovation landscape: Acquire a thorough comprehension of the innovation ecosystem, encompassing technological, social, economic, and regulatory elements. This analytical procedure of contextual

[40] GoNano is a Coordination and Support Action funded by the European Union under the NMBP Programme of Horizon 2020, with explores the strategies of co-creation: http://gonano-project.eu/wp-content/uploads/2020/08/D5.3-Three-white-papers-with-suggestion-for-realising-RRI-conditions-in-nanotechnology-RI.pdf

mapping will facilitate the recognition of possible obstructions, advantages, and collaborative potentials for joint creation.

- Demonstrate the value proposition of co-creation: Efficiently convey the benefits of involving stakeholders in the process of value creation. Emphasize the potential benefits of collaborative initiatives in developing innovative, inclusive, and sustainable water use technologies, enabling positive societal outcomes.
- Establish a systematic approach: Formulate a precise and organized approach for facilitating the co-creation process. This comprises of laying down clear and concise objectives and outcomes, delineating the respective tasks and accountabilities of the participants, devising robust communication mechanisms, and incorporating proficient feedback mechanisms to guarantee ongoing enhancement.
- Ensure a harmonious integration of co-creation and R&I objectives in scheduling: Achieve a well-balanced approach by seamlessly integrating co-creation activities with research and innovation goals (R&I). Efficient planning and management of tasks will enhance the collaboration and progress of water management technology through co-creative endeavors.
- Facilitate alignment of viewpoints: Promote the establishment of efficient communication and comprehension between scientists, actors, and the community. To foster productive collaboration, it is recommended to cultivate open communication, attentive listening, and a shared desire for mutual understanding, thereby bridging potential gaps and aligning perspectives.
- Reconfigure the setting: Foster a collaborative spirit by renovating the institutional and organizational milieu. Cultivate a conducive and inclusive environment that upholds varied viewpoints, promotes experimentation, and acknowledges cooperation as a key success driver.
- Integrating Cultural Factors and Mitigating Anticipated Challenges: The incorporation of cultural factors is imperative when devising co-production experiments. By undertaking a thorough analysis of the cultural environment, it is possible to uncover variations in beliefs and attitudes amongst demographic groups, such as age and gender, as well as levels of public mistrust towards participation in scientific endeavors. Taking into account these cultural nuances while conceptualizing the co-creation methodology guarantees a comprehensive approach and amplifies the efficacy of collaborative endeavors.

Moreover, it is crucial to detect and mitigate potential issues and hazards that may arise in the experimental design. The promotion of successful co-creation is contingent upon bridging the sharp boundaries that exist between scientific disciplines, fostering productive exchange between industry/business sectors and societal spaces, and ensuring that innovation trajectories encompass crucial societal concerns.

Thorough and meticulous planning, coupled with thoughtful contemplation, are imperative for the successful implementation of a co-creation approach in water use technology research. Through the implementation of the recommendations articulated in this document, researchers and societal actors can effectively cultivate productive partnerships, spur ingenuity, and tackle intricate societal dilemmas that are linked to water management. The adoption of co-creation methodologies has the potential to foster the creation of water use technologies that are not only efficient and sustainable, but also cater to the specific requirements of societal actors, thereby promoting a water-secure future.

5.9.2.4 Lessons learned

Looking at examples of European projects, certain Horizon 2020 Framework Programme endeavors have incorporated and executed tactics in their methodology to advance and elevate Responsible Research and Innovation (RRI) approaches, thus illuminating noteworthy insights. Such initiatives include New HoRRIzon, RI Configure, and Co-Change.[41] The aforementioned initiatives have yielded valuable manuals and guides that draw upon empirical data and theoretical frameworks pertaining to experiential learning, active experimentation, and organizational change.

We can highlight three characteristics of those experiences:

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[41] New HoRRIzon, RI Configure and Co-Change are projects funded by the Horizon 2020 Framework Programme. New HoRRIzon project strives to advance the concept of responsible research and innovation by incorporating it into varied research and innovation scenarios, including but not limited to nascent technologies, unrestricted science, and civic science. The primary objective of the initiative is to improve the comprehension and implementation of RRI principles through research activities, the formulation of frameworks and tools, and the provision of directives to policymakers, researchers, and other concerned entities. It aims to promote conscientious and comprehensive research and innovation methodologies that tackle communal issues and enhance sustainable progress (EC, 2022a).

The primary objective of the RI-Configure initiative is to incorporate principles of Responsible Research and Innovation (RRI) into the domain of cybersecurity research and innovation. This endeavor seeks to reinforce an all-embracing, lucid, and responsible methodology that regards societal interests, values, and concerns. It endeavors to tackle multifarious implications by involving stakeholders in the decision-making process (EC, 2022b).

The Co-Change Project aims to effect a comprehensive and enduring change at the individual, organizational, and systemic echelons, achieved through concerted engagement with Regional Project Offices (RPOs) and Regional Funding Organizations (RFOs) spanning the breadth of Europe. Co-Change facilitates the wider implementation of RRI-related institutional modifications and nurtures networks for enduring influence via the provision of a toolbox and field book (EC, 2022c).

1. They are social experiments. They foster the participation of a variety of societal actors who come together as a collective entity with the intent of accomplishing more ambitious goals than those achievable through mere consultation. Within our project, we view the process of operationalization as a socio-technical experiment, encompassing not only participants but also other key actors, as outlined in the Network Actor Theory (Barrenechea & Ibarra, 2019). These include technical tools, laboratories, and research products, expanding beyond the realm of traditional social participation. The agency is also linked with them in the realm of interconnections for collaborative production.
2. They are experimental. These designs are formulated using an iterative methodology that systematically tackles relevant issues and hurdles, while presenting multiple solutions for careful analysis and assessment. Their approach is distinct from other interventions, such as project-based interventions, that have a more focused aim towards final targets.
3. They are systemic. The findings should be analyzed comprehensively in a systemic manner, avoiding any narrow focus on specific aspects pertaining to the given problem or challenge.

5.9.2.5 The Publics

The traditional view of societal actors an experimental design is captured by two conditions: 1) the interest of societal actors in the issues under analysis, and 2) the representative nature of the sectors involved.

A co-constitutive vision of knowledge and societal actors should be sustained: the public should be constituted simultaneously to the process of knowledge production in a process of unique nature. It can be called the process of constitution of the epistemic subject of the co-production of knowledge, a collective subject with conditions of constitution that are activated in that co-production.

The epistemic nature of the subject - of the experiment's actors - is a function of the interactions and interrelations among the actors and, therefore, of the relational conditions in which the co-production experiment operates. One of the expected results of the project is to show the correlation between anticipatory power and the relational quality of the interactions between the actors in the experiment. For this purpose, a diagnostic and validation tool of interactional inclusiveness based on the concept of relational quality will be developed. Quantitative dimensions, factors and indicators will be identified - based on quantitative and qualitative aspects of the interrelationships - to build the connectivity of the co-production space, both currently existing and potentially developable in the collective learning exercise.

5.9.2.6 Learning tool: reflexivity of the results

The enhancement of the co-constitution of the epistemic subject and learning should be done with the support of other instruments of assessment. The following tool (adapted from Barrenechea & Ibarra, 2019) is an instrument of learning to strengthen relational quality. For this, a questionary is elaborated and applied to the actors. to gather data for this learning tool can be followed the questionnaire in Appendix D as a template.

This tool should be used as a part of the operationalization phase, and is structured in Factors, Dimensions, and indicators and it is the instrument of co-constitution of the epistemic subject (a network of actors), with key elements as it follows:

1. **Institutional conditions**
   - 1.1. **Frame Networks**: is calculated from the indicators Number of networks and Domain of networks.
     - 1.1.1. **Number of Networks**: the value is calculated according to intervals of number of networks previously defined.
     - 1.1.2. **Domain of the Networks**: calculated according to the diversity of the domains of networks.
2. **Profile**
   - 2.1. **Size**: calculated from the Number of links indicator.
   - 2.2. **Number of links**: calculated according to the intervals of number of links previously defined.
   - 2.3. **Institutional complexity**: calculated from the indicators Type, Sector, and R&I
     - 2.3.1. **Type**: is calculated based on the ratio of the number of public, private, and mixed links.
     - 2.3.2. **Sector**: based on the diversity of the sectors of links.
     - 2.3.3. **R&I**: ratio on links with an R + D department on the total number of links.
   - 2.4. **Spatial complexity**: calculated from the Domain of links indicator.
     - 2.4.1. **Domain of links**: it is calculated on the diversity of domain of links.
   - 2.5. **Disciplinary complexity**: calculated from the indicator Number of disciplines.
     - 2.5.1. **Number of disciplines**: calculated according to pre-defined intervals of number of disciplines.
   - 2.6. **Activity profile** is calculated from the Profile indicator.

2.6.1. **Profile indicator** is calculated on the basis of five domains: collaboration and visibility; science and knowledge; education and human resources; innovation and professional field; public policies.

3. **Contents**
   3.1. **Inputs received** is obtained from the indicator Type of inputs acquired.
   3.2. **Inputs offered** is obtained from the indicator Type of inputs given.
   3.3. **Type of inputs received**: calculated on the diversity of types of inputs acquired.
   3.4. **Type of inputs offered**: calculated on the diversity of types of inputs given.
4. **Dynamics**
   4.1. **Links attribution** is obtained from the indicator Type of formalization.
      4.1.1. Type of formalization is based on the ratio between formal and informal links.
   4.2. **Interaction** is calculated from the indicators Level of complexity and Type of interchange.
      4.2.1. **Level of complexity**: the ratio between links of combination (interchange, complementary, collaborative).
         4.2.1.1. **Type of interchange**: based on the percentage of links with interactions of type (i) meetings, (ii) reports, (iii) informal communications.
5. **Potentiality**:
   5.1. **Capacity for linking** is calculated from the indicators Resources at origin and Articulation of demands.
      5.1.1. **Resources at origin:** based on the diversity of the resources at origin.
      5.1.2. **Articulation of demands**: based on the diversity of articulations of demands.
   5.2. **Consolidation** is calculated from the indicators State vs. size.
      5.2.1. **State vs. size** is based on the ratio between links with strategic alliance type links and the total number of links.
   5.3. Extension is calculated from the indicators State of the network, Potential composition for the sector, and Extension profile.
      5.3.1. **State of the network**: ratio between links already formed and the number of identified potential links.
      5.3.2. **Potential composition** for the sector: based on the diversity of the sectors of links.

5.3.3. **Extension profile**: based on the diversity of the extension profiles of the potential links.

We should conclude by pointing out that the simulation present seeks (i) the construction of an RRI-responsible concept of sustainable management of water use (main objective of the thesis) and (ii) a technology assessment instrument conceived as an instrument of reflexivity aimed at improving the relational quality (internal and external connectivity) of the network of actors.

5.10 The INOVPLAT: Knowledge as a connection - the digital deliberation space architecture

To support the designed simulation for assessing the technology, based on the operationalization of anticipatory governance based in the quality of relations in the network of actors, we propose the development of a digital deliberation space. This platform was named InovPlat, which stands for Innovation Platform, which aims to foster co-creation and access to a certified knowledge base for each project, with a connection to governments and initiatives. Having the platform as a space — not physical, but digital — for the deliberation of an anticipatory governance makes it possible and more efficient for that model to be in place.

As previously mentioned, an RRI-responsible assessment, through the process of innovation of technologies for the use of water, is articulated with the socio-technical problem of building a space for anticipatory governance. In its turn, anticipatory governance is articulated on the double axis of actors' inclusivity and deliberative anticipation. Following that, the digital platform InovPlat will be proposed as a materialization of the construction of an anticipatory governance space for decision-making in the innovation process.

InovPlat is an electronic space (web) to share demands, visions, scientific and technological knowledge, regulations, social experiences, uncertainties, and others, as well as to promote responsiveness and deliberation between societal actors. In InovPlat, a whole variety of such actors are summoned (inclusivity) and the methodologies proposed by Popper (2008) (anticipation) are also applied, in a transparent and sufficiently complete manner.

InovPlat allows to securely centralize all data and information in one place, guaranteeing accessibility to the tests as well as facilitating the exchange of information to favor inclusive anticipatory deliberation. Although not essential to the proposed approach, it is relevant for operative effects of the assessment that InovPlat has a validation mechanism, which allows assigning certifications and validating information to add an additional layer of "responsibility" to the projects and products that are object of the anticipatory inclusive assessment exercise.

The platform design should be able to accommodate all the phases of the operationalization of an anticipatory governance and materialize a source of knowledge.

On the following sections, the grounding and the main elements that make up the architecture of the platform can be found.

The platform should be seen a space where it will be possible to identify the main societal challenges to include research are trying to respond and to encourage the involvement of publics in collaborative exercises, aimed at addressing these challenges. It should be the articulating axis of the experiment and also be able to gather co-production of knowledge based on open anticipatory governance.

The fact that the proposed deliberation space becomes digital improves the possibilities of applying the methodology in many levels of geography and regions (worldwide, continental, national, regional, municipal) according to the scope of the problem and decision to be made. It is a matter of defining the area of application (level of application at the first phase of the experiment.

The aim of this section is to identify the tasks, problems, and challenges to be developed in the experiment, offering a roadmap, with an alignment of moments and proposals for instruments and resources included for each of them.

This framework is a starting point to build a background and a logic to develop a digital platform where it can all be done. The goal is to be able to gather all these phases inside the digital platform, from the architecture structure to the functional components, as it all should be able to respond to the phases of the research.

Also, the consolidation of a diverse range of public engagement and decision-making mechanisms, made possible by this digital space, aimed at achieving the objectives of enhancing water cleanliness and sanitation, has the potential to yield outcomes that are both more efficient and enduring, incorporating a broader spectrum of societal actors. It serves to guarantee the participation of individuals directly impacted by water and sanitation concerns, thereby improving the chances of attaining the objectives outlined under SDG 6.

The functional requirements should be able to accomplish the following tasks.

5.10.1 Deliberation space: platform architecture

This subsection will start by describing the pillars of the platform structure in terms of its general architecture. Then, the technical and functional architecture will be described.

The platform must be accessible from any Internet device through any browser, in its updated version, through the address *inovplat.com*.

InovPlat is based on a cloud platform that allows the creation of instances for governments and other governance and decision-making centers, ensuring semantic and technical interoperability and integrated artificial intelligence instruments and mechanisms. This is possible thanks to the use of a multi-layered structure:

a) **User interaction layer:** This layer includes the integrated registration of users with electronic authentication through the official identification document. Validation mechanism and access to discussions; forms; knowledge tools and libraries; forum tools; availability of related applicable laws. Users will have different profiles: corporate actors, government entities and other institutions and technical support staff.
b) **Module, service, and integration layer:** In this layer is included the validation and approval of projects with responsible research certificate, registration for participation in tests of products or solutions admissible in various stages. Integration services and modules interoperability are also included.
c) **Data processing layer:** Corresponds to the entire data layer and experiences how it is stored. With a message broker, a mechanism is defined to send messages and alerts to the users of the platform, for example, notifications about the various publications, meetings, and activities in the forums. This data may be exported in Excel format.
d) **Registration and results review layer.**

To go forward with the task of building an architecture for the platform, it is necessary to perform a comprehensive analysis of user requirements to create a comprehensive and cohesive information architecture that systematically arranges content, functionalities, and features in an intuitive and rational manner. The platform should contemplate the creation of distinct sections, categorized segments and labeled tags, to facilitate seamless navigation and expedite content exploration.

The platform should be designed considering modules as pillars of its structure, including the following.

5.10.1.1 User Registration Module

The User Registration API is responsible for managing user registration, authentication, and profile information.

The User Database function entails the include storage of essential user information, including but not limited to full name, email address, password (subjected to hashing), and other pertinent profile details relevant to the system.

5.10.1.2 Module for Online Forum and Virtual Meetings and Workshops

Discussion Forums API: Manages the creation, retrieval, and modification of discussion threads and posts.

The Online Meetings API seamlessly facilitates the coordination, attendance, and administration of virtual meetings, encompassing video conferencing and messaging capabilities.

Utilizing WebSocket or analogous technology, our communication infrastructure enables seamless real-time chat and updates.

5.10.1.3 Polling and Applications Module

The Polling API facilitates seamless management of polls, surveys, and questionnaires, including their creation, retrieval and submission. The API for Applications facilitates the end-to-end process of submitting, reviewing, and processing applications or forms.

The Application Database is designed to serve as a secure repository for application data and relevant metadata.

5.10.1.4 Certifications Module

The Certification Management API effectively manages the certification procedures by streamlining documentation submission, accurately tracking progress, and facilitating efficient issuance of certifications.

The Certification Database is responsible for housing and managing a variety of certification-related information, such as user certifications and their corresponding credentials.

5.10.1.5 Knowledge Base Module

The content Management System Provides a user-friendly interface for content creation, curation, and organization. The Knowledge Base API facilitates the efficient retrieval, search and filtration of knowledge assets that are organized and classified using categories, tags and metadata.

The knowledge base database is specifically designed to house a diverse array of intelligently structured knowledge resources, such as articles, documents, presentations, and multimedia materials.

5.10.1.6 Governmental Links with APIs

The system is designed to facilitate integration with external governmental APIs, thus enabling seamless retrieval and exchange of pertinent data, including public records and services. The API Integration Layer incorporates essential authentication and authorization mechanisms to establish secure communication with government APIs.

5.10.1.7 Backoffice Admin Module

The Admin Dashboard serves as a functional interface that empowers administrators to efficiently oversee user accounts, content management, and system configurations at large scale. This Admin board should handle administrative tasks, including user management, access controls, content moderation, and analytics. The analytics and reporting engine functions as a data aggregation and analysis tool that captures usage data from the platform, enabling the administrators to glean informed insights via comprehensive reports. This database should be used to preserve crucial administrative information and configuration settings.

5.10.1.8 Technical considerations

It should be taken into consideration to employ front-end technologies such as HTML, CSS, and JavaScript frameworks including but not limited to React and Angular to facilitate the development of the user interface.

Regarding the backend, a programming language (e.g., Python, Java) and a web framework (e.g., Django, Laravel) should be defined for server-side development. On the Database side, an appropriate database management system such as MySQL, PostgreSQL, or MongoDB there should be researched and selected for efficient and effective storage and retrieval of data.

For enhancing Security Protocols, robust user authentication methods, such as hash-based and salted password encryption techniques, should be employed. Implement SSL/TLS protocols to ensure secure transmission of data. Implement appropriate access controls to regulate administrative and user privileges in accordance with established guidelines.

Since we want to make this a borderless and limitless deliberation space, the scalability and performance should be highly enhanced by defining a scalable server infrastructure and preferably cloud-based deployment options. Incorporating caching methodologies and distributing load balancing will help efficiently manage heightened levels of traffic and guarantee prime functionality.

On the API design, the RESTful API design principles should be considered by ensuring accurate resource naming, appropriate and standard usage of HTTP methods, and effective management of error handling. A visually engaging and user-friendly interface, leveraging user experience (UX) and user interface (UI) design principles, must also be designed, to assure an easy-to-use navigation, well-structured information layering, and coherent design components implemented throughout the platform.

Considering the workshops and side meetings that should take place should be considered such a real-time document editing, task management, or chat functionality. It is also necessary to identify or create suitable mechanisms and integrations to facilitate user collaboration.

Last, but not least, every decision and specification should be part of the documentation, every aspect should be drafted as extensive technical documentation, thus facilitating developers to incorporate API specifications, detailed data models, and archetypal guidelines.

5.10.2 Functional architecture: qualitative component of the assessment

This section describes the functional architecture for the platform and materializes the qualitive component of the assessment tools in the platform.

The functionalities should include:

- Form and workflows of project registration.
- Integration with knowledge tools and online libraries (ResearchGate; Academia; Online Knowledge Library (B-On); Google Scholar) with information entered by the actors, ensuring different sources of knowledge.
- Forum to share visions, clarifications, meetings, and questionnaires.
- Publication of laws and regulations for rapid investigation by key terms.
- Functional architecture: quantitative/semi-quantitative component of the assessment.

- Voting system associated with user identification.
- System of indicators and parameters for measuring data and results.
- Possibility of designing algorithms and decision trees.

Subsequently, the set of functional elements (including the tasks to be performed by the instrument and reflecting the logic and needs of the purpose) and non-functional elements (technical component of support to the functional, defined to operate based on the instrument, considering the processing needs, the volume of the data, the availability, and the physical location) will be detailed.

6

CONCLUSIONS

The goal of this work was to comprehensively understand the phenomenon and concept of sustainability regarding the application of technology for the responsible management of water and to propose a novel approach to tackle the current and emerging issues pertaining to the topic. By employing an interdisciplinary methodology that incorporates key components of sustainability science, innovation studies, political economy, and water resource management, the present investigation delved into the constraints associated with the conventional notion of sustainability, and advanced a holistic framework that surpasses the concept of sustainability and encompasses the key dimensions of anticipatory governance and inclusivity.

This thesis has yielded a novel outcome that introduces a fresh perspective on the sustainable management of water resources through the application of a relational anticipatory governance framework. The term "relational" pertains to the development the constitution of the epistemic subject through the strengthening of their capacity for relationships, which is linked to their ability to interact, relate, think critically, and deliberate among other members who contribute to their co-constitution as the subject of the co-production process.

The objective of this work is to enhance comprehension and use of responsible technology and innovation in the realm of water use management, by implementing open anticipatory governance and presenting a simulation.

This approach presents a platform for fostering collaboration among various societal actors, including not only researchers, practitioners, and other relevant parties, but a full range of societal actors to enable the sharing of invaluable knowledge and specialized skills. Through the active involvement of practical experimentation, researchers can acquire valuable insights from the vantage point of societal actors involved in the innovation process, thereby enabling a more all-encompassing and thorough assessment.

The results of this research elucidate several crucial facets. Primarily, it has become apparent that the conventional interpretation of sustainability fails to incorporate the fundamental aspects of responsibility in water technology. The pursuit of sustainable management of water resources, while undoubtedly critical to ensure their long-term viability, may overlook the crucial role of anticipatory governance and inclusive decision-making processes. Hence, it is imperative to undertake a paradigm shift that expands the comprehension of sustainability, encompassing anticipatory measures for forthcoming challenges and promoting inclusiveness among societal actors.

Due to the shift in comprehension regarding the relationship between science and society, Science, Technology, and Innovation (STI) public policies now acknowledge the urge to comprehend and oversee the intersections and dynamics of their mutually formative nature as a means to progressively incorporate both domains into a more radical and integrated process. The symbols representing the diverse STI Framework Programs of the European Union, ranging from Science and Society to Science in Society, Science for Society, and, ultimately, Science for and with Society, serve as a compass for understanding the conceptual progression of the relationship between science and society within these Framework Programs (Barrenechea & Ibarra, 2019).

According to Barrenechea and Ibarra (2019), the contribution of the RRI approach to the production of scientific knowledge was associated with the relational quality dimension of the production mechanism itself. The authors list three elements that are included in the simultaneous production of knowledge and mobilization around processes that link to the futures of science to and from society. Those elements are:

(i) the inclusion of multiple and diverse perspectives.
(ii) mutual responsibility in anticipatory terms.
(iii) a learning dimension established by mobilizing the "capital reflexive".

Additionally, the research underscored the importance of responsible innovation and its correlation with inclusive planning and comprehensiveness. By integrating the principles of Responsible Research Innovation (RRI), technology development and evaluation can transcend from the solitary focus on results and give paramount importance to the responsible and comprehensive procedures involved. By incorporating foresight methodologies and incorporating diversity in decision-making processes, it becomes possible to recognize potential hazards and benefits connected to water technology, ensuring that technological progress coincides with the values and goals of society.

The study accentuated the nexus between political economics and advancements in water technology. It is of paramount importance for governance and policymaking to comprehend the political and social determinants that influence the advancement of water technology. The analysis of policy objectives, performance indicators, and societal actors' viewpoints yielded valuable perceptions into the intricacies of technology integration in water management and the corresponding adversities and prospects.

By scrutinizing the prevailing water management technologies, the results underscored the necessity of engaging societal actors and beneficiaries in the stages of both development and evaluation. Insufficient participation can result in the development of technologies that are not in sync with the requirements and anticipations of stakeholders, compromising their efficacy and durability.

This research entails substantial contributions to the field of responsible assessment of water technology. The proposed framework transcends conventional concepts of sustainability and integrates dimensions of co-constitution of the epistemic subject, using a learning tool and a digital platform to enhance anticipatory governance and inclusiveness. Through this means, a more inclusive method is presented for assessing the responsibility and durability of water technologies, thereby affording policymakers, professionals and invested parties the ability to make judicious decisions.

The key difference between the participation process proposed and the existing examples mentioned relates to the public itself, and the awareness of the co-constitution of the subjection within the co-production of knowledge, encompassing the decision making that uses public enquiry to validate their options There were mentioned examples where public can ask questions to the decision making entities, or even can participate with their opinion in forums, but it is usually a one way process and does not promote the co-constitution of the subject, and the connections in the network of actors.

The operationalization process presented with a single process of co-construction of knowledge functionally oriented in two directions (Figure 7) — co-production of knowledge and co-constitution of the epistemic subject (network of actors) —, using a unique process structured in two phases — exploratory and operational —, with the integration of a learning tool to improve the relational quality of the network, represents an advancement on the understanding of the epistemic subject as part of the process of co-creation of knowledge.

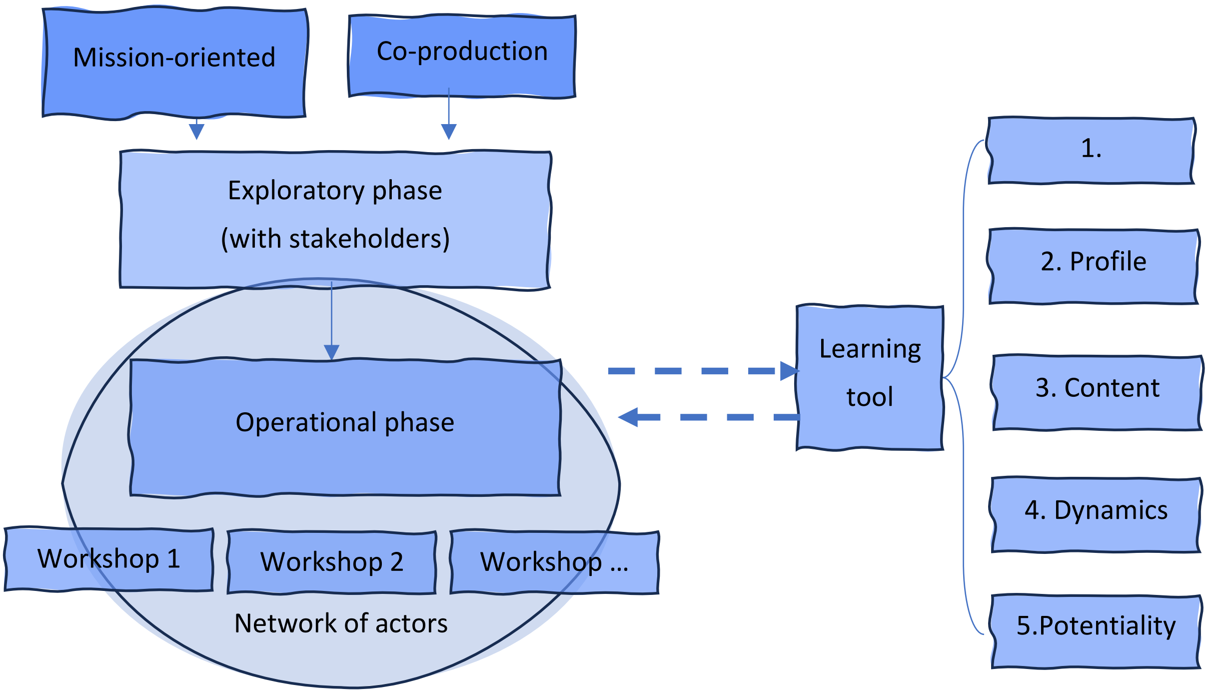

Figure 7 - Simulation of the Operationalization Process.

The study stressed the importance of considering societal actors besides the stakeholders. Only in the exploratory phase of the experiment it is proposed to consult stakeholders to carry on with test to design the next steps for the operational phase.

An open operational phase, to be carried out with actors who constitute the subject of co-production (the network of actors), was presented, using the learning tool to develop the co-constitution of the subject. Furthermore, this research augments the comprehension of conscientious innovation and its correlation with foresight and comprehensiveness. The research underscores the significance of conscientious procedures, thereby contributing towards the advancement of ethical and socially responsible technological progressions.

In addition, a thorough investigation of the political economy pertaining to water technology elucidates the contextual variables that impact the advancement and implementation of technology. This comprehension can guide policy measures and administrative frameworks that foster conscientious and lasting governance of water resources.

6.1 Further future work

The outcomes of this study present noteworthy ramifications for decision-makers, professionals, and individuals concerned with the management of water resources. The suggested structure for the responsible assessment of water technology may function as a pragmatic instrument to steer the processes of technology innovation and assessment. The integration of innovative anticipatory governance and inclusive decision-making techniques may facilitate the alignment of water technologies with societal requisites, tackle nascent impediments, and further advance sustainable water use.

Regarding the scope of application of the simulation, it should be noted that the next step to test and validate the approach present should be to select a geographic region and a specific function in more detail. As an example, is suggested, in the context of this work, that this simulation should be applied in the south region of Portugal (Algarve), in particular to what concerns the distribution of water to Golf Courses.

To do that, it should be involved key stakeholders to design the range of the ecosystem to be assessed. The range of stakeholders should include public entities who provide access to water, namely ARBA (Associação de Regantes e Beneficiários do Alvor), Political agents, namely government departments and agencies (Municipalities of Algarve (AMAL - Comunidade Intermunicipal do Algarve), utility providers (water and energy), golf course managers, golf course users, and Research entities (Universidade do Algarve); promotion entities (local and regional)

Depending on the level of application the range of stakeholders and societal actors can be adjusted.

In light of the research outcomes, a number of suggestions may be put forth:

- Policymakers could give greater importance to the incorporation of anticipatory governance and inclusive decision-making procedures within policy frameworks pertaining to the development and utilization of water technology. This objective can also be accomplished through the active involvement of a wide range of societal actors and the integration of their diverse viewpoints and specialized knowledge.
- Developers and innovators in the digital field should embrace the principles of Responsible Research Innovation (RRI) in their endeavors. Through a comprehensive assessment of the societal and moral ramifications of their innovations, along with the active engagement of all stakeholders during the development stages, responsible and sustainable resolutions can be attained.
- **The application of the methodology designed in the simulation in different case studies, with distinct geographies, using the digital platform as the deliberation space** (requires funding).
- Additional inquiry is deemed necessary to examine the implementation of the suggested framework in varying settings and industries. This will aid in the

verification and fine-tuning of the methodology, further augmenting its versatility to suit heterogeneous environments.

- The fine-tuning should be able to provide with a geographic delimitation of the case-study.
- The case-study is required to be function specific regarding the water use, not general, and technology scope needs to be a short scope.
- Education has the capability to provide authority to individuals and societies, compelling them to play an active role in shaping the evolution and assessment of water technologies.

6.2 Final considerations

This research has presented an all-encompassing comprehension of the phenomenon and idea of sustainability concerning the implementation of technology for the responsible management of water. Through the introduction of a framework that integrates anticipatory governance and inclusivity, the constraints associated with the conventional approach of sustainability can be tackled in a more efficient way, by promoting co-creation and inclusiveness. This study has made a significant contribution to the domain of responsible water technology assessment, by furnishing tangible means and principles for accomplishing a process to the follow responsibility and sustainability of water technologies.

By embracing responsible innovation, anticipatory governance, and inclusive decision-making, we can foster a future where water technologies effectively address societal needs, protect the environment, and contribute to the well-being of present and future generations.

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A

APPENDIX: TECHNOLOGY ASSESSMENT FOR SUSTAINABILITY IN WATER USE

Title: Technology Assessment for Sustainability in water use

Subtitle: Operationalization of a responsible governance based in RRI (anticipation and inclusiveness)

Keywords: sustainability; water; technology; anticipation; anticipatory governance; technology assessment; inclusiveness; participation; open innovation; efficiency

Palavras-chave: sustentabilidade; água; tecnologia; antecipação; governança antecipatória; avaliação de tecnologia; inclusividade; participação; inovação aberta; eficiência

Objetivos / Goals	**Hipóteses / Hypotheses**	**Tarefas / Tasks** **T.**	**Resultados esperados / Expected results**	**Produtos / Deliverables** **D.**
General Objective: To understand the phenomenon and concept of sustainability, with regard to the application of technology for responsible use of water	General hypothesis: The concept of sustainability does not accommodate the essential dimensions of responsibility in technologies for the management of water use	T: Create a framework for responsible assessment of water technology, based not only on sustainability, but encompassing the dimension of anticipatory and inclusive governance	R: Elaboration of methodology for evaluation of the responsibility of water technology; based on anticipatory governance	D: Proposal of methodology for evaluation of water technology, based on a model of inclusivity, transparency and anticipation
Specific objective 1 Understand the conceptual dimension of sustainability	Specific hypothesis 1: Sustainability should unequivocally encompass the concept of anticipation, but its meaning is too trivialized.	T1 • Historically framing the concept of sustainability • Make an analysis of the most important current sustainability concepts. • Explore the relationship between sustainability and efficiency. • Define a definition of sustainability incorporating anticipation practices	Design of "new" definition of sustainability incorporating practices of anticipation and RRI.	D1.a. Chapter: Sustainability dimensions Including: • the various dimensions of sustainability; • Threats to sustainability in water use. • A "new" possible definition;
Specific objective 2 Understand the dimension of responsibility in innovation based on RRI and	Lack of insight into RRI-based approaches, considering anticipation and inclusivity. That is, the current concepts of	T2a: Define the meaning of responsible innovation and its points of contact. T2b: Definir inclusividade	R2b: Definition of anticipation;	D2.Cap: RRI-based responsibility and its relation with the concept of anticipation

Objetivos / Goals	Hipóteses / Hypotheses	Tarefas / Tasks T.	Resultados esperados / Expected results	Produtos / Deliverables D.
inclusivity, as well as its relationship with the concept of anticipation and its dimensions.	sustainability are not sufficiently encompassing RRI, where the focus is on the result and not on the process.	T2c: Define the concept of anticipation and its framework in responsible innovation, namely in the field of water use T2d: Define open innovation	R2b1 Definition of the anticipation framework in water use R1,2a: Definition of the anticipation framework in responsible innovation. Presentation of the concept of anticipation and possible points of contact with sustainability and innovation	Sub-Chapter 1: Responsible Research Innovation (RRI) 1. Concept 2. Examples of use 3. Application opportunities Sub-Chapter 2: Anticipation and inclusivity applied to the sustainable innovation process • Concept of anticipation • Application opportunities in sustainability and technology for water use
Specific objective 3: Understand the "political economy" associated with developments in water technology and its social framework (i.e. concerns; demands, values and expectations of the actors)	In the public domain, the financing of the technology is based on Community funds; At the public level, the financing of the technology is motivated by tax benefits in compliance with metrics associated with environmental protection.	T3.a) Político: To know the political and social forces associated with the concept of sustainability in the use of water To know the policy objectives and metrics defined for the integration of technology in water use and interpretation of their results	R3.b. Understanding of the metrics, values, demands and expectations in the political, social and economic dimension, in the scope of sustainability for the use of water.	D3: Chap: Political dimension; social and economic D3.a. Sub-Chap: Political view on the sustainability of water use: • Specific policies; • Specific regulation in the field of sustainability and the application of technologies to water use

Objetivos / Goals	Hipóteses / Hypotheses	Tarefas / Tasks T.	Resultados esperados / Expected results	Produtos / Deliverables D.
		T3.c1. Social/Actors: • To know the social objectives and concerns about the technology for the use of water • Collect and describe visions of social actors in a literature review		D3b: Sub-Chap. The role of financing mechanisms in the innovation and development process: • Matrix of models and financing mechanisms. D3.c Sub-Cap: Vision of social actors on the concept of sustainability in water use. D3.c2. Classification of actors (list).
Objetivo específico 4: Descrever as tecnologias para o uso da água a nível funcional e os resultados alcançados e métricas existentes para a medição e avaliação de tecnologias no uso sustentável da água.	Specific hypothesis 4: The technologies are not open to social actors, nor to the end user, that is, there is no involvement of the actors in the development and definition of objectives, nor are there specific mechanisms defined for the evaluation of technologies in the use of water	T4.a. To know the process of developing technologies for the use of water; T4b: Understand how developers measure the innovation of what they are developing and how they validate the features of the technology. T4c. Describe how the choice of technologies for the use of water is effected and how it is measured by the entity responsible for this task.	R4a. Review of the development and innovation process of companies that develop water technology and how sustainability is measured. • Systematic diagram of stakeholders and decision models on water technologies	D4.a. Capítulo sobre: O Ecossistema tecnológico associado: quem, o que e como. • Who and how water technology is developed. • Innovation metrics and the responsibility of processes and results. • Systematization of recent and current processes used to support decision

Objetivos / Goals	Hipóteses / Hypotheses	Tarefas / Tasks T.	Resultados esperados / Expected results	Produtos / Deliverables D.
		T4d. Collect examples from the present and recent past to obtain possible approaches to a technology assessment model; metrics used; Actors involved T4e. Elaborate diagram of stakeholders and decision models on water technologies.		making and technology assessment; identification of strengths and weaknesses, with opportunities for improvement.
Specific objective 5 Develop methodology for technology evaluation based on the operationalization of anticipatory governance	Specific hypothesis 5:	T5a: Conceive and specify a deliberation space (digital). T5b: Define the relationships between the deliberative space and other entities. T5c: Define the objectives for early governance as a platform. T5d: Define of a proof of concept.	D5: Specification of the methodology for operationalizing anticipatory governance, including references to the digital component.	R5: Cap: Operationalization of technology assessment: an anticipatory governance model 1. Introduction: opportunities and rationale 2. Possible functional model for technology assessment platform 3. Platform interfaces with actors and other entities • Conclusions

B

APPENDIX: INOVPLAT - CONSENT FORM

Data collection, processing, and storage

In the current phase of the project, we are organizing qualitative interviews. For this purpose, we collect the following data:

- Name, job/position, email address
- Interview recordings, handwritten notes, and transcripts to enable scientific analysis

The data will be stored on secure servers hosted by the IT Center related to the project. Data will be archived for 10 years after the end of the project in order to ensure results can be verified if required.

Voluntary participation

The interview and workshops are voluntary. You have the right to refrain from answering any question and leave the interview or workshop at any time without a statement of reasons. You may ask for the deletion of all records at any time and without a statement of reasons. You will not be financially compensated for the interview.

Benefits and risks

By participating, you will support the project team in gaining a better understanding of the eco- system of nano-plastics, the potential and challenges of nanotechnologies in solving societal challenges.

The interview questions do not aim to disclose sensitive information. However, if any information or data of this kind is mentioned during the interview, you have the option to refuse to disclose this information or to interrupt / terminate participation (see the section on "Voluntary participation" above).

Confidentiality

Citations or identifiable information will not be published without your explicit permission. Some personal data will be gathered (e.g., name, email, job position, title) to help contextualize the in- formation gathered during this interview. However, none of these data will be made public without your consent.

You will not be asked to provide any sensitive personal data as described in the EU General Data Protection Regulation (GDPR) Article 9, e.g., data concerning health, political opinions, religious, or philosophical beliefs.

Sharing of the results

The results will also be presented in internal reports, which can be used in academic publicati- ons, (conference) presentations, etc. Please note, that no citations or identifiable information will not be published without your explicit permission (please see the section 'confidentiality' above).

☐ I have read the foregoing information, or it has been read to me. I had the opportunity to ask questions about it, and any questions I have asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study. Specifically, I consent to (please check if appropriate – you can also give or revoke your permission anytime at a later stage)

☐ I wish to review the notes, transcripts, or other data collected based on my participation in the research.

☐ I agree that the researchers may publish articles, reports, or similar that contain information I shared.

☐ I agree to be quoted directly.

☐ I agree to be quoted directly if my name is not published, and either a description of my role or a made-up name (pseudonym) is used to enable understanding.

☐ I understand that I can request insight into data collected on me and the project I am involved in at any time and that I can revoke consent at any time without providing reasons.

Date

Print Name of Participant

Signature of Participant

C

Appendix: Interview invitation

Dear _____________,

We would like to invite you as an interview partner as part of the new research project "Inovplat – Technology Assessment for Water Use" as a result of a PhD Program on Technology Assessment from NOVA University of Lisbon. The project's focus is on better embedding responsibility in water use technology into societies while engaging publics. This engagement will be fueled by collective reflection on the possible futures of water use technologies. Hereby, water and more specifically technologies used to manage water are relevant topics for both sides, research as well as the public. These are therefore put into the center of our attention.

To approach this topic, we are conducting an exemplary inventory of research and development in this sector. Therefore, we would like to invite you, or a member of your team, to a 45-60 minutes interview (Online, via Zoom, in English, or Portuguese) within the following dates (from DD-MM-YYYY to DD-MM-YYYY).

The interview will be mainly about your organization's perspective and experiences in the research field of water use technologies, in more detail, research related to sustainable technologies, and interaction with society.

By accessing the platform[42], you will find more information and a tool where you can select suitable appointments for your interview.

For more information, please find our information sheet and consent form attached.

[42] Not available at this time, just as a design prototype.

If you have any further questions, do not hesitate to contact us.

Best regards,
Sofia Romeiro

sofia.romeiro@inovplat.com
a.romeiro@campus.fct.unl.pt

D

Appendix: Relevant connectivity questionnaire

This questionnaire is addressed to the actors participating in the experiment ("Forum"). Its objective is to map the connective and interrelation capacities in which the Forum's actors are involved. One actor may be involved in a cultural project, another in a research or innovation project, another in a religious or sports program, another in a feminist, political or environmental program. Given the great diversity of the fields concerned, not all the issues raised will be relevant to all the actors or will be relevant to them in the same way, so it will not be necessary to answer them in all cases. The purpose of the questionnaire is to provide information for an initial diagnosis of the initial interrelationship of the Forum's actors, while also offering a learning tool to enrich this interrelational capacity.
Although the issues are oriented to activities in different environments, the questionnaire will always refer to them as part of an "activity".

MODULE A: General Issues

1 - Which institutional agent/s had the initiative to propose the activity?

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2 - Is the activity sponsored by an institution or is it part of a political/social program, research framework program, ...? Which one?

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3 - What is the origin of the activity and the line of work? Does it arise from an institutional proposal (e.g. sponsor), has it been structured according to the coordinator's background or does it have another origin?

a) Activity's Coordinator
b) Sponsor
c) Other (who?)

4 - Mention the institutional agents that have been involved in defining the orientation and objectives of the activity (whether or not they are part of the current network developing the activity).

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5 - Which is currently the lead institution of the activity?

---

6 - What are the main scientific/technological disciplines involved in the development of the activity?

---

7 - To what extent has the activity design articulated demands or priorities from the following sectors?

Sector/ agents	**High**	**Medium**	**Low**	**Not incorporated**
1. Governmental and regulators				
2. Service providers and business (includes tourism and agriculture)				
3. Watershed institutions				
4. Scientific/Technology				
5. Civil society				
6. Other agents (financial agencies, media				

MODULE B: Issues to complete the general table that includes all the agents participating in the activity according to the list of agents of the activity made by the forum's actor

Show the list: according to the information provided by the forum's actor, the agents participating in the project are those registered in that list, could you tell us if this is correct, if any of them have not participated or if any agent has been added (complete or remove if indicated).

The following issues concern the relationship of forum's actor on this activity with each of the above-mentioned agents.

8 - Prior to the start of the activity, the contact with agent x1(x2, x3...) originated mainly from:

Personal links of the coordinator
Personal links of the forum's actor
Institutional links of the actor
Previous services
Informal and trusted relationships
No previous linkage and no previous references
They spontaneously came forward wanting to be part of the activity
Other (Which one?)

9 - General characterization of each agent: (Profile and institutional complexity of the activity is evaluated)

A -Type of institution	B - Sector	B.1 – R+I Dpt.	C – Scope of origin
1 Public	Companies	1 YES/ 2 NO	1 Regional
2 Private	Scientific-Academic		2 State
3. Mixed	Technological		3 EU
	Governmental	1 YES/ 2 NO	4 International
	Services		
	Hospitals		
	non-governmental organizations		

10 - Attributes of the links: In relation to the current link with the agent x1 (x2, x3...) it is a link (ask the whole block for each agent)

A	1 Formalized	2 Informal	
B	1 Flexible	2 Requires following procedures	
C	1 Exchange of capacities, resources, and products	2 Complement of capacities and resources (subdivision)	3 Combination of capacities and resources (joint work)
D	1 Weekly	2 Monthly	3 Annual

11 - Which of the following attributes have influenced the incorporation of agent x1 (x2, x3...) in the activity? (main)

1. Professional/technical/academic quality of the institution
2. Geographical proximity
3. Common membership of another framework network
4. Highly specialized profile of the institution
5. Need to develop or consolidate the local network
6. National projection of the network
7. International projection of the network
8. Other (Which one?)

12 - As for the objectives underpinning the collaboration with agent x1 (x2, x3...) they are:

1. Limited to a specific stage or task in the activity
2. Linked to the development of the activity as a whole
3. Strategic alliance according to objectives beyond the activity

13 - What type of input gives (13.1)/offers (13.2) the forum's actor from its link with agent x1 (x2, x3...)? (fill in the column of receives and offers at the same time for each agent)

Scientific knowledge
Information
Technical assistance/services
Laboratory infrastructure/equipment/materials
Databases
Funding
Samples or species
Training of human resources
Invitations for researcher stays (mobility)
Proposals for co-authorship in publications
Others

14 - In general terms, the communication with agent x1 (x2,x3...) has been:/

Very difficult	Difficult	Easy	Very easy

MODULE C: General issues

15 - In general terms and referring to cases where communication/collaboration has been difficult or very difficult, could you describe the agents that from your point of view have interfered with communication?

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16 - Regarding the interaction mechanisms used among the activity's agents for the monitoring the activity, could you please indicate what percentage of these are?

Working meetings	
Formal written communications (reports)	
Informal written communications (e-mail, etc.)	
Total	100%

17 - Are there other institutions/agents that would be important to incorporate into the activity in the medium or long term? Which ones? Please indicate for each of them whether or not a relationship ("link") currently exists or is in the process of being established:

Institution/agent	Sector	YES	NO	In process	Purpose

18 - For each of the possible new links mentioned item 17, could you identify what is the need for their incorporation? (RECORD IN TABLE ABOVE)

an extension of the activity's objectives
the emergence of unforeseen problems
the need to give the network a higher profile
the need to increase the outputs of the activity
Other...

19 - In addition to the evaluations to which the activity and its products are subjected, is it planned to include assessment of the functioning of the collaborative network itself? If so, what aspects are taken into account (e.g. the relevance of the agents involved, the need to

incorporate new ones, the collaboration practices, the stability of the network, etc.), and who is in charge of this assessment?

---

20 - If you were to broadly define the current profile of the activity according to its objectives and distribution of resources, what percentage of participation would you assign to each of these areas (adding up to 100% in total)?
(Submit graph of areas of activity)

21 - How do you assess your (institutional or subjective) pattern model in terms of collaboration development?

It is a more enabling and flexiblethan others	
It is not different from other pattern models	

22 - What is your assessment of the current state of the activity network?

Unstable	
Incipient with a tendency to stabilize	
Incipient with difficulties to stabilize	
Stable	
Consolidated	

Interviewee information:

Name and surname:
Institution/organization and country where he/she mainly developed his/her main occupation:

Registration table

Question	8	9. A	9.B	9.b. 1	9.C	10. A	10. B	10. C	10. D	11	12	13. 1 (3)	13. 2 (3)	14
Name of institution / agent	Ori gin	Typ e	Sec tor	Fiel d	R+ D	No For m.	Flex ib	Mo dal.	Fre q	Rec rut	Obj.	Giv es	Off ers	Co mm uni.
Institution 1 / Agent 1														
Institution 2 / Agent 2														
....														

2022

ANDREIA SOFIA ALBINO ROMEIRO

TECHNOLOGY ASSESSMENT FOR SUSTAINABILITY IN WATER USE