Master´s Thesis – master Sustainable Development

Analysing productive interactions to explain societal impacts in transdisciplinary research

Case study analysis of European Nexus projects

Loreto Alegría López Gamboa

UU Supervisor: Prof. Dr. Peter Driessen

Second assessor: Dr Dries Hegger

Internship at KWR Water Research Institute

KWR Supervisor: Caro Mooren

01 – July – 2024

ECs: 45

MSc Sustainable Development - Earth System Governance

Faculty of Geosciences

Utrecht University

Summary

Sustainability challenges are deeply interlinked and pressured by the climate change context. Given these interrelated and complex challenges, there is an increasing agreement that new approaches to knowledge production and decision-making are required. Likewise, more science-policy interactions are needed to bridge the gap between science and policy and improve the use of knowledge for decision-making. Thus, integrative research approaches become essential to responding to sustainability issues.

Transdisciplinary approaches, as integrative approaches, are crucial to facing sustainability challenges since they address the science-policy interactions involving several sectors and actors in complex interactions. One example of this approach is the Nexus approach, which emerged to respond to sustainable challenges among different sectors. Due to the complex nature of the transdisciplinary approaches, societal impacts in transdisciplinary research are not straightforward and they need to be assessed to learn from their performance for future project design and promote impact delivery. Thus, the concept of productive interactions emerged as a potentially useful approach to assessing and studying societal impacts. Despite a consensus on the importance of interactions between researchers and stakeholders and the interest in its contribution to societal impacts, interaction analysis in the study and assessment of research impact are scarce, and undervalued.

In this context, this research aimed to increase the understanding of how productive interactions contribute to achieving societal impacts in transdisciplinary research by analysing productive interactions throughout outputs and outcomes in Nexus projects. For this, a framework based on the productive interactions approach, complemented by the theory of change concepts and contextual conditions, was used to analyse two European Nexus projects (SIM4NEXUS and NextGen). This resulted in an overview of the outputs, outcomes and potential societal impacts in each case, the type of interactions, the extent to which contextual conditions stimulated or hampered productive interactions, and how productive interactions contributed to achieving societal impact in Nexus projects. The research showed that Nexus projects achieve outputs and outcomes and increase the chance for societal impacts through productive interactions that emerge when stimulating contextual conditions (“broad stakeholder participation”, “problem definition”, “roles and contribution”, and “resource availability”) are met. Productive interactions lead to societal impact in Nexus Projects through a sequence of changes (outputs

and outcomes) that entail exchanges and utilisation of knowledge produced by those exchanges. The results provided insights into the interaction process and recommendations to improve research design and enhance the societal impact of future transdisciplinary research.

Key concepts
Productive interactions, outputs, outcomes, societal impacts, transdisciplinary research, Nexus projects.

Preface
This thesis is part of the Master's programme Sustainable Development (Earth System Governance track) at Utrecht University. It was developed as an internship at KWR Water Research Institute in the context of the *COST Action CA20138 - NexusNet (Network on water-energy-food nexus for a low-carbon economy in Europe and beyond).*

Acknowledgements

Throughout this process, several people positively influenced and supported me, allowing me to carry out this thesis. First, I would like to thank my supervisor, Prof. Dr. Peter Driessen, for his guidance, clear explanations, helpful feedback, and encouragement throughout the entire process of this thesis. Furthermore, I would like to express my sincere gratitude to Caro Mooren, my supervisor at KWR, for her empathy, motivation, advice, and helpful and extensive feedback. In addition, I would like to thank Stefania Munaretto for her support and helpful suggestions during my internship and for, together with Caro, encouraging and supporting me to participate in the NexusNet Workshop and Forum carried out in Malta and the Training School in North Macedonia. Overall, thanks to KWR for the opportunity to do an internship in a pleasant working environment, which allowed me to have a valuable experience.

As part of the research, I conducted interviews with researchers and stakeholders involved in the SIM4NEXUS and NextGen projects. I would like to thank all of them for their willingness to participate in this research and provide valuable information and insights for my thesis. I would also like to express my gratitude to COST Action NexusNet for allowing me to participate in the Malta event, where I could validate my results with experts in the Nexus approach field. Thank you to all those experts who were present and contributed an important step in this research.

Table of contents

Figures

Tables

Abbreviations and Acronyms

CSA	Case study analysis
CSL	Credible, salient and legitimate
JKP	Joint knowledge production
NA	Nexus approach
NP(s)	Nexus project(s)
PIs	Productive interactions
SI(s)	Societal impact(s)
ToC	Theory of change
TDR	Transdisciplinary research

1 Chapter 1: Introduction

1.1 Introduction to sustainable issue

Global sustainability challenges, such as food and energy insecurity and water scarcity, are deeply interlinked (Hoff, 2011; WEF, 2011; Liu et al., 2018, 2021). Energy production requires water as well as water requires energy for lifting, moving, distributing, desalination, and treating water. Likewise, food production requires not only energy for mechanisation and modernisation measures to increase yields but also water, which uses most of the consumptive blue water (Hoff, 2011). In the context of climate change, these interlinked challenges are increasingly pressing since the rise in global temperature aggravates the pressure on those resources (Liu et al., 2018; IPCC, 2015). Given the interrelated and complex sustainability challenges, there is an increasing agreement that new approaches to knowledge production and decision-making are required (Hegger et al., 2012; Lang et al., 2012). Likewise, more science-policy interactions are needed to bridge the gap between science and policy to improve the use of knowledge for decision-making (Sarkki et al., 2013).

Different values and uncertainties of the sustainability challenges, as well as the different timeframes, objectives, and processes, separate the science and policy domains, making it difficult to provide the required knowledge for the needed solutions (Hegger et al., 2012). In this sense, science-policy interactions, understood as the interactions between scientists and actors in the policy process (Van Den Hove, 2007), are complex and entail challenges and trade-offs (Turnheim et al., 2020). In this context, integrative research approaches are essential to respond to sustainability issues (Macleod et al., 2008).

Transdisciplinary approaches, as an integrative approach, are understood as a collaborative mode of knowledge production that integrates different disciplines and contributions from researchers and non-researchers (Macleod et al., 2008; Schneider, Büser et al., 2019). Sustainability challenges involve several sectors and actors in complex interactions; therefore, transdisciplinary approaches addressing the science-policy interactions by integrating disciplines and actors are crucial to facing those challenges (Jähn et al., 2012).

Despite increasing agreement that transdisciplinary approaches are suitable to address sustainability challenges (Jähn et al., 2012; Lang et al., 2012), the manners in which their

societal impacts are achieved are not straightforward. Societal impacts (SIs) can be defined as "cultural, economic, industrial, environmental, or social changes that are entirely or in part the consequence of knowledge and expertise generated by research" (NWO, 2020, p.2). In the process of achieving SIs, there is a sequence of outputs (direct results obtained by research project) and outcomes (changes in behaviour, relationship, actions of stakeholders as a result of the knowledge exchange process and the use of outputs) (NWO, 2020). Outputs and outcomes can be considered intermediate phases of the SI process (Douthwaite et al., 2003), which can be explained through the theory of change approach.

Due to the complex nature of transdisciplinary approaches and their dynamic interaction process among stakeholders, societal impacts in transdisciplinary research (TDR) are difficult to plan and, sometimes, unexpected and unintended (Spaapen & Van Drooge, 2011a). Therefore, they need to be assessed to learn from their performance for future project design and to promote impact delivery (Munaretto et al., 2022). In this context, traditional criteria and assessment approaches are insufficient to capture the complexity of TDR and assess their societal impacts (Belcher et al., 2015; 2020; Belcher & Hughes, 2020; Lang et al., 2012). Joly et al. (2015), Belcher and Hughes (2020), and Munaretto et al. (2022) agreed on the necessity of considering new approaches to capture the complexity of mechanisms generating impact in TDR.

In this context, Spaapen and Van Drooge (2011b) proposed the concept of productive interactions (PIs), which can be understood as exchanges between researchers and different stakeholders during which knowledge is generated and used for societal goals (NWO, 2020). The concept suggests that analysing PIs of research leads to recognising and evidencing potential research impacts. Based on this, Molas-Gallart and Tang (2011) argued that PIs provide an effective manner to study societal impacts. In this line, the concept of PIs provides a lens for retrospectively studying societal impacts (De Jong et al., 2022). Different studies have incorporated the PIs concept to study the societal impact in health, social science, and humanities fields (De Jong et al., 2022). For instance, Olmos-Peñuela et al. (2014), based on a PIs analysis, highlighted the importance of collaboration for policy implementation. In turn, Muhonen et al. (2018) identified 12 mechanisms in which social sciences and humanities research led to societal impacts.

One transdisciplinary approach that has emerged as a response to sustainability challenges is the Nexus approach (NA) (Albrecht et al., 2018; Hoff, 2011), which can be defined as "an approach that integrates management and governance across sectors and scales" (Hoff, 2011, p. 7). Understanding the interdependencies among different sectors allows the identification of mutually beneficial responses to increase resource use efficiency, reduce trade-offs, and optimise synergies among them (Hoff, 2011; Scott et al., 2011). Examples of projects that have used the Nexus approach are SIM4NEXUS and NextGen. They aimed to face sustainability challenges, such as land use changes, water scarcity, poor water management and policy inconsistencies, by integrating different sectors at different levels.

Analysing the PIs of Nexus projects, such as SIM4NEXUS and NextGen, allows to understand to what extent they achieve SIs and learn about the interaction process. This understanding is essential to improve research design to enhance the SI of future transdisciplinary research (Belcher et al., 2020; Belcher & Hughes, 2020).

1.2 Knowledge gap, objective, and research question

Although there is an increase in research based on integrative approaches, there is a gap between the knowledge produced by researchers and the knowledge used by policy-makers (Jacobi et al., 2022; Lemos et al., 2012; Yung et al., 2019). Likewise, despite a consensus on the importance of interactions between researchers and stakeholders and an increasing interest in how these interactions contribute to societal impacts (Hansson & Polk, 2018), analysis of those interactions in the study and assessment of research impact are scarce, and undervalued (Spaapen & Van Drooge, 2011b). Moreover, there is a lack of empirical evidence about the critical participatory components that favour sustainability research (Hansson & Polk, 2018).

On the other hand, although there is an agreement that transdisciplinary research (TDR) approaches are needed to address sustainability issues, there is limited guidance on how they can be carried out to achieve their expected results (Thompson et al., 2017). Furthermore, despite offering systematic learning exercises to analyse how changes occur, the use of the theory of change in TDR is still lacking (Schneider, Giger et al., 2019). Particularly, since the Nexus approach has become a common approach to bridging science and policy, Yung et al. (2019) suggest an increasing need to unpack the methods and assumptions used. In this line, Endo et al. (2017; 2020) argue that there are few reviews on Nexus projects (NPs), and they

should be facilitated and implemented uniformly (adjusted to each case) to realise their potential impacts. Thus, if NPs are well implemented as transdisciplinary approaches, they could foster integrated planning and governance; however, NPs, in general, are still in an early stage of development (Liu et al., 2018).

Additionally, Albrecht et al. (2018) and Avellán et al. (2022) suggest that Nexus projects (NPs) should be more aware of the integration of stakeholders in their assessment. Moreover, Jacobi et al. (2022) concluded that incorporating specific actors from the project design could benefit in achieving research impacts, suggesting the importance of considering the stakeholders' interactions when it comes to studying Nexus impacts. Shannak et al. (2018) also argued that there is a need for approaches to assess NPs across actors to contribute to policymakers developing evidence-based policies, to face sustainability challenges, and to manage resources efficiently. Lastly, although the Nexus approach aims to promote policy coherence, Weitz et al. (2017) suggest that Nexus literature falls short of insights about conditions for cross-sector coordination, making it difficult to achieve policy coherence.

The lack of analysis of productive interactions (PIs) in research projects when studying societal impacts (SIs) of research hinders the identification of conditions that lead to them. Furthermore, the lack of reviews of NPs and the assessing approaches incorporating PIs in their analysis hampers the understanding of how SIs were generated. This, in turn, hinders the learning from the research process, which is essential to improve research design to enhance the SIs of transdisciplinary research and bridge science and policy.

To address this knowledge gap, the objective of this research was **to increase the understanding of how productive interactions contribute to the achievement of societal impacts of transdisciplinary research by analysing productive interactions throughout outputs and outcomes in Nexus projects.** Analysing the stakeholders' interactions in different cases of study (SIM4NEXUS and NextGen projects) shed light on how societal impacts can best be achieved in future transdisciplinary research, such as Nexus projects. The research question that follows from this is: **To what extent do Nexus projects achieve expected outputs, outcomes, and societal impacts through productive interactions, and what are their leading contextual conditions?** To guide the research and achieve the knowledge to answer the previous research question and objective, four sub-questions were elaborated:

1. What were the achieved outputs, outcomes, and (potential) societal impacts of the SIM4NEXUS and NextGen projects?
2. What were the interactions throughout the SIM4NEXUS and NextGen projects?
3. To what extent were contextual conditions met in each project, and to what extent did they stimulate or hamper productive interactions?
4. To what extent did these productive interactions lead to those societal impacts?

1.3 Scientific relevance

Analysing the productive interactions (PIs) in Nexus projects (NPs) allows for insights into to what extent interactions between researchers and stakeholders contribute to societal impacts (SIs). This contributes to the development of the understudied research field on PIs and the assessment of SI of research (Spaapen & Van Drooge, 2011b).

Additionally, analysing the PIs throughout the sequence of output and outcomes of NPs allows to understand how they achieve SIs (or increase the chances for SIs), leading to learning about the research process, which is essential to improve the research design of these projects (Belcher et al., 2020; Belcher & Hughes, 2020). This, in turn, can contribute to the field of science-policy interactions and the knowledge gap between the knowledge produced by researchers and the knowledge used by policy-makers, as suggested by Lemos et al. (2012) and Yung et al. (2019).

1.4 Societal relevance

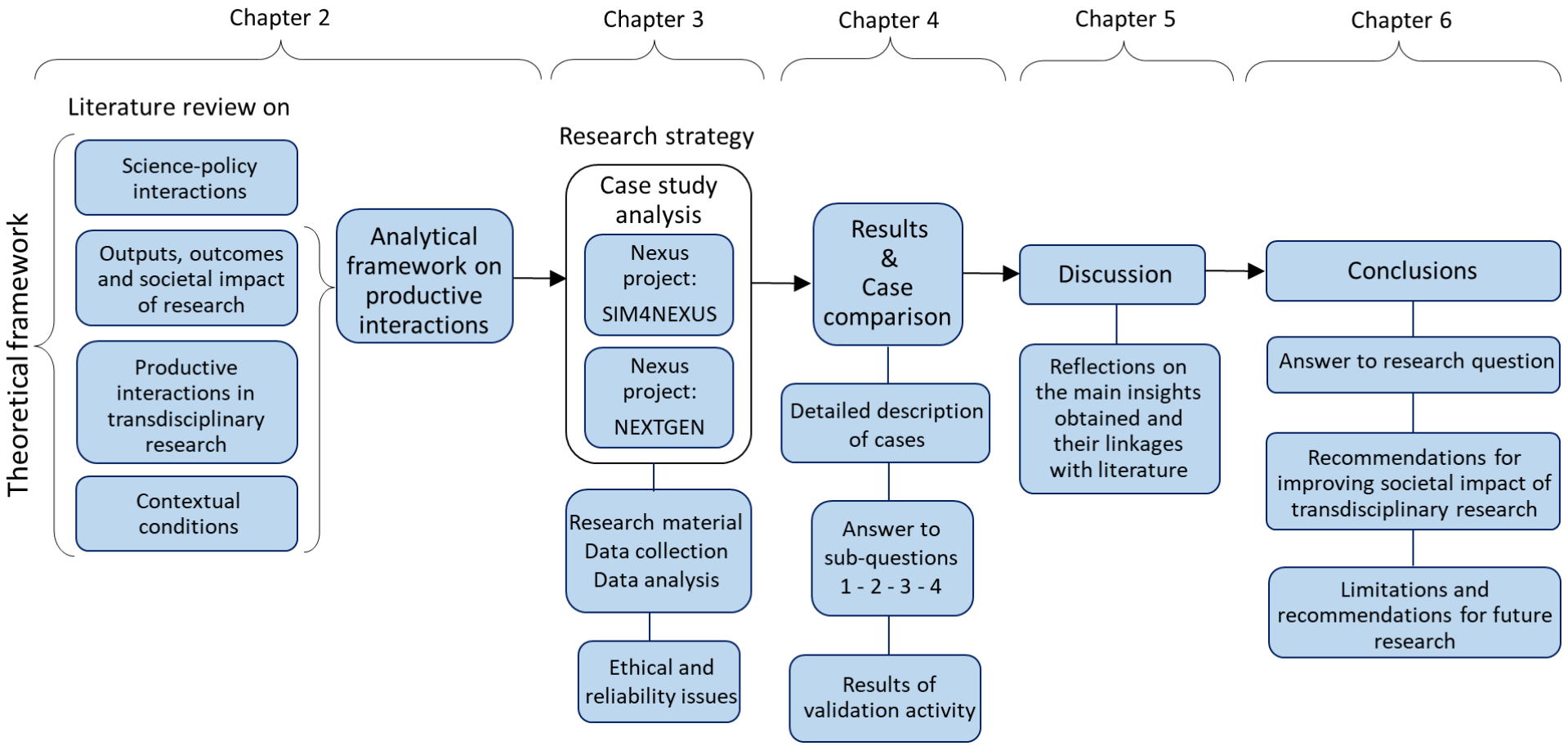
By contributing to the science-policy interactions field, this research promotes deliberative policy-making (Macleod et al., 2008). In turn, it may help policy-makers develop evidence-based policies to face sustainability challenges (Shannak et al., 2018), which in turn could lead to achieving the SDGs (Liu et al., 2018).

Lastly, this research sheds light on certain conditions leading to interactions becoming productive and contributing to achieving or enhancing the societal impacts of NPs. This could contribute to solving the gap in Nexus literature about conditions for cross-sector coordination and collaboration and, consequently, to solving the governance issue of policy coherence (Weitz et al., 2017).

1.5 Outline of the thesis

The following chapter (Chapter 2) provides the theoretical framework, which was built upon a literature review on science-policy interactions, the concepts of outputs, outcomes and societal impacts, productive interactions in transdisciplinary research and contextual conditions for these productive interactions. Based on this literature review, an analytical framework was developed, which was used to analyse productive interactions within the case studies (SIM4NEXUS and NextGen projects). The methodology used is presented in Chapter 3, which describes the research strategy, criteria for case selection, data collection, data analysis (including validation of the results) and issues related to the ethics and reliability of the research. Based on the collected information, Chapter 4 presents the results and case comparison. This Chapter starts with a description of each case, followed by insights into outputs, outcomes, societal impacts (answer to sub-question 1), the type of interactions among researchers and stakeholders (answer to sub-question 2), and the contextual conditions that stimulated or hampered productive interactions (answer to sub-question 3). This chapter provides a conclusion of the results which explains the extent to which productive interactions lead to societal impacts (answer to sub-question 4). Chapter 4 finalises by presenting the results of the validation activity, where external Nexus researchers contributed to the validation and generalisation of the research findings. The results are discussed in Chapter 5, which presents reflections on the main insights obtained and their linkages with literature. Finally, Chapter 6 answers the research question by explaining how Nexus projects achieve societal impacts, followed by recommendations for improving societal impact in transdisciplinary research. This chapter also includes the limitations of this research and further recommendations for future studies. Figure 1 presents the research framework, which provides an overview to guide the research development explained above.

Figure 1: Research framework

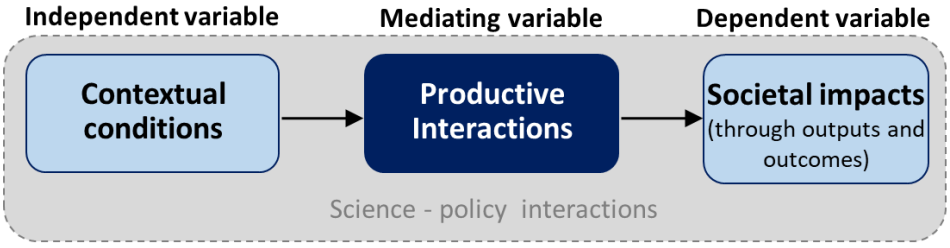


2 Chapter 2: Theoretical foundation and analytical framework

2.1 Introduction

Before providing the theoretical foundations and presenting the analytical framework, a brief explanation of the basic rationale of this research is provided to facilitate the understanding of the interlinkages between the theories and the main concepts presented below. In this research, societal impacts (dependent variable) are influenced by productive interactions (mediating variable), which in turn are influenced (stimulated or hampered) by contextual conditions (independent variable). Therefore, productive interactions as the mediating variable (intermediary) intervene or mediate between the independent and dependent variables (Verschuren & Doorewaard, 2010). Figure 2 illustrates how these concepts are related to being better understood through the following sections.

Figure 2: Conceptual framework



This research analyses productive interactions (PIs) to increase the understanding of their contribution to achieving societal impacts (SIs) in transdisciplinary research. This research followed a retrospective rationale to analyse PIs throughout outputs and outcomes as a process of exchanges and changes that led to potential societal impacts. Because PIs are limited to explaining, on their own, SIs, the analysis was complemented by contextual conditions that stimulate or hamper these productive interactions. Under this line of reasoning, after presenting a brief explanation of the science-policy interactions, which is the general context of this research (section 2.2), this chapter presents the concepts of outputs and outcomes as part of the change process that leads to the SIs of research in which interactions occur (section 2.3). Section 2.4 addresses PIs in the context of transdisciplinary research, highlighting that the interactions that occur in this process must be productive to promote changes and societal impacts. Section 2.5 presents contextual conditions that allow uncovering the conditions for PIs to emerge and for SIs to be promoted. Finally, section 2.6 presents the analytical framework derived from this literature review and how the research's variables were operationalised.

2.2 Science-Policy interactions as a general context

Scientific knowledge has become essential in informing policy-making processes to face sustainability challenges (Van Enst et al., 2014). It is suggested that although science can play an important role in policy, science-policy interactions are often contested, non-linear, and one-directional. Thus, these interactions entail trade-offs and problems such as strategic misuse of knowledge, strategic knowledge production, and a misfit between demand and supply of knowledge (Van Enst et al., 2014).

These problems could be explained due to the lack of credibility, salience, or legitimacy of the knowledge produced (Cash et al., 2003). Salience alludes to the relevance and usability of the knowledge for stakeholders' needs; credibility involves the perception of the information in terms of scientific plausibility and adequacy and reliable sources; and legitimacy refers to whether the produced knowledge is unbiased in its process and respectful regarding the beliefs of stakeholders (Cash et al., 2003; Hegger et al., 2012; Van Enst et al., 2014). Based on Cash et al. (2003) and Kirchhoff et al. (2013, as cited in Andrews et al., 2024), "for knowledge to be used, it must be perceived as credible, salient and legitimate (CSL)" (p. 1). In this sense, science-policy interactions can be enhanced by promoting the production of CSL knowledge (Van Enst et al., 2014).

Considering the highest degrees of knowledge integration of transdisciplinary research (TDR) (Thompson et al., 2017; Pohl et al., 2021), TDR can provide credible, relevant (salient), and legitimate knowledge (Veisi et al., 2022). Thus, TDR can be understood as an intervention at the science-society interface, contributing to solving the issues of science-policy interaction (Schneider, Giger et al., 2019). This implies that there are assumptions about how societal changes unfold and how knowledge can induce those changes. In this context, the theory of change can support the understanding of that societal transformation process through the use of the concepts of outputs, outcomes and (societal) impacts.

In order for TDR to achieve its expected results, interactions between researchers and stakeholders must be productive (Wiek et al., 2014), which means that the knowledge produced by the interactions, which is scientifically robust and socially relevant, is used to fulfil societal goals (NWO, 2020). In addition, since productive interactions do not come automatically (NWO, n.d.), they need contextual conditions to emerge (De Jong et al., 2022), which can

stimulate the productivity of the interactions to produce knowledge that can be used to lead the necessary changes for solutions to sustainability challenges.

Thus, for the understanding of the achievement of societal impact in the context of science-policy interaction, the process of change (outputs, outcomes, impact), the productive interactions, and the contextual conditions under which they can emerge are essential elements which are presented in the next sections (2.3, 2.4 and 2.5).

2.3 Output, outcomes and societal impact of research

The route from knowledge to societal impact does not come automatically (NWO, n.d.). Scientific research, through the utilisation of knowledge produced, can make changes that lead to societal impact, providing solutions for the complex challenges that society is increasingly facing (NWO, n.d.). In this context, societal impact (SI) of research can be defined as "cultural, economic, industrial, ecological or social changes that are (partly) the result of research-generated knowledge and skills" (NWO, n.d.) and it occurs as a result of changes in attitudes, opinions, and behaviours of stakeholders (outcomes), as a consequence of the research results (outputs) (De Jong et al., 2014). In this research, stakeholders include civil society, governments, NGOs, industry, consultancy firms, and researchers from other fields (De Jong et al., 2014). Therefore, SIs do not occur spontaneously, but rather are a result of interactions between researchers and stakeholders who create, exchange, and make use of new knowledge (Sivertsen & Meijer, 2019).

SI of research has been relevant for policy and scientific agenda for a long time; however, during the last decades, the impact approaches shifted from focusing on results to focusing on the interaction process (De Jong et al., 2022). In order to understand this process of interactions, in which SIs are generated, scholars have started to make use of the theory of change (ToC) (Schneider, Giger, et al., 2019). ToC provides a "description and illustration of how and why a desired change is expected to happen or has happened in a particular context" (Munaretto et al., 2022, p. 3). In this sense, it can serve as an analytical framework to explain how research projects contribute to the change process (impacts). Through a logical flow, ToC makes clear what a project does (outputs) and what it is expected to achieve (outcomes and impacts) (Belcher et al., 2020). The path from outputs via outcomes until societal impacts is defined in an impact pathway, which can be understood as a schematic representation of how outputs, via

interactions between researchers and stakeholders, can contribute to societal impacts (NWO, 2020). This research used the logical flow of the ToC to explain the impact generation through outputs and outcomes as a sequence of changes led by productive interactions. These concepts are often used ambiguously; therefore, Table 1 presents the definitions for this research.

Table 1: Definitions of output, outcome, and impact

Concept	Definition
Output	Belcher et al. (2020) define output as the direct products, goods, and services of the research and the research process (i.e., knowledge, fora, and processes generated by the activities). Belcher and Halliwell (2021) highlight the concept of insights produced by research. **This research adopted the definition by NWO (2020): Direct results obtained by a research project.**
Outcome	Changes in the agency and actions of system actors when they are informed/influenced by research output. It can be perceived as changes in knowledge, attitudes, skills, and relationships manifested as behaviour changes (Belcher et al., 2020; Belcher & Halliwell, 2021). Following the definition proposed by NWO (2020), **this research considered outcomes as changes in behaviour, relationships, actions, and activities of stakeholders as a consequence of knowledge exchange and the use of outputs.**
Impact	Belcher et al. (2020) define impact as changes in flow or state as a result of whole or part of the chain of events to which the research has contributed (e.g., higher annual income, increased water discharge from a river, changes in socio-economic status, water quality in a reservoir, etc.). Belcher and Halliwell (2021), in turn, conceptualise this definition as realised benefits. To highlight the importance of the produced knowledge in the impact generation process, **this research considered the definition by NWO (2020): cultural, economic, industrial, ecological, or social changes that are entirely, or in part the consequence of knowledge and expertise generated by research.**

Source: Based on Belcher et al. (2020); Belcher and Halliwell (2021); NWO (2020).

As Wiek et al. (2014) suggested, outputs and outcomes represent intermediate effects of research that are expected to occur during the project's execution, while impacts represent changes that might occur after the project ends. In this context, because achieving societal impacts usually exceeds the lifetime of a research project, the assessment of societal impacts can be based "on the efforts made and successes achieved in promoting the knowledge utilisation process" (NWO, 2020, p. 4). In this line of idea, Spaapen and Van Drooge (2011b) highlighted the importance of analysing the process of interactions that induce societal impacts since it allows the recognition of potential impacts that otherwise are not evident. The Nexus projects studied did not achieve societal impacts within the project's lifetime; therefore, this research analysed the process of interactions throughout outputs and outcomes. The next section presents the concept of productive interactions in the context of transdisciplinary research, which refers to the interaction process that induces outputs, outcomes and finally societal impact.

2.4 Productive interactions in transdisciplinary research

Interactions between researchers and stakeholders are particularly important in transdisciplinary research (Lang et al., 2012). Transdisciplinary approaches (also known as post-normal science, Mode-2 knowledge production, or knowledge co-production) are understood as collaborative modes of knowledge production aimed at solving societal issues through knowledge integration from different disciplines and actors (Macleod et al., 2008; Schneider & Büser, 2017; Schneider et al., 2019; Veisi et al., 2022). Considering the high level of knowledge integration of Transdisciplinary research (TDR), it can provide credible, relevant (salient), and legitimate knowledge (Veisi et al., 2022). This, in turn, leads TDR to produce science-based and socially accepted solutions to complex issues (Scholz & Steiner, 2015a).

Given the complex and interrelated nature of sustainability challenges, TDR approaches are essential to create societal impact and provide the required solutions (Jähn et al., 2012). However, TDR cannot achieve its effects (impacts) as a simple result of interactions between researchers and stakeholders. In other words, societal impacts do not occur when researchers and stakeholders interact in any way (Wiek et al., 2014), but when interactions are productive. Productive interactions (PIs) can be defined as "exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant" (Spaapen and Van Drooge, 2011b, p. 212). In this context, PIs can promote knowledge utilisation to fulfil societal goals due to the characteristics of the knowledge produced. Thus, whether the chance of productive interactions and knowledge utilisation increases, the chance of societal impact also increases (NWO, 2020).

Given the importance of the interactions in the process of achieving societal impact in TDR, Spaapen and Van Drooge (2011a) developed a framework (SIAMPI) to study societal impact of research through PIs. SIAMPI (Social Impact Assessment Methods through Productive Interactions) distinguishes three types of interactions: direct or personal interactions; indirect interactions through a medium; financial or material exchanges (Table 2).

Table 2: Types of interactions proposed by Spaapen and Van Drooge (2011a)

Type	Description
Direct interactions	Involve direct personal connections through face-to-face encounters, phone, email, or videoconferencing. These can be established through formal institutional channels (joint research centres, research projects, and programmes, technology centres), but they can also be informal; for instance, contacts established through collaborations are not mediated by any contract or formal agreements.
Indirect interactions	Contacts are established through some intermediate "carrier". The intermediate can be inanimate media, like all types of texts (articles, books, patents, reports, web pages, standards, codes of practice, clinical guidelines), exhibitions, designs, models, films, and musical arrangements. It can also be another person or group of individuals; in these cases, the user or beneficiary of the research will become aware of the researcher's activities or their results through social networks or chains of different organisations.
Financial interactions	It occurs when stakeholders engage in an economic exchange with researchers (e.g., a research contract or a financial contribution). This type of interaction cannot take place in isolation; it is accompanied by direct or indirect interactions or both. Yet, financial interactions inject different dynamics into the relationship and usually provide stronger feedback into the researcher's activities than other forms of interaction. They directly affect the organisation of research and often the research agenda itself.

Source: Spaapen and Van Drooge (2011a, p. 14).

SIAMPI framework has not been exempted from criticism. Although Spaapen and Van Drooge (2011a) suggested that interactions are productive when they induce behavioural changes aimed at societal goals, it is unclear how they can do it. Thus, despite contributing to unpacking the mechanism that generates impacts, this framework, on its own, is limited to explaining the impact of science on society prospectively (De Jong et al., 2022). In this line, Hansson and Polk (2018) suggest that productive interactions (PIs) are an intermediate step in reaching societal impacts (p. 13). According to Kalliomaki et al. (2021), the SIAMPI has remained superficial by being mainly aimed at separating direct, indirect, and financial exchanges. Díaz-Mariño et al. (2021), in turn, suggest PIs must be interpreted considering the context where impacts occur. In this line of ideas, Muhonen et al. (2018) argued that the PIs approach has been operationalised as "counting interactions", limiting its potential to explain the process in which societal impacts are generated.

In this line of ideas, the current debate on the societal impact of research has not only demonstrated interest in the interactions between researchers and stakeholders (Spaapen & Van Drooge, 2011b) but also in how the productivity of these interactions unfolds (Annemans & Heylighen 2020; Muhonen et al., 2018; Sivertsen & Meijer, 2019). In this context, PIs can be

characterized by a context-dependent nature when creating societal impacts (Spaapen and Van Drooge, 2011b); therefore, productive interactions are not productive automatically (NWO, n.d.). In the same line of ideas, De Jong et al. (2022) suggest productive interactions emerge under enabling conditions, which in this research are considered contextual conditions.

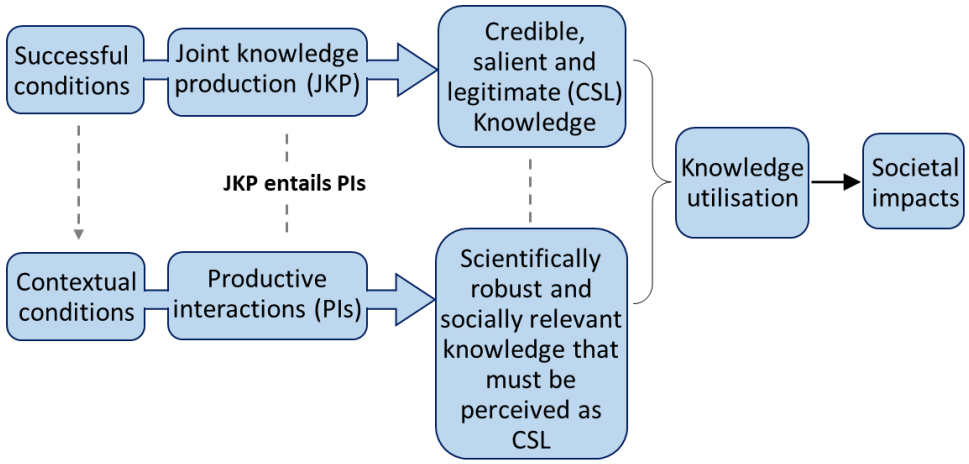
Considering the limitations and suggestions mentioned above, to analyse productive interactions in transdisciplinary research, this research used the SIAMPI framework, complemented by the previously explained theory of change approach and contextual conditions. The former allowed the operationalisation of the process of achieving societal impacts through outputs and outcomes, and the latter uncovered the conditions for productive interactions to occur. The contextual conditions that allow productive interaction to emerge are presented in the next section.

2.5 Contextual conditions for productive interactions

As mentioned, productive interactions require contextual conditions to emerge and to produce knowledge that is scientifically robust and socially relevant. To produce socially relevant knowledge leading to the effective production and mobilization of knowledge between science and action (utilisation of the knowledge), the knowledge produced should be perceived by all participating actors as credible, salient, and legitimate (CSL) (Cash et al., 2002; 2003). Following reasoning based on derivation, PIs should produce CSL knowledge so that it can be used. In this context, the production of CSL knowledge can be led by joint knowledge production (JKP), defined as a social process in which scientists, policymakers, and other societal actors cooperate in the exchange, production, and application of knowledge to enrich decision-making (Hegger et al., 2012; Van Den Hove, 2007). Hegger et al. (2012) proposed a framework with seven successful conditions for a JKP, which in turn, leads to CSL knowledge. Considering the definition of JKP and productive interactions, this research considers that the social process of JKP entails productive interactions. In addition, it can be considered that these successful conditions that lead to CSL knowledge via JKP can also lead, by a derivation rationale, to the production of scientifically robust and socially relevant knowledge, via productive interactions. This is under the rationale that JKP leads to CSL knowledge, which is the knowledge that productive interactions should produce to be scientifically robust and socially relevant, and lead to societal impacts. Thus, in this research, the contextual conditions under which productive interactions emerge should be understood as a result of the derivation

of the successful conditions for JKP. Therefore, it is worth noting that this research is not focused on JKP per se, but rather, it makes use of JKP to derive from there the conditions to lead productive interactions. Based on the relation among the concepts explained previously, Figure 3 provides a diagram that illustrates the rationale for deriving the contextual conditions of PIs from successful conditions of JKP.

Figure 3: Representation of the derivation rationale of contextual conditions for productive interactions from successful conditions for JKP



The framework of 7 successful conditions proposed by Hegger et al. (2012) (Table 3) makes use of the policy arrangement approach, which conceptualizes the relationship between actors and their context into four dimensions (Arts et al., 2006; Liefferink, 2006): 1) actors and actor coalitions involved in a policy domain; 2) discourses and programs; 3) rules of the game; and 4) resources available. Since this framework is grounded on a social theoretical perspective, it can be considered as an "actor in context" approach. By focusing on actors and their context, it considers that changes in social processes can be induced by any of the four dimensions (Hegger et al., 2012).

Table 3: Conditions for joint knowledge production by Hegger et al. (2012)

Dimension	Success condition for JKP
Actors	Broadest possible actor coalition within limits present.
Discourses	Shared understanding of goals and problem definitions.
	Recognition of stakeholder perspectives.
Rules	Organized reflection on the division of tasks by participating actors.
	Role of researchers and their knowledge is clear.
	Presence of innovations in reward structures.
Resources	Presence of specific resources such as boundary objects, facilities, organizational forms, and competencies.

Some adjustments were made to make use of the framework proposed by Hegger et al. (2012). Regarding the conditions from the discourse domain, they were combined, with the objective that one of them (recognition of stakeholder perspectives) serves the other (shared understanding of goals and problem definitions). Focusing the recognition of stakeholders' perspectives to address the problem perception allows to find a shared problem definition, which conduces to produce CSL knowledge. Concerning rule conditions, those that did not have a straightforward relationship regarding credibility and salience, and their influence on legitimacy was included in another condition, were eliminated. As a result of these adjustments, four contextual conditions were obtained to use in this research (Table 4).

The rationale for using this framework is given by the nature of its approach and by the objective of this research. The researcher-stakeholder interactions analysis, in a knowledge production process, to explain societal impacts requires the incorporation of contextual conditions that allow to understand how those interactions emerged and led to societal impacts. That need can be met by using the described framework based on an "actor in context" approach. The contextual conditions were analysed to identify to what extent they stimulated or hampered the productive interactions.

Table 4: Conditions for analysing productive interactions derived from Hegger et al. (2012)

Dimension	Condition	Short name	Explanation	Justification
Actors	The broadest possible actor coalition within limits present	Broad stakeholder participation	Stakeholder participation is a key aspect of the production of knowledge required for solving sustainable challenges that society faces (Lang et al., 2012). To create more relevant and robust knowledge, it is necessary to link scientific and stakeholder perspectives (Schneider, Giger, et al., 2019). Broad actor networks could lead to more socially robust knowledge because they involve an extended group of experts (Hegger et al., 2012).	This condition leads to CSL knowledge through the inclusion of both different knowledge in science (from different actors) (credibility and salience) and various perspectives in the knowledge production process (from different actors) (legitimacy).
Discourses	Shared understanding of goals and problem definitions based on recognition of stakeholder perspective	Problem definition	Problem definition can vary based on different problem perceptions or different ways to frame problems, based on a lack of insights or political and strategic reasons, which could undermine the perceived salience or credibility of the knowledge produced in a project. To achieve a reconciliation of the problem definition, actors should be brought together and manage expectations regarding the outcomes of a process (Hegger et al., 2012).	Managing the expectations of the research outcomes favours the problem definition reconciliation. This leads to CSL knowledge since fundamental epistemological differences are absent (credibility), the knowledge produced is coherent with the needs perceived by policymakers as well as societal stakeholders (salience), and actors believe rights questions concerning the right problem have been asked (legitimacy).
Rules	The role of researchers and their knowledge is clear	Roles and contribution	Researchers' roles must be clear to stakeholders to promote the credibility and legitimacy of the process. The usefulness of scientific knowledge for politics is given by its contents and putative objectivity. Therefore, researchers need to be explicit and clear about their roles and knowledge, and other actors need to be clear regarding their expectations about this (Hegger et al., 2012).	Clear and explicit researcher and knowledge roles lead to CSL knowledge since they enhance trust in researchers (credibility and legitimacy) and provide clarity about the contribution of their work (salience).
Resources	Presence of specific resources such as boundary objects, facilities, organizational forms, and competencies	Resource availability	Collaborative process needs resources such as (Hegger et al., 2012): Boundary objects: According to Weger (2020), boundary objects can support connections between different practices and narratives through different manners, such as discourses (concepts), artefacts (e.g., computer tools), and encounters (site visits). They can be understood as mediators of narratives. Facilities and organizational forms: resources stimulating the interconnection and sharing of forms of knowledge (e.g., administrative support, places to meet). Three types of space promote knowledge creation: physical space (meeting rooms), virtual space (computer networks), and mental space (common goals). Physical proximity conduces to the creation of knowledge as face-to-face relations, which promote trust between actors enhancing the sharing of tacit knowledge. Competences: Actors need specific competencies in terms of negotiations, mediation, translation, etc for collaboration.	The presence of specific resources leads to CSL knowledge. Through boundary objects, facilities and organizational forms, and competences, it is possible to improve the mutual understanding of viewpoints and interests, promote human relationships, and efficiently transfer information (credibility, salience, and legitimacy).

Analysing contextual conditions sheds light on the quality of the interaction process. As Spaapen and Van Drooge (2011b) stated, productive interactions *per se* are not important, but their role in the process of achieving societal impacts. In this line, achieving societal impacts requires appropriate processes, which are important for societal impacts. The analysis of productive interactions through contextual conditions in TDR implies analysing the quality of the process by which interactions become productive since the quality of the interaction process is essential to achieving societal impacts (Scholz & Steiner, 2015a, 2015b).

In this respect, Wiek et al. (2014) propose that the quality of the participatory process can be described by the following variables: representation of all relevant opinions and perspectives; fulfilment of critical roles; adequate interaction level; consideration and processing of stakeholder input; mapping out and resolving disagreement and conflict; and diversity of participatory activities. Similarly, Fulgenzi et al. (2020) propose a framework to analyse the co-production of knowledge in a participatory process based on 30 indicators grouped into six factors: organizational support, atmosphere of meeting, representation and engagement, convergence on shared perspective, identification of opportunities and challenges, and generation of knowledge.

Considering the importance of the quality of the process under which interactions become productive, this research included the variables proposed by Wiek et al. (2014) and the framework by Fulgenzi et al. (2020) to enrich the analysis of productive interactions. Thus, based on those variables and that framework, indicators were derived and associated with the contextual conditions for productive interactions (Table 5). The indicators were used as indicators of the extent to which the contextual conditions were met, contributing to the identification of to what extent the contextual conditions stimulated or hampered the productive interactions throughout the projects.

Finally, the quality of the interaction process that leads to societal impacts sheds light on the chances for social impacts when societal impacts have not occurred (NWO, 2020). Therefore, given that the Nexus projects studied did not achieve societal impacts within the project's lifetime, describing the quality of the interaction process through these indicators throughout the process of change (outputs and outcomes) allowed to shed light on the chances for social impact.

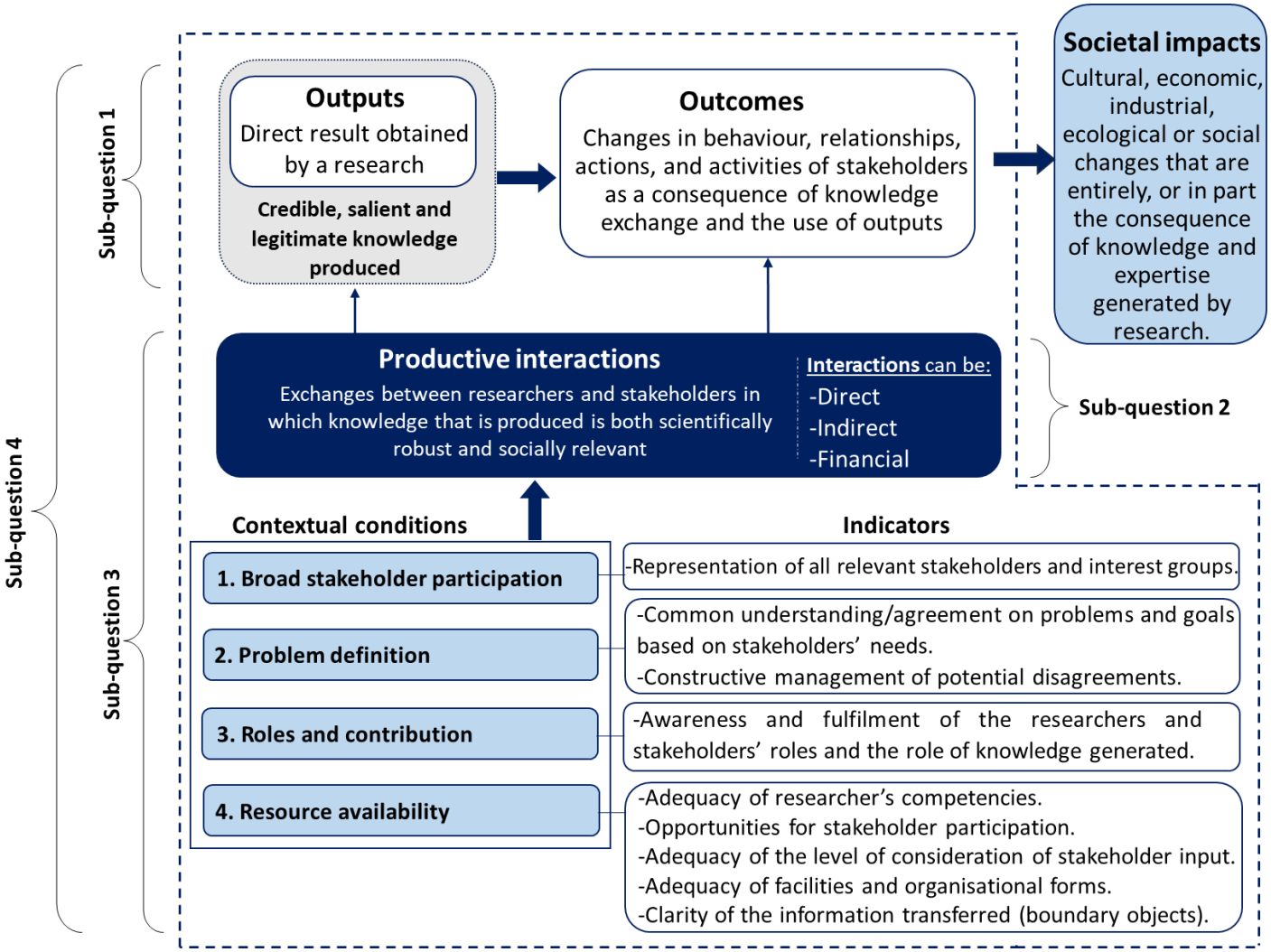
Table 5: Contextual conditions for productive interactions and indicators derived from Hegger et al. (2012), Wiek et al. (2014) and Fulgenzi et al. (2020)

Contextual conditions	Indicators
Broad stakeholder participation	-Representation of all relevant stakeholders and interest groups
Problem definition	-Common understanding/ agreement on problems and goals based on stakeholders' needs. -Constructive management of potential perspective disagreements
Roles and contributions	-Awareness and fulfilment of the researchers and stakeholders' roles and the role of the knowledge generated.
Resource availability	-Adequacy of the level of interaction, given by the researcher's competencies (e.g., quality of moderation of the discussion) -Opportunities for stakeholders' participation -Adequacy of the level of consideration of stakeholder input -Adequacy of facilities and organisational forms - Clarity of the information transferred (boundary objects)

2.6 Analytical framework

Based on the theoretical foundations explained above, an overview of how productive interactions were analysed is presented in Figure 4. To support the understanding of the process of changes that lead to societal impacts, the analysis started with the identification of outputs (what a project does?) and what it is expected to achieve (outcomes and potential impacts) (sub-question 1) by following the logical flow of the theory of change (ToC). After this, the interactions (direct, indirect or financial) throughout this process of changes were identified (sub-question 2). Because the framework of productive interactions (Spaapen and Van Drooge (2011a)), on their own, is limited in explaining the impact of research, contextual conditions derived from the framework defined by Hegger et al. (2012), operationalized by indicators derived from Wiek et al. (2014) and Fulgenzi et al. (2020), were incorporated to the analysis. Contextual conditions were used to analyse the extent to which productive interactions were stimulated or hampered (sub-question 3). Based on the extent to which contextual conditions were met, productive interactions (PIs) were stimulated (or hampered), generating outputs and outcomes and promoting (or not) the chance for societal impacts (SIs) (sub-question 4). Following the logical flow of theory of change (ToC) and starting by identifying outputs and outcomes allowed to build the storyline of the process of changes in which PIs led to SIs (or to the chance for SIs) and to explain how Nexus projects achieved those SIs through PIs retrospectively. The punctuated line in the figure aims to focus the analysis of this research.

Figure 4: Analytical framework



The identification of outputs, outcomes and societal impacts was operationalised by following the definition of these concepts (Table 6). The identification of the type of interactions was operationalised through the SIAMPI framework, which was complemented by ToC elements (Table 7), to understand how interactions contributed to achieving societal impacts (or chance for societal impacts). The productivity of the interactions was given by the extent to which contextual conditions were met. Contextual conditions that stimulated or hampered the productivity of interactions were operationalised by indicators as Table 8 presents.

Table 6: Identification of outputs, outcomes and (potential) societal impacts based on NWO (2020).

	Operationalisation
Outputs	Direct results obtained from SIM4NEXUS and NextGen.
Outcomes	Changes in behaviour (knowledge, skills etc), relationships, actions, and activities of stakeholders involved in SIM4NEXUS and NextGen projects as a result of knowledge exchange and the use of outputs.
(Potential) Societal impacts	Potential cultural, economic, industrial, ecological, or social changes that could be entirely, or in part, the consequence of knowledge and expertise generated (outputs and outcomes) by SIM4NEXUS and NextGen projects.

Table 7: Identification of interactions based on the SIAMPI framework

Type of interaction	**Operationalisation**
Direct	Interactions given throughout outputs and outcomes as a result of contacts among researchers and stakeholders involved in Nexus projects through face-to-face encounters, phone, email, or videoconferencing.
Indirect	Interactions given throughout outputs and outcomes as a result of contacts among researchers and stakeholders involved in Nexus projects that are established through inanimate media, such as all types of texts (e.g., articles, books, web pages, etc), exhibitions, designs, models, films, and musical arrangements.
Financial	Interactions given throughout outputs and outcomes as a result of stakeholders engaging in an economic exchange with researchers (e.g., a research contract, a financial contribution).

Table 8: Operationalization of conditions for productive interactions, derived from Hegger et al. (2012), and use of indicators derived from Wiek et al. (2014)and Fulgenzi et al. (2020)

Contextual condition	Operationalisation
Broad stakeholder participation	**Indicator:** • **Representation of all relevant stakeholders and interest groups.** This condition is met if interactions in Nexus projects involve relevant and representative stakeholders with knowledge and interest in the area under consideration. Examples: universities, municipalities, research institutes, consultancy companies, NGOs, etc. The number of actors needs to be limited to keep the process manageable. • If the condition is met, then it stimulates productive interactions; otherwise, productive interactions are hampered by the condition.
Problem definition	**Indicators:** • **Common understanding/agreement on problems or goals based on stakeholders' needs.** • **Constructive management of potential perspective disagreements** This condition is met if the stakeholders' perceptions and needs are recognized and considered to define the goals or problem to be solved and if potential disagreements during their interactions in Nexus projects are constructively managed. • If the condition is met, then it stimulates productive interactions; otherwise, productive interactions are hampered by the condition.
Roles and contribution	**Indicator:** • **Awareness and fulfilment of the researchers and stakeholders' roles and the role of the knowledge generated.** This condition is met if the researchers clearly explain to stakeholders their role in the project and the expected contribution of the project's results and if those are fulfilled. • If the condition is met, then it stimulates productive interactions; otherwise, productive interactions are hampered by the condition.
Resource availability	**Indicators:** • **Adequacy of the level of interaction, given by the researcher's competencies (e.g., quality of moderation of the discussion)** • **Opportunities for stakeholders' participation** • **Adequacy of the level of consideration of stakeholder input** • **Adequacy of facilities and organisational forms** • **Clarity of information transferred (presence of boundary objects)** This condition is met if specific resources that facilitate communication and the transfer of information are in place. These resources include the competencies of researchers that promote the adequacy level of interactions, proper opportunities for stakeholder participation, and consideration of their inputs; boundary objects (conceptual, site visit, or computer tools); and physical space and facilities. • If the condition is met, then it stimulates productive interactions; otherwise, productive interactions are hampered by the condition.

3 Chapter 3: Methodology

3.1 Introduction

This chapter explains the strategy and methods used to carry out this research. It starts with the research strategy (section 3.2), which includes a brief description of the cases selected. The type of information that was used and its sources are described in Section 3.3 and how the information was collected, processed, analysed and validated is presented in the section 3.4. Finally, section 3.5 refers to issues about ethic and reliability of this research.

3.2 Research strategy

This research employed an inductive approach and a case study analysis (CSA) as the main research strategy, which seeks to gain deep insights and accurate information about the research object (Verschuren & Doorewaard, 2010). Particularly, productive interactions were analysed throughout two Nexus projects to explain how potential societal impacts are achieved. CSA is useful to understand complex social phenomena (Yin, 2003). Thus, analysing productive interactions (the research object) through a CSA allowed to explain societal impacts, whose generation process has complex social interactions. According to Gerring (2004), CSA focuses on depth rather than breadth. In this respect, depth insights into processes led to a better understanding of the societal impact generation (Matt et al., 2017). As a complementary strategy, a qualitative interpretive analysis was used to analyse the results of the case study.

Based on the research object and questions, this research followed a holistic multiple-case design (Yin, 2003), in which two different Nexus projects implemented in Europe (SIM4NEXUS and NextGen) were identified as the cases of study. The unit of analysis of this case study is the Nexus project that was studied in each case. The cases were selected based on a "most similar" design, which maintains contextual variables as similar as possible, to neutralize their effect on the dependent variable (Burnham et al., 2008) (in this case: societal impacts). Using two different cases in the same context (Europe) favours the control of the contextual variables. Criteria for the case selection are presented in Table 9.

The CSA was mainly carried out through semi-structured interviews with experts (researchers and stakeholders involved in Nexus projects) since it required specific knowledge. Additionally, the CSA used material produced by others (scientific papers, grey literature, etc)

in combination with own reflection, therefore, semi-structured interviews were complemented by desk research (Verschuren & Doorwaard, 2010). Additionally, the results obtained were validated by Nexus researchers through a validation activity (further details on section 3.4.2).

Table 9: Criteria for case selection

Criteria	Requirement	Justification
Location	Projects implemented in Europe	Practical reasons led to the selection of European projects. Since most of them speak English, and due to previous relationships established with KWR (NexusNet), there were more possibilities to contact researchers of European projects.
Successful	Projects whose expected outputs and outcomes were achieved	This research aims to understand how productive interactions contributed to the achievement of potential societal impacts. Therefore, considering projects that achieved their outputs and outcomes allows to analyse interactions throughout that process and understand the process of impact achievement by drawing lessons from them.
Ending date	Projects completed at least 1 year ago	Analysing projects that finished at least one year ago allows a margin of time to obtain final reports and scientific papers written after the projects finish, which include results and valuable insights for the case study analysis.
Project duration	3-5 years	This range of time allows projects to establish several interactions between researchers and stakeholders through which outputs, outcomes and potential impacts could have been achieved.
Accessibility of documentation	Information and documentation about the projects should be available and accessible.	This CSA requires information and knowledge that contribute to gaining deep insights into the research object. The sources of this knowledge are documents (grey literature), literature (scientific papers), and experts. Having access to documentation and channels to contact experts allows to access the knowledge and information required for the case study analysis.
Accessibility of experts	Researchers and stakeholders involved in the projects should have an effective contact channel to facilitate communication and be willing to participate in interviews.	
Scale of the project	Large-scale projects	This research aims to analyse interactions among researchers and stakeholders. Large-scale projects involve more actors, which provides sufficient participants for both interactions to be analysed and interviews.

Despite the fact that both projects selected were successful, one case where SIM4NEXUS was applied (Sweden) did not achieve sufficient changes in activities and actions to increase the chance for societal impacts. However, it was included in the analysis since it allowed to analyse

the interactions among researchers and stakeholders and identify what was missing and what was done that hampered the chance for societal impacts, drawing lessons about what needs to be improved.

3.2.1 General description of the case study: Nexus projects

The Nexus represents a promising transdisciplinary approach to facing sustainability challenges and bridging science and policy (Scott et al., 2011). Based on the understanding of the interdependencies of different nexus sectors, the Nexus approach identifies mutually beneficial responses, increasing resource use efficiency, reducing trade-offs, and optimising synergies among different sectors (Hoff, 2011). It was first used to provide integrated solutions to food and energy scarcity (Liu et al., 2018). Later, it involved mainly the water, energy, and food (WEF) sectors, although ecosystem, health, and climate sectors have also been included in the last years (Liu et al., 2018). Table 10 summarises the guiding principles of this approach.

Table 10: Guiding principles of the Nexus approach

Principle	Description
Investing to sustain ecosystem services	Investing in natural capital with the objective of ecosystem contributes to human well-being.
Creating more with less	If interventions and investments increase the productivity of one nexus sector and are designed with the nexus in mind, they do not negatively affect other sectors but can increase overall resource use efficiency.
Accelerating access, integrating the poorest	When improving living conditions and livelihood opportunities, synergies can be built, and positive feedback can be generated across the nexus sectors. Investment and innovation accelerate equitable access, and benefits for the poor can have high rates of return regarding development and environmental sustainability. The poor themselves can become effective and efficient actors in a nexus approach.

Source: Based on Hoff (2011, p. 14-15).

Nexus projects consider aspects such as cross-sectoral integration, transboundary interlinkages (geographical, political, or administrative), policy integration at different levels (from local to global), and the stakeholders' involvement in science, policy, and society (Estoque, 2023). Due to the importance of stakeholders' involvement in the Nexus approach and the growing interest in addressing global sustainability challenges (Estoque, 2023), this research used two European Nexus projects as a case study to analyse productive interactions and explain to what extent they contribute to the chance of achieving societal impacts. Based on the criteria for case selection, two large-scale European Nexus projects (SIM4NEXUS and NextGen) were

selected. Both lasted around four years, achieved their outputs and outcomes, and finished over a year ago. Documentation and participants were available and accessible. Each selected project considers two cases where each project was implemented. The following sections describe each Nexus project.

3.2.2 Case 1: Nexus project SIM4NEXUS

SIM4NEXUS was a project implemented on 12 case studies at regional, national, transboundary, European and global scales. It came to address sustainability challenges in Europe such as land use changes; poor water management; and policy inconsistencies and incoherence affecting resource efficiency (Grant Agreement No. 689150, 2016) (see Table 11).

For the purpose of this research, the analysis of this case (Nexus project SIM4NEXUS) considered 2 national cases where the project was implemented: Latvia and Sweden. These cases focused on the transition to a low-carbon economy and policy coherence analysis to understand forest-water interlinkages, respectively, and were selected based on the criteria for case selection presented in Table 9 (specific case description in section 4.2.1.1 and 4.2.1.2.).

Table 11: Objectives, actors and achievements in SIM4NEXUS

Project title	• Sustainable Integrated Management FOR the NEXUS of water-land-food-energy-climate for a resource-efficient Europe.
Main goals	• To improve the understanding of interconnections among water, energy, food, land and climate. • To develop innovative methodologies to facilitate the design of policies and bridge knowledge and technology gaps in the water-land-food-energy-climate Nexus under climate change conditions.
Main actors involved	• 26 actors: Universities, non-profit research organisations, international organisations, private foundations, ministries, water companies, and NGOs.
Key achievements	• Stakeholders gained knowledge of the Nexus and their countries' Nexus issues. • Stakeholders actively participated in identifying Nexus challenges, collecting data, developing scenarios, and formulating policy recommendations. • Stakeholders mobilised through diverse means: workshops, interviews, surveys, Serious Game tests or field trips in an iterative process with SIM4NEXUS researchers.
Relevant expected societal impact	• Contribute to the reinforcement of the culture of ex-ante evaluation and assessment of public policies in the EU and especially at the sub-national level.

Source: Brouwer & Fournier (n.d.); Grant Agreement No. 689150 (2016).

3.2.3 Case 2: Nexus project NextGen

NextGen was a project implemented on 10 demo cases at the local level throughout Europe. It addressed the water scarcity and resource depletion issues (NextGen, n.d.a). Due to climate change, water availability has decreased, making water treatment processes important in this context of water scarcity. Therefore, a different model from the linear model of production-consumption-disposal is required to advance in a more sustainable manner of treating water without affecting resources such as raw materials and energy (Grant Agreement No. 776541, 2018). (see Table 12).

For the purpose of this research, the analysis of this case (Nexus project NextGen) considered 2 demo cases where the project was implemented: Athens and Costa Brava, both of which focused on circular water solutions. These cases were selected based on the criteria for case selection presented in Table 9 (specific case description in section 4.2.2.1 and 4.2.2.2).

Table 12: Objectives, actors and achievements in NextGen

Project title	• "Towards next generation of water systems and services for the circular economy".
Main goals	• To evaluate innovative and transformational circular economy (CE) solutions for resource use in the water sector. • To demonstrate novel technological, business and governance solutions for water in the CE in ten demonstration cases across Europe and to develop the necessary approaches, tools, and partnerships to transfer and upscale. • To produce new understandings to enhance the process of recovering, refining, reusing, repurposing, capturing value from, and extending the use-life of an ever-increasing range of resources.
Main actors involved	• 32 actors: water companies, industry, applied research institutes, technology platforms, city and regional authorities.
Key achievements	• Advanced treatment technologies and nature-inspired storage to optimise water resources. • Groundbreaking nutrient mining and reuse that create new products from waste streams. • Managing and recovering energy more efficiently to turn treatment plants into positive energy generators.
Relevant expected societal impacts	• Significant reduction of the current water and energy consumption at regional and/or river basin scale. • Replication of new business models in other areas and replication of models for synergies between appropriate funding instruments. • Implementing the Sustainable Development Goals (SDGs), in particular, SDG 12, "Ensure sustainable consumption and production patterns", and SDG 6 "Ensure availability and sustainable management of water and sanitation for all".

Source: NextGen (n.d.a); Grant Agreement No. 776541 (2018).

3.3 Research materials

This research used insights and theories developed previously by others. This type of research material or information is known as “knowledge”, which was obtained from documents, literature and experts (Table 13). The term “experts” considers knowledge suppliers with expertise based on experience and not restricted to specialised theoretical and practical knowledge due to higher education (Verschuren & Doorwaard, 2010).

Table 13: Source of research material

Sub-question	Source
What were the achieved outputs, outcomes, and (potential) societal impacts of the SIM4NEXUS and NextGen projects?	**Documents:** grey literature such as project reports, final period reports, deliverables of Nexus projects, and survey results applied to stakeholders involved in the NextGen project to evaluate community of practices (CoPs) in terms of their effectiveness in enabling social learning and achieving the CoP and project objectives. - **Literature**: scientific papers based on the results of Nexus projects. -**Expert people**: researchers (project coordinators, case study leaders and general researchers) and stakeholders (ministries, local authorities, private companies, etc).
What were the interactions throughout the SIM4NEXUS and NextGen projects?	
To what extent were contextual conditions met in each project, and to what extent did they stimulate or hamper productive interactions?	
To what extent did these productive interactions lead to those societal impacts?	

3.4 Data collection and data analysis

3.4.1 Data collection

Data were collected through different methods depending on the type of source. Data from documents (e.g., grey literature such as project reports, final period reports, and deliverables of Nexus projects) were collected from each project's official website. The raw data of the CoP evaluation results were provided by the coordinator of NextGen. Data from literature (e.g., scientific papers based on the results of Nexus projects) were collected by using the snowball principle method. This method considered key concepts from this research that were used as keywords to guide the literature search (Table 14). The bibliographies of the main publications were used to get other relevant articles. Thus, the main articles were sources for other publications (Verschuren & Doorwaard, 2010).

Table 14: List of search terms

Project	Case	Key concepts
SIM4NEXUS	Latvia	• SIM4NEXUS Latvia • Nexus Latvia • Low carbon nexus Latvia
	Sweden	• SIM4NEXUS Sweden • Nexus Sweden • Policy coherence Sweden
NextGen	Athens	• NextGen Athens • Nexus Athens • Water treatment Athens NextGen
	Costa Brava	• NextGen Costa Brava • Nexus Costa Brava • Tratamiento de agua Tossa de Mar NextGen

Data from experts people was collected by conducting interviews with researchers and stakeholders who participated in SIM4NEXUS and NextGen projects. The interviewees were recruited following a snowball sampling methodology (Thompson et al., 2017), starting by contacting the project coordinators, who provide the contact of other researchers, who, in turn, provide the contacts of stakeholders and so on (Figure 5). The criteria for interviewee selection are presented in Table 15. Information was extracted by semi-structured interviews, and questions were defined previously, although additional questions were formulated during the interviews (Appendix A presents the guide for interviews used. See section 8.1). To experts, feel free to answer in any way; questions were formulated in open questions. The interviews were conducted between the 8th of February and the 2nd of April 2024. All interviews lasted, on average, 1 hour and were conducted online by Microsoft Teams app, which allowed the recording and transcribing of the interviews automatically. Most of them were conducted in English except the interviews with experts from Spain (Costa Brava case of NextGen project), which were conducted in Spanish.

Figure 5: Snowball Sampling of each Nexus project

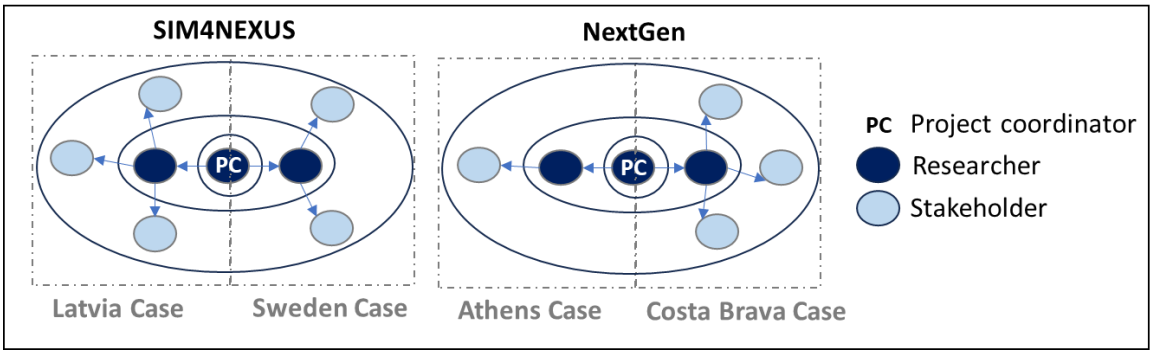


Table 15: Criteria for interviewee selection

Criteria	Explanation
High level of involvement in the project	The focus of this research was analysing interactions throughout Nexus projects; therefore, interviewees who have been highly involved in the project are needed to provide valuable information about interactions carried out.
Language	An implicit criterion related to language was present since English and Spanish speakers were invited to participate in the interview.
Participant availability	Due to the time limitation and planning of the research, interviews needed to be conducted between February and March. Therefore, the availability of researchers and stakeholders during this time frame was another criterion for selecting interviewees.

Data were collected from 8 interviewees who participated SIM4NEXUS (3 researchers and 5 stakeholders) and 7 interviewees from NextGen (3 researchers and 4 stakeholders). Additionally, data from SIM4NEXUS was complemented by 3 more interviews with researchers who participated in the project and data from NextGen was complemented by the results of the CoP evaluation survey (survey answered by stakeholders). Thus, in total 18 interviews were conducted in this research (9 with researchers and 9 with stakeholders) (Table 16). The list of the interviewees and the dates is presented in Appendix B (section 8.2).

Table 16: Interviews with researchers and stakeholders in each case

Project	Researchers	Stakeholders	Complement ed by
SIM4NEXUS	3	5	+ 3 researcher interviews
NextGen	3	4	+ Results of CoP evaluation survey

3.4.2 Data analysis (processing, analysis and validation)

The information from documents and literature was analysed through the content analysis method, which consists of extracting relevant information from a large amount of material based on points of interest to answer the research question (Verschuren & Doorewaard, 2010).

The interviews were recorded and transcribed automatically by the Microsoft Teams app; therefore, before analysing the data, transcripts were checked and edited, when necessary, according to the recordings. After the data processing, the data was analysed using “coding”, a process aimed at examining, transcribing, and giving labels to the components, defining interactions among those (Corbin & Strauss, 1990). Transcripts were coded using Nvivo software. A codebook (group of nodes and sub-nodes) was developed to analyse the interviews

(Appendix C presents the codebook used. See section 8.3). Information collected from experts was classified and organised through deductive coding since the codebook was based on the analytical framework proposed. References and quotes were added to back up the information and insights provided in the results.

Finally, the main results of this research were presented to senior researchers and experts on the Nexus approach for further validation and generalisation. The activity was developed during the "Nexus EXCELLENTIA Workshop", which took place at the National Water Conservation Awareness Centre, in Rabat, Malta (13th of May 2024). The workshop was organised by COST Action NexusNet in the context of the "NexusNet Mentoring Program", which aims to bring together young and senior researchers to offer learning opportunities to young researchers and support their career development. Not all researchers who attended the workshop answered all the questions, but the number of participants was estimated at an average of 17 Nexus experts.

This validation activity was carried out through a participative Mentimeter activity (hereinafter as validation activity) with the objective of generalising the results and conclusions and recommendations that can be applied to broad contexts of transdisciplinary research or other Nexus projects. For this purpose, a presentation with the context of this research and key concepts was presented, followed by a Mentimeter activity. The validation activity lasted around 15-20 minutes and included three types of questions that Nexus researchers had to answer based on their viewpoints and experiences. In the first type, participating researchers were asked to express their extent of agreement (from 1 to 5) on 11 statements, which were elaborated based on the main results and conclusions. The second question was: How do Nexus projects achieve expected outputs and outcomes and contribute to the societal impacts? The third question was to rank the contextual conditions from 1 to 4 according to what they thought was most important to stimulate productive interaction and promote societal impacts in Nexus projects. The results of this activity are presented at the end of Chapter 4, after presenting the research results (section 4.7).

3.5 Ethical issues and reliability of research

The interviews were conducted under informed consent. Thus, experts were previously informed about the objective of this research and how the collected information would be processed and used. Appendix D presents the informed consent form used for the interviews in English and Spanish (section 8.4).

This research used theories and approaches based on scientific literature, which supports the suitability of the proposed methods and provides validity. Additionally, the main insights were shared with the interviewed experts by email to receive their feedback and check with them if the knowledge collected was interpreted appropriately. Moreover, as mentioned before, the results were validated with other Nexus experts (senior researchers), allowing the findings to be generalised to similar contexts of Nexus projects.

4 Chapter 4: Results

4.1 Introduction

This section starts with a description of the cases studied (section 4.2), followed by the identification of the outputs, outcomes, and potential impacts (section 4.3) (sub-question 1). After this, the section 4.4 presents the interactions identified among researchers and stakeholders (sub-question 2). The contextual conditions that stimulated or hampered the productive interactions are presented in the section 4.4 (sub-question 3). The chapter presents a conclusion of the results (section 4.6) that explains the extent to which productive interactions led to societal impacts (sub-question 4) and a summary table of the main results. Finally, the chapter ends with the results of this validation activity (section 4.7), where all the results that answered the four sub-questions were validated by other senior nexus experts.

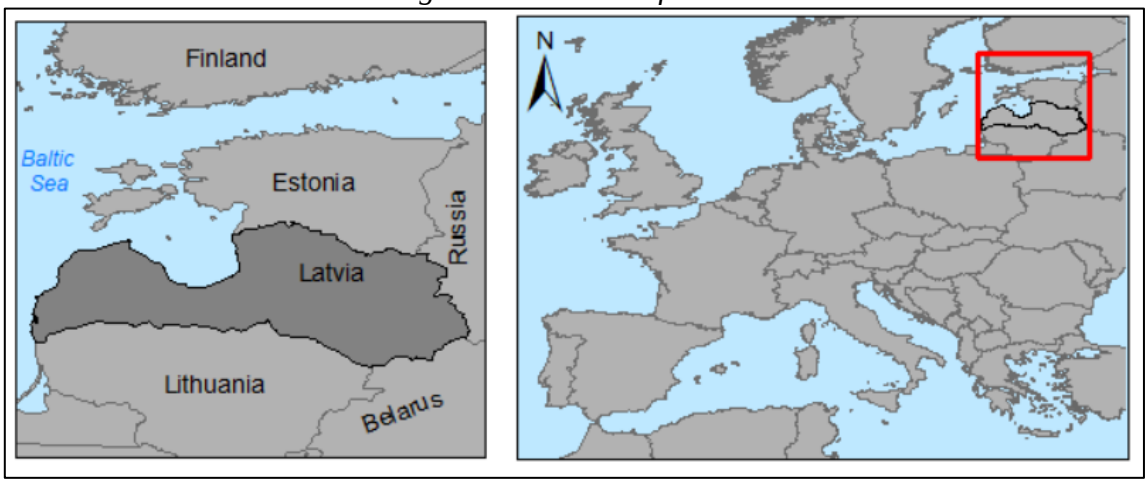
4.2 Description of selected cases

4.2.1 Case of study 1: SIM4NEXUS

4.2.1.1 Latvia: "Biomass and sustainable land-use in Latvia"

Latvia is located in north-eastern Europe (Figure 6). It covers an area of 64,573 km^2 and has a population of around 2 million people (Sušnik et al., 2021). Most of the total area is covered by forest land (48%), followed by agricultural land (38%) and urban land (14%). The main economic activity is based on sectors of retail trade, transport, accommodation and food service, and the timber and wood industry (Sušnik et al., 2021).

Figure 6: Location of Latvia

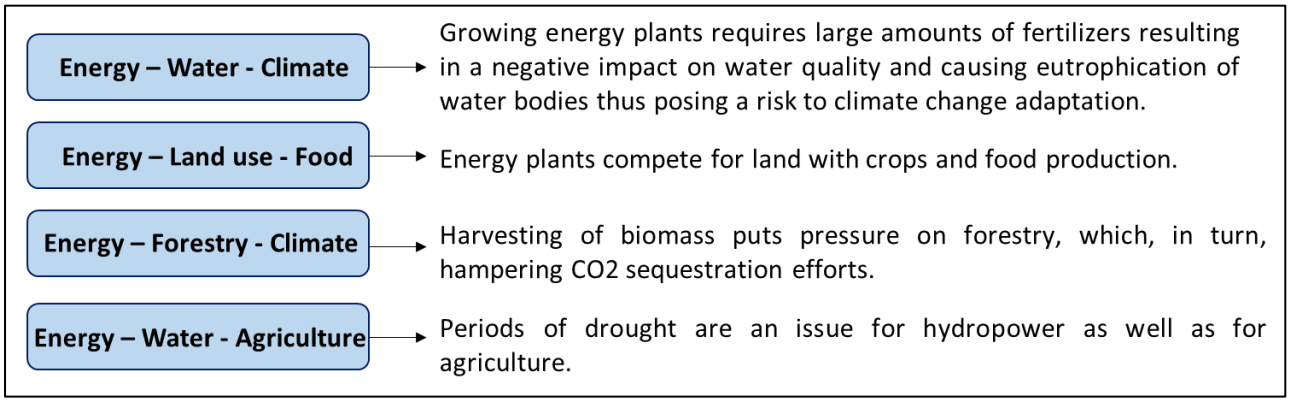


Source: Own elaboration made by ArcGIS with free vector map data from Natural Earth.

Despite Latvia's high potential for renewable energy (e.g., hydropower, biomass), it still depends on imported fossil fuels and electricity (Sušnik et al., 2021). In this context, Latvia's case analysed the policy interactions among the different sectors to explore the possibilities of low-carbon development to reduce its energy dependency. Thus, the goal of SIM4NEXUS, in this case, was focused on promoting the use of renewable energy and ensuring economic development while reducing greenhouse gas emissions (Brouwer et al., 2018; Sušnik et al., 2021).

In this case, the key sectors of concern are energy, climate, agriculture, land use, water, food production and forestry (Brouwer & Fournier, 2017). By interacting with different stakeholders from those sectors, researchers provided information, built understanding, obtained feedback, and engaged to participate in the project. The main nexus issues and interlinkages are presented in Figure 7, and the main goals, actors and achievements of this project application are described in Table 17.

Figure 7: Main nexus interlinkages in SIM4NEXUS Project - Latvia



Source: Based on Sušnik et al. (2021).

Table 17: Objectives, actors and achievements in SIM4NEXUS Project - Latvia

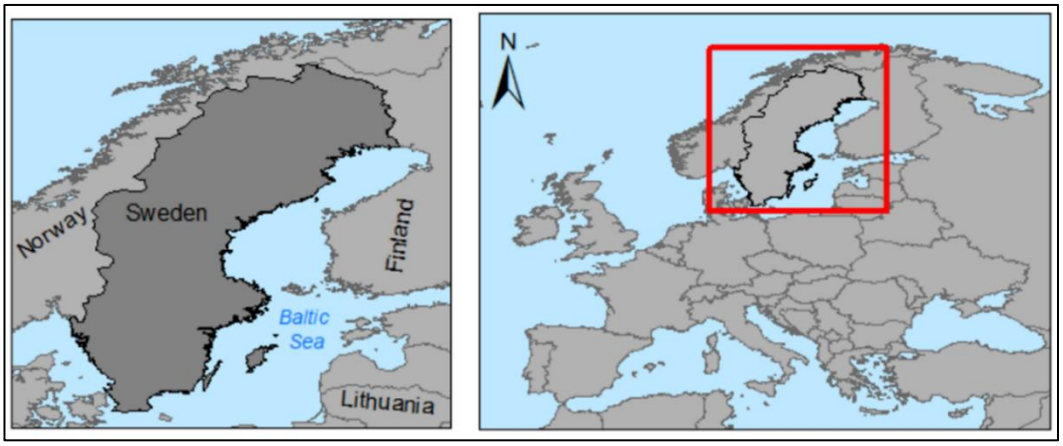
Main goals	• To boost energy self-supply, by expanding the use of renewable energy sources, mainly bioenergy sources from within the country. • To explore which trade-offs between sectors would be acceptable when achieving policy goals.
Main actors involved	• Ministry of Agriculture; Ministry of Economy; Ministry of Environmental Protection and Regional Development • Baltic Environmental Forum Latvia\ • Latvian Environment, Geology, and Meteorology Centre • Foundation "Latvian Fund for Nature"; Foundation "Pasaules Dabas Fonds"; Foundation "Green Liberty"
Key achievements	• Stakeholders are thinking beyond the sector silos dimension. • Awareness of biomass is a local resource in Latvia now and in the future; resource efficiency requires diversification of land use, and innovative technologies are essential for low-carbon development. • Translated the conceptual model into an operational System Dynamics Model. • Co-developed a conceptual model of the Latvian Nexus together with stakeholders. • The applied approach is transferrable to the countries in the Baltic Sea Region.

Source: Papadopoulou et al. (2020) and Bremere & Indriksone (n.d.).

4.2.1.2 Sweden: "Cross-sectoral collaboration"

Sweden is located in Northern Europe, bordered by Norway, the North Sea and the Baltic Sea (Figure 8). Two-thirds of Sweden is covered by forests and has a large number of lakes and rivers (Van Den Heuvel et al., 2020). Based on these natural characteristics, almost half of Sweden's electricity is generated from renewable sources (hydropower and forest biofuels) (Van Den Heuvel et al., 2020). Forestry and forest products are important to the Swedish economy, which is one of the least dependent on fossil fuels and has one of the lowest carbon emission rates. (Brouwer & Fournier, 2017, 2020).

Figure 8: Location of Sweden

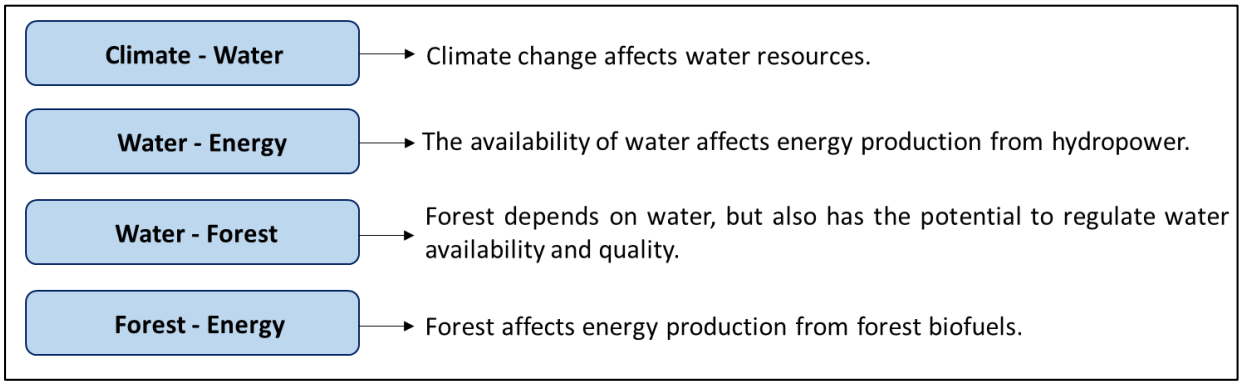


Source: Own elaboration made by ArcGIS with free vector map data from Natural Earth.

The forest industry has been promoted by the demand for bioenergy, which in turn has generated the introduction of fast-growing tree species (Teutschbein & Blischarska, 2018). Climate change has intensified the competition among forests, water, and energy sectors even more and put pressure on biodiversity. In this context, this case focused on performing a policy coherence analysis, including policy priorities, goals, and means concerning the nexus sectors of interest (Teutschbein & Blischarska, 2018).

In this case, the key nexus sectors of concern are forest, water, energy, and climate. By interacting with different stakeholders from those sectors, researchers explored pressures put on the nexus components as well as clarified the interlinkages among the nexus sectors to contribute to the formulation of better future decisions to mitigate climate change (Brouwer & Fournier, 2017). The main nexus issues and interlinkages are presented in Figure 9, and the main goals, actors and achievements of this project application are described in Table 18.

Figure 9: Main nexus interlinkages in SIM4NEXUS Project – Sweden



Source: Based on Brouwer & Fournier (2017).

Table 18: Objectives, actors and achievements in SIM4NEXUS Project - Sweden

Main goals	• The goals of the case study are to increase the understanding of forest-water interlinkages in the context of climate change through policy coherence analysis, as well as to bring research and stakeholders together and communicate the results.
Main actors involved	Researchers (case study leader): • Upsala University Stakeholders: • Forestry Agency • Food Agency • Local Municipalities • Water Sector • Consultancy company • Researchers
Key achievements	• Established a dialogue with stakeholders across all 5 Nexus sectors • Performed a policy analysis of the Swedish Nexus and disentangled the complex interlinkages. • Co-developed a conceptual model of the Swedish Nexus together with stakeholders. • Collected data from different sectors to support drawing a comprehensive picture of the Swedish Nexus. • Translated the conceptual model into an operational System Dynamics Model. • Developed final policy recommendations (based on the policy analysis, inputs from stakeholders and results from the System Dynamics Model).

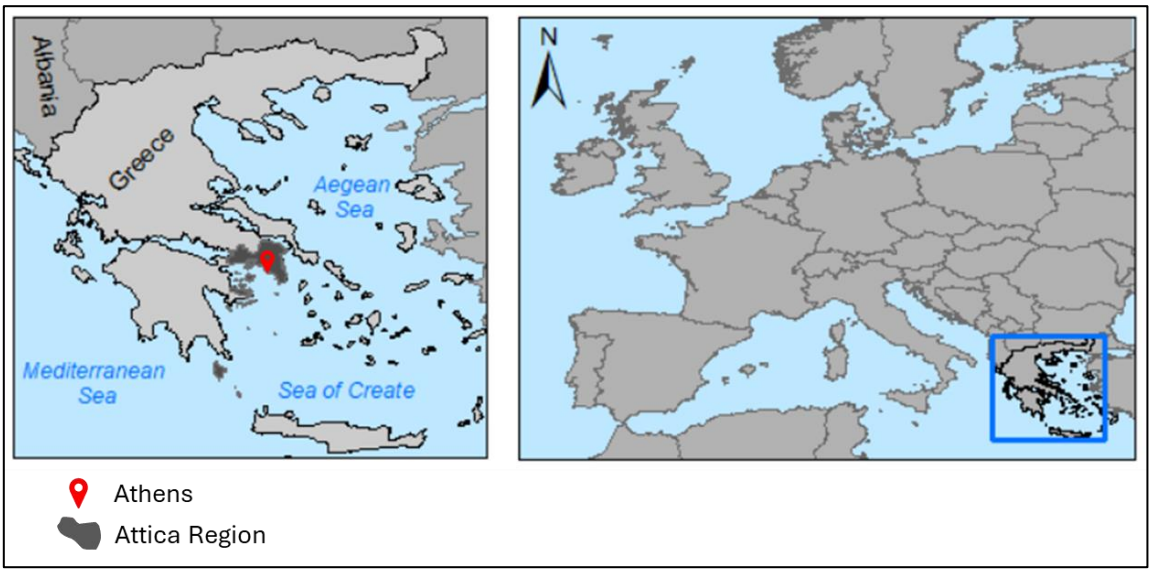
Source: Brouwer & Fournier (2020) and Teutschbein & Blischarska (n.d.).

4.2.2 Case of study 2: NextGen

4.2.2.1 Athens: "Circular solutions for water-energy-materials"

Athens, located in the Attica Region, in Greece (Figure 10), has a population of 4 million. Citizens in Athens are suffering from emerging water scarcity issues. This area includes urban green and urban agriculture spaces as well as administration and residential uses (Plevri et al., 2020). The Athens Urban Tree Nursey forms part of the Goudi Park, which is located in the centre of Athens and is being redeveloped to be a metropolitan park of Athens to promote the local economy and to improve the quality of the region's inhabitants (Plevri et al., 2020).

Figure 10: Location of Athens



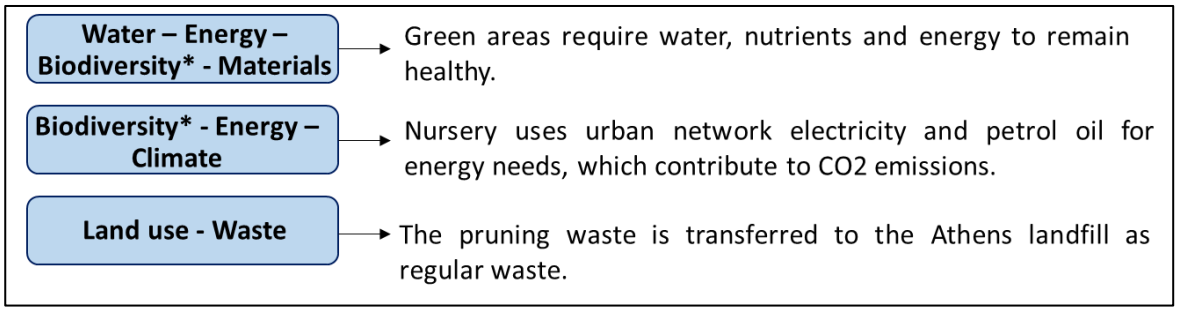
Source: Own elaboration made by ArcGIS with free vector map data from Natural Earth and DIVA-GIS.

The nursery covers 4 ha of vegetation, supplies all parks and green areas of the city with plant material, and uses potable water from Athens's Water Supply and Sewerage Company for irrigation (Plevri et al., 2020). Additionally, pruning waste from urban parks in Athens without being treated is deposited in the nursery, and later partly carried to the landfill. Furthermore, fertilisers used in the nursery are bought in the market, while energy needs are supplied from the urban network and petrol oil (Plevri et al., 2020).

In this case, interdependencies were identified among different sectors such as water, energy, biodiversity, materials, climate, land use and waste. The Athens case aimed to find alternative water sources to achieve environmental, social and financial benefits to reduce the use of freshwater resources in water-scarce cities such as Athens (Plevri et al., 2021). The main nexus

issues and interlinkages are presented in Figure 11, and the main goals, actors and achievements of this project application are described in Table 19.

Figure 11: Main nexus interlinkages in NEXTGEN Project - Athens



Biodiversity: Green areas
Source: based on Plana-Puig et al. (2022).

Table 19: Objectives, actors and achievements in NEXTGEN Project - Athens

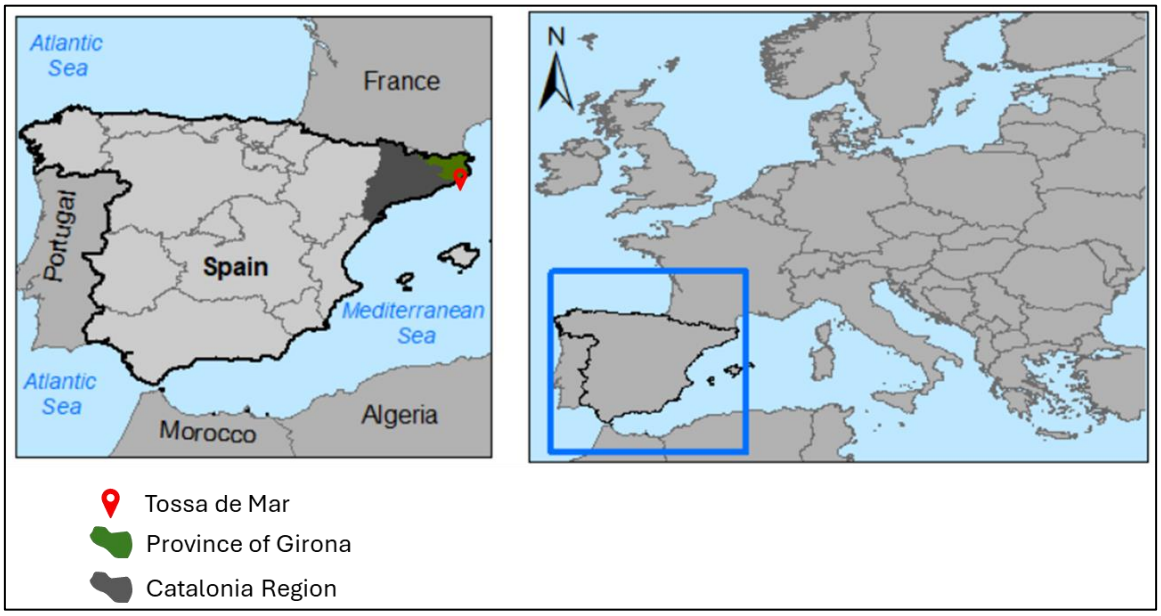
Main goals	• To produce treated water from urban wastewater through a sewer mining modular unit, at the point of demand, to irrigate urban green areas and other non-potable uses, to benefit the sustainability of the new Metropolitan Park. • To implement an integrated energy and nutrient recovery technology to cover thermal energy needs. • To produce an on-site fertilizer, derived from mixing wastewater sludge with treated wood and green wastes.
Main actors involved	• National Technical University of Athens • City of Athens (Municipality of Athens) • Biopolus (The Living Technology Alliance) • EYDAP (Athens's Water Supply and Sewerage Company) • CHEMITEC (Water and Environmental Technologies)
Key achievements	• Demonstration of a sewer mining modular unit for wastewater treatment. • Enabling novel wastewater reuse options at the point of demand for urban green irrigation, urban agriculture and other non-potable uses such as fire protection, and washing of municipality vehicles. • Solutions for nutrient and energy recovery for more complete autonomy. • Evaluating innovative circular solutions for their ability to address real-world problems in water-scarce cities.

Source: Plana-Puig et al. (2022) and NextGen (n.d.b).

4.2.2.2 *Costa Brava: "Circular solutions for water -materials"*

Tossa de Mar is located in Costa Brava, a tourist area, which consists of the coast of the province of Girona, in the region of Catalonia (Spain) (Figure 12). Costa Brava is characterised by a high water demand during summer and frequent water scarcity episodes and is one of the first areas to apply water reuse in Europe (Plana-Puig et al., 2022). Specifically, the wastewater treatment plant of Tossa de Mar has a surface area of 1.7 ha, and even though its maximum treatment capacity is around 35 m³/h, its average flow working rate is 7.4 m³/h (KWB, UBATH & EURECAT, 2020).

Figure 12: Location of Tossa de Mar (Costa Brava)



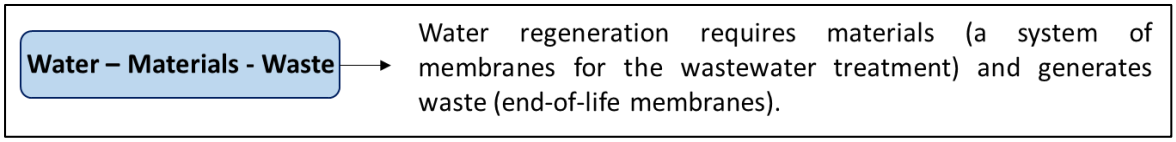
Source: Own elaboration made by ArcGIS with free vector map data from Natural Earth and DIVA-GIS.

Due to water scarcity, water reuse is a practice utilised in Costa Brava to supply water for agricultural irrigation and environmental and non-potable water uses. During the summer, the number of tourists increases, increasing the water demand and the wastewater flow rate to be treated, which leads to the necessity of improving the water quality to broaden its use (Plana-Puig et al., 2022).

In this case, the sectors of concern are mainly water and materials, but also waste is related. The case seeks to demonstrate strategies for regenerating disposed reverse osmosis membranes to be used in the processes of water treatment. The regeneration of membranes leads a decreasing of the generated waste (KWB, UBATH & EURECAT, 2020). This membrane

system, in turn, aimed at improving the water quality of treated water to respond to the high and increasing demand for water. The main nexus issues and interlinkages are presented in Figure 13, while the main goals, actors and achievements of this project application are described in Table 20. It is worth noticing that the health sector was also involved indirectly since the water quality depends on the health sector regulations.

Figure 13: Main nexus interlinkages in NextGen Project – Costa Brava



Source: based on Plana-Puig et al. (2022).

Table 20: Objectives, actors and achievements in NextGen Project – Costa Brava

Main goals	• To improve the regenerated water quality using a membrane system to meet the limits for private uses (private garden irrigation), which are more restrictive than the limits for public purposes. • To evaluate the viability of the RO-recycled membranes. • To reduce the electricity consumption of the ultrafiltration and nanofiltration processes compared with conventional Nanofiltration membranes (current value).
Main actors involved	• EURECAT (Centre Tecnologic de Catalunya) • Agencia Catalana de l'Aigua • DASA (Technology service for water supply) • ESGAP (Water treatment Company) • Department of Health • Consorcio de la Costa Brava • Ayuntamiento de Tossa de Mar • Agriculture sector • Domestic sector
Key achievements	• The plant installed on the Costa Brava demo site has been proven to remove contaminants of high toxicity, both for the environment and for human health. • The increase in water quality during the application of the nanofiltration system was noticeable since all the water quality values at the outlet improved. • Increase of 80% of water on the Costa Brava.

Source: Plana-Puig et al. (2022), NextGen (n.d.c) and Andreu et al. (2021).

4.3 Outputs, outcomes, and societal impacts

As mentioned, this research used the logical flow of the theory of change (ToC) to support the understanding of the process of change that leads to (potential) societal impacts or that promote the chance for societal impacts. Thus, the analysis started with identifying the outputs, outcomes, and potential impacts to obtain a storyline of the change process upon which interactions were analysed.

To answer sub-question 1, outputs, outcomes, and potential societal impacts identified throughout the implementation of SIM4NEXUS and NextGen projects are presented separately, followed by a comparison between them. Figure 14 and Figure 15 show the diagram with an overview of outputs, outcomes, and potential societal impacts of each project.

Figure 14: Overview of outputs, outcomes and potential societal impacts of SIM4NEXUS

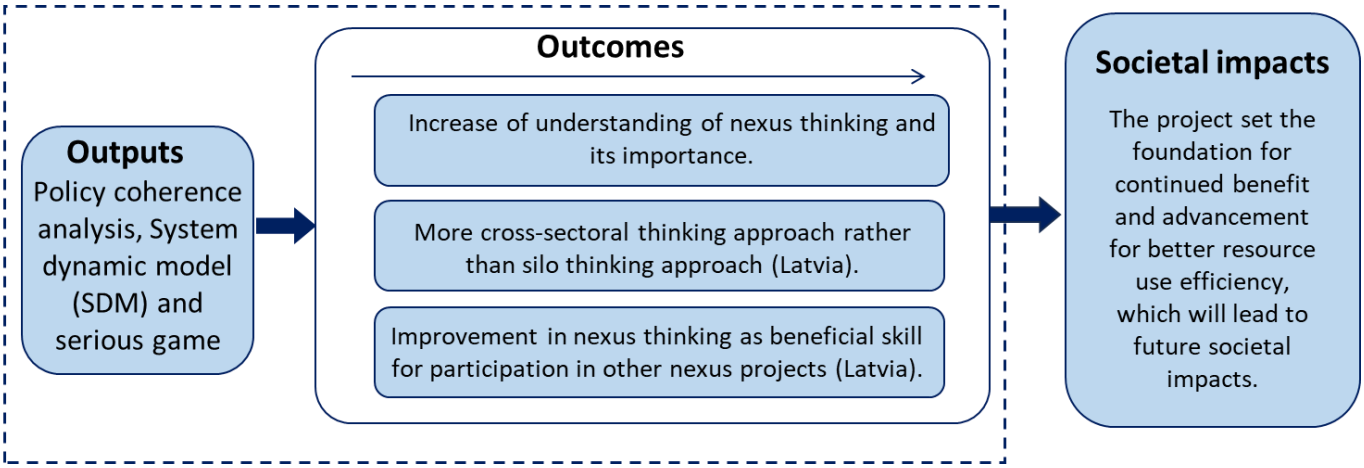
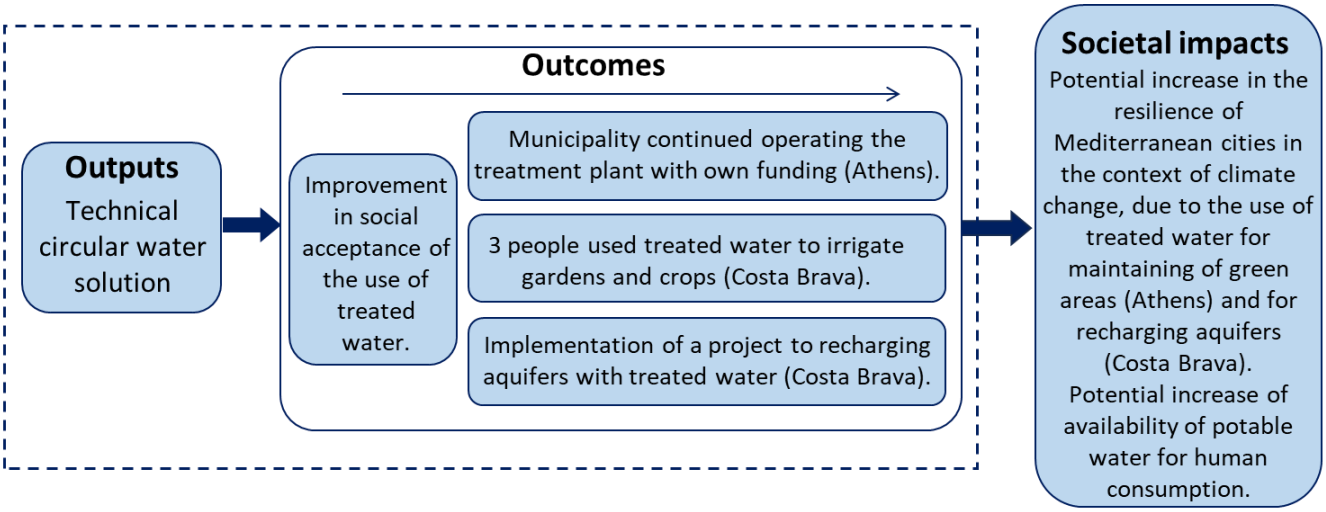


Figure 15: Overview of outputs, outcomes and potential societal impacts of NextGen



4.3.1 SIM4NEXUS

Output

The main outputs in the SIM4NEXUS case study were system dynamic models (SDM) and policy coherence analysis, which were built based on the information provided by the stakeholders. The SDMs captured and represented different interlinkages, synergies, and trade-offs among each different nexus sectors (energy, water, land, food, and climate) of each country. The SDMs were used to develop a serious game, a tool to better understand cross-sectoral interactions to support decision-making. However, this tool was not used by policy-makers in Sweden as planned, but by students to increase their knowledge of nexus thinking.

Outcomes

As a consequence of these direct results obtained, changes in behaviour (knowledge and skills) were identified in both Latvia and Sweden. Stakeholders increased their knowledge and understanding of nexus thinking, gaining awareness of a cross-sectoral perspective. They understood that is important to avoid silo thinking and shift to nexus thinking since any sectorial decision can affect other sectors.

In Latvia, this change in knowledge and understanding, by acquiring skills and intellectual capacities about nexus thinking, provided a good basis for further participation in future Nexus projects such as the Nexogenesis Project (Interviewee 2). Additionally, this change led stakeholders to be curious about playing the serious game in the case of Latvia (Interviewee 1).

Particularly in Sweden, even though stakeholders obtained a new perspective and agreed that nexus thinking was a good and interesting way of thinking, they did not express a high interest in the serious game and did not perceive it as a useful tool for making decisions (Interviewee 12). This was because the stakeholders did not see the need for a cross-sectoral tool as they already had their sectorial tools that fit their needs (Interviewees 12 and 17).

Societal impact

At the time of this analysis, it was not possible to observe any specific societal impact generated by the project. However, based on the quality of productive interactions in Latvia and the contextual conditions that influenced them (which are explained later in section 4.5.1), the chance of societal impacts in this country could be increased by those productive interactions.

Outputs obtained through productive interactions have triggered an increase in the awareness of nexus thinking. This outcome, in turn, can be considered as a legacy of knowledge that sets the foundation for continued benefit and advancement for better resource use efficiency (Grant Agreement No. 689150), leading to future societal impacts.

Based on the productive interactions in Sweden and the contextual conditions that stimulated and hampered them (which are explained later in section 4.5.1), the chance of societal impact would be lower than in Latvia. However, overall, the project, through productive interactions, put the Nexus concept on the table, raising awareness about it in both Latvian and Swedish cases, which favours the chance of future societal impacts, although to a different extent in each country.

4.3.2 NextGen

Outputs

The outputs in the NextGen case study were technical circular water solutions. In Athens, the direct result was the development and implementation of a sewer mining unit for reusing water for irrigation purposes (related nexus component: water) in parks and green areas (related nexus component: biodiversity). The sewer mining unit consisted of a small treatment plant that could fit in a container and could be installed where the demand for water exists by doing all the processes locally. Additionally, the sludge produced by the unit was mixed with the city's pruning waste to produce compost (related nexus components: materials and waste) and biogas energy (related nexus component: energy). Similarly, the Costa Brava case demonstrated the technical feasibility of a circular water solution based on further treatment of wastewater using recovered membranes (related nexus component: materials). Thus, specific water quality was obtained to be reused for irrigation of private gardens (related nexus component: water).

Outcomes

As a consequence of these direct results obtained, changes in behaviour and in actions and activities were identified in both cases. Regarding changes in behaviour, there was a change in attitude, increasing awareness and interest in the usefulness of treating water as a valuable resource for irrigation purposes. This led the Municipality of Athens to continue operating and using the implemented sewer mining unit after the end of the project, using public funding (changes in activities and actions). In Costa Brava, in turn, at a public institutional level, the

project increased the interest in using membranes for water treatment which led to starting a local project to monitor the water quality at different steps of the process and evaluate the potential uses. Additionally, three people from the local community used the treated water to irrigate their gardens and crops during the implementation of the project, which can be considered a change in their activities and actions as a consequence of the results of this project. On the other hand, this year (2024), a new project for the recharge of the aquifer Port de la Selva (basin close to the Tossa de Mar) with treated water will be implemented. This is considered a change in actions at the institutional level, as a result in part of NextGen project, together with a previous project, because, as claimed by the interviewees, this initiative is in part a consequence of the increase of awareness about the usefulness of treated water generated by NextGen and the previous project.

Societal impact

Currently, the unit for reusing water for irrigation purposes implemented at the Athens Urban Tree Nursey in Goudi Park is still operating (based on the interview date, February- March 2024). The use of treated water for irrigation purposes leads to sustainable maintenance of parks and green areas in Athens. This, in turn, can be considered a potential ecological change that will contribute to green area availability and will increase the resilience of Mediterranean cities in the context of climate change. By reducing potable water consumption for irrigation, the availability of potable water for human consumption will increase, which could be also considered potentially as a societal impact.

On the other hand, recharging the aquifer with treated water in Port de la Selva could lead to ecological changes in Mediterranean regions, favouring its resilience to long periods of drought in the context of climate change. Furthermore, considering that three people used treated water to irrigate their crops and garden in Costa Brava, it could be possible to explore a potential economic change, as they claimed that they saved money on water utilities by using treated water as a result of the project. It is worth noting that this economic change was obtained by only three people who lived close to the treated plant. Therefore, to be considered a potential societal impact, it should be adopted at a larger scale of users and further studies and analysis should be done, considering all installations and costs required to cover all those potential users.

4.3.3 Case comparison

Outputs and outcomes were identified clearly in both cases of study. Outputs generated in SIM4NEXUS were tools for a better decision-making process, while in NextGen technological developments for circular water solutions. The outcomes identified in both cases were related to changes in attitude and knowledge (changes in behaviour); however, by the end of the projects, those changes triggered only further outcomes for NextGen (changes in activities and actions).

Regarding the societal impacts, none of the projects has measured their impact yet, since societal impacts imply long-term changes. However, the chance of potential societal impacts could be based on the characteristics of the productive interactions (which are explained later in sections 4.5.1 and 4.5.2) during the implementation of these projects. In this context, in the NextGen project, it was possible to foresee the chance for more concrete societal impacts in terms of ecological changes in Athens and Costa Brava. Particularly, in the case of Latvia (SIM4NEXUS), productive interactions set the foundation for continued benefit and advancement for better resource use efficiency, which will lead to future societal impacts in terms of low-carbon developments. In the Swedish case of the SIM4NEXUS project, in turn, the chance for societal impacts could be lower than in the other cases due to the lack of productivity in the interactions among researchers and stakeholders during the implementation of the project.

Outputs, outcomes and societal impacts identified throughout each project are summarized in Table 21.

Table 21: Summary of outputs, outcomes and societal impact per project

	SIM4NEXUS	NextGen
Outputs	• Policy coherence analysis, system dynamic model (SDM), and serious game.	• Demonstration of the technical feasibility of a circular water solution to obtain a specific water quality for irrigation purposes.
Outcomes	• Changes in behaviour: Increase in knowledge and understanding of nexus thinking and its importance. Stakeholders started to think in a more cross-sectoral approach rather than in a silo approach. • Changes in behaviour: These were perceived as changes in skills. There was an improvement in nexus thinking, which has been beneficial for participation in other nexus projects.	• Changes in behaviour: Perceived as a change in attitude. There was an improvement in social acceptance of the use of treated water. • Changes in actions and activities: -The municipality of Athens incorporated the technological solution which is still operating with public funding. -Implementation of a project aimed at recharging aquifers with treated water (Costa Brava). -3 people used the treated water to irrigate their gardens and crops (Costa Brava).
Societal impacts	• The project set the foundation for continued benefit and advancement for better resource use efficiency, by assessing public policies, which will lead to future societal impacts.	• Ecological changes: -Potential increase in the resilience of Mediterranean cities in the context of climate change. Due to the use of treated water for irrigation purposes, green areas can be maintained sustainably (Athens). -Potential increase in the resilience of Mediterranean regions to long periods of drought in the context of climate change due to recharging the aquifer with treated water benefits (Costa Brava). -By reducing potable water consumption for irrigation, the availability of potable water for human consumption increases.

4.4 Interactions among researchers and stakeholders

Given the outputs, outcomes, and potential societal impact that form the storyline to better understand the process of change in each project, this section describes the interactions among researchers and stakeholders that contributed to this storyline, providing the answer to sub-question 2. Each project presents its interactions, followed by a comparison between them.

4.4.1 SIM4NEXUS

Most interactions where knowledge exchange took place among researchers and stakeholders were direct, mainly through face-to-face encounters. Since the project was implemented before COVID-19 (between 2016 and 2020), online meetings were not common at the time. Additionally, calls and emails were used to invite stakeholders to participate in the meetings or workshops. There were indirect interactions (e.g. reports and surveys), while financial interactions were only identified in the Swedish case. The interactions identified throughout SIM4NEXUS are described below:

<u>Direct interactions</u>

- *Interviews*: Individual interviews with key stakeholders in Latvia to inform them about the project. Stakeholder also provided their inputs based on their needs during these interviews.
- *Workshops:* There were three workshops in both countries. These were encounters where researchers explained the project and its main advances throughout its implementation. Stakeholders were asked about their views on conflicts and synergies between specific policy goals from different sectors to be used as input for the policy coherence analysis and modelling. Stakeholders worked in both small and large groups.
- *Conferences:* There were three conferences in Sweden. These were encounters to discuss specific nexus challenges with stakeholders. One of them was organized by the Swedish Forest Agency, in which project researchers participated to present the case of Sweden.
- *Training course:* Courses organized for highly educational students in Latvia to demonstrate to them how serious games work.
- *Calls and emails:* These interactions were used to reach participants and invite them to participate in the activities.

Indirect interactions

- *Reports:* In Latvia, before each workshop, researchers sent background materials (research, reports, and web pages) to participants to familiarise themselves with other nexus sectors and prepare beforehand. In the Sweden case, a paper with the case results was sent to the stakeholders.
- *Surveys:* In the Swedish case, there were two surveys. The first was to get a general overview of the project's interest, knowledge about the Nexus approach, and willingness to collaborate. The second was to feed the policy coherence analysis.

Financial interactions

- *Financial support:* Flight tickets for some stakeholders in Sweden to attend the workshops were funded by the Swedish case.

Specifically, during the direct interactions carried out in Latvia (workshops and interviews), stakeholders were asked to express their viewpoints and to prioritise their issues, which were incorporated into the modelling work. By accounting for the stakeholder's inputs and feedback, the model incorporated different policies from different sectors aimed at promoting and increasing environmental performance and possibilities for Latvia to move towards a low-carbon economy.

On the other hand, workshops in Sweden were important for the policy coherence analysis and for building the SDM. Stakeholders provided feedback on the policy assessment and, together with researchers, defined the score of policy coherence. Likewise, stakeholders were asked about inputs for the model based on their expertise. Thus, stakeholders helped refine the findings by providing some more on-the-ground information to improve the outputs (Interviewee 12).

4.4.2 NextGen

Most interactions where knowledge exchange took place among researchers and stakeholders were direct, such as in-person and online meetings. Interactions by email and phone were mainly used to invite stakeholders to participate in meetings. There were some indirect (e.g. reports), while there were no financial interactions. The interactions identified throughout NextGen are described below:

Direct interactions

- *Regular meetings:* In-person encounters in the premises of the Municipality of Tossa de Mar (Costa Brava case), the Athens Urban Tree Nursey in Goudi Park, and the premises of the Municipality of Athens (Athens case). These meetings did not include all stakeholders.
- *Community of practices (CoPs):* CoPs can be understood as a management tool that entails a process that enables stakeholders to engage and share different perspectives, interests, and needs to co-produce knowledge (Fulgenzi et al.,2020). In the NextGen project context, they were in-person encounters that were set up at each demonstration case, where researchers, together with stakeholders, discussed the results, the drivers or barriers for the technology implemented in the site, the public acceptance, and the further upscale of the technology. There were 4 CoPs in Costa Brava, while in Athens, due to the time constraints, there were 3 CoPs. The first, in both cases, was developed in person, while the others were developed online due to the COVID-19 pandemic.
- *Online meetings:* During the COVID-19 pandemic, CoPs had to be online. These meetings were a good opportunity for stakeholders who would not have participated if the meetings had been in person due to the distance.
- *Calls and emails:* These interactions were used to reach participants and invite them to participate in the activities.

Indirect interactions

- *Reports:* Mainly articles for magazines and journals.

The in-person encounters (e.g., CoPs and regular meetings) were crucial to negotiate and reach a consensus on technical and health aspects to achieve the required specific water quality in Costa Brava (Interviewee 6). In that sense, face-to-face interactions allowed them to easily exchange and gain new insights about the conditions required to use this technology and obtain appropriate water quality.

In Athens, in turn, in-person interactions inspired and informed local authorities and policymakers about the technology for water treatment (Interviewee 3), which opened the door for further discussions and collaborations on this topic (e.g., operation of the treatment water plant after finalising the project, which is currently operating).

Direct interactions such as CoPs, regular meetings, online meetings, and calls, were more effective than indirect interactions (e.g. reports) in transferring specific information or knowledge. By sending a report, there is no certainty that recipients read what they received (Interviewee 9), hampering the expected exchange for producing knowledge.

Online meetings facilitated the participation of stakeholders and allowed for more agile follow-up of the project implementation in each case due to the advantages of the costs and time (participants can join without needing to travel). However, meetings in person were essential to promote trust in the relationships among researchers and stakeholders (Interviewee 7), which is, in turn, crucial for interactions to be productive and for achieving the outputs, and outcomes and increase the chances for societal impacts.

4.4.3 Case comparison

Both projects had direct and indirect interactions. Unlike SIM4NEXUS, NextGen had several online meetings because the former finished before the COVID-19 pandemic started, and therefore, there were no restrictions on in-person meetings.

Most of the interactions in both case studies were direct, which allowed researchers to obtain inputs and feedback from stakeholders to reach consensus and produce outputs. Direct interactions contributed to establishing more trusting relationships and, in most cases, to achieving a better understanding of the needs.

Regarding financial interactions, in contrast to SIM4NEXUS, most of the stakeholders who participated in NextGen were also project partners, which implied that they received funding from the European Union. It is worth noting that there was not a financial exchange between researchers and stakeholders, but European Union and stakeholders, since they participated in the project as partners. In project SIM4NEXUS, stakeholders were not partners but volunteers which in some cases hampered the commitment to participate in the project due to the lack of economic incentives (Interviewee 12). However, in Sweden, it was possible to identify one financial interaction between researchers and stakeholders associated with the purchase of flight tickets to attend the workshops, which encouraged the participation of stakeholders. Table 22 summarises the interactions throughout the projects.

Table 22: Summary of interactions

	SIM4NEXUS	NextGen
Direct	-Interviews -Workshops -Conferences -Training course -Emails and phone calls	-Regular meetings -Community of practice (CoP) -Online meetings -Emails and phone calls
Indirect	-Reports and surveys	-Reports
Financial	-Financial support (flight tickets)	-No financial interactions

4.5 Contextual conditions and their influence on productive interactions

This section presents the contextual conditions that stimulated or hampered the productivity of the interactions described above. Each case describes the extent to which contextual conditions were met by using their indicators and the extent to which they stimulated or hampered productive interactions (sub-question 3). The section ends with a case comparison.

4.5.1 SIM4NEXUS

4.5.1.1 Broad stakeholder participation

Indicator:

-Representation of all relevant stakeholders and interest groups

The involved sectors were represented in the Latvian case by the relevant experts on water, energy, climate, and agriculture. All relevant sectors were well covered. The research team paid great attention to having as many representatives from each sector as possible to obtain a cross-sectoral dialogue by doing a detailed stakeholder analysis and mapping (Interviewee 2).

The representation and participation of relevant stakeholders in the Swedish case, despite not being optimal, were enough (Interviewee 12). In other words, all nexus sectors were represented by at least one stakeholder; however, several municipalities were asked to give input through online surveys without being actively involved in workshops (Brouwer & Fournier, 2020). This was due to difficulties in encouraging stakeholders to participate since they did not have time or enough interest in the project due to the lack of real incentives for them (Interviewee 12). Additionally, because of the travel time, most participants came from

the region where the workshops took place (Uppsala and Stockholm) (Brouwer & Fournier, 2020). Most of the participating stakeholders had expertise in forestry, water management, and local planning.

Since the participants were not fully familiar with the other sectors, the participation of different stakeholders with different expertise from different sectors allowed participants to learn other viewpoints and knowledge (Interviewee 2). Thus, having the broadest possible participation in Latvia provided distinct perspectives and knowledge since everyone brought their background to the interactions (Interviewees 13 and 14), contributing to interesting discussions and meaningful results for future decision-making (Interviewee 5). One example of that was a discussion about climate adaptation measures, where experts from biodiversity, water, forestry and agriculture were disputing the best measure based on what was good for their sectors but also on the potential synergies (Interviewee 2). Likewise, the representation of relevant stakeholders in Sweden provided good discussions (Interviewee 18).

Additionally, the SDM generated was used to feed the serious game, which also led to one of the outcomes obtained in the project (i.e. the increase of knowledge and understanding of nexus thinking). In this way, the involvement of experts provided with specific knowledge and experience, promoting learning and encouraging changes in behaviour (changes in attitudes and thinking from silo and sector to cross-sectoral thinking) and changes in activities and in actions (see outcomes Table 21). It is worth noticing that stakeholders actively participated and were keen to provide inputs and feedback to obtain a good output (Interviewee 2). According to Interviewee 2, stakeholder participation and their substantial inputs were essential to achieving outputs and outcomes.

It is worth noting that civil society's lack of participation in the interactions was a missing aspect of SIM4NEXUS, which could be considered a bias regarding the diversity of participants (Interviewee 15). Furthermore, according to Interviewees 15 and 16, civil society participation could increase social acceptance of the issues, which could influence the achievement of societal impact. In that context, the importance of preparing stakeholders to make them participate was highlighted (Interviewees 16).

4.5.1.2 Problem definition

Indicators:
-Common understanding/agreement on problems or goals based on stakeholders' needs.
-Constructive management of potential perspective disagreements

Despite the fact that the general objective was given by the project, in the Latvian case, the Ministry of Agriculture and Ministry of Environmental Protection and Regional Development contributed to the goal setting for the implementation of the project in this case (Brouwer & Fournier, 2020). The jointly defined goal contributed to meeting the stakeholder's needs, which were related to achieving a low-carbon economy. They reached a common understanding of the issues resulting from one sector making unilateral decisions without considering the potential effects on another sector. Therefore, they agreed that it is important to think in a nexus way. Thus, they were interested in using the SDM and the serious game as tools to facilitate cross-sectoral decision-making. It was important to have a common understanding based on the recognition of stakeholders' perspectives since it made stakeholders commit to the project, positively influencing the production and use of socially relevant and scientifically robust knowledge.

In Sweden, to some extent, it was perceived that the goal (to analyse the interactions of the policies to build the model to facilitate future decision processes) was given by the project and not defined by the case: "…I felt that it was from the beginning, like a bit top-down…" (Interviewee 12). In this respect, stakeholders should be asked about the problem even before a research proposal is written, but this is usually not possible due to time constraints, the load of work, and the requirements for this type of research and its funding application (Interviewee 12). In Sweden, different sectors (water, energy, forestry, etc) have their own goals and regulation systems (Interviewee 17). Thus, despite stakeholders understanding the project's goals and that the decisions of one sector can trigger effects on other sectors, the proposed goal was not based on their needs or perspectives. In this context, they accepted the goal (to analyse the interactions of the policies to build the SDM), but they did not seem to be interested in using the result nor approaching the sectorial needs in a cross-sectorial way.

As a result, stakeholders in the Swedish case did not perceive the need for an SDM or a serious game as a decision-making tool; however, this was not considered in an early stage of the

project to define the objective of this case. This hampered productive interactions and with that, the utilisation of the knowledge produced (SDM and serious game) since it was not relevant for policy-makers (socially relevant). In that sense, even though the interactions in Sweden contributed to the achievement of the outputs (SDM, serious game, and policy coherence analysis) and outcomes (an increase in understanding of nexus thinking), they were not productive enough (due to the lack of the problem definition based on the needs and perspective of stakeholders) to contribute to increasing the chance for societal impacts. Therefore, the low productivity of the interactions in the case of Sweden and the less chance for societal impacts than in other cases might be attributed to the fact that researchers and stakeholders did not work with the correct focus from the start. This, in turn, can explain why the problem definition was not based on the stakeholders' needs.

There were conflicting views in both cases due to the different backgrounds of stakeholders. For example, in the Swedish case, one stakeholder from an environmental consultancy was very focused on the conservation of biodiversity, while the representative from the forest sector was much more focused on production (Interviewee 12). However, there was an appropriate constructive management of controversial perspectives, since case study leaders moderated smoothly the discussions and encouraged stakeholders to participate without judgements (Interviewee 12).

4.5.1.3 Roles and contribution

Indicators: **-Awareness and fulfilment of the researchers and stakeholders' roles and the role of the knowledge generated.**

The role of participants (researchers and stakeholders) and the role of the expected results were clear in both cases, as well as they were fulfilled. The stakeholders' role was mainly to contribute to the identification of critical Nexus interlinkages, contribute with their knowledge and more on-the-ground information, and help refine and validate the results obtained (policy coherence analysis, SDM, etc.). In turn, researchers' roles were aimed at the stakeholder involvement process, performing the policy coherence analysis, collecting data from stakeholders to provide to SIM4NEXUS partners, who, based on the stakeholders' inputs collected by researchers, built SDMs and serious game (Brouwer & Fournier, 2020).

The role of the researchers and stakeholders as well as the purpose of the knowledge produced or expected results, were provided by the case study leader at the beginning of the implementation of the project in each case, by email and during initial meetings, and also throughout the project as it evolved. Having clear definitions from the beginning was positive for the process: "made the process and the workshops that we had more efficient or effective, we knew what was expected of us….it was very pedagogic if you could say…" (Interviewee 18).

Providing clear explanations about the roles and expected results, allowed stakeholders to set their expectations and create trust and confidence in the process (Interviewee 1). In these cases, where stakeholders were not partners and their work was voluntary, it was important to create trust; otherwise, stakeholders, who were the source of data, could stop attending, and without them, there would be no inputs or interactions (Interviewee 1). Additionally, clear roles allowed stakeholders and researchers to act in a smooth collaborative way, with each one committed and focused on a specific task (Interviewee 11).

4.5.1.4 Resource availability

Indicators:
-Adequacy of the level of interaction, given by the researcher's competencies (e.g quality of moderation of the discussion)
-Opportunities for stakeholders' participation
-Adequacy of the level of consideration of stakeholder input
-Adequacy of facilities and organisational forms
-Clarity of information transferred (presence of boundary objects)

The researcher's competencies promoted a proper level of interaction in both cases. Case study leaders were able to moderate and mediate the interactions to manage disagreements smoothly so all viewpoints were heard. It was noted that the project in Latvia "was moderated wisely" (Interviewee 5), and in Sweden, the case study leaders "did it in a great way" (Interviewee 18) by the case leaders.

All case study leaders made efforts to create an interactive setting to encourage key stakeholders to participate. Different communication tools and methods, such as World Café

methods, using materials such as sticky notes and colourful dots, were applied to obtain as many viewpoints as possible (Interviewee 1). Time for open discussion was allocated after presentations during meetings to ensure all participants were able to express their viewpoints without judgment (Interviewees 2 and 12). During the meetings, stakeholders were informed about the progress of the project, the next steps, and how suggestions from stakeholders had been taken into consideration, presenting the results and validating these with the stakeholders. The case study leaders discussed sectoral issues and potential solutions with stakeholders. Furthermore, stakeholders felt that their opinions were respected and therefore allowed them to openly discuss controversial ideas (Interviewee 5).

All facilities and organizational forms were in place. In Latvia, meetings were held on the premises of the Baltic Environmental Latvian Forum and a conference room. Depending on the number of participants, the project budget provided funding for a suitable venue and catering. Likewise, in Sweden, "facilities and organizational forms were excellent" (Interviewee 18).

None of the cases had to use boundary objects (such as concepts, computer tools, maps, or site visits). It was not necessary to translate the information to increase understanding since all stakeholders had basic knowledge of the issue. However, when concepts were unknown to some stakeholders, they were explained during the meeting to favour all participants' understanding (Interviewee 2). Overall, the required resources were available and were "essential to the success of stakeholder interaction" (Interviewee 1).

It is worth noting that some interviewees (2 and 12) alluded to time constraints as an issue for participating, further outcomes, and the chance of societal impacts. Similarly, Interviewees 13 and 14 claimed that to achieve societal impacts, it is important to promote the project's results after the project finishes to avoid the information produced disappearing or being forgotten, alluding to the importance of the project's afterlife.

4.5.2 NextGen

4.5.2.1 Broad stakeholder participation

Indicator:
-Representation of all relevant stakeholders and interest groups

Both Athens and Costa Brava cases had representation of most relevant stakeholders except for civil society, who participated only as end users of the treated water in Costa Brava. In this respect, it was suggested that the inclusion of civil society as stakeholders in the interactions could facilitate the diffusion of the results of this kind of project and increase the chance of societal impact (Interviewees 6 and 9). All the participants had the required experience and expertise, mainly on water treatment and management in both cases as well as on health in the context of water quality (Costa Brava case) and on compost-based energy (Athens case).

Including relevant stakeholders led to their involvement in the issue and allowed them to exchange their needs and viewpoints, which differed among all stakeholders (Interviewee 8). For instance, the experts' participation from the health sector helped to define the limit for the emerging contaminants in water in the case of Costa Brava. Agronomists in Athens provided their expertise on composting production, while engineers helped to increase the system's energy efficiency. Having the representation and expertise of relevant and different stakeholders during the interactions, allowed them to see the project and the issue from different perspectives (Interviewee 11).

Based on the results of the surveys to evaluate the CoPs in Athens and Costa Brava (NextGen, 2022), respondents scored 4 over 5, the indicator associated with this condition ("all relevant stakeholders were present"). This demonstrated that overall, stakeholders agreed that relevant stakeholders were present in the meetings, and therefore, this condition was met. Particularly, respondents highlighted the opportunity to increase and exchange knowledge and viewpoints by discussing with different stakeholders as a positive aspect.

4.5.2.2 Problem definition

Indicators: **-Common understanding/agreement on problems or goals based on stakeholders' needs.** **-Constructive management of potential perspective disagreements**

Both Athens and Costa Brava cases had a good level of common understanding/ agreement on the problem and goals and appropriate constructive management of potential perspective disagreements. Based on the results of the surveys to evaluate the CoPs in Athens and Costa Brava (NextGen, 2022), the indicators related to the constructive management of potential disagreement reached an average of 4.3 over 5 points. In both cases, there were diverse perspectives and interests. However, all opinions were respectful and constructive in benefit of the project and the final objective of reusing the water. One example of this is the effort by both researchers and the health and water management sectors to obtain an agreement on the selection of 4 over 200 emerging contaminants in water to monitor monthly (Interviewee 6).

Achieving a common understanding based on the recognition of the stakeholder needs implied agreement despite the existing different points of view or interests. During the CoPs, researchers and stakeholders worked jointly, making choices together: "It was not so much that the project decided…" (Interviewee 4). In this way, the interests and needs of stakeholders influence the outputs.

By sharing a common understanding of the issue and making them part of the project, stakeholders were motivated and, therefore, more prone to engage and to continue working towards the same direction (obtaining the specific quality of water to reuse it) (Interviewee 6). In this sense, it is important to make stakeholders understand that what they were doing was not only for the researchers and the scientific project but also for them and that they would be impacted by what they were doing (Interviewee 7). Thus, this condition facilitated the interactions among researchers and stakeholders since the latter perceived that their needs had been recognized, and therefore, they felt part of the process, and there was a better willingness and commitment to participate.

As Interviewees 4 and 7 highlighted, sometimes the discrepancies are not in the problem definition but in the joint vision for the future, the solutions, and how to implement those

solutions. This indicates that having a shared problem definition is not only important, but also maintaining a joint vision of the future and sharing the manner of implementing the solutions during the entire process.

4.5.2.3 Roles and contribution

Indicators: **-Awareness and fulfilment of the researchers and stakeholders' roles and the role of the knowledge generated.**

Both in the Athens and Costa Brava cases, there was awareness of the roles of researchers and stakeholders, as well as of the role of the expected results or expected knowledge generated. The stakeholder's role was mainly to contribute to the identification of key issues from their perspectives to contribute to defining the common objectives of the cases, taking into account their needs and the demo-specific characteristics (Frijns & Bouziotas, 2023). In turn, researchers' roles were mainly aimed at organising and managing the stakeholder involvement process. Those roles were fulfilled in both cases. Based on the results of the surveys to evaluate the CoPs in Athens and Costa Brava (NextGen, 2022), the indicator about the awareness of their role reached an average score of 4.3 over 5 points, which demonstrates that this condition was met.

The role of the researchers and the usefulness of the knowledge produced were provided during the initial meetings with the stakeholders. The coordinators of the NextGen project developed a roadmap with guidelines where tasks were defined. Having clarity about the roles and responsibilities, as well as the usefulness of the expected results, allowed the participants to work in a coordinated way as "one entity" (Interviewee 8) and to have a "better collaboration" (Interviewee 4).

4.5.2.4 Resource availability

Indicators:
-Adequacy of the level of interaction, given by the researcher's competencies (e.g., quality of moderation of the discussion)
-Opportunities for stakeholders' participation
-Adequacy of the level of consideration of stakeholder input
-Adequacy of facilities and organisational forms
- Clarity of information transferred (presence of boundary objects)

In both cases, researchers developed suitable settings for cooperation and participation. The coordinator, together with other researchers of the NextGen project, created a guideline to support case study leaders in having proper interactions with participants by including different methods that they could use for moderation and stakeholder engagement. Thus, the researchers (case study leaders) were able to encourage and facilitate the stakeholders' participation and moderate and mediate discussions appropriately. In this respect, without such suitable settings for cooperation, "we could not implement anything" (Interviewee 8). Based on the results of the surveys to evaluate the CoPs in Athens and Costa Brava (NextGen, 2022), the indicators related to this contextual condition reached an average of 4.5 over 5 points, which demonstrates that this condition was met.

The activities carried out were aimed not only at inviting stakeholders and informing them but also at engaging them and asking them to discuss specific questions (Interviewee 3). Stakeholders had the opportunity to provide their opinions, and in both cases, they felt that their inputs or recommendations were considered. The feedback and concerns provided by stakeholders were used to find solutions (Interviewee 3).

The meetings, both in person and online, were well organised and facilitated appropriately; the researchers explained clearly the objectives of the meetings and the next steps. Furthermore, all required facilities and organizational forms were in place. In the case of Costa Brava, it was possible to implement the technology on the premises of the water treatment plant in Tossa de Mar, and the meetings were carried out on the premises of the Municipality of Tossa de Mar. In turn, the Municipality of Athens facilitated its premises for the implementation of the project in the Athens case. Having the physical space to implement the technologies as well as to meet

with stakeholders in person fostered trusting relationships, which not always can be achieved through online meetings (Interviewee 7).

Regarding the boundary objects (such as concepts, computer tools, maps or site visits), NextGen had site visits by developing meetings with stakeholders at the demo site (e.g., CoPs before COVID-10 started and technical meetings). Additionally, the case of Athens developed an augmented reality app for the general public so that if they visit the park, people could understand, through the app on their phones, the technical circular water solution and the sewer mining during the implementation of the project (Interviewee 4). It was not necessary to use concepts to translate the information to increase understanding since all stakeholders had basic knowledge of the issue. However, when technical aspects hampered stakeholders' understanding, the researchers explained clearly to favour all participants' understanding (Interviewees 3 and 10).

It is worth noticing that the survey results, applied to stakeholders in the NextGen project, suggested that the lack of time was a less positive aspect of the meetings (NextGen, 2022). Additionally, Interviewee 9 suggested that the results of the case in which they participated could have been better disseminated (e.g., to encourage private companies to use the new technical circular water solution). Likewise, Interviewee 6 also referred to the need for dissemination of the results generated to reach more people and create more changes.

4.5.3 Case comparison

Broad stakeholder participation

The contextual condition "broad stakeholder participation" was met differently in each case study. Having broad participation in the NextGen and Latvia case (SIM4NEXUS), including diverse sectors at different levels (municipality, region, water companies, etc) and relevant experts, provided distinct perspectives and allowed stakeholders and researchers to have different views for exchanging. Thus, by bringing together different needs and views from the different relevant stakeholders, this condition stimulated, to a great extent, productive interactions, enabling the production of credible, salient and legitimate (CSL) knowledge required for socially relevant and scientifically robust knowledge (e.g. SDMs and technical circular water solutions based on representative expert inputs). In the case of Sweden

(SIM4NEXUS), this condition also stimulated productive interactions, although to a lesser extent than in the other cases.

Problem definition

Regarding the contextual condition "problem definition", in the NextGen project there was a common understanding of the issue and goal based on the stakeholder's needs and perspectives, whereas in the Swedish case of the SIM4NEXUS project, despite stakeholders understanding the goal of the project, the goal seemed to be not based on their needs or perspectives. As a consequence of this, stakeholders did not perceive the usefulness of using the output (serious game) of the project for the purpose that it was proposed (to improve the decision-making process in a cross-sectoral way), therefore, the knowledge produced was not utilised. In this case, this condition was not met properly and therefore, the contextual condition "problem definition" hampered productive interactions in the Swedish case. Sharing a common understanding of the issue based on the stakeholder perspective, made stakeholders feel part of the project in both cases of NextGen project and the Latvian case. Thus, they felt motivated and, therefore, more prone to engage and to continue participating in the project. This facilitated the exchanges between them and researchers, stimulating productive interactions and with this, enabled the production of CSL knowledge required for socially relevant and scientifically robust knowledge.

Roles and contribution

The contextual condition "roles and contribution" was met in both case studies. The expectations of researchers and stakeholders about their role, as well as the purpose of the final results, were clear, which contributed to smooth collaboration. Providing clarity about their roles and the contribution of their work, and later fulfilling them, led stakeholders to increase trust and confidence in the interaction process. This stimulated productive interactions among them and, with this, enabled the production of CSL knowledge required for socially relevant and scientifically robust knowledge.

Resource availability

The contextual condition "resource availability" was met to a great extent in both case studies. Resources, such as boundary objects (on a case-by-case basis), physical infrastructure, and actors' competencies for mediation and engaging stakeholders, allowed researchers to engage with the stakeholders and provide a space where they felt safe and respected, encouraging them

to share their viewpoints openly. The results demonstrated that the proper competencies of researchers to engage stakeholders and mediate processes were essential for stimulating productive interactions. The resources facilitated the information transfer and the mutual understanding among all actors involved, allowing the actual exchange between researchers and stakeholders to produce the required knowledge that made interactions productive. Thus, by facilitating the translation of the information and mutual understanding, this condition stimulated productive interactions, positively influencing the production of CSL knowledge required for socially relevant and scientifically robust knowledge.

Although time constraints and an afterlife project were not considered as part of the resources for this analysis, it is worth noticing that the results highlighted the time constraints and the lack of an afterlife project as barriers to further outcomes and societal impacts.

4.6 Conclusion of results

This section starts by answering sub-question 4, which aims to understand the extent to which productive interactions led to societal impacts in each case, and ends by presenting a table summarizing the key findings of this research.

The results showed that the achievement of outputs and outcomes that led to an increase in the chance of achieving societal impacts involves a chain of changes, which required exchanges (e.g., feedback from stakeholders to build models, inputs from stakeholders to find a certain quality of water, etc.) and the utilization of knowledge produced throughout those changes (e.g., utilization of the treatment water plant to reuse the water and irrigate green areas or to recharge aquifers once acceptance of use treated water increased). As several interviewees claimed (Interviewees 4, 7, 8, and 11), achieving outputs, outcomes and potential societal impacts is not possible without productive interactions.

On the one hand, in the Latvian case (SIM4NEXUS), productive interactions led to the utilization of the knowledge produced (policy coherence analysis, SDM, serious game) to fulfil its societal goals or issues associated with policy inconsistencies and incoherence affecting resource efficiency. It was seen that by working on the policy coherence analysis and using the serious game, stakeholders increased their knowledge and understanding of nexus thinking,

starting to think in a cross-sectoral approach (changes in behaviour). This promoted the chance for the achievement of future societal impacts in terms of resource use efficiency. In contrast, interactions in the Swedish case (SIM4NEXUS) were less productive due to a more top-down problem definition of the case, which was not based on the stakeholders' needs. The lack of shared perspectives of the future led to the no utilisation of the knowledge produced (a misfit between demand and supply of knowledge). Therefore, productive interactions in Sweden did not contribute to the same extent to the chance for societal impacts as in the other cases.

On the other hand, the productivity of the interactions in both cases of the NextGen project led to the utilisation of the knowledge produced (technical solutions for reusing water) to fulfil societal goals or issues associated with water scarcity and resource depletion. It was seen that stakeholders used the solutions for reusing water produced through productive interactions (changes in actions and activities). This promoted the chance for the achievement of ecological changes, mainly in terms of a potential increase in the resilience of Mediterranean cities in the context of climate change (societal impacts).

Finally, Table 23 summarizes the influence of contextual conditions on productive interactions. From this, it can be derived that contextual conditions "broad stakeholder participation", "problem definition", "roles and contribution", and "resource availability" were met to a great extent, stimulating the productive interactions in both the case of Latvia (SIM4NEXUS) and the NextGen project, which contributed to the achievement of outputs and outcomes and led to an increase in the chance for societal impacts. In the case of Sweden (SIM4NEXUS), productive interactions were stimulated by the contextual conditions "broad stakeholder participation", "roles and contribution", and "resource availability", which were met to a good and great extent. However, the contextual condition "problem definition" was met to a small extent, which hampered the productivity of the interactions hindering the chances for societal impacts in that case.

Table 23: Summary of contextual conditions and their influence on productive interactions

Contextual condition	Influence on productive interactions
Broad stakeholder participation	• The relevant stakeholders and interest groups were well represented, allowing broad participation from different sectors and bringing diverse viewpoints. Despite having the majority of relevant stakeholders represented, the interviewees in both cases suggested that civil society's involvement could have been positive for further discussion and diffusion of the results. • This contextual condition was met to a good and great extent (in Swedish and Latvian cases, respectively); therefore, overall, it stimulated productive interactions in both case studies.
Problem definition	• A common understanding of the issue and goal promoted commitment and collaborative work in the same direction. In contrast, the absence of a common shared goal based on the stakeholders' needs and perspectives led some stakeholders to lose interest in the process, making it difficult for them to engage, participate, and use the results obtained. • This contextual condition stimulated productive interactions for the cases of the NextGen project and the Latvian case of the SIM4NEXUS project and hampered productive interactions for the Swedish case of SIM4NEXUS.
Roles and contribution	• There was a clear role of the researchers as well as the purpose of the expected results, which contributed to better collaboration among stakeholders and researchers and building trust. • This contextual condition was met to a great extent and stimulated productive interactions in both case studies.
Resource availability	• There was an adequate level of the researcher’s competencies for engaging and encouraging stakeholders as well as for moderating discussions that led to an adequate level of interaction, making participatory activities an appropriate process. • The researcher considered the feedback and concerns provided by stakeholders to build the models and implement the technological circular water solutions in SIM4NEXUS and NextGen, respectively. • There was an adequate level of facilities and organizational forms which allowed the development of the meetings properly. • No conceptual boundary objects were needed to translate the information for better understanding since all stakeholders had basic knowledge of the issue. Boundary objects such as computer tools and site visits were used in the NextGen project. • This contextual condition was met to a great extent and stimulated productive interactions in both case studies.

4.7 Validation of the results

This section presents the results obtained in the validation activity carried out in the "Nexus EXCELLENTIA Workshop", in which approximately 17 senior Nexus expert researchers participated (Appendix E presents all results of this activity, see section 8.5). The activity included three types of questions (to what extent do you agree from 1 to 5, short answer question and rank from 1 to 4). Regarding the first type of question, 11 statements were built based on the main results described in Chapter 4. Overall, the results demonstrated a high level of agreement, with an average score of 4.4 over 5. Regarding statements No 6 and 11 ("*Promoting the stakeholders' trust in researchers, contribute to productive interactions*" and "*An effective process of stakeholder engagement is key for nexus projects to achieve societal impacts*"), all participants agreed to some extent (agreed and strongly agreed), reaching an average score of 4.8 and 4.9, respectively. In contrast, statement No. 4*, "If stakeholders' needs are considered when defining project objectives or goals, the knowledge produced is socially relevant",* received the least agreement (in comparison to the other statements), but still reaching an average score of 3.7 out of 5. It is worth noticing that even though 22% of participants were neutral regarding this statement, the majority of participants agreed (see the specific percentages in Appendix E, section 8.5). Table 24 summarizes the average score of agreement level of these 11 statements.

Table 24: Level of agreement on main results

No.	Statement	Average score of agreement level (1-5)
1	Bringing together different needs and views from the relevant stakeholders involved contributes to productive interactions.	4.6
2	Civil society should be involved in the Nexus project to improve productive interactions and increase the chance for societal impacts.	4.5
3	Considering stakeholders' perspectives in defining the problem/goal makes stakeholders commit to projects, contributing to productive interactions.	4.2
4	**If stakeholders' needs are considered when defining project objectives or goals, the knowledge produced is socially relevant.**	**3.7**
5	Stakeholders should be involved from the beginning of the project so that they can contribute to the definition of the goal.	4.4
6	**Promoting the stakeholders' trust in researchers, contribute to productive interactions.**	**4.8**
7	Facilitating the translation of information (from technical to simple language) and mutual understanding contributes to productive interactions.	4.6
8	Economic incentives for stakeholders to participate in research projects, positively influence productive interactions.	3.9
9	The utilisation of the knowledge produced by productive interactions leads to societal impacts.	4.1
10	Broad stakeholder participation and resource availability are the contextual conditions most essential for productive interactions.	4.6
11	**An effective process of stakeholder engagement is key for nexus projects to achieve societal impacts.**	**4.9**

The level of agreement achieved reflects that the research findings were validated by Nexus experts, which allows us to generalise them and apply these insights not only to the projects studied (SIM4NEXUS and NextGen) but also to European Nexus projects in broad terms.

In addition to asking about the extent to which researchers agreed to these statements, they were asked to provide a short answer to the question: How do Nexus projects achieve expected outputs and outcomes and contribute to societal impacts? Most of the answers (18 over 20) alluded to interconnection, collaboration, and interactions (Table 25). This suggests that interactions, collaboration, and interconnection among sectors are crucial for Nexus projects to achieve expected outputs and outcomes and contribute to societal impacts. In turn, this validates the results obtained in this research, allowing us to generalise the findings to other European Nexus projects.

Table 25: Answers to the question How do Nexus projects achieve expected outputs, and outcomes and contribute to societal impacts

How do Nexus projects achieve expected outputs and outcomes and contribute to societal impacts?
"Enhancing the understanding of interconnected challenges and integrated solutions."
"By initiating and streamlining collaboration between stakeholders (and hopefully assuring that it will last after the project ends)."
"Collaboration among different disciplines."
"Enhancing synergies between actors at different levels."
"First, they take into account the natural connections existing between managed resources, second, they encourage contributive participation from all the involved stakeholders."
"By paving the pathway for strong collaborations."
"Reveal hidden trade-offs and synergies, quantify them, and reveal hidden obstacles, benefits and threats for stakeholders. Also, they advance in methodologies, tools, database semantics, etc."
"Buy building cross-sectoral relationships and cross-sectoral understanding of nexus interdependence and linkages."
"Better understanding and management of existing/future trade-offs."
"Multi-sectoral experts engagement towards strong evidence-based solutions."
"By facilitating SH dialogue across sectors."
"Outputs having social impact and change of behaviour."
"Interconnect academy, industry and government in the goals. Transdisciplinary studies."
"Good transdisciplinary cooperation and process reflections."
"Direct results obtained by a research project."
"Good methods for co-creation."
"Integration of different dimensions."
"The nexus projects enable connections of various researchers and stakeholders, hence improving the possibility for the successful impact."
"Enhancing networking."

Finally, participants were asked to rank the contextual conditions from 1 to 4 according to what they thought was most important to stimulate productive interactions and promote societal impacts in Nexus projects. As a result of this, the contextual conditions "broad stakeholder participation" and "problem definition" were both ranked as the most important while the conditions "roles and contribution" and "resource availability" were both ranked in second place. These results showed that all contextual conditions were perceived as important by the researchers since no contextual condition obtained a third or fourth place in the ranking.

5 Chapter 5: Discussion

5.1 Introduction

This chapter discusses the results, including own reflections on the results obtained and interlinkages with scientific literature. It starts with reflections on the output, outcomes and impact of the research (section 5.2), which is linked with the results of sub-question 1. From the results of the sub-question 2, some insights were derived and presented in the section 5.3. After discussing the type of interactions, reflections on the contextual conditions studied in this research are presented in the section 5.4, which are linked to sub-question 3. Finally, section 5.5 present insights about the influence of productive interactions on societal impacts in transdisciplinary research, which were derived from the answer to sub-question 4. This structure is also aligned with the line of reasoning of the Analytical framework previously explained (section 2.6).

5.2 Reflections about outputs, outcomes and societal impact in research

Identifying outputs, outcomes and potential societal impacts in each case allowed to clearly understand the process of changes that lead to (potential) societal impacts in transdisciplinary projects. As Schneider, Giger et al. (2019) suggest, the inclusion of theory of change to reflect on how changes are achieved in transdisciplinary research is lacking since ToC has only recently entered academic institutions. Therefore, *the use of the elements of the theory of change (ToC) in this research could contribute to the systematic learning exercise to reflect on how societal impacts are achieved in transdisciplinary research.*

Additionally, by combining the framework of productive interactions with the elements of the ToC, the understanding of the process of changes in which exchanges among researchers and stakeholders occur was clearer. *Thus, this research could offer a more robust framework when assessing societal impact through productive interactions.*

When conducting the interviews, it was identified that the interviewees' understanding of the terms output, outcomes, and societal impacts was somewhat ambiguous. This is aligned with Belcher and Halliwell (2021), who argue that these terms are used ambiguously, hindering evaluation in research. *This suggests the need to be careful when addressing the concepts of outputs, outcomes, and impacts to avoid inconsistencies.*

5.3 Insights about the type of interaction

In addition to the influence of contextual conditions on productive interactions described, some insights about the influence of the type of interaction on the productivity of interactions were identified and are presented below.

It can be derived from the research results that direct interactions were more prone or likely to be productive since they were effective in transferring specific information and essential to establishing confident relationships. This is aligned with Díaz-Mariño et al. (2020), who suggested that when communication occurs "face-to-face", participants can experience facial expressions, body language and vocal tone, which could increase the likelihood of cooperation and the trust in interaction process. *Due to the essential role played by direct interactions throughout the cases in the achievement of outputs, outcomes and (chance for) potential societal impacts, it is suggested the inclusion of this type of interaction in transdisciplinary research.*

On the other hand, it was observed that financial support (such as providing flight tickets to facilitate the attendance of the in-person events) or economic incentives (by making stakeholders partners in the project, even though in this case was not a financial interaction by definition) encouraged participation and feedback from stakeholders. In that sense, financial interactions facilitated the productivity of the interactions among researchers and stakeholders, contributing to the achievement of outputs and outcomes. In this respect, Spaapen and Van Drooge (2011a) suggested that financial interactions provide stronger feedback from stakeholders into the researcher's activities than other forms of interactions. In the same vein, Wiek et al. (2014) suggested that financial incentives influence the societal impacts generated by research processes. Although the results of this research are aligned with the literature, not all Nexus researchers who participated in the validation activity fully agreed on the positive influence of financial interactions on productive interactions (average agreement score 3.9 over 5). It may be considered that financial interactions could trigger conflicts of interest or bias in the results. Therefore, *further studies could help to incorporate financial incentives to lead financial interactions without triggering those negative consequences, such as bias or conflicts of interest.*

5.4 Contextual conditions

5.4.1 Broad stakeholder participation and resource availability

The contextual condition "broad stakeholder participation" was considered essential to promote productive interactions by most of the researchers interviewed. By including different knowledge in science from different actors and perspectives in the knowledge production process, this condition led to credible, salient, and legitimate (CSL) knowledge. This is aligned with Lang et al. (2012), who stated that stakeholder participation is a key aspect of the production of knowledge required for solving sustainable challenges that society faces. Furthermore, it confirms the ideas of Schneider, Giger, et al. (2019), who highlighted the need to link scientific and stakeholder perspectives to create more relevant and robust knowledge.

In turn, most of the stakeholders interviewed gave importance to the researchers' competencies for engaging stakeholders and mediating the participatory process to promote productive interactions. Therefore, "resource availability" was also an essential contextual condition. In this context, the finding results are aligned with Cash et al. (2003) and Hegger et al. (2012), who suggested that the researcher's competencies in terms of negotiation, mediation and translation contribute to the production of CSL knowledge. Additionally, having the availability of physical spaces for in-person meetings influenced positively productive interactions, confirming what the literature states about the importance of facilities and organizational forms in stimulating knowledge exchange (Hegger et al., 2012). Likewise, the site visits, were helpful for the achievement of productive interactions and outputs, which confirms the contribution of using boundary objects to contribute to CSL knowledge (Hegger et al., 2012).

Having said that, *the contextual conditions "broad stakeholder participation" and "resource availability" were identified as key contextual conditions for interactions to be productive and for the achievement of the outputs, outcomes and potential societal impacts (or for increasing the chance of them).* The importance of these conditions was also claimed by researchers who participated in the validation activity, where most of them agreed that "bringing together different needs and views from the relevant stakeholders involved contributes to productive interactions" and that "facilitating the translation of information (from technical to simple language) and mutual understanding contributes to productive interactions". Thus, it might be argued that these conditions are more important than the two others ("problem definition" and

"roles and contribution") in leading productive interactions and contributing to the achievement of outputs, outcomes and potential societal impacts. However, although the contextual condition "broad stakeholder participation" and "resource availability" were properly met in the Swedish case, interactions in this case were not highly productive and they did not lead to the achievement of potential societal impacts. Furthermore, the condition "problem definition" was not met in Swedish case, which hampered productive interactions. In that sense, the contextual condition "problem definition" seemed to be also important for the productivity of the interactions and contribution to the achievement of potential societal impacts. In this respect, Hegger and Dieperink (2014) conducted a comparative analysis to identify successful conditions for joint knowledge production (JKP), in which the conditions of "broad possible actor coalition" and "presence of specific resources" were identified as essential. The authors argued that these conditions can be expected to enable and constrain the extent to which the other conditions can be met, which makes these conditions the "main leverage points for setting up successful joint knowledge production" (p.12). Taking into account the results of this thesis, despite "broad stakeholder participation" and "resource availability" being properly met, the contextual condition "problem definition" was not met in all cases, which shed light on the that the former conditions do not play the role of "leverage points" for productive interactions. However, following a similar approach of Hegger and Dieperink (2014), *certain linkages and interdependencies among the contextual conditions were identified*, which are described below.

It would seem that *for the contextual conditions "broad stakeholder participation", "problem definition", and "roles and contribution" to be met, the contextual condition "resource availability" should be in place*, since resources such as boundary objects; physical infrastructure; and actors' competencies, facilitate both the engagement of broad stakeholder participation, the mediation of a shared problem definition and the clear communication and fulfilment of roles and the expected results.

In this line of ideas, *the contextual condition "broad stakeholder participation" needs to be met first for the contextual condition "problem definition" to be met.* This is because it would not be possible to build a common understanding of the problem or goal grounded on different perspectives without bringing together all relevant stakeholders and their different needs and views. Furthermore, "resource availability", such as boundary objects and competencies of researchers for engaging and moderating stakeholder participation, becomes key for the contextual condition "problem definition" to be met. This rationale is coherent with the line of

ideas proposed by Hegger et al. (2012), who stated that once stakeholders are brought together, the problem definition does not come automatically, but it requires a process to manage the expectations and reconciliation of perspectives.

Similarly, meeting the contextual condition "resource availability" allowed to explain clearly roles and expected results, which created trust and confidence in the process and, consequently, stimulated productive interactions. In this sense, the results, together with the validation activity, confirmed that clarity about the role of researchers and their contribution leads to CLS knowledge by enhancing stakeholders' trust in researchers, as was suggested by Hegger et al. (2012). Additionally, it could be observed that a shared problem definition should make the fulfilment of the roles (contextual condition "roles and contribution") easier. In this sense, if there is no common definition and understanding of the issue or goal, it could be hard to advance in a coordinated way towards the same direction because there is no common direction.

Having said that, it can be argued that *contextual conditions, "broad stakeholder participation" and "resource availability", may be considered* necessary *for other contextual conditions can be met and together stimulate productive interactions*. Furthermore, it is worth noting that all researchers who participated in the validation activity agreed to some extent that the process of stakeholder engagement is key for Nexus projects to achieve societal impacts (Appendix E, section 8.5). This can confirm the idea of understanding "broad stakeholder participation" and "resource availability" as necessary conditions, since *without stakeholders and resources, no stakeholder engagement can be done,* and following that rationale, no other conditions could be met, hampering productive interaction and the achievement of societal impacts (or the chance for potential societal impacts).

Finally, despite having a good representation of the actors involved in each case, the lack of civil society as a stakeholder was noticed in both cases, which makes it interesting to reflect on civil society participation. As identified in the results, it is important to include civil society to promote the societal impacts of projects but also prepare them to participate. This is aligned with Driessen and Vermeulen (1993, as cited in Hegger et al., 2012) who stated that "actors need to be prepared to participate" (p. 56). In addition, the European Junior Water Programme (EJWP) (2023) recommends that Nexus projects work on the ground, involving local communities. This was also confirmed by participants in the validation activity, where most

Nexus researchers, to some extent, agreed that civil society should be involved in Nexus projects to improve productive interactions and increase the chance for societal impacts. *Therefore, it could be suggested that future transdisciplinary projects consider analysis for including civil society and prepare them in order to broaden stakeholder participation and stimulate productive interactions.*

5.4.2 Further reflections on contextual condition "problem definition"

The research findings confirmed the importance of involving stakeholders' needs for interactions to be productive and contribute to the achievement of outputs, outcomes, and the achievement or chance for societal impacts. *The results also shed light on administrative barriers (e.g., time constraints and research funding requirements) that sometimes could hamper the participation of stakeholders in the early stage of the research design.* In this respect, Talwar et al. (2011) suggested there is a paradox in which there is consensus about the objective of sustainability research, which leads to significant contributions to sustainable transitions through a user engagement approach, but there is a lack of recognition of the new requirements, standards and needed structures to implement it (e.g., the inclusion of stakeholders in the research design stage is not completely recognised). In this line, in the NexusNet Regional Stakeholders Forum carried out in Malta, researchers suggested that research funding should provide the needed time or be more flexible and open to the stakeholders' needs can be considered in the project (Laborgne, 2024). This is with the objective of obtaining practical solutions that stakeholders really need and not providing them with solutions or tools that stakeholders do not need and will not use (Kandarakis, 2024), which was the case in the Swedish case of SIM4NEXUS.

Based on the results of the validation activity, participants agreed (average agreement score of 4.4 over 5) that stakeholders should be involved from the beginning of the project so that they can contribute to the definition of the goal. Similarly, participants agreed (average agreement score of 4.2 over 5) that considering stakeholders' perspectives in defining the problem or goal contributes to productive interactions. The level of agreement regarding the importance of consideration of stakeholders' needs when defining project objectives or goals to produce socially relevant knowledge was lower (3.7 over 5). It is worth noticing that although 22% of the participants were neutral, the majority (67%) still agreed on that last statement (see the specific percentage in Appendix E, section 8.5). *Even though this confirms an agreement that*

stakeholders should be included from the beginning, it could reflect a lack of consensus on the importance of this, in terms of whether it influences the achievement of societal impact. In this respect, Maasen & Weingart (2005, as cited in Frijns & Bouziotas, 2023) and Talwar et al. (2011) suggested that the importance of ensuring that all stakeholder's perspectives and their needs are taken into account in the early phases has been underestimated. *Thus, this could explain the results mentioned above and why the contextual condition "problem definition" was not met in Sweden. The underestimation of the importance of ensuring that all stakeholders' perspectives and their needs are taken into account in the early phases may continue if there is still a neutral opinion about this.*

5.5 Productive interactions and societal impacts in transdisciplinary research

Based on the results, it can be argued that productive interactions lead to a great extent to societal impacts (or the chance for) on transdisciplinary research. In other words, the productivity of the interactions among researchers and stakeholders led to the utilisation of the knowledge produced to fulfil societal goals. *Thus, productive interactions contributed to closing the gap between the knowledge demanded and the knowledge supplied*. Nexus researchers who participated in the validation activity also confirmed this since most of them, to some extent, agreed that utilisation of the knowledge produced by productive interactions leads to societal impacts. Therefore, the research findings are aligned with NWO (2020), which alludes to the utilisation of knowledge as a process towards societal impacts (p.2). Similarly, the results are coherent with Belcher et al. (2020) and Munaretto et al. (2022, as cited in Andrews et al., 2024), who suggested that the knowledge used might lead to different outcomes, which, in turn, lead to impacts.

Productive interactions (through the exchanges among researchers and stakeholders that generate scientifically robust and socially relevant knowledge) might be considered needed to bridge the science-policy gap. In this sense, *this research could contribute to the science-policy interactions literature by suggesting that when contextual conditions such as "broad stakeholder participation," "problem definition," "roles and contribution," and "resource availability" are met, productive interactions can contribute to solving the science-policy interactions problems*.

On the other hand, *it could offer the literature on the societal impact of transdisciplinary research a basis for a framework based on the productive interactions approach, complemented by the concepts of the theory of change and the four contextual conditions utilised (and their indicators) to assess the process of achievement of societal impact by analysing interactions.* Furthermore, *this framework could shed light on how future transdisciplinary projects should be designed to ensure that contextual conditions are met and, with this, steer interactions and ensure that productive interactions emerge among researchers and stakeholders*. This could, in turn, *contribute to the achievement of outputs and outcomes for improving the impact delivery and, lately, to the creation of changes required to contribute to solutions to sustainable challenges, leading to the achievement of the SDGs.*

Specifically, the research results might contribute to making more impactful transdisciplinary research that uses the Nexus approach. According to Ramos et al. (2022, as cited in EJWP, 2023), there is a lack of procedures for identifying and assessing the impacts of Nexus projects due to there being no clear indicators of the success and positive impact of these projects. In this context, *contextual conditions used in this research together with their indicators, could serve as a basis for a framework for assessing Nexus projects or as a basis for a framework to guide the design of impactful Nexus projects.* This might stimulate productive interactions, promoting cross-sector coordination and collaboration. In this respect, Weiz et al. (2017) claimed that the Nexus approach promotes policy coherence across the nexus sectors (water, energy, food, etc.), but Nexus literature lacks a clear explanation of how to achieve the required coherence. Thus, *the framework used in this research could contribute to solving the issue of policy coherence by steering productive cross-sector interactions.*

6 Chapter 6: Conclusion

6.1 Introduction

This chapter provides the answer to the research question, recommendations derived from the results, and the limitations of this research. Section 6.2 includes a summary of what was done, the answer to the research question and insights about the potential contribution of this answer. Section 6.3 provides recommendations for improving societal impacts in transdisciplinary research, followed by the section 6.4 which describes the limitations of this research, as well as further suggestions for future studies.

6.2 Overall conclusion

The objective of this thesis was to increase the understanding of how productive interactions contribute to the achievement of societal impacts of transdisciplinary research by analysing productive interactions throughout outputs and outcomes in Nexus projects. Thus, this research was steered by the question: **To what extent do Nexus projects achieve expected outputs, outcomes, and societal impacts through productive interactions, and what are their leading contextual conditions?** The analysis of productive interactions used elements from the theory of change (outputs, outcomes and impacts) to facilitate the understanding of the process of changes that lead to potential societal impacts and included an analysis of contextual conditions under which productive interactions emerged. A multiple-case study of two Nexus projects was conducted to develop this analysis. The case study was mainly conducted through semi-structured interviews with stakeholders and researchers who participated in those projects. Interviews provided a comprehensive understanding of the productive interactions and the contextual conditions that stimulated or hampered these productive interactions in each project. The data collected from interviews was complemented by data from deliverables and final reports of each project. The information obtained in each case was compared to each other and validated by Nexus expert researchers. The results were discussed and linked to the literature, allowing to reflect on them and their applicability for further studies.

The research showed that Nexus projects can achieve outputs, outcomes, and (the chance for) societal impacts to a great extent through productive interactions that emerge under four contextual conditions: “broad stakeholder participation”, “problem definition”, “roles and

contribution" and "resource availability". When these contextual conditions are met, productive interactions are stimulated, leading to the production of scientifically robust and socially relevant knowledge. This knowledge, given its characteristics (credible, salient and legitimate knowledge), can be used to create the changes needed to fulfil societal goals and create societal impacts. Thus, productive interactions contribute to achieving societal impacts through an active process, which entails a chain of changes (outputs and outcomes) that, in turn, implies exchanges among researchers and stakeholders and the utilization of the knowledge produced by those exchanges.

To achieve societal impacts in transdisciplinary research such as Nexus projects, efforts should be aimed at meeting the contextual conditions of "broad stakeholder participation" and "resource availability" so that the other conditions ("problem definition" and "roles and contribution") can be met more easily and the 4 contextual condition together stimulate productive interactions. However, it can be derived from this research that the influence of defining the problem (or goals) based on the stakeholders' needs regarding the achievement of societal impacts is, in some cases, still underestimated. This could trigger administrative barriers that hinder the incorporation of stakeholders' needs from the beginning. Therefore, effort should be also aimed at considering stakeholders' needs when defining the goals of the project as much as possible. By meeting all contextual conditions, different perspectives would be present; knowledge exchange would be transferred properly; the defined goals would meet the stakeholders' needs; and trust and confidence in the process of participation would be promoted, leading to the achievement of (or increasing the chance for) societal impacts.

Additionally, this empirical research contributed to overcoming the limitations of the traditional framework of productive interactions to analyse societal impacts in research. Thus, this study could offer to the current literature on the societal impact assessment of transdisciplinary research a framework inspired by the productive interactions approach but complemented by the theory of change and contextual conditions. In this manner, as demonstrated by this research, it is possible to understand the process of change that leads to impact and uncover the conditions that lead to productive interactions and societal impact.

Finally, the framework used in this research to analyse productive interactions in transdisciplinary research can be used for enhancing the design of impactful transdisciplinary research by promoting productive interactions. Enhancing the design of impactful

transdisciplinary research contributes to solving issues related to scientific-policy interactions since an impactful transdisciplinary project should supply the required knowledge to solve sustainability challenges that society is facing nowadays. Lastly, an impactful transdisciplinary project could contribute to policy coherence across sectors, which is essential to face the complex and interrelated sustainability challenges.

6.3 Recommendations for improving societal impacts of transdisciplinary research

This section provides recommendations derived from this research and existing literature that might help to guide the design of future transdisciplinary research, thereby ensuring that contextual conditions are met and productive interactions emerge among researchers and stakeholders. This, in turn, may contribute to achieving outputs and outcomes and, lately, improve the impact delivery of transdisciplinary research.

- It is suggested that a stakeholder analysis and mapping be done to include all relevant stakeholders before starting the project. It is suggested that civil society be included whenever relevant and that they be prepared in advance for effective participation.
- It is recommended that relevant stakeholders be involved from the beginning of the project and that the project's goals meet their needs.
- It is suggested that in addition to achieving a common goal, stakeholders can share a joint vision for the future, and share the vision on how to implement the proposed solutions.
- A clear explanation of the roles of researchers and stakeholders and the purpose of the expected results should be provided. This contributes to creating trust and confidence in the process. It is essential that stakeholders understand that what they are doing is not only for research purposes but also to fulfil societal goals that cover their needs.
- It is highly recommended that an expert on stakeholder engagement leads stakeholder interactions. Otherwise, it is suggested that a guide on carrying out a proper stakeholder engagement process be provided to researchers who must play the moderator role throughout their interactions with stakeholders. This guide should include different methods for moderation and stakeholder engagement.
- To promote trust in the relationship between researchers and stakeholders, comfortable physical space for in-person meetings may be considered. Additionally, virtual space may be offered to facilitate the participation of those who could not attend in person due to time

and economic constraints (e.g., long-distance travel). Moreover, online meetings could offer more agile follow-up of the project implementation. Therefore, it is suggested that facilities for in-person meetings and virtual space for online meetings be considered.

- It is suggested that boundary objects, such as concepts, site visits, computer tools, etc., be used to facilitate information transfer and mutual understanding among researchers and stakeholders.
- It is recommended that the best way to include financial support, such as an incentive for stakeholders' participation, is analysed without creating bias or conflicts of interest. One alternative could be to make key stakeholders partners in the project.
- Resources for the afterlife are important for disseminating and promoting the results after the project finishes to prevent the information produced from disappearing. It is suggested that the relevance of afterlife resources be further analysed to be included in transdisciplinary projects.

6.4 Limitations and further recommendations for future research

This research was not exempt from limitations. Regarding the interviews' limitations, it is worth noting that there was a language barrier. The cases of the projects studied were implemented in Latvia, Sweden, Athens and Costa Brava. Although the researchers speak English, not all stakeholders speak English, which generated a selection bias regarding the interviewees' selection. Thus, interviewees were not randomly selected; only interviewees who spoke English (or Spanish in the case of Costa Brava, NextGen) were interviewed.

Despite several efforts to contact stakeholders from Athens (NextGen), only one person was available to participate. The lack of information on this case from stakeholders was compensated by the CoP evaluation results (a survey applied to stakeholders who participated in NextGen CoPs, only data from Athens and Costa Brava). Furthermore, one more person from Costa Brava was interviewed to obtain at least four interviews with stakeholders in the NextGen project.

During the interviews, ambiguity about the understanding of the terms output, outcome, and impact among the interviewees was noticed, as they had different understandings of each concept. Despite explaining the definition of these concepts, misunderstandings occurred in the first interview. This issue was solved by using only the definitions during the following

interviews, without mentioning the concepts of outputs, outcomes and societal impacts, which allowed us to collect the right information. Under the same rationale, the interview for stakeholders was modified in order to be easily understood by people who are not experts on research concepts.

Because the SIM4NEXUS project started in 2016 and finished in 2020, some interviewees did not remember all the information and details of the case in which they participated. Therefore, for further research, it could be suggested to add the start date (not only the ending date, as in this case) as a criterion for case selection to avoid memory issues that can affect the reliability of the information to be collected.

Regarding the sample size limitations, this research studied two European Nexus projects, which could not represent all Nexus projects. In order to overcome this limitation, the results of this research were presented to other Nexus expert researchers to obtain external validity. Although a brief context and key concepts of the research were presented before the validation activity (and definitions were visible during the activity), there was no time to discuss with researchers the questions they were asked to answer due to the time constraints. Therefore, answers could contain bias because some questions could have been misunderstood. It is worth noting that around 17 Nexus expert researchers participated in this validation activity. Therefore, it is necessary to be cautious when generalising the results. Additionally, most of the Nexus researchers who participated in this validation are part of a European network of researchers, and most of their experience is in Europe. Therefore, the validity of the results should be considered for European projects.

Lastly, based on the research findings, further research in the field of productive interaction in the context of the societal impacts of transdisciplinary research could analyse economic resources as a stimulating condition for productive interactions to achieve societal impact. This could focus on properly implementing financial incentives for stakeholder participation to prevent bias and conflicts of interest. Likewise, further research could analyse how a “joint vision for the future” influences productive interactions among researchers and stakeholders. Finally, it could address the influence of the project's afterlife and how to implement this element to enhance the societal impact of research.

7 References

Albrecht, T. R., Crootof, A., & Scott, C. A. (2018). The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. *Environmental Research Letters*, *13*(4), 1–26. https://doi.org/10.1088/1748-9326/aaa9c6

Andreu, A., Fernandez, E., Latorre, R., & Parra, R. (2021). Proyecto H2020NEXTGEN: Hacia una próxima generación de sistemas y servicios de agua para la economía circular. *Idi Agua*, *3*, 1–79. http://eprints.imdea-agua.org:13000/1312/1/RevistaIDIAGUA21.pdf

Andrews, L. M., Munaretto, S., Mees, H., & Driessen, P. (2024). Conceptualising boundary work activities to enhance credible, salient and legitimate knowledge in sustainability transdisciplinary research projects. *Environmental Science & Policy*, *155*, 1–12. https://doi.org/10.1016/j.envsci.2024.103722

Annemans, M., & Heylighen, A. (2020). Productive interactions to exchange knowledge in healthcare building design. *Building Research and Information*, *49*(3), 281–293. https://doi.org/10.1080/09613218.2020.1749822

Arts, B. J. M., Leroy, P., & van Tatenhove, J. P. M. (2006). Political Modernisation and Policy Arrangements: A Framework for Understanding Environmental Policy Change. *Public Organization Review: a Global Journal*, *6*(2), 93–106. https://doi.org/10.1007/s11115-006-0001-4

Avellán, T., Hahn, A., Kirschke, S., Müller, A., Benavides, L., & Caucci, S. (2022). Co-Generating knowledge in Nexus Research for sustainable wastewater treatment. *Resources*, *11*(10), 1–25. https://doi.org/10.3390/resources11100093

Belcher, B., Davel, R., & Claus, R. (2020). A refined method for theory-based evaluation of the societal impacts of research. *MethodsX*, *7*, 1–20. https://doi.org/10.1016/j.mex.2020.100788

Belcher, B., & Halliwell, J. (2021). Conceptualizing the elements of research impact: towards semantic standards. *Humanities and Social Sciences Communications*, *8*(183), 1–6. https://doi.org/10.1057/s41599-021-00854-2

Belcher, B., & Hughes, K. (2020). Understanding and evaluating the impact of integrated problem-oriented research programmes: Concepts and considerations. *Research Evaluation*, *30*(2), 154–168. https://doi.org/10.1093/reseval/rvaa024

Belcher, B., Rasmussen, K. E., Kemshaw, M., & Zornes, D. (2015). Defining and assessing research quality in a transdisciplinary context. *Research Evaluation*, *25*(1), 1–17. https://doi.org/10.1093/reseval/rvv025

Bremere, I., & Indriksone, D. (n.d.). *Biomass and sustainable land-use in Latvia* [Brochure]. SIM4NEXUS. https://sim4nexus.eu/userfiles/Sim4nexus_brochure_Latvia.pdf

Brouwer, F. & Fournier, M. (n.d.). *Case studies and stakeholder engagement* [Brochure]. SIM4NEXUS. https://sim4nexus.eu/userfiles/Sim4nexus_brochre_CS_stakeholder.pdf

Brouwer, F. & Fournier, M. (2017). *The main Nexus challenges in 12 case studies (Deliverable D5.2)*. SIM4NEXUS. https://sim4nexus.eu/userfiles/Deliverables/Deliverable%20D5.2.pdf

Brouwer, F. & Fournier, M. (2020). *Outcome of task 5.2 Supporting decision making in 12 case studies (Deliverable D5.5)*. SIM4NEXUS. https://sim4nexus.eu/userfiles/Deliverable_D5.5.pdf

Brouwer, F., Vamvakeridou-Lyroudia, L., Alexandri, E., Brēmere, I., Griffey, M., & Linderhof, V. (2018). The Nexus Concept Integrating Energy and Resource Efficiency for Policy Assessments: A Comparative Approach from Three Cases. *Sustainability*, *10*(12), 1–18. https://doi.org/10.3390/su10124860

Burnham, P., Gilland-Lutz, K, Grant, W., Layton-Henry, Z., (2008). Comparative Methods. In P. Burnham, K. Gilland-Lutz, W. Grant, & Z. Layton-Henry (Eds.), *Research Methods in Politics (pp.* 69–95). Houndmills Palgrave Macmillan.

Cash, D. W., Clark, W., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(14), 1–6. https://doi.org/10.1073/pnas.1231332100

Cash, D. W., Clark, W., Alcock, F., Dickson, N. M., Eckley, N., & Jäger, J. (2002). Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. *RePEc: Research Papers in Economics*. 1–23. https://EconPapers.repec.org/RePEc:ecl:harjfk:rwp02-046

Corbin, J., & Strauss, A. L. (1990). Grounded Theory Research: Procedures, Canons and Evaluative Criteria. *Zeitschrift Fur Soziologie*, *19*(6), 418–427. https://doi.org/10.1515/zfsoz-1990-0602

De Jong, S., Balaban, C., & Nedeva, M. (2022). From 'productive interactions' to 'enabling conditions': The role of organizations in generating societal impact of academic research. *Science and Public Policy*, *49*(4), 643–645. https://doi.org/10.1093/scipol/scac015

De Jong, S., Barker, K., Cox, D., Sveinsdottir, T., & Van Den Besselaar, P. (2014). Understanding societal impact through productive interactions: ICT research as a case. *Research Evaluation*, *23*(2), 89–102. https://doi.org/10.1093/reseval/rvu001

DIVA-GIS. (n.d.). *Country-level shapefile data* [Data set]. https://diva-gis.org/

Díaz-Mariño, B. L. D., Rico, F. C. C., Hernández, R. V. R., De León, J. a. R., & González-Bandala, D. A. (2021). Towards the construction of productive interactions for social impact. *Sustainability*, *13*(2), 1–20. https://doi.org/10.3390/su13020485

Douthwaite, B., Kuby, T., Van De Fliert, E., & Schulz, S. (2003). Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. *Agricultural Systems*, *78*(2), 243–265. https://doi.org/10.1016/s0308-521x(03)00128-8

Endo, A., Tsurita, I., Burnett, K., & Orencio, P. M. (2017). A review of the current state of research on the water, energy, and food nexus. *Journal of Hydrology: Regional Studies*, *11*, 20–30. https://doi.org/10.1016/j.ejrh.2015.11.010

Endo, A., Yamada, M., Miyashita, Y., Sugimoto, R., Ishii, A., Nishijima, J., Fujii, M., Kato, T., Hamamoto, H., Kimura, M., Kumazawa, T., & Qi, J. (2020). Dynamics of water–energy–food nexus methodology, methods, and tools. *Current Opinion in Environmental Science & Health*, *13*, 46–60. https://doi.org/10.1016/j.coesh.2019.10.004

Estoque, R. C. (2023). Complexity and diversity of nexuses: A review of the nexus approach in the sustainability context. *Science of the Total Environment*, *854*, 1–12. https://doi.org/10.1016/j.scitotenv.2022.158612

European Junior Water Programme (EJWP). (2023). *Towards an impactful Nexus project – a pilot survey & recommendations for practitioners*. https://www.academia.edu/103672747/Towards_an_Impactful_NEXUS_Project_a_pilot_survey_and_recommendations_for_practitioners

Frijns, J., & Bouziotas, D. (2023). *D3.5 CoP's cross-fertilisation report (Deliverable D3.5).* NextGen. https://nextgenwater.eu/wp-content/uploads/2023/03/D3.5-CoPs-cross-fertilisation-report.pdf

Fulgenzi, A., Brouwer, S., Baker, K., & Frijns, J. (2020). Communities of practice at the center of circular water solutions. *WIREs. Water*, *7*(4), 1-15. https://doi.org/10.1002/wat2.1450

Gerring, J. (2004). What Is a Case Study and What Is It Good for?. *The American Political Science Review*, *98*(2), 341–354. https://www-jstor-org.proxy.library.uu.nl/stable/pdf/4145316.pdf?refreqid=fastly-default%3A9c587b848877497bafdc4824c7e9aaa6&ab_segments=&origin=&initiator=&acceptTC=1

Grant Agreement No. 689150. (2016). *Sustainable Integrated Management for the NEXUS of water-land-food-energy-climate for a resource-efficient Europe (SIM4NEXUS)* (Amendment Reference No AMD-689150-10)

Grant Agreement No. 776541. (2018). *NexGen: Annex 1 (Part A). Innovation action*. *Towards a next generation of water systems and services for the circular economy.*

Hansson, S., & Polk, M. (2018). Assessing the impact of transdisciplinary research: The usefulness of relevance, credibility, and legitimacy for understanding the link between process and impact. *Research Evaluation*, *27*(2), 132–144. https://doi.org/10.1093/reseval/rvy004

Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012). Conceptualizing joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. *Environmental Science & Policy*, *18*, 52–65. https://doi.org/10.1016/j.envsci.2012.01.002

Hegger, D., & Dieperink, C. (2014). Toward successful joint knowledge production for climate change adaptation: lessons from six regional projects in the Netherlands. *Ecology and Society*, *19*(2), 1–15. https://doi.org/10.5751/es-06453-190234

Hoff, H. (2011). *Understanding the Nexus. Background Paper for the Bonn2011 Nexus Conference: The Water, Energy and Food Security Nexus*. Stockholm Environment Institute. https://mediamanager.sei.org/documents/Publications/SEI-Paper-Hoff-UnderstandingTheNexus-2011.pdf

IPCC. (2015*). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* https://archive.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Jacobi, J., Llanque, A., Mukhovi, S., Birachi, E. A., Von Groote, P., Eschen, R., Hilber-Schöb, I., Kiba, D. I., Frossard, E., & Robledo-Abad, C. (2022). Transdisciplinary co-creation increases the utilization of knowledge from sustainable development research. *Environmental Science & Policy*, *129*, 107–115. https://doi.org/10.1016/j.envsci.2021.12.017

Jähn, T., Bergmann, M., & Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. *Ecological Economics*, *79*, 1–10. https://doi.org/10.1016/j.ecolecon.2012.04.017

Joly, P., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., & Matt, M. (2015). ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. *Research Evaluation*, *24*(4), 440–453. https://doi.org/10.1093/reseval/rvv015

Kalliomaki, H., Ruoppila, S., Airaksinen, J. (2021). It takes two to tango: Examining productive interactions in urban research collaboration. *Research Evaluation*, *30*(4), 529-539. https://doi.org/10.1093/reseval/rvab028

Kandarakis, A. (2024). *Stakeholder engagement in Nexus projects: good practices and lessons learned* [Forum session] NexusNet Regional Stakeholders Forum on "Resource Recovery and Reuse in the Water-Energy-Food Nexus for a Low-Carbon Economy". Rabat, Malta.

KWB, UBATH & EURECAT (2020). *Assessment of baseline conditions for all case studies (Deliverable D.1.1)*. NextGen. https://nextgenwater.eu/wp-content/uploads/2020/10/D1.1-Assessment-of-baseline-conditions_revised.pdf

Laborgne, P. (2024, May 14). *Stakeholder engagement in Nexus projects: good practices and lessons learned* [Forum session] NexusNet Regional Stakeholders Forum on "Resource Recovery and Reuse in the Water-Energy-Food Nexus for a Low-Carbon Economy". Rabat, Malta.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, *7*, 25–43. https://doi.org/10.1007/s11625-011-0149-x

Lemos, M. C., Kirchhoff, C., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, *2*, 789–794. https://doi.org/10.1038/nclimate1614

Liefferink, D. (2006). The Dynamics of Policy Arrangements: Turning Round the Tetrahedron. In: Arts, B., Leroy, P. (eds) *Institutional Dynamics in Environmental Governance* (pp. 45–68). Springer. https://doi.org/10.1007/1-4020-5079-8_3

Liu, J., Hull, V., Godfray, H. C. J., Tilman, D., Gleick, P. H., Hoff, H., Pahl–Wostl, C., Xu, Z., Chung, M. G., Sun, J., & Li, S. (2018). Nexus approaches to global sustainable development. *Nature Sustainability*, *1*(9), 466–476. https://doi.org/10.1038/s41893-018-0135-8

Liu, J., Dietz, T., Carpenter, S. R., Taylor, W. W., Alberti, M., Deadman, P., Redman, C. L., Pell, A. N., Folke, C., Ouyang, Z., & Lubchenco, J. (2021). Coupled human and natural systems: The evolution and applications of an integrated framework. *AMBIO: A Journal of the Human Environment*, *50*, 1778–1783. https://doi.org/10.1007/s13280-020-01488-5

Macleod, C., Blackstock, K., & Haygarth, P. M. (2008). Mechanisms to improve Integrative Research at the Science-Policy Interface for Sustainable Catchment Management. *Ecology and Society*, *13*(2), 1–17. https://doi.org/10.5751/es-02648-130248

Matt, M., Gaunand, A., Joly, P., & Colinet, L. (2017). Opening the black box of impact – Ideal-type impact pathways in a public agricultural research organization. *Research Policy*, *46*(1), 207–218. https://doi.org/10.1016/j.respol.2016.09.016

Molas-Gallart, J., & Tang, P. (2011). Tracing "productive interactions" to identify social impacts: an example from the social sciences. *Research Evaluation*, *20*(3), 219–226. https://doi.org/10.3152/095820211x12941371876706

Muhonen, R., Benneworth, P. S., & Olmos-Peñuela, J. (2018). From productive interactions to impact pathways: Understanding the key dimensions in developing SSH research societal impact. *Research Evaluation, (29)*1, 34–47. https://doi.org/10.1093/reseval/rvz003

Munaretto, S., Mooren, C., & Hessels, L. K. (2022). Valorization of transdisciplinary research: An evaluation approach and empirical illustration. *Research Evaluation*, *31*(3), 355–371. https://doi.org/10.1093/reseval/rvac019

Natural Earth. (n.d.). *Cultural vectors country boundaries* [Data set]. https://www.naturalearthdata.com/

NextGen. (n.d.a). *Welcome to the next generation of managing our most important resource.* NextGen. https://nextgenwater.eu/about/

NextGen. (n.d.b). *Athens, Greece.* NextGen. https://nextgenwater.eu/demonstration-cases/athens/

NextGen. (n.d.c). *Costa Brava Region, Spain.* NextGen. https://nextgenwater.eu/demonstration-cases/costa-brava-region/

NextGen. (2022). *CoP Meeting Evaluation Form* [Unpublished raw data]. KWR.

NWO. (n.d.). *Theory – Societal impact and the route to it*. NWO. https://impact.nwo.nl/en/working-with-an-impact-plan/theory-societal-impact-and-the-route-to-it

NWO. (2020). *Societal Impact through Knowledge Utilisation*. Dutch Research Council. NWO. https://www.nwo.nl/sites/nwo/files/documents/Leaflet%20Knowledge%20Utilisation%20-%20web.pdf

Olmos-Peñuela, J., Molas-Gallart, J., & Castro-Martínez, E. (2014). Informal collaborations between social sciences and humanities researchers and non-academic partners. *Science and Public Policy*, *41*(4), 493–506. https://doi.org/10.1093/scipol/sct075

Papadopoulou, C.A., Papadopoulou, M., Laspidou, C., Albin, X.D., Fournier, M., Pereira, E., Brouwer, F. (2020). *Use cases for SIM4NEXUS case studies (Deliverable D1.6)*. https://sim4nexus.eu/userfiles/Deliverables/Deliverable_D1.6.pdf

Plana-Puig, Q., Casas, S., Zhiteneva, V., Frijns, J,. Nanu, C., (2022). *New approaches and best practices for closing the water cycle (Deliverable D.1.3)*. NextGen. https://nextgenwater.eu/wp-content/uploads/2023/03/D1.3-New-approaches-and-best-practices-for-closing-the-water-cycle.pdf

Plevri, A., Lytras, E., Samios, S., Lioumis, C., Monokrousou, K., & Makropoulos, C. (2020). Sewer Mining as A Basis for Technological, Business and Governance Solutions for Water in the Circular Economy: The NextGen Athens Demo. *Environmental Science Proceedings*, *2*(1), 1–7. https://doi.org/10.3390/environsciproc2020002054

Plevri, A., Monokrousou, K., Makropoulos, C., Lioumis, C., Tazes, N., Lytras, E., Samios, S., Katsouras, G., & Tsalas, N. (2021). Sewer mining as a distributed intervention for Water-Energy-Materials in the circular economy suitable for dense urban environments: a real world demonstration in the city of Athens. *Water*, *13*(19), 1–15. https://doi.org/10.3390/w13192764

Pohl, C., Klein, J. T., Hoffmann, S., Mitchell, C., & Fam, D. (2021). Conceptualising transdisciplinary integration as a multidimensional interactive process. *Environmental Science & Policy*, *118*, 18–26. https://doi.org/10.1016/j.envsci.2020.12.005

Sarkki, S., Niemelä, J., Tinch, R., Van den Hove, S., Watt, A., Young, J. (2013). Balancing credibility, relevance and legitimacy: A critical assessment of trade-offs in science–policy interfaces. *Science and Public Policy, 41*(2), 194–206. https://doi-org.proxy.library.uu.nl/10.1093/scipol/sct046

Schneider, F., & Büser, T. (2017). Promising degrees of stakeholder interaction in research for sustainable development. *Sustainability Science, 13*, 129–142. https://doi.org/10.1007/s11625-017-0507-4

Schneider, F., Büser, T., Keller, R., Tribaldos, T., & Rist, S. (2019). Research funding programmes aiming for societal transformations: Ten key stages. *Science & Public Policy*, *46*(3), 463–478. https://doi.org/10.1093/scipol/scy074

Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., Schmid, L., Tribaldos, T., & Zimmermann, A. (2019). Transdisciplinary co-production of knowledge and sustainability transformations: Three generic mechanisms of impact generation. *Environmental Science & Policy*, *102*, 26–35. https://doi.org/10.1016/j.envsci.2019.08.017

Scholz, R., & Steiner, G. (2015a). The real type and ideal type of transdisciplinary processes: part I—theoretical foundations. *Sustainability Science*, *10*, 527–544. https://doi.org/10.1007/s11625-015-0326-4

Scholz, R., & Steiner, G. (2015b). The real type and ideal type of transdisciplinary processes: part II—what constraints and obstacles do we meet in practice? *Sustainability Science*, *10*, 653–671. https://doi.org/10.1007/s11625-015-0327-3

Scott, C. A., Pierce, S. A., Pasqualetti, M. J., Jones, A. L., Montz, B. E., & Hoover, J. (2011). Policy and institutional dimensions of the water–energy nexus. *Energy Policy*, *39*(10), 6622–6630. https://doi.org/10.1016/j.enpol.2011.08.013

Shannak, S., Mabrey, D., & Vittorio, M. (2018). Moving from theory to practice in the water–energy–food nexus: An evaluation of existing models and frameworks. *Water-Energy Nexus*, *1*(1), 17–25. https://doi.org/10.1016/j.wen.2018.04.001

Sivertsen, G., & Meijer, I. (2019). Normal versus extraordinary societal impact: how to understand, evaluate, and improve research activities in their relations to society? *Research Evaluation*, *29*(1), 66–70. https://doi.org/10.1093/reseval/rvz032

Spaapen, J., & Van Drooge, L. (2011a). *Social Impact Assessment Methods for research and funding instruments through the study of Productive Interactions between science and society (SIAMPI). Final report.* SIAMPI. http://www.siampi.eu/Content/SIAMPI/SIAMPI_Final%20report.pdf

Spaapen, J., & Van Drooge, L. (2011b). Introducing "productive interactions" in social impact assessment. *Research Evaluation*, *20*(3), 211–218. https://doi.org/10.3152/095820211x12941371876742

Sušnik, J., Masia, S., Indriksone, D., Brēmere, I., & Vamvakeridou-Lydroudia, L. (2021). System dynamics modelling to explore the impacts of policies on the water-energy-food-land-climate nexus in Latvia. *Science of the Total Environment*, *775*, 1–16. https://doi.org/10.1016/j.scitotenv.2021.145827

Talwar, S., Wiek, A., & Robinson, J. (2011). User engagement in sustainability research. *Science and Public Policy/Science & Public Policy*, *38*(5), 379–390. https://doi.org/10.3152/030234211x12960315267615

Teutschbein, C., & Blischarska, M. (n.d.). *Cross-sectoral collaboration in Sweden* [Brochure]. SIM4NEXUS. https://sim4nexus.eu/userfiles/Sim4nexus_brochure_Sweden.pdf

Teutschbein, C., & Blischarska, M. (2018). *Swedish case study: Policy Analysis.* SIM4NEXUS. https://www.waternature4future.com/wp-content/uploads/2020/05/WP2-T2.2_Policy-report_Sweden_FINAL.pdf

Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., & Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environmental Science & Policy*, *74*, 30–39. https://doi.org/10.1016/j.envsci.2017.04.006

Turnheim, B., Asquith, M., & Geels, F. W. (2020). Making sustainability transitions research policy-relevant: Challenges at the science-policy interface. *Environmental Innovation and Societal Transitions*, *34*, 116–120. https://doi.org/10.1016/j.eist.2019.12.009

Van Den Heuvel, L., Blicharska, M., Masia, S., Sušnik, J., & Teutschbein, C. (2020). Ecosystem services in the Swedish water-energy-food-land-climate nexus: Anthropogenic pressures and physical interactions. *Ecosystem Services*, *44*, 1–13. https://doi.org/10.1016/j.ecoser.2020.101141

Van Den Hove, S. (2007). A rationale for science–policy interfaces. *Futures*, *39*(7), 807–826. https://doi.org/10.1016/j.futures.2006.12.004

Van Enst, W., Driessen, P., & Runhaar, H. (2014). Towards productive science-policy interfaces: a research agenda. *Journal of Environmental Assessment Policy and Management*, *16*(1),1–25. https://doi.org/10.1142/s1464333214500070

Veisi, H., Jackson-Smith, D. B., & Arrueta, L. (2022). Alignment of stakeholder and scientist understandings and expectations in a participatory modeling project. *Environmental Science & Policy*, *134*, 57–66. https://doi.org/10.1016/j.envsci.2022.04.004

Verschuren, P., & Doorewaard, H. (2010). *Designing a research project* (2nd ed.). Eleven International Publishing.

Weitz, N., Strambo, C., Kemp-Benedict, E., & Nilsson, M. (2017). Closing the governance gaps in the water-energy-food nexus: Insights from integrative governance. *Global Environmental Change*, *45*, 165–173. https://doi.org/10.1016/j.gloenvcha.2017.06.006

WEF. (2011). *Water Security: The Water-Food-Energy-Climate Nexus*. World Economic Forum. https://www3.weforum.org/docs/WEF_WI_WaterSecurity_WaterFoodEnergyClimateNexus_2011.pdf

Wiek, A., Talwar, S., O'Shea, M., & Robinson, J. (2014). Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation, 23*(2), 117–132. https://doi.org/10.1093/reseval/rvt031

Yin, R. K. (2003). *Case Study Research: Design and Methods* (3rd ed.). Sage Publications.

Yung, L., Louder, E., Gallagher, L., Jones, K., & Wyborn, C. (2019). How methods for navigating uncertainty connect science and policy at the Water-Energy-Food Nexus. *Frontiers in Environmental Science, 7*(37), 1–17. https://doi.org/10.3389/fenvs.2019.00037

8 Appendices

8.1 Appendix A – Guide for interviews

Interview

Analysing productive interactions to explain societal impacts in transdisciplinary research - Case study analysis of European Nexus projects

I. GENERAL QUESTIONS

1. What was the main goal/ objective of the project/CS?

2. What was your role in the project/CS?

II. OUTPUT, OUTCOMES, AND IMPACTS

3. What were the direct results or insights (outputs) obtained from the project/CS?

4. What were the changes in behaviour (knowledge, attitudes, skills), relationships, activities and actions as a result of the project/CS?

5. Was there knowledge and/or expertise generated by the project/CS?
   5.a Were there cultural, economic, industrial, ecological or social changes produced, entirely or in part, as a consequence of this knowledge generated? Could explain it?

III. PRODUCTIVE INTERACTIONS (PER OUTPUT/OUTCOME/IMPACT)

6. What type of interactions between researchers and stakeholders occurred throughout the project/CS?

7. How did the interactions we have discussed in this conversation influence the outputs and/or outcomes that you mentioned previously?

IV. CONTEXTUAL CONDITIONS

Condition: Broad stakeholder participation

8. What type of stakeholders (civil society, governments, NGOs, industry, other) participated in the project/CS? (Who?)

9. To what extent was the stakeholder selection representative?

10. To what extent did the project/CS include all relevant expertise and experience to tackle the problem or goal?

11. How did the broadness of the actor participation influence the interactions and the achievement of societal impacts (future/potential societal impacts)?

Condition: Problem definition

12. To what extent researchers and stakeholders were encouraged to understand the viewpoints and interests of others to achieve a common problem definition?

13. To what extent were those different interests recognized and considered by other participants?

14. How were disagreements and conflicts mapped and dealt with?

15. Did the researchers and stakeholders reach a common understanding of the problem/objective to be addressed and did they accept a joint definition of this?

16. How did the common understanding of the sustainability problem influence the interactions among researchers and stakeholders and the achievement of the societal impacts (future/potential societal impacts)?

Condition: Role of researchers and the results of the project/CS

17. Was there a clear definition of the tasks and roles of the researchers and stakeholders who participated in the project/CS? If so, please, provide further information about the role definition of researchers and stakeholders.

18. Was there a clear explanation of the expected results of the project/CS and its purpuse? If so, how was the explanation carried out?

19. To what extent were the agreed roles fulfilled?

20. How did the definition of the role of both researchers and the expected results influence the interactions among researchers and stakeholders and the achievement of the societal impacts (future/potential societal impacts)?

Condition: Resource availability

21. What resources were available in the project/CS and to what extent did they facilitate the interactions in the project/CS? (boundary objects, facilities, capabilities of researcher, etc).

22. How did the resource availability influence the achievement of the societal impacts (future/potential societal impacts)?

23. To what extent did the research team develop suitable settings for cooperation among different disciplines and sectors and knowledge integration?

24. Did the research team use clear language to communicate with stakeholders?

25. What type of participatory activities were developed? To what extent and way was the stakeholder input considered and processed?

V. FINAL QUESTIONS

26. How did the stakeholder participation influence the interactions and the achievement of the societal impacts (future/potential societal impacts)?

27. To what extent do Nexus projects achieve expected outputs, outcomes, and societal impacts through productive interactions?

28. What are the conditions (among the actor participation, problem definition, role of researchers and outcomes and resource availability) most important that lead to productive interactions?

8.2 Appendix B – List of interviewees

Participants of interviews	Date of the interview
Interviewee 1	February 08, 2024
Interviewee 2	February 09, 2024
Interviewee 3	February 14, 2024
Interviewee 4	February 15, 2024
Interviewee 5	February 16, 2024
Interviewee 6	February 22, 2024
Interviewee 7	February 28, 2024
Interviewee 8	February 28, 2024
Interviewee 9	February 28, 2024
Interviewee 10	February 29, 2024
Interviewee 11	March 07, 2024
Interviewee 12	March 11, 2024
Interviewee 13	March 12, 2024
Interviewee 14	March 12, 2024
Interviewee 15	March 20, 2024
Interviewee 16	March 22, 2024
Interviewee 17	March 26, 2024
Interviewee 18	April 02, 2024

8.3 Appendix C – Codebook

Node	Sub-node	Sub-node (indicator)
Outputs	-	-
Outcomes	-	-
Potential impacts	-	-
Interactions	Direct	-
	Indirect	-
	Financial	-
Contextual conditions	Broad stakeholder participation	Representation of all relevant stakeholders and interest groups.
	Problem definition	Common understanding/agreement on problems and goals based on stakeholders' needs.
		Constructive management of potential disagreements.
	Roles and contribution	Awareness of the researchers and stakeholders' roles and the role of knowledge generated.
		Fulfilment of the researchers and stakeholders' roles and the role of knowledge generated.
	Resource availability	Adequacy of researcher's competencies.
		Opportunities for stakeholder participation.
		Adequacy of the level of consideration of stakeholder input.
		Adequacy of facilities and organisational forms.
		Clarity of the information transferred (boundary objects).
Contextual conditions influence productive interactions (and lead to potential societal impacts)	Broad stakeholder participation	-
	Problem definition	-
	Resource availability	-
	Resource availability	-
Productive interactions influence outputs, outcomes, and societal impacts	-	-
Recommendations	-	-

8.4 Appendix D – Informed consent form

English version

INFORMED CONSENT FORM FOR INTERVIEW

INTRODUCTION

You have been invited to participate in an interview within the framework of a master´s thesis research. This thesis aimed at analysing exchanges between researchers and different stakeholders during which knowledge is generated for societal goals to explain societal impacts. Specifically, the purpose of the study is to learn how Nexus projects achieve societal impact by analysing those exchanges, known as productive interactions. The study is conducted Loreto Alegría López Gamboa who is a student in the MSc programme Sustainable Development at the Department of Sustainable Development, Utrecht University. This research is being dev eloped as an internship at KWR Water Research Institute and under the umbrella of the *Cost action Ne xusNet*. The study is supervised by Peter Driessen (Utrecht University) and Caro Mooren (KWR).

PARTICIPATION

Your participation in this interview is completely voluntary. You can quit at any time without providing any reason and without any penalty. Your contribution to the study is very valuable to us and we greatly appreciate your time taken to complete this interview. It is estimated that it will take approximately 1 hour to complete the interview. The questions will be read out to you by the interviewer. Some of the questions require little time to complete, while other questions might need more careful consideration. Please feel free to skip questions you do not feel comfortable answering. You can also ask the interviewer to clarify or explain questions you find unclear before providing an answer. The interview will be audio-taped for transcription purposes. The data you provide will be used for writing a Master thesis report and may be used for other scientific purposes such as a publication in a scientific journal or presentation at academic conferences.

DATA PROTECTION

The audio recordings will be available to the Master's student and academic supervisors. We will process your data under data protection legislation (the General Data Protection Regulation and Personal Data Act). Audio recordings will be deleted after the project finalization.

INFORMED CONSENT

Participation in this interview is voluntary and you can quit the interview at any time without giving a reason and without penalty. Your answers to the questions will be shared with Utrecht University, KWR (Water Research Institute) and Cost action NexusNet. Your personal data will be used for general context, but it will not be used for the analysis of this research. Please respond to the questions honestly and feel free to say anything you like.

I confirm that:

- I am satisfied with the received information about the research.
- I have no further questions about the research at this moment.
- I had the opportunity to think carefully about participating in the study.
- I will give an honest answer to the questions asked.
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.
- I understand that I have the right to see the research report afterwards.
- I understand that my responses will be kept strictly confidential. I understand that my name will not be linked with the record of the interview and any written documentation or valuation in the context of the interview, and will not be identified or identifiable in the report or reports that result from the research.
- I understand that the audio records of the interview will be deleted after the project finalization.

I agree that:

- The data to be collected will be obtained and stored for scientific purposes;
- The collected research data can be shared and re-used by scientists to answer other research questions, such as publications related to this study after the completion of the study.
- This interview to be recorded. I understand that the audio recording made of this interview will be used only for analysis by this master's thesis research and NexusNet and that anonymised written extracts from the interview, may be used in conference presentations, reports or journal articles developed as a result of the research.

Do you agree to participate? ☐Yes ☐No

_____	_____	_____
Name of participant	Date	Signature
_____	_____	_____
Name of researcher	Date	Signature

Copies: *Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, and the information sheet. A copy of the signed and dated consent form should be placed in the main project file which must be kept in a secure location.*

Spanish version

FORMULARIO DE CONSENTIMIENTO INFORMADO PARA ENTREVISTA

INTRODUCCION

Ha sido contactado para participar en una entrevista en el marco una tesis de maestría. Esta investigación tiene por objeto aumentar el entendimiento sobre cómo la generación de conocimiento, producto de procesos de intercambio entre investigadores y los diferentes stakeholders, contribuye al logro de impacto social. En concreto, el objetivo del estudio es conocer cómo los proyectos Nexus logran un impacto social mediante el análisis de esos intercambios, conocidos como interacciones productivas. El estudio está dirigido por Loreto Alegría López Gamboa, estudiante del Máster en Desarrollo Sostenible del Departamento de Desarrollo Sostenible de la Universidad de Utrecht, Países Bajos. Esta investigación se está desarrollando como una pasantía en el Instituto de Investigación del Agua KWR y bajo el alero de Cost Action NexusNet. El estudio está siendo supervisado por Peter Driessen (Universidad de Utrecht) y Caro Mooren (KWR).

PARTICIPACION

Su participación en esta entrevista es totalmente voluntaria. Puede renunciar en cualquier momento sin dar ninguna razón y sin ninguna penalización. Su contribución es muy valiosa para este estudio y se le agradece enormemente el tiempo destinado a esta entrevista, la cual tiene una duración estimada de 1 hora. El entrevistador le leerá las preguntas en voz alta. Algunas de las preguntas requieren poco tiempo para responderlas, mientras que otras pueden requerir una reflexión más detenida. No dude en omitir las preguntas que no se sienta cómodo contestando. También puede pedir al entrevistador que aclare o explique las preguntas que no le parezcan claras antes de dar una respuesta. La entrevista se grabará para su transcripción. Los datos que proporcione se utilizarán para redactar el informe de tesis de máster y podrán utilizarse para otros fines científicos, como publicaciones en revistas científicas o presentaciones en congresos, conferencias y actividades académicas o de investigación.

PROTECCION DE DATOS

Las grabaciones de audio estarán a disposición del estudiante de máster y de los supervisores. Sus datos ser[an tratados de acuerdo a la legislación sobre protección de datos (Reglamento general de protección de datos y Ley de datos personales). Las grabaciones de audio se eliminarán una vez finalizado el proyecto.

CONSENTIMIENTO INFORMADO

La participación en esta entrevista es voluntaria y puede abandonarla en cualquier momento sin dar ninguna razón y sin penalización. Sus respuestas a las preguntas serán compartidas con la Universidad de Utrecht, KWR (Instituto de Investigación del Agua) y Cost Action NexusNet. Sus datos personales se utilizarán para el contexto general, pero no para el análisis de esta investigación. Por favor, responda a las preguntas con sinceridad y no dude en decir lo que quiera.

Confirmo que:

- Estoy satisfecho con la información recibida sobre la investigación.
- No tengo más preguntas sobre la investigación en este momento.
- He tenido la oportunidad de reflexionar detenidamente sobre mi participación en el estudio.
- Responderé con sinceridad a las preguntas que se me formulen.
- Entiendo que mi participación es voluntaria y que soy libre de retirarme en cualquier momento sin dar ninguna razón y sin que ello tenga consecuencias negativas. Además, si no deseo responder a alguna pregunta o preguntas, soy libre de negarme.
- Entiendo que tengo derecho a ver posteriormente el informe de la investigación.
- Entiendo que mis respuestas serán estrictamente confidenciales. Entiendo que mi nombre no estará vinculado al registro de la entrevista ni a ninguna documentación escrita o valoración en el contexto de la entrevista, y que no seré identificado o identificable en el informe o informes que resulten de la investigación.
- Entiendo que los registros de audio de la entrevista se borrarán una vez finalizado el proyecto.

Acepto que:

- Los datos que se recopilen se obtendrán y almacenarán con fines científicos;
- Los datos de investigación recopilados pueden ser compartidos y reutilizados por los científicos para responder a otras preguntas de investigación, como publicaciones relacionadas con este estudio una vez finalizado el mismo.
- Esta entrevista será grabada. Entiendo que la grabación de audio realizada de esta entrevista se utilizará únicamente para el análisis de esta investigación de tesis de maestría y NexusNet y que los extractos escritos anónimos de la entrevista, pueden ser utilizados en presentaciones, congresos, conferencias, informes o artículos de revistas desarrollados como resultado de la investigación.

Está de acuerdo en participar? ☐Yes ☐No

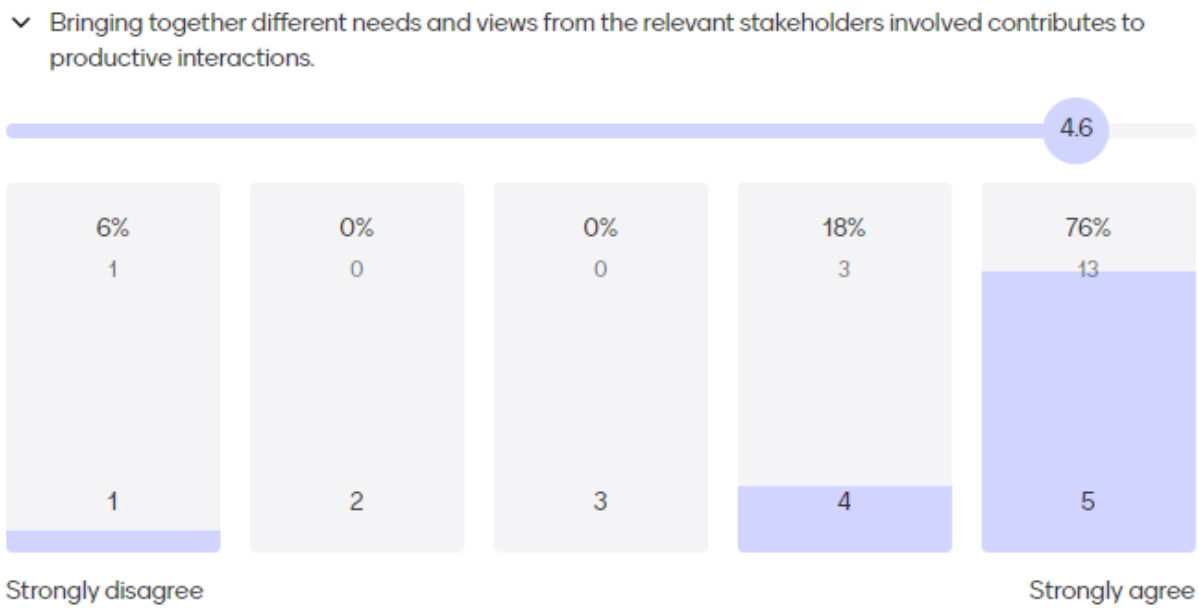
_____	_____	_____
Nombre del participante	Date	Signature
_____	_____	_____
Name of researcher	Date	Signature

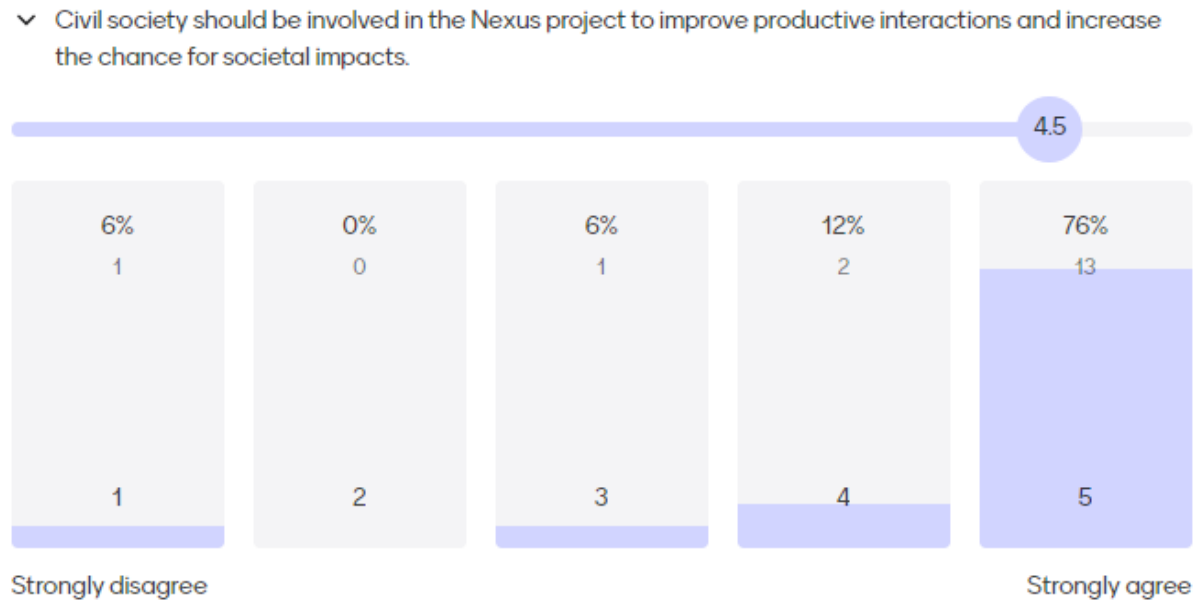
Copias: *Una vez firmado por todas las partes, el participante recibirá una copia del formulario de consentimiento firmado y fechado, así como de la hoja de información. Una copia del formulario de consentimiento firmado y fechado deberá incluirse en el expediente principal del proyecto, que deberá conservarse en un lugar seguro.*

8.5 Appendix E – Results of validation activity

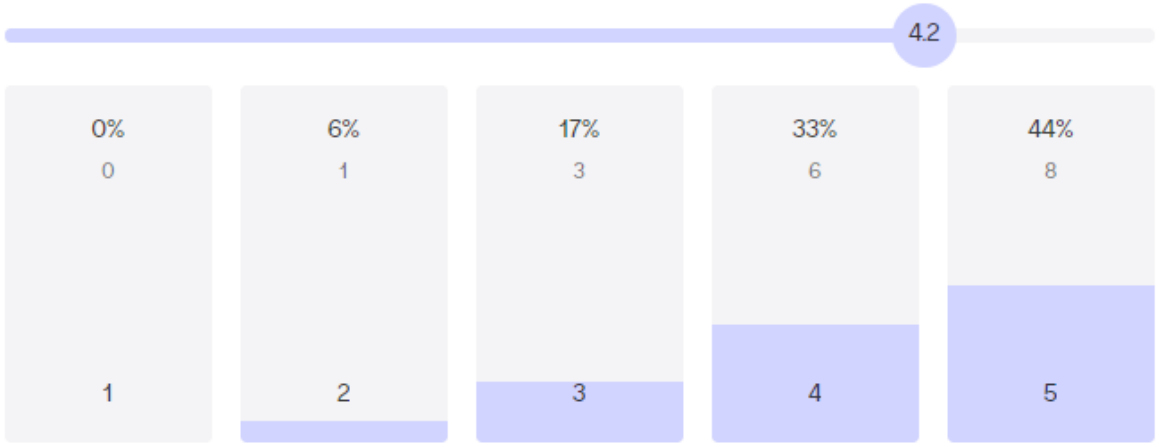
To what extent do you agree with these statements?

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

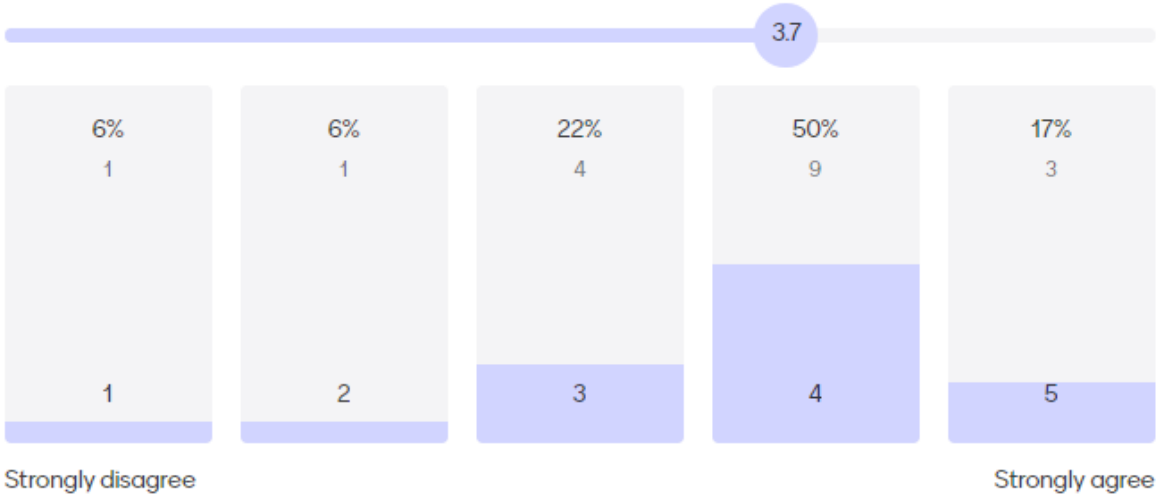




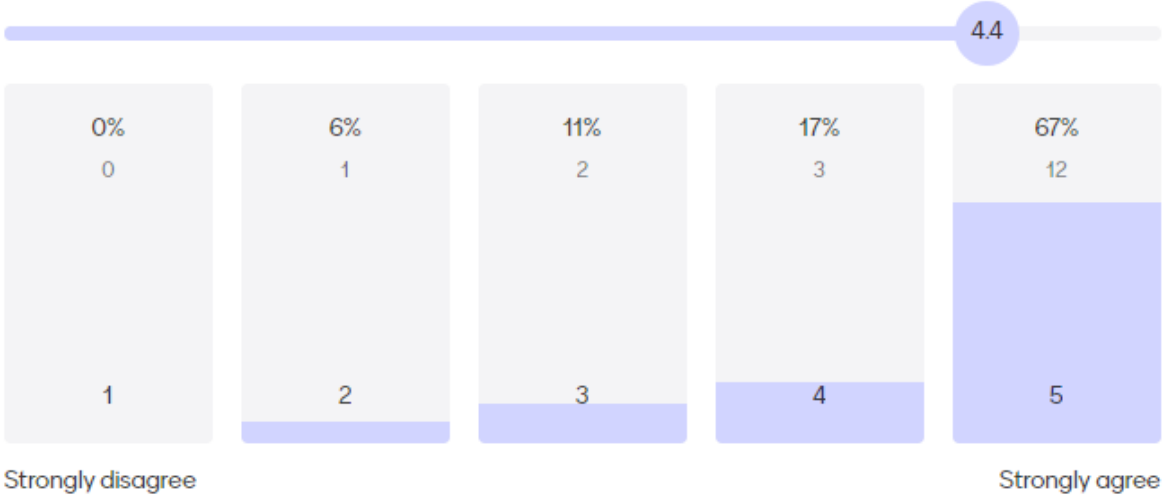
Considering stakeholders' perspectives in defining the problem/goal makes stakeholders commit to projects, contributing to productive interactions.



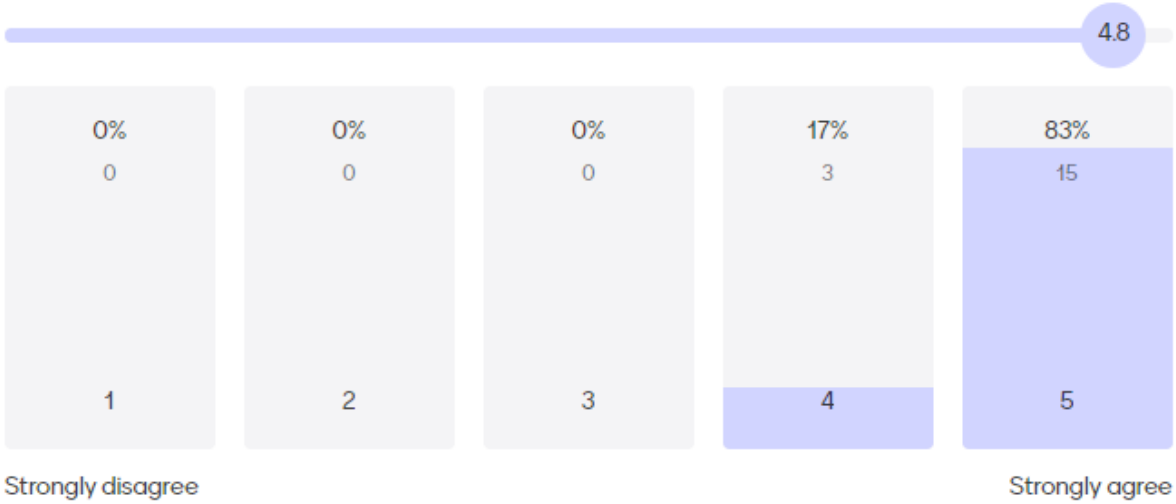
If stakeholders' needs are considered when defining project objectives or goals, the knowledge produced is socially relevant.



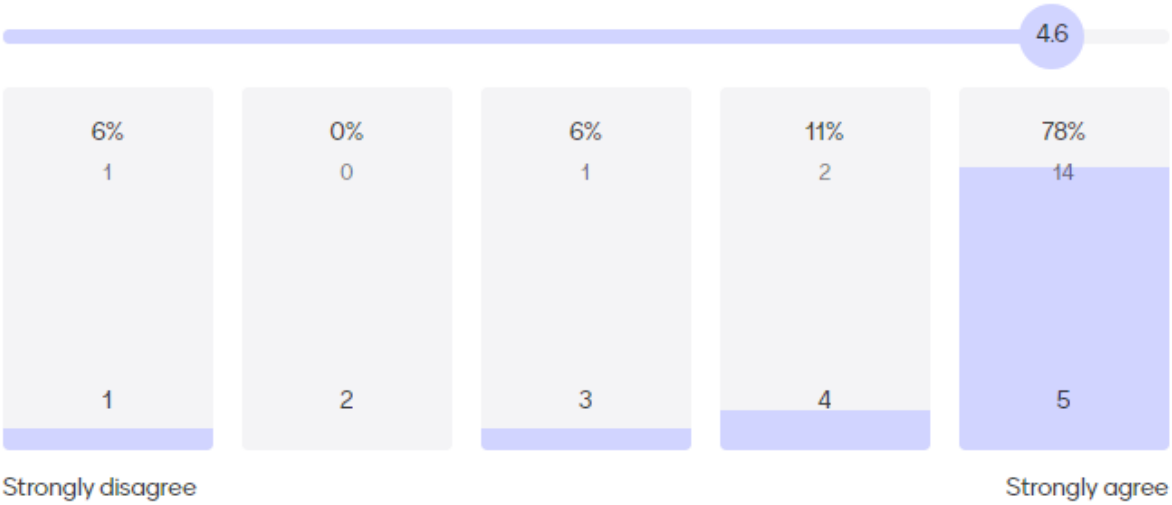
Stakeholders should be involved from the beginning of the project so that they can contribute to the definition of the goal.



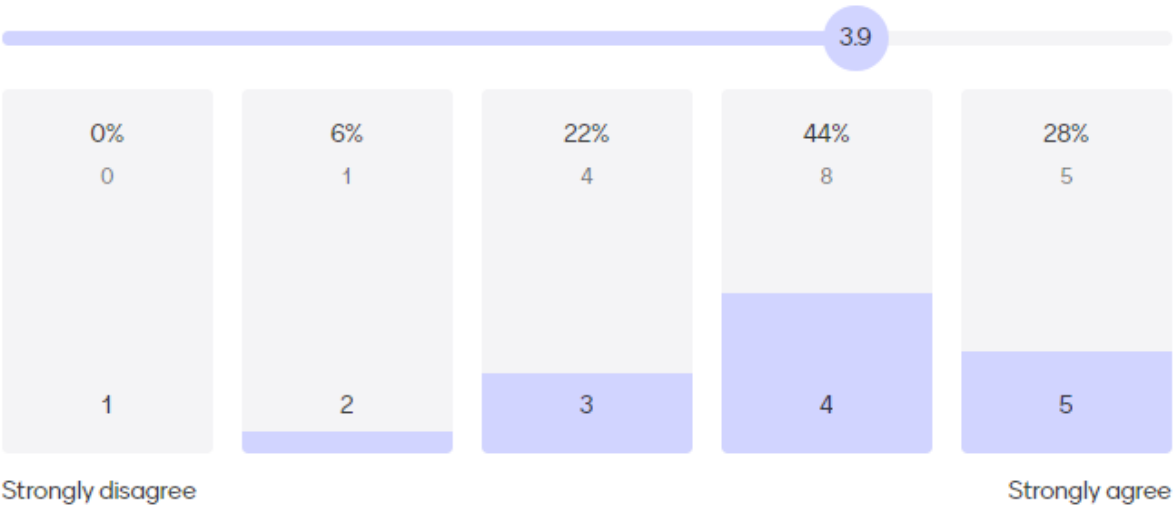
Promoting the stakeholders' trust in researchers contributes to productive interactions.



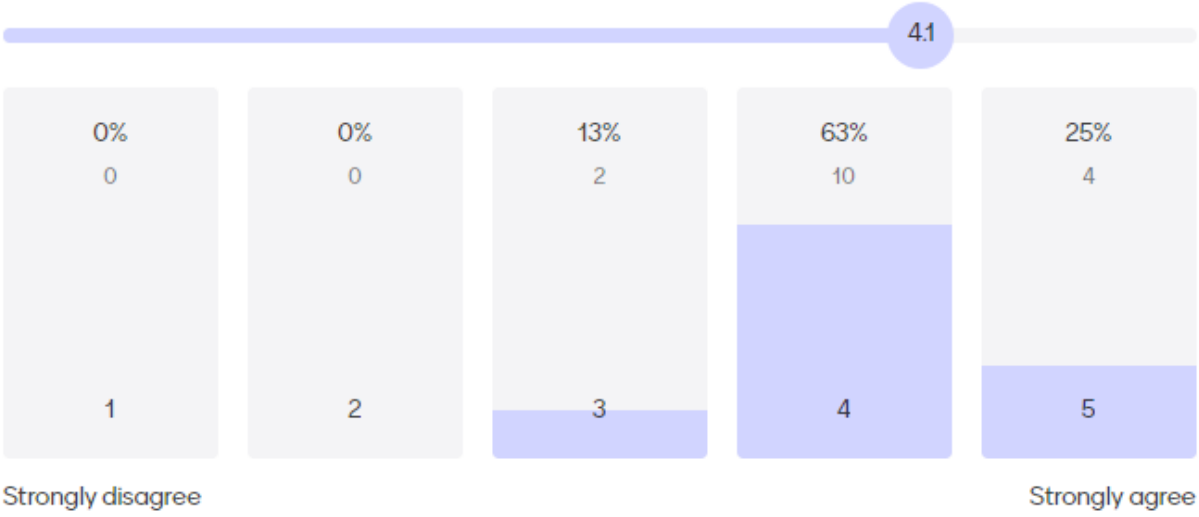
Facilitating the translation of the information (from technical to simple language) and mutual understanding, contribute to productive interactions.



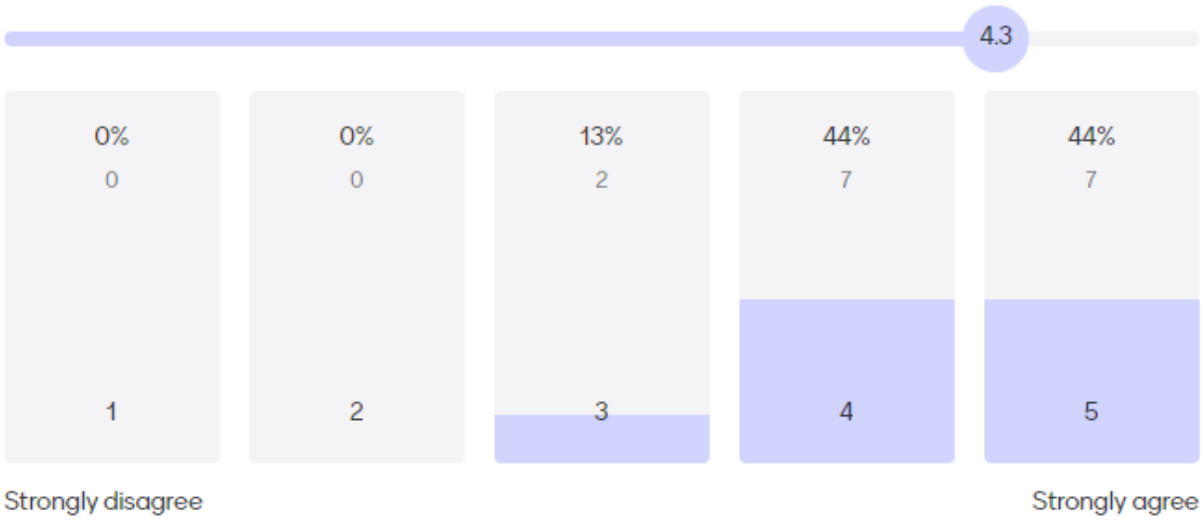
Economic incentives for stakeholders to participate in research projects, positively influence productive interactions.



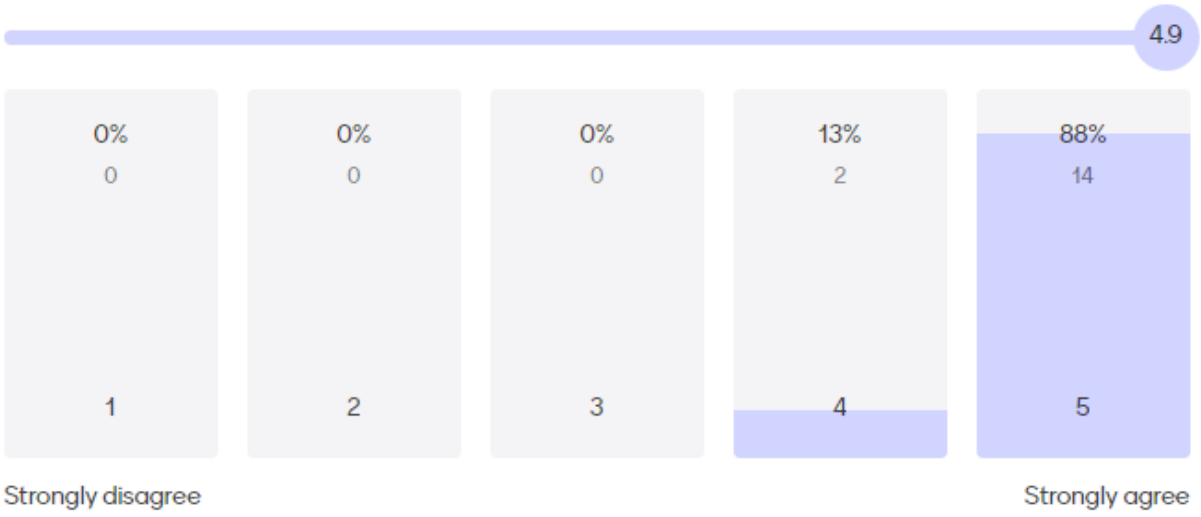
The utilisation of the knowledge produced by productive interactions leads to societal impacts.



Broad stakeholder participation and resource availability are the contextual conditions most essential for productive interactions.



An effective process of stakeholder engagement is key for Nexus project to achieve societal impacts



In few words, how do the Nexus projects achieve expected outputs and outcomes and contribute to societal impacts?

15 of 20 responded • 19 responses

Enhancing the understanding of interconnected challenges and integrated solutions

By initiating and streamlining collaboration between stakeholders (and hopefully assuring that it will last after the project end)

Collaboration among different disciplines

Enhancing synergies between actors at different levels

First they take in account the natural connections existing between managed resources, second they encourage a contributive partecipation from all the involved stakeholders

By paving the pathway for strong collaborations

Reveal hidden trade offs and synergies, quantify them, and reveal hidden obstacles, benefits and threats for stakeholders. Also they advance in methodologies, tools, data bases semantics, etc

buy building cross sectoral relationships and cross sectoral understanding of nexus interdependence and linkages

Better understanding and management of existing/future trade-offs

Multi-sectoral experts engagement towards strong evidence-based solutions

by facilitating SH dialogue across sectors

Outputs having Social impact and change of behaviour

Interconnect academy, industry and government in the goals. Transdisciplinary studies

Good transdisciplinary cooperation and process reflection

Direct results obtained by a research project.

Good methods for co-creation

Integration of different dimensions

The nexus projects enable connections of varios researchers and stakeholders hence improving the possibility for the successful imapct.

Enhancing networking

What contextual condition would be the most essential for productive interactions to promote societal impacts in Nexus projects?

11 of 20 responded

> 1st Broad stakeholder participation

> 1st Problem definition

> 2nd Role of researchers and stakeholders and their contribution

> 2nd Resource availability