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Public Engagement Practices in EC-funded RRI Projects: Fostering Socio-Scientific Collaborations

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Abstract: The 'ambiguity' of Research and Innovation (R&I) within the present contemporary society triggers increasing manifestations of public concerns concerning science. Apart from some implications it has, this mistrust also functions as a stimuli towards integrating the public view and public (social) needs into the development and implementation of R&I policies. With reference to European communities, the European Commission (EC) has provided funding to various projects aiming to capitalise on the concept of Responsible Research and Innovation (RRI) and the RRI 'key' of Public Engagement (PE) in order to engage the public in R&I, enhance a human-centric and inclusive R&I approach, and ultimately foster a mutually responsible relation between science and society. This study aims to examine how PE practices are implemented within the context of EC-funded projects addressing RRI-driven public engagement. Seventeen PE practices that have been implemented during the lifespan of five EC projects were qualitatively and thematically analysed. The identified themes indicate the implementation patterns of PE and contribute to reaching a set of conclusions towards realising a participatory, human-centric and inclusive R&I, fostering in its own turn future socio-scientific collaborations. Policy-makers, researchers, practitioners and stakeholders interested in public engagement in R&I can capitalise on the study's conclusions and contribute to manifestations of responsible innovation.

Keywords: RRI; public engagement; citizens; science; socio-scientific collaboration

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1. Introduction

The final decade has witnessed significant efforts towards the embedding of Responsible Research and Innovation (RRI) into the European Research Area (ERA) and the R&I systems at an institutional, national, and territorial level. The increasing popularity of RRI and efforts for its enhancement can be comprehended when considering RRI both as an EU policy concept, and as a response to contemporary societies affected by postmodernism. A series of important milestones gave rise to RRI in the policy discourse. These refer to: RRI discussions within nanotechnology, as described in (Shelley-Egan et al. 2018); to the EC declarations in the Lisbon Treaty concerning a paradigmatic shift through a transparent dialogue with civil society (De Saille 2015); and up to the socio-technical integration in EU-funded programmes including Science in Society (Owen et al. 2012). Nevertheless, the potential of Science, Technology and Innovation (STI) to produce both harm and benefit (Stilgoe et al. 2013) increased public objections and ethical controversies, and this attributed RRI the potential to: challenge the traditional social contract between science and society; foster new reconfigurations of actors and responsibilities in scientific processes (Rip and Shelley-Egan 2010); and ultimately introduce an ameliorated socio-scientific collaboration. The ability of RRI both to enhance the EC vision on a responsible ERA through specific policy lines, as well as to restore the science–society relationship is characterised by: (a) investing in public participation in science; (b) being oriented around societal challenges; and (c) fostering a democratically accountable governance of science, where society can revitalise its trust concerning R&I, recognising both its rights and responsibilities, and actively participating in the new state of affairs in the European community.

In order to articulate the responsible ERA vision and the prominent benefits of a new science–society collaboration, the EC heavily acknowledges the 'pillars' approach of RRI. The six RRI keys (or the holistic 'RRI package') form the basis for initiatives enhancing a socially driven science (European Commission and Directorate-General for Research 2007) and addressing grand societal challenges. The RRI key of PE particularly encourages new profitable 'partnerships' fostering shared responsibility within the context of a human-centric approach to R&I, where a human-centric approach is described by the National Institute of Standards and Technology (ISO standards) as developing solutions to problems by involving the human perspective in all development stages. As for defining PE, the European Commission (2020) argues that 'Public Engagement is about co-creating the future with the public and civil society organisations, and also bringing on board the widest possible diversity of people that would not normally interact on matters of science and technology' (working definition also adopted in this paper). Owing to the PE-driven robust knowledge that emerges (Jasanoff 2003; Marschalek 2017), advancements can be noticed concerning: (a) acquiring a new social science–society contract exhibiting a mutual and prudential acquiescence concerning R&I outcomes (Rip 2014); (b) addressing some long-standing 'wicked' problems in R&I, described by (Rittel and Webber 1973) as policy problems difficult to address due to their nature (i.e., constantly changing requirements and conditions, having no single verified solution and often meeting resistance). As for a notable example of 'wicked' problems in R&I, it refers to STI procedures frequently being 'hijacked' by experts refusing to leave their 'ivory tower' and allowing little or no public participation. Finally, it should be noted that along with the EC definitions of PE and scholarly arguments on PE benefits, investigating the current status of PE from a practitioner's point of view is still of interest, given: (a) the existence of mostly theoretical rather than empirical work on the topic of practical PE implementation; (b) the 'infancy' of the existing arguments on PE implementation (Marschalek 2017).

The above circumstances have 'steered' the aim of this study, which is to address the following research question: 'How are RRI-driven PE practices implemented within the context and lifespan of EC-funded projects, so as to afterwards foster an inclusive and human-centric R&I implementation?' PE practices are seen as any type of activity implemented in the project lifespan and related to applying public engagement in practice (e.g., consultation activities with citizens, events, development of tools for PE etc.). In more detail, in order to address the study's research question, seventeen PE practices identified in five RRI-oriented and EC-funded PE projects were qualitatively examined: INHERIT, BigPicnic, ACTION, GRECO, MARINA[1]. After examining the project documents (deliverables) for identifying the seventeen PE practices, a thematic analysis (Braun and Clarke 2006) was conducted for detecting the core implementation patterns (themes) across these practices. The PE implementation patterns identified contribute to drawing a set of conclusions, which can function as experience-based learning points and evidence-based suggestions. Their contribution is found in providing input concerning: (a) which implementation patterns can truly facilitate inclusive and human-centric R&I implementation, as opposed to some patterns potentially functioning as hindering factors; (b) implementing inclusive R&I actions that consider a multitude of views; (c) enhancing manifestations of a socially oriented and sustainable R&I future, compatible with international and European policies (2030 Agenda for Sustainable Development, UN). Responsible transformations can in this way be enhanced, referring to: (a) bringing society a step closer to STI and generally R&I systems; (b) linking R&I to grand societal challenges including health and well-being (INHERIT), food security (BigPicnic), pollution (ACTION), energy (GRECO), and environment/marine protection (MARINA); (c) ensuring a greater scientific and societal awareness on behalf of the public for R&I and STI. Finally and with reference to the target groups potentially exploiting the study's conclusions, these refer to policy-makers, PE implementers, researchers, citizens, and any other stakeholders interested in (implementing) PE in the R&I field.

The following sections are structured as follows. The literature review firstly sets the scene around the rise of RRI and PE, while its remaining part describes the various forms and multi-layered features of PE (theoretical aspect). Concrete arguments on how PE is implemented in practice are also provided based on previous literature. The methodological section reports the framework employed for analysing the PE practices, followed by a thorough description of the study's findings. The final sections outline the emerging discussion, as well as the conclusions and suggestions reached concerning the practical implementation of constructive PE activities and their potential contribution to the R&I field.

2. Literature Review

2.1. 'Official' Incorporation of Concerns into Contemporary R&I Policies

Irrespective of instances of common acceptance of R&I outcomes within the final years, society's hesitation concerning the 'emancipation' of science is also evident (Mejlgaard et al. 2018). Mistrust and anxiety concerning scientific activities can be traced long back, even to the onset of the industrial revolution (Turney 1998), and in instances where scientists themselves exhibit scepticism concerning their own practices, for example, see Rip (2014) and the example of the mathematician Tartaglia. To comprehend how our times reached the official incorporation of such concerns into R&I policies—an incorporation taking various forms, including social (corporate) responsibility, educational training on ethical R&I, EC policy lines—a few landmarks related to postmodernist society can be considered. Some rather troubling features of the postmodernist society seem to have created additional 'burdens' for science, technology and innovation (STI), and a debate on their potential to produce both benefit and harm (European Commission and Directorate-General for Research and Innovation 2013; Owen et al. 2012). The alternation of the STI governance can be indicatively expressed through Beck's risk society (Beck 1992), where fears and uncertainties are prominent concerning manufactured risks including technological/scientific developments taking the wrong turn due to human agency; Van Dijk's network society (Van Dijk 1999), which exhibits the paradox of being both connected and fragmented due to technology-based and network communication; Hartmut's high-speed society (Rosa 2003), where public feelings of discomfort are evoked due to social and technological acceleration; Bauman's liquid society, where increasing consumerism linked to the latest technological products leads to discomfort due to dominant consumerism-driven forms of socialisation (Bauman 2000). Based on such long-standing public concerns, concepts concerning scientific and technological responsibility came as a (re-)articulation of claims about the troubling relation between society and innovation. One can mention ELSA (Ethical, Legal and Social Aspects), often seen as a precedent to RRI, or the EU concept on 'responsible development'. As a mitigation attempt, these concepts obtained a prominent position in official policies for addressing ethical and societal aspects of science, and concerns about emerging technologies (Rip 2014; Shelley-Egan et al. 2018).

Irrespective of official policy lines, society and its representatives often lack the 'privilege' to engage in STI and inform official processes—a challenge put forward even thirty years ago (Fischer 1999) and indicated by scholars till the present years. Mitcham (2003) and Stilgoe et al. (2013) highlighted the incapacity concerning harmonising the commands for producing reliable knowledge with social responsibility. In other words, knowledge does not cease to be a product of experts so as to then receive social guidance and become a social construct (Innerarity 2013). As similarly argued by Frahm et al. (2021), society is not easily included in innovation policy-making and, when included, their engagement in policy and practice is somehow 'mechanistic' (7). Established forms of participation often fail to consider the diverse concerns and values of the public (Chilvers and Kearnes 2020) or rely to fixed forms of participation, thus creating obstacles for more reflexive engagement (Chilvers 2017). Consequently, public-deficit issues and questions are raised about the extent to which PE achieves its goals and expected impact (Groves 2017)—thus highlighting the need to find effective ways for consensus-building and public engagement (OECD 2015).

This need is further enhanced by indications that permanent 'settlements' of society in science can be valuable, since a new science–society collaboration can create space for public dialogue (Irwin 2006) and democratisation of science and innovation (Callon and Lacoste 2011; Marschalek 2017) based on pluralist democracy (Durant 1999). In fact, these permanents 'settlements' of society built through the synergistic engagement of Quadruple Helix stakeholders can further contribute to developing contextually appropriate R&I practices under a human-centric design (Carayannis et al. 2021). As for the European public perception on the above, EU citizens (55%) do consider that public dialogue is necessary, and are eager to undertake shared responsibilities and engage to democratic scientific systems (based on the special Eurobarometer on citizens' general attitudes concerning science and technology). As the EC (European Commission and Directorate-General for Research 2007) has pinpointed, 'citizens are not only becoming more sceptical and less deferential, they are also becoming increasingly interested' (19). Therefore, all the above parameters ultimately reflect a 'paradox' comprised of: (a) the concerns of society concerning science, citizens' overall willingness to delve into participatory STI processes, and the prominent benefits of science–society collaboration; (b) the fact that such concerns have been incorporated into official policies but are not adequately addressed, and the public is still not adequately and genuinely engaged.

2.2. Public Engagement in Science within the European Context

Attempting to respond to the aforementioned 'paradox', the EC acknowledges the necessity to co-create the future European R&I systems with society, bringing on board a diversity of actors that would normally not interact with each other. The 'linkage' between co-creation and democratised science has therefore given rise to the concept of PE as a key policy agenda of RRI (Stahl 2012). RRI can be seen as a re-articulation of long-standing claims about STI (as its precedents ELSA or responsible development), but further emphasises the 'creation of spaces for collective forms of engagement, the experimentation in new constellations of actors and the reconsideration of the diverse values at stake in innovation' (Felt 2018). Overall, RRI has attracted the attention of a broader discourse, encompassing academic, policy and European (EC) discourse with reference to various scientific fields (Marschalek 2017). In particular, regarding the EC discourse, RRI is promoted by the EC as a policy rather than as an analytical concept, as follows:

> A transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products. (Von Schomberg 2011)

RRI encompasses specific core dimensions (procedural RRI approach) and policy agendas, the RRI 'keys' (pillars approach of RRI). According to Stilgoe et al. (2013), the core dimensions refer to *anticipation*, *reflexivity*, *inclusion*, and *responsiveness*. Based on the EC-acknowledged pillars approach (Pellé and Reber 2015), responsible R&I systems should address six keys: *Public Engagement*, *Gender Equality*, *Science Education*, *Ethics*, *Open Access*, *Governance*. As for Public Engagement, the EC operationalises well-structured initiatives within EC-funded projects aiming to bring citizens closer to STI and R&I under various approaches. EC funding calls explicitly addressing PE projects mainly refer to H2020 and the SwafS programme, while the funding call of Horizon Europe addresses PE in a horizontal way and within the context of other key concepts. Nevertheless, PE is seen in all these European occasions as a means to provide sustainable and inclusive solutions to R&I, and particularly as a means to respond to the renewed human-centric paradigm, where the users' (i.e., the public's) needs are addressed from the very beginning (Carayannis et al. 2021).

Finally, the emergence of PE within the RRI context—albeit the general recognition of its beneficial nature—brought to the surface some anticipated obstacles for its implementation within the RRI context. As argued by EU stakeholders participating in a relevant EU conference, notable obstacles refer to: the indifferent public; distrust; conflicts of interest; 'complexity' of science; and lack of concrete methodologies for managing public participation (for an overview, see Marschalek (2017).

2.3. The Features of Public Engagement within the RRI Context

While attempting to precisely depict the essence of PE, various definitions have emerged (see indicatively (Grand et al. 2015; Phillips and Orsini 2002; Powell and Colin 2009). A core EC definition within the RRI context, in alignment to the one provided in the introduction, is quoted below European Commission (2020):

> Public engagement implies the establishment of participatory multi-actor dialogues and exchanges to foster mutual understanding, co-create research and innovation outcomes, and provide input to policy agendas. It is about bringing on-board researchers, policy makers, industry, civil society organisations, NGOs and citizens, to deliberate on matters of science and technology.

It is worth noting that all PE-related arguments coincide in co-creation, encompassing public inclusion and participatory processes. Co-creation held a prominent position in scholarly literature long before the rise of RRI. Scholars have associated co-creation with the post-normal comprehension of science within science and technology studies (STS) (Callon et al. 2011; Latour 2004) as well as with 'collective responsibility' (Owen 2014; Stilgoe et al. 2013), building on Beck's concept of 'organised irresponsibility'. The triple-helix approach (academia, industry, government) in co-creation had similarly gained increased attention in previous literature (Etzkowitz and Leydesdorff 1995), and has now been replaced by the quadruple helix approach, adding the fourth helix of civil society (Fagerberg 2018; Foray 2014)—with the role of civil society and citizens being multi-rational and focusing on common good, as characterised by Stern (1997). Having in particular partnerships with different QH actors can ensure the inclusive engagement of diverse actors within a society and enhance user-driven, inclusive innovation, as indicated by previous EU projects (Wittrock and Forsberg 2019). Overall benefits finally refer to co-creation in STI and R&I providing valid and vital knowledge concerning addressing major societal challenges thanks to: (a) the creation of 'hybrid forums' (Barthe et al. 2001) that go beyond co-constructing scientific knowledge and lead to ameliorating its definition and accreditation; (b) the multitude of viewpoints considered (Blok 2014) and the consequent democratisation of relevant discussions (Van Oudheusden 2014). It is worth noting that the alignment that exists between the nature/beneficial effects of co-creation and the nature of RRI led to employing co-creation as a recurrent approach in the SwafS funding programme, and in particular to its intended use in public engagement, citizen science, and participatory agenda setting (for more details, see Robinson et al. 2021).

Proceeding to the content of the term 'public engagement', along with its emphasis on co-creation it exhibits a relative ambiguity —probably resulting from the lack of agreement on how the public should be engaged in practice (Delgado et al. 2011). PE can consequently take several implementation forms, which introduce different engagement paths within the desirable science–society collaboration. Figure 1 indicatively describes: (a) a PE typology with five broadly accepted forms of PE (Andersson et al. 2014); (b) the PE classification in three vantage points (Thompson et al. 2012); (c) an EC-acknowledged distinction of citizen engagement forms (Craglia and Shanley 2015, as quoted in Guimarães Pereira et al. 2016), where citizen engagement is seen as part of the PE umbrella concept.

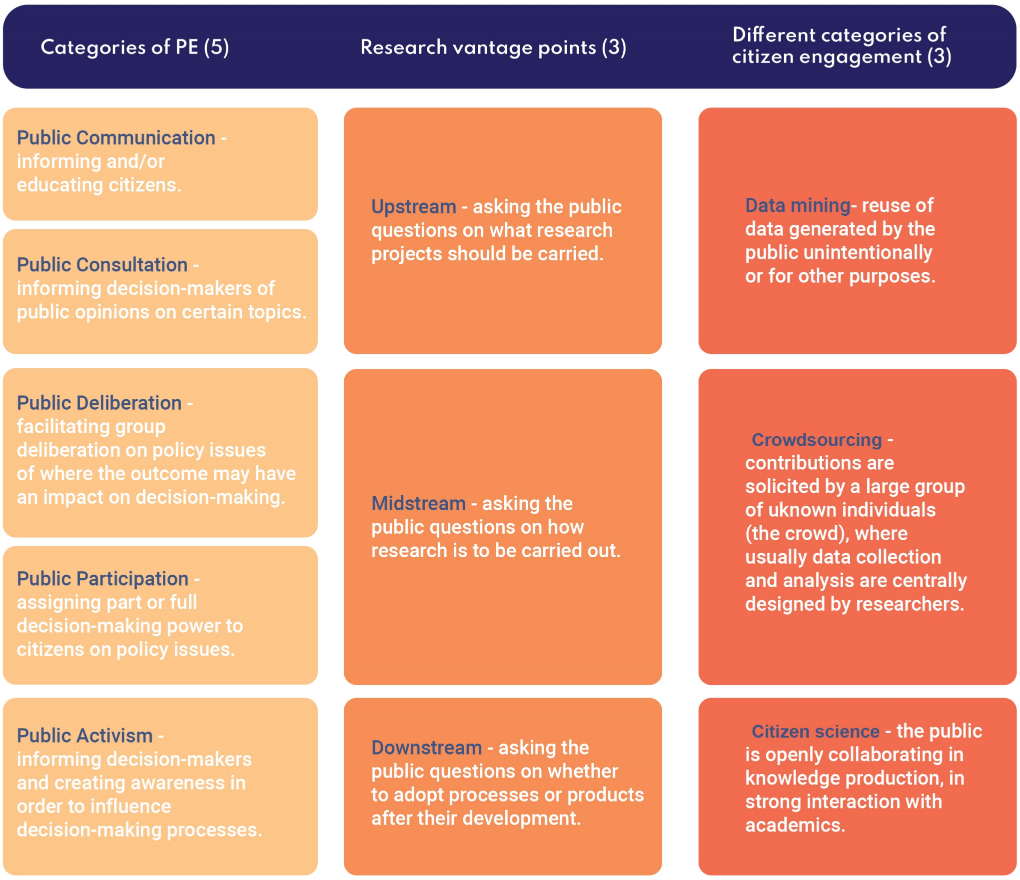

Figure 1. The multilayered nature of PE.

Figure 1 is read vertically, providing three different 'conceptualisations' of PE forms frequently encountered in the literature. However, the various descriptions of PE forms under each 'conceptualisation'/column are certainly non-mutually exclusive; they encompass differentiated degrees of citizens' influence and agency in the knowledge production processes, thus building the overall PE concept and its different interpretations. For instance, data mining and citizen science are seen as a contributing rather than a collaborative PE form (Bonney et al. 2009)—thus as a subtle PE form or as a means to 'boost' PE (Guimarães Pereira et al. 2016). In particular, citizen science is an ambivalent term (Guimarães Pereira et al. 2016), with previous literature arguing on different and multiple CS functions and degrees of public agency at a time ranging from simply raising scientific literacy (Nascimento et al. 2014) up to using it as means to become involved in science and scientific research (Martin 2017). Proceeding further, other features are likewise overlooked in some definitions, including questioning scientific assumptions and speaking back to science and its experts (Shelley-Egan et al. 2020). Criticisms on PE have similarly been raised. It has been argued that PE often appears in pre-determined forms (Groves 2017) or lacks spontaneity (Bucchi and Neresini 2008) when PE activities are initiated by expert 'sponsors'—potentially leading to low participation of lay people in knowledge production. PE may additionally be treated by experts as a means to ensure public legitimacy for their actions (Barthe et al. 2001) and create new expert elites (Thorpe and Gregory 2010; Voß and Amelung 2016). Nevertheless and under the proper circumstances and 'use', the open-ended idea of PE can still pave the way for new scientific affairs, interactive dynamics and new relationships between the actors of an R&I ecosystem.

Along with the PE theoretical underpinnings, discussions are evolving around its practical operationalisation. Concrete methods for practically implementing the RRI keys were missing on the onset of RRI, with most academic publications focusing on the theoretical RRI foundations (Blok and Lemmens 2015; Burget et al. 2017). This situation now seems to be subtly changing. RRI implementation within EC programmes has indicated specific methods and practices of RRI and its keys (Mejlgaard et al. 2018). Valuable implementation insights are, for example, yielded by Wittrock and Forsberg (Wittrock and Forsberg 2019) in the RRI-practice EU project, by detailed accounts of PE methods and tools developed in PE2020 (Ravn et al. 2014) and e-anthologies in ENGAGE2020 (Andersson et al. 2014). With reference to Wittrock and Forsberg (Wittrock and Forsberg 2019), overall observations have been drawn for RRI and its keys, encompassing PE: for instance, it is suggested that overlap among RRI keys and dimensions is likely to take place, as these cannot be seen as unidimensional scientific concepts. Concurrently, RRI implementation could be enhanced by: (a) incentives and funding; (b) organisational policies, functioning as learning points/points of departure; (c) external or international cooperation; (d) accompanying sustainability agendas. Finally, suggestions on operationalising RRI aspects and PE have also been made concerning mainstreaming these in the Horizon Europe funding programme. Braun et al. (2018) and Braun and Griessler (2018) suggested that RRI should be better aligned to the rules of R&I programming, and that emerging knowledge should include (more diverse) stakeholder and citizen perspectives. Gerber et al. (2020) additionally argued that interdisciplinary approaches to RRI increase its quality, and being 'responsible' in R&I signifies integrating all RRI aspects and emphasising 'fairness (social, gender, etc.)' (710). Ultimately, expectations and requirements on publicly engaging various stakeholders in the R&I activities of Horizon Europe have been adequately maintained in the descriptions and requirements of the new funding calls. The major differentiating factor is that these no longer fall within specific demands for RRI application.

Overall, the literature review conducted suggests why and how RRI and PE gained such a prominent position in the EU social, policy, and academic sphere, and further exemplifies the PE 'nature' and its links to other seminal concepts (e.g., co-creation), as well as PE practices. However it is noticed that the abundance of previous literature is mostly based on theoretical rather than empirical work; the majority of scholarly arguments describe the 'desired' PE features based on theory, and stress its benefits, contributions, and occasionally back-firing effects. With the exception of some more practically oriented work coming mostly from EU projects—occasionally characterised as 'infant', too (Marschalek 2017)—more detailed insights are needed on how PE can be practically implemented, and what is entailed in the implementation of a PE practice. Existing literature therefore provides mostly theoretical evidence and normative assumptions on how (RRI-driven) PE is or should be placed in practice, accompanied by a few more practical contributions. The present study addresses the identified research gap by examining the implementation patterns of PE practices; it complements the few existing and relevant arguments through its practical and empirical insights, as well as by providing conclusions on the PE practices' implementation during the lifespan of H2020 RRI projects funded by the EC.

3. Methodology

After considering existing insights on RRI and PE and identified research gaps, the present study aims to delve deeper into PE practical implementation and enhance the relatively few existing arguments by addressing the following research question: 'How are RRI-driven PE practices implemented within the context and lifespan of EC-funded projects, so as to afterwards foster an inclusive and human-centric R&I implementation?' Five H2020 RRI projects implemented by European RPOs have been examined, and seventeen PE practices identified as implemented during their lifespan have been further analysed. Figure 2 describes the five projects examined, and reports the PE practices identified in each project. These practices are examined within a functionalist paradigm, aiding to acquire new knowledge and provide explanations for the practical PE implementation. The present analysis also eludes the provision of an exhaustive (and impossible) overview of PE implementation in RRI European contexts; it therefore shifts the focus onto seventeen specific PE practices, sorted out after a detailed methodological procedure. This section reports the methodological processes followed; these encompass the selection procedure and criteria concerning selecting the final RRI projects and identifying the final PE practices, and the six-step framework employed for the qualitative analysis of the PE practices.

H2020 project	Project description	Identified practices
INHERIT: INTer-sectoral Health and Environment Research for InnovaTion	INEHRIT is about stimulating effective policies, practices and innovations that address key environmental stressors of health inequity. It also aims to encourage individuals to modify current lifestyles, characterized by a 'take, make, consume, dispose' model of growth, and overall promote a sustainable future.	1. Online Database of promising practices. 2. Visioning and scenario planning (Future 2040 scenarios). 3. Transformation of best practices into 15 case studies related to "living, moving and consuming".
BigPicnic: Big Questions - engaging the public with Responsible Research and Innovation on FoodSecurity	The project builds public understanding of food security issues through public debate and co-creation approaches, and enables people across Europe and in Africa to debate and articulate their views on Responsible Research and Innovation (RRI) in this field to their peers, scientists and policy-makers.	4. Big Picnic Basket: Development of outreach exhibitions. 5. Science cafés on the topic of food security. 6. Co-creation toolkit.
ACTION: Participatory science toolkit against pollution	ACTION project aims to make citizen science more open and inclusive, and supports volunteers to take leading roles in setting up new initiatives and using results as evidence for new policies. The project entails partnerships with 5 European CS initiatives tackling major forms of pollution, and contributing to Sustainable Development Goals.	7. Development of a citizen science toolkit (socio-technical toolkit). 8. Set up of a citizen science accelerator. 9. Coordinating six case studies on citizen science. 10. Development of Lifecycle- aware Citizen Science templates.
GRECO: Fostering a Next Generation of European Photovoltaic Society through Open Science	GRECO addresses the challenge of putting Open Science into action in a research project concerning Photovoltaic (PV) Energy Research. Six responsible and innovative solutions are provided, building on Open Science along with citizen engagement, under the ultimate aim of increasing PV technology useful life, reducing its cost through increased performance and demonstrating novel competitive solutions in agriculture and buildings.	11. Integration of citizen science to an Ageing Model for Photovoltaic Modules and Repairing Procedure of PV Systems. 12. Open innovation exercises with representatives of the irrigation field. 13. Mobilization and Mutual Learning (MML) actions/meetings. 14. Development of a generation solar app.
MARINA: Marine Knowledge Sharing Platform for Federating Responsible Research and Innovation Communities	The MARINA project engages researchers, Civil Society Organisations (CSOs), citizens, policy and decision-makers, research funders, industrial and societal actors in order to share knowledge, include the citizens' vision and social needs in it, and create a synergy between R&I and the environmental safeguard. The RRI approach is used with all stakeholders in 8 different marine topics, addressing specific challenges indicated by H2020.	15. Mobilization and Mutual Learning (MML) Workshops. 16. Development of the online Web Knowledge Sharing Platform – MARINA WKSP. 17. Development of the Science-Society-Industry-Policy Interface.

Figure 2. Description of final PE projects and identified PE practices.

3.1. Selection Procedure for PE Practices

Following a step-by-step selection procedure, 80 interesting RRI projects[2] were initially sorted out by examining specific databases, and led to identifying the final five projects and the seventeen PE practices embedded in them. Figure 3 depicts in detail each step of the selection procedure, the inclusion and exclusion criteria employed in each stage, as well as the results retrieved.

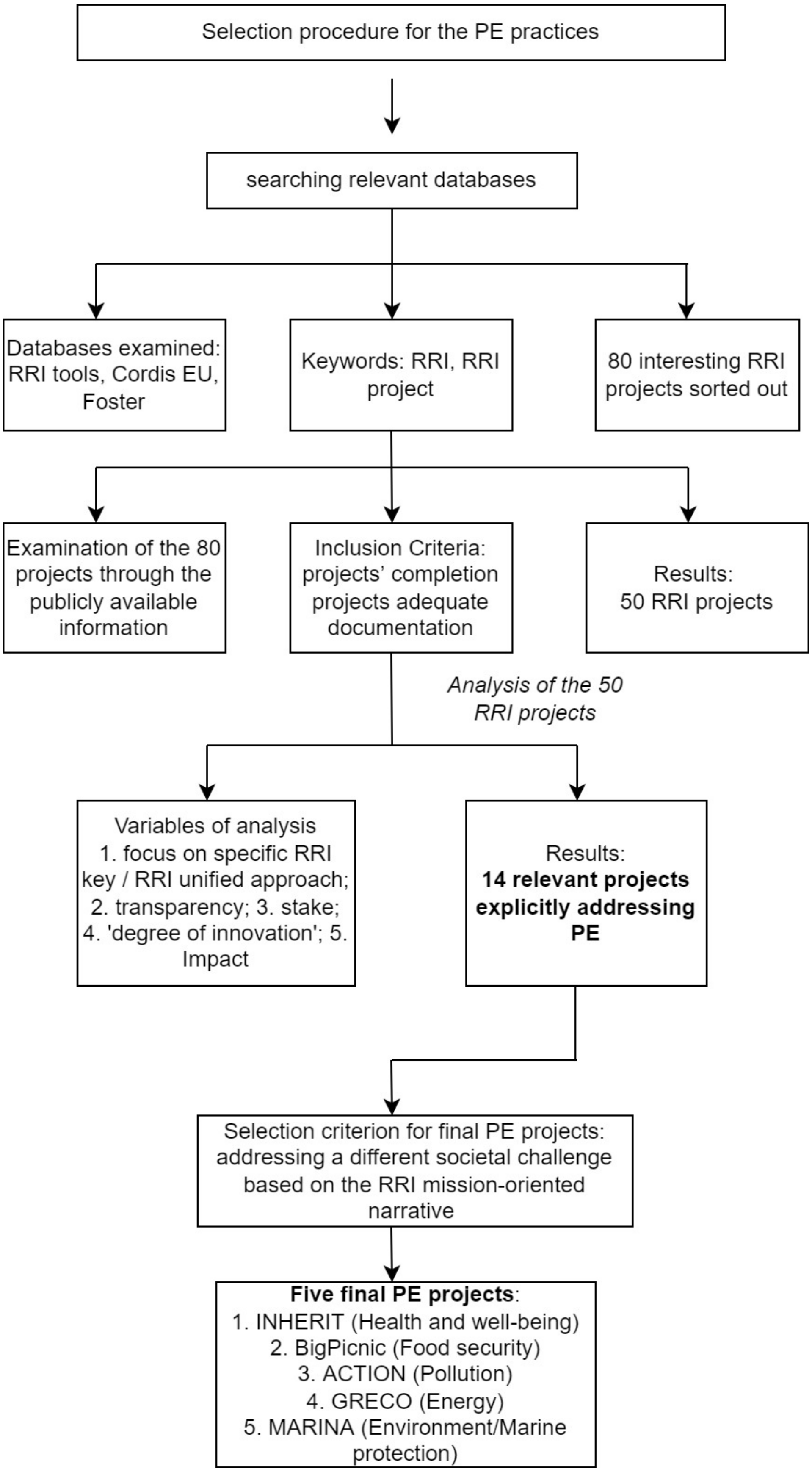

Figure 3. Selection procedure for the final 5 PE projects (and their 17 PE practices).

As illustrated in Figure 2, INHERIT, BigPicnic, ACTION, GRECO and MARINA projects were the final ones selected for having an adequate and transparent documentation and, most importantly, addressing a different societal challenge in correspondence to the EC grand societal challenges that are indicated for H2020 lifespan and are intimately linked to R&I [3]. Each project's deliverables were at this point retrieved and contributed to detecting seventeen PE practices in the five projects. The deliverables constitute documents produced by the project's partners and describe the project's activities, progress, and results, as well as additional processes addressing the communication and dissemination of the project, and its overall management. For meeting the aims of the present study, project deliverables examined were the ones reflecting the design and implementation of PE practices. The deliverable data led to cataloguing the seventeen practices and structuring their content according to new variables that referred to: *objectives*, *policies and strategies*, *synergies and correlations*, *barriers and incentives*, and *impact inside and outside the ecosystem*. In particular, information grouped under *impact* was highly important; they provided indications and concluding remarks based on the project deliverables (and thus the arguments of the implementers themselves) on whether PE implementation proved effective in terms of (a) addressing the EC project goals (impact inside the ecosystem), and (b) in terms of overall promoting and fostering an inclusive and human-centric R&I implementation in the field addressed by the project (health, energy, climate etc.) (impact outside the ecosystem).

Irrespective of the deliverables' rich input for classifying the practices and compiling the data corpus, few obstacles emerged during data collection. Interpretative viability (Benders and Van Veen 2001), described as the general tendency for varying meaning or necessity of any concept to be open to various interpretations, was a considerable challenge. The target PE practices were embedded in different projects—thus in differentiated regional, national, and societal contexts—addressing different recipients at a time for ensuring an efficient uptake of PE (and RRI). In addition, more 'confidential' insights on PE implementation could not easily be retrieved from public documentation. Thus, further data were compiled for two out of the five EU projects after semi-structured, open-ended interviews with the coordinator of each project. The one interview was conducted virtually lasting approximately one hour, while the other took place in an asynchronous way through a questionnaire (Google form format). In the case of the virtual interview, the interviewees received the questions beforehand. Both the virtual interview and the questionnaire included the same set of open-ended questions on the projects' PE practice implementation, and particularly on processes that were not clear in the deliverables and needed clarification. Notes were kept from the online interviews, and in the second case the interviewee's answers were extracted from the Google forms. Afterwards, both the data from the interviews and those from the cataloguing of the practices were integrated in the data corpus of the study found in the qualitative software database NVivo12, in order to be thematically analysed.

3.2. Qualitative Analysis (Thematic Analysis)

The qualitative software program NVivo12 was employed for analysing the data collected, and a Thematic Analysis (TA) and the six-step framework of Braun and Clarke (Braun and Clarke 2006) were applied (familiarising with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, producing the report). Selecting this qualitative method relied on the following: (a) TA can be applied across various research approaches including inductive, deductive, or semantic, unlike other qualitative methods (e.g., Grounded Theory, Discourse Analysis), where a specific explanatory model must be developed and/or the analyses should address a particular theoretical or epistemological position; (b) it can be employed not only for unravelling the 'surface' of reality, but also for reflecting reality within a functionalist paradigm (like in the case of PE implementation in EU projects); (c) a wide range of data can be thematically analysed (Herzog et al. 2019), from focus groups and interviews to secondary sources and online documents—like in the case of EU project deliverables (see indicatively Ditchfield and Meredith 2018; Massey 2011 for different instances of TA).

As argued by Braun and Clarke (Braun and Clarke 2006), 'thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data, while simultaneously minimally organising and describing the data set in rich detail' (79). *Themes* are defined as 'patterned responses or meanings that capture something important about the data' (Braun and Clarke 2006). The acquisition of our themes signified acquiring the implementation patterns of the PE practices examined—resembling 'tendencies' and learning points consulted when attempting to have inclusive R&I practices and foster new collaborations between experts and the public.

In order to generate the final themes and based on the six-step framework, data compilation was followed by an immersion in the data. The initial codes were generated based on the data content and through an open-coding process. Theme development then took place based on the inductive/bottom-up approach (Braun and Clarke 2006; Frith and Gleeson 2004), with data-driven themes (Patton 1990). We further allude to the development of semantic themes reflecting the explicit meanings of the data within a realist framework (Boyatzis 1998). This framework accordingly allows reporting the reality evident in the data. In the present case, the reality of the data signifies the implementation patterns evident in PE practices, as reflected from the data/EU project deliverables. These deliverables are actually seen as inscription devices (Salk et al. 1986) based on the representation of EU practices' implementation and the consequent knowledge communication.

4. Results

The present section thoroughly presents the analysis of the themes developed. The initial themes and corresponding thematic map were developed during step 3 of the thematic analysis, and were reviewed and refined during step 4. The reviewing/cross-checking of the candidate themes took place with reference to (a) the coded extracts and (b) the entire data set. This led to some themes becoming sub-themes, or being collated with each other and becoming one theme. The refinement that took place in step 5 finally highlighted the essence of each theme (and themes overall).

Five themes and thirteen sub-themes were ultimately detected within and across our data. As previously argued, these themes and sub-themes indicate the implementation patterns of the seventeen PE practices examined; in other words, how they are put in practice, most common PE activities, what methods, strategies, and/or tools are used, as well as aims and achievements (impact) of the practices.The final five themes are: (1) *public engagement activities*; (2) *methods for bridging the science–society gap*; (3) *development of new tools*; (4) *social impact*; (5) *knowledge mobilisation*. Figure 4 depicts the final thematic map, described in the following section and exemplified through quotes as indications of practices.

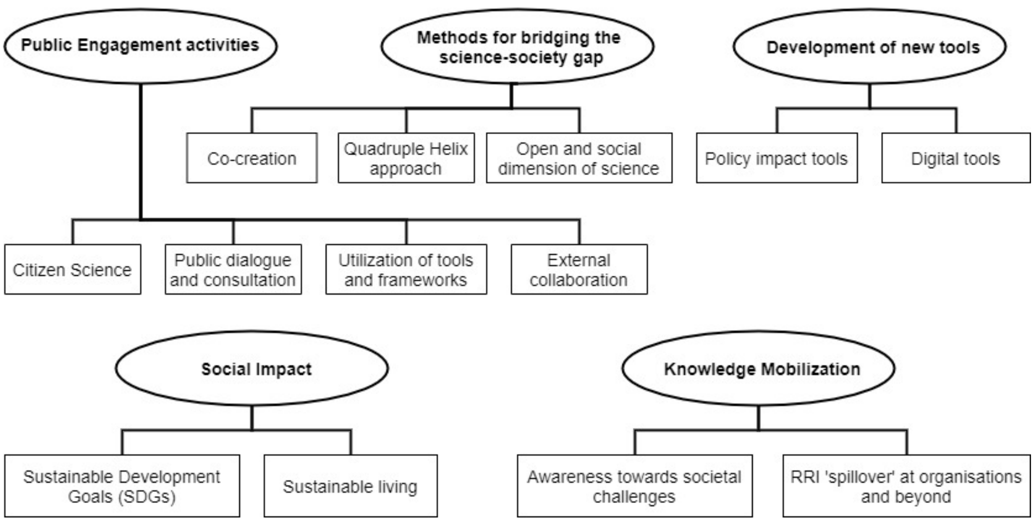

Figure 4. Final thematic map with five themes and thirteen sub-themes.

4.1. Theme 1: Public Engagement Activities

The first theme refers to the differentiated ways that PE was tangibly put in practice throughout the PE practices. Different activities would take place, differing based on (a) the means for engaging the public and citizens, and (b) their degree of engagement—thus resulting in a broad classification between *(a) citizen science* and *(b) public dialogue and consultation*. Supplementary actions for enriching PE implementation and maximising impact would also take place, mostly by *utilising existing tools and frameworks* and/or by capitalising on *external collaborations*.

4.1.1. Sub-Theme: Citizen Science

Citizen science (CS) is classified as any process where scientists and public cooperate for exploring real-world scientific topics, with the public collecting and/or processing scientific data or performing observations (West and Pateman 2017). Drawing on our data, the GRECO Consortium implemented CS by launching a Citizen Science App, where citizens collected scientific data related to photovoltaic installations:

> The generation of the solar app focused on providing to its users: The ability to record the highest installed capacity (either huge installations or many small ones); The ability to report as many solar installations as they can. (GRECO)

Occasionally, citizens may also contribute to the development of new scientific-technological products through their involvement in CS initiatives, such as in GRECO with the development of an Ageing Model for Photovoltaic Modules and a Repairing Procedure of PV systems. In particular, data generated by citizen scientists are most often integrated into the research process, so that scientists capitalise on them for developing the target products.

Some PE practices, though, do not enhance the application of CS per se, but provide relevant demonstrations, workshops, and hand-on activities on CS during public events. BigPicnic initiated the BigPicnic basket outreach exhibitions, which were defined as the '*co-creation sessions on a food security topic by using the metaphor of a picnic basket*' (BigPicnic). A range of relevant activities was incorporated, for instance, the workshop 'Observing bees with binoculars' promoting the application of CS). On other occasions, the PE implementation addressed CS by providing resources towards supporting any CS manifestation. Indicatively:

> Developing the citizen science toolkit, which follows the participatory science lifecycle [...] it consequently helps citizen scientists (or anyone interested in citizen science) plan, create, improve, and maximise the impact of their projects. (ACTION)

4.1.2. Sub-Theme: Public Dialogue and Consultation

PE implementation would often take place through public dialogue and consultation that enables (a) information-raising activities, and/or (b) a two-way communication and consultation between scientists (experts) and citizens. Such activities tend to focus on mobilisation and mutual learning (ML) processes and on the concept of mutuality:

> The corresponding workshops have been part of the Mobilisation and Mutual Learning process to be carried throughout the end of the MARINA project. The MML workshops are seen as an essential activity for federating RRI communities, as well as for exploring and finding better solutions to marine and societal challenges through wide involvement of stakeholders. (MARINA)

Public dialogues and consultations also evolve in context-based formats, indicatively including '*World Café, Focus group, Reversed Science Café*' (GRECO). Visioning and Scenario planning is also a notable method enhancing public dialogue and fostering citizen consultation; the scenario-building process entails the collaborative construction of future scenarios, which do not predict the future but rather illustrate possible futures (Joint Research Centre and Institute for Environment and Sustainability and European Commission 2008). For example:

> Citizens of five European countries were consulted through a focus group exercise (a form of citizen consultation), so as to gain qualitative insights into citizens' perceptions of the INHERIT future 2040 scenarios and to explore similarities and heterogeneity in perception. (INHERIT)

4.1.3. Sub-Theme: Utilisation of Tools and Frameworks

PE implementation builds on existing tools, theories, and frameworks for ensuring optimum results. The MARINA Consortium utilised PLAKSS (Platform for Knowledge and Services Sharing) for developing its own knowledge platform. The ACTION citizen toolkit capitalised on the CONEY tool (conversational survey toolkit) aiding researchers in collecting data from users, while the (STEEPLE) Horizon Scanning Approach was employed for constructing the future 2040 scenarios and identifying *'the trends and drivers that were relevant to the triple-win areas of health, environment and equity'* (INHERIT). As for theoretical frameworks, the Behavioural Change Wheel (BCW) and the Theory of Change were employed as a source of inspiration for the the INHERIT future scenarios. Finally, the Team-Based Inquiry approach (TBI) was employed in BigPicnic for collecting data from the food security science cafés, referring to *'a cyclical process of inquiry: question, investigate, reflect and improve'*.

4.1.4. Sub-Theme: External Collaboration

A collaboration extending beyond the consortium would often enhance the effective PE implementation. External collaboration is often encountered in the form of collaboration with 'sister' EU projects (cross-project collaboration); indicatively, the MARINA final workshop was conducted under a synergy with the ResponSEAble project, while the BigPicnic co-creation navigator was collaboratively developed with MUV-Mobility Urban Values and Cities-4-people H2020 projects. Finally, external collaboration can entail cooperation with experts (individuals and organisations) on the respective field and societal challenge addressed by each PE practice. For example:

> Prior to implementing this practice [science cafés], an FSAG—Food Security Advisory Group (experts related to food and food security) was established in each country. The role of the FSAGs was to provide information about food, production, food security, food research [...] comprised professionals from agriculture and farming, industry, academia, NGOs, retail, grass-roots organisations etc. (BigPicnic)

> Links were established with main representatives of Water Governmental Departments, CEOs of SMEs, Presidents of Irrigators Communities, Heads of National Irrigators Associations, Farmers and Irrigators. (GRECO)

4.2. Theme 2: Approaches for Bridging the Science-Society Gap

Throughout the differentiated ways that PE was tangibly put in practice, concrete approaches were applied and/or promoted for successfully bridging the science–society gap. These approaches are the following: (a) *co-creation approach*; (b) *quadruple helix approach*; (c) *open and social dimension of science*.

4.2.1. Sub-Theme: Co-Creation

The instances of co-creation encountered in the data set would build on close interactions between the promoters of PE practices and their recipients (i.e., the public, society's representatives). Co-creation processes fostered active dialogues and tested how research and development can benefit from different actors' perspectives and stakeholder inclusion. A holistic vision was also developed by the ones participating in the co-creation process, and collaborative methods for knowledge-sharing would be systematically exploited. A specific example of co-creation is quoted below:

> The MML workshops had the objective to activate participants to identify and prioritise solutions to the marine and societal challenges related to the hot topic and co-create personal, local and international roadmaps based on the RRI criteria and socio-technical approach. (MARINA)

A few PE practices took another direction, and spread knowledge on how to successfully apply co-creation. The GRECO Open Innovation Toolkit defined three types of co-creation approaches: those devoted to gathering insights, those for ideation, and the ones devoted to prototyping and testing.

4.2.2. Sub-Theme: Quadruple Helix Approach

Most PE practices aspired to create coalitions among the various Quadruple Helix (QH) representatives; the ultimate aim was to bring together the expertise from many areas of knowledge and draw scientists closer to citizens (and vice versa). Such interactions contributed to achieving inclusiveness of science and delivering products with a human-centric design as a result of fruitful collaboration between policy-makers, RRI implementers, and the public. For example:

> Multidisciplinary target groups were approached and engaged to the project's practices (e.g., citizens, NGOs and CSOs, students, researchers, business representatives, policy makers, experts in communication and other kind of stakeholders). (MARINA)

As for the specific QH groups addressed, they varied based on the nature of the PE practices; indicatively, the INHERIT 2040 scenarios targeted policy-makers and stakeholders interested in a better European future. Efforts for engaging diverse groups of people from the societal QH category, including minority and vulnerable groups, were finally noticed.

> The audiences selected included 'hard to reach' individuals: refugees, migrants, schoolchildren, students, individuals living in lower social and economic areas, senior citizens, families, urban gardeners, middle class consumers, activist groups, policy makers, socially disadvantaged children as well as teenagers. (BigPicnic)

4.2.3. Sub-Theme: Open and Social Dimension of Science

All the PE practices examined were realised based on the principles of transparency and open innovation; in other words, all stages of PE implementation were open to the interested stakeholders and publicly communicated to the wider audience. As for the socially driven orientation of the PE practices, it enhanced the development of scientific products that are aligned to current societal challenges, needs, and stakeholder expectations. It is finally worth noting that facilitating factors for the above were the following: (a) enhancing RRI and PE in every stage of a research project; (b) improving the visibility of PE results. In particular, Open Science and Open Innovation exercises, and Open Access to research outputs can highly enhance participatory and socially infused forms of science (e.g., Big Picnic navigator). More specifically:

> The methodological procedures applied capitalise on the open innovation design principles. Open Innovation is a process that refers to the inclusion of external experts into a solution finding process [. . .] thus ensuring an active participation of stakeholders in research activities. (GRECO)

4.3. Theme 3: Development of New Tools

The next PE implementation pattern refers to the overall PE implementation and the goal of bridging the science–society gap being enhanced by the development of PE-related tools during the projects' lifespan. In correspondence to their objectives and functionalities, these tools are classified as (a) *policy impact tools*, and (b) *digital tools*.

4.3.1. Sub-Theme: Policy Impact Tools

These tools allude to policy guidelines and recommendations; such content contributes to formulating and implementing policies and overall (and potentially) influencing decision-making. Recommendations are developed by drawing on lessons learned and expertise generated during PE initiatives, and tend to be accompanied by collections of good practices. Exploitable suggestions on the following are usually provided: (a) addressing core societal challenges through public participation; (b) integrating the RRI approach (including PE) to the scientific sectors/fields addressed by each project for enhancing the inclusive and human-centric features of R&I (e.g., marine sectors in MARINA). Indicatively:

> ...A policy roadmap with 20 policy interventions related to the four lifestyles of the scenarios [...] ranging from legislative, environmental and social planning to service provision or communication and marketing policy types (e.g., reducing private car use, securing big data etc.) (INHERIT)
>
> Policy recommendations were formed (Evaluation Goal No 2). They targeted both policy makers and informal learning sites, they are relevant to the United Nations' Sustainable Development Goals (SDGs) as well as to the European Union's Food 2030. (BigPicnic)

4.3.2. Sub-Theme: Digital Tools

This category refers to developing a digital PE infrastructure composed by toolkits, databases, apps, and knowledge platforms. The digital tools developed within the seventeen analysed practices are:

- Citizen science toolkit/socio-technical toolkit (ACTION)
- Lifecycle-aware Citizen Science templates (ACTION)
- Solar Generation App (citizen science app) (GRECO)
- Online Web Knowledge Sharing Platform—MARINA WKSP (MARINA)
- Online Database of Promising Practices on 'living, moving, consuming' (INHERIT)
- Co-creation navigator (BigPicnic)

Databases of practices and toolkits are resource collections addressing multiple audiences. The ACTION socio-technical toolkit indicatively *'addressed everyone interested in using citizen science against pollution, while simultaneously offering resources for a wide range of citizen science characteristics'* (ACTION). Concurrently, the INHERIT database identified more than 100 good practices for triple-win cases (i.e., environment, health, and reducing of health inequalities). As for the remaining tools, these provide to users the opportunity to collect scientific data (Solar Generation App in GRECO), and to create robust RRI networks and stakeholder synergies addressing a common mission (e.g., a specific societal challenge). For instance:

> The Platform aims at providing actors and stakeholders with a set of on-line resources and tools to enable discussion, and co-production of ideas related to societal challenges, with a focus on the marine thematic area [...] and to foster the creation of the Federation of the RRI communities. (Web Knowledge Sharing Platform, MARINA)

4.4. Theme 4: Social Impact

Proceeding a step further to the results of PE, PE implementation outcomes would heavily allude to a social impact. A new state of affairs is firstly created for citizens at an individual level with reference to their everyday life, habits, behaviors—summarised under the sub-theme of (a) *sustainable living*. Extending social impact at the broader collective level, society is gradually transformed owing to PE practices that address societal challenges acknowledged by the EC and the United Nations—thus overall contributing to addressing the (b) *Sustainable Development Goals (SDGs)*.

(a) *Sub-theme: Sustainable living*: Citizens are provided with the opportunity to adopt a new mode of living through the PE practices they participate in; for instance, they are encouraged to adopt healthy behavior and change lifestyles for supporting the environment. Such a context surrounded the INHERIT triple-win cases, as well as the BigPicnic efforts to inform people on *'how sustainable ways of eating can be achieved, how alternative ways of food production and consumption may contribute to changing food habits.'*

PE practices that foster sustainable living throughout their implementation target individual behavior at a first stage, and consequently attempt to trigger lifestyle changes at a broader societal level. Such transformations indicatively *'ensure that EU citizens live within the limits of our blue planet and that European societies evolve in ways that enable all people to live and behave in ways that enhance quality of life'* (INHERIT). Individual transformations are thus the stepping stone concerning achieving the collective goals analysed in the following sub-theme.

(b) *Sub-theme: Sustainable Development Goals (SDGs)*: PE-driven changes enabling collective social impact can contribute to addressing some of the SDGs and to building the 'Future We Want' (2030 Agenda). In more detail, PE can function as a facilitating factor encouraging governments and businesses to take action while cooperating with citizens, thus enhancing the emergence of societal transformations necessary for fulfilling the goals within reach (West and Pateman 2017). The SDG-related societal transformations can indicatively address: *'major forms of pollution'* (ACTION); *'8 main marine challenges'* (MARINA); *'Energy, Circular Economy, Agriculture'* (GRECO); *'Local and global food security issues, as well as the key Food and Nutrition Security priorities (Food 2030)'* (BigPicnic).

It is finally worth noting that while participating in such PE practices, citizens also become horizontally informed on how RRI principles can address grand challenges and enhance sustainable development:

> Core topics discussed referred to 'How can Responsible Research and Innovation contribute concerning making tourism in EU coastal and marine areas a driver for sustainability'—thus informing concerning the EU Blue Growth strategy, the UN Sustainable Development Goals, and the International Year of Sustainable Tourism. (MARINA)

4.5. Theme 5: Knowledge Mobilisation

The final theme similarly refers to the outcomes and impact of PE implementation, but acknowledges and emphasises the PE practices' beneficial and multiplier effect. Participatory R&I processes and inclusive QH engagement result in a broad knowledge transfer with two reference points: (a) *awareness concerning societal challenges* and (b) *RRI 'spillover' at organisations and beyond*.

4.5.1. Sub-Theme: Awareness concerning Societal Challenges

PE-driven R&I practices often 'tailor' their features on societal needs, thus giving prominence to new socio-scientific processes. Actors and particularly citizens involved in these processes acquire a realistic awareness concerning contemporary societal challenges intimately linked to STI and R&I. For instance, awareness is spread concerning challenges to be confronted for having *'more equitable and sustainable European societies by 2040: Health, Health Equity and Environmental Sustainability'* (INHERIT). Awareness-raising on societal challenges may also be an objective set a priori for some PE practices within the context of sensitising contemporary societies.

4.5.2. Sub-Theme: RRI 'Spillover' at Organisations and Beyond

Knowledge diffusion on societal challenges is accompanied by a diffusion of scientific knowledge on RRI. RRI knowledge mobilisation addresses in its own turn two target groups; (a) European RPOs wishing to implement RRI in their scientific and operational activities; (b) QH representatives potentially interested in (and benefited by) responsible R&I activities. In the latter case, RRI visibility in the STI and scientific area can also give prominence to RRI at the local and regional level.

> Additional researchers may also be reached within the same context, perceive RRI as a 'mission possible' and be encouraged to apply RRI policies within new projects. This consequently leads to an effective application of RRI principles, realisation of follow-up RRI initiatives, and to a widespread RRI uptake. (GRECO)

Finally, digital infrastructure accompanied by a well-planned communication and dissemination strategy can considerably extend RRI knowledge diffusion and the fruitful exchange of RRI experiences. Indicatively, the ACTION platform aimed to help citizen scientists in using existing 'specialised' platforms and publishing the PE results according to RRI principles, thus additionally assigning high visibility to the RRI experience.

Overall, the present section outlined the findings of the thematic analysis in the form of the themes. The five themes and thirteen sub-themes developed indicate how PE practices that evolve during the lifespan of EC-funded projects tend to be implemented; in summary, the implementation patterns identified reflect which activities public engagement is put in practice through, which approaches and tools enhance PE and at a broader level RRI implementation, as well as main goals, achievements, and emerging contributions. The description of themes is also accompanied by a critical interpretation and discussion in Section 5.

5. Discussion

The present study overall identified the implementation patterns of RRI PE initiatives, and suggests in an evidence-based way how RRI-driven public engagement practices can be fruitfully operationalised, so as to afterwards foster an inclusive and human-centric R&I implementation. Insights regarding successful operationalisation broadly relate to *Actions* and *Results*. These insights primarily provide PE practitioners with suggestions concerning the practical 'execution' and implementation of a PE practice, and outcomes potentially entailed by the practice per se. Apart from PE practitioners, stakeholders, and citizens interested in organising or participating in PE practices, researchers and policy-makers can similarly exploit the study results. Researchers can gain valuable insights on how to approach society, build a relationship of trust with them, and conduct human-centric research that corresponds to genuine societal needs and 'end-user' perspectives. Policy-makers on the other hand can become informed on how to: (a) pursue inclusive and human-centric innovation, particularly at local and regional levels where interaction among the quadruple helices in more direct and promising; (b) how to ensure the realisation of responsible R&I activities, which consider and take action for a multitude of visions and ensure the genuine commitment rather than mere participation of the public.

In terms of *actions*, the analysed practices indicated and verified that RRI PE activities vary and will take different forms depending on the needs of engagement. It was also verified that most PE activities tend to 'methodologically' correspond to classifications of PE forms that have been acknowledged both by scholars and the EC; in particular, the most frequently performed PE activities are the downstream ones, enabling public communication and consultation through dialogue, events, and learning activities. On some occasions, emphasis is also on presenting to the public a 'mutual' R&I governance vision unifying 'the (tacit) assumptions, meanings, values, and consequences of new science and technology for society' (Krabbenborg and Mulder 2015) for collecting further feedback and actively fostering an inclusive and co-created R&I vision—fostering in its own turn an inclusive R&I implementation. Nevertheless, the tendency of EU project practitioners to implement PE mostly in a downstream way may unintentionally verify the scholarly concerns about performing PE in a way that allows little space to the public for participation (Bucchi and Neresini 2008), and even attempts to ensure legitimacy for the proposed actions (Barthe et al. 2001) rather than a human-centric approach. Such arguments may concurrently be further enhanced by the absence of upstream engagement in the analysed practices, where the public can take a more 'leading' role and 'define' the directions of future research. Finally, it is worth noting that few interactive activities would be embedded in the downstream and 'informative' PE activities (but less frequently), alluding to instances—rather than stand-alone activities—of midstream PE where the experts rely on mutual learning processes and ask for the public's feedback after informing them. This exploitation—even minor—of midstream engagement further reminds of the PE-related category of crowdsourcing, which is also one of the acknowledged PE forms (Guimarães Pereira et al. 2016). Implementing PE through crowdsourcing allows the acquisition of collective and inclusive feedback and finally verifies that interaction with external environments is considered to be enriching the opportunities (or agendas) for advancement (Wittrock and Forsberg 2019).

PE activities in the form of CS have not been so systematically performed within the practices and projects examined. Nevertheless, the analysis of the PE practices suggested that CS methods for introducing and engaging the public in scientific processes often have a digital interface—for instance, relevant apps or online toolkits. This can be associated with the pan-European character of the PE initiatives and the goal of reaching multiple audiences and engaging 'anyone interested' (as also mentioned within the data analysed). Concurrently, digital and distant engagement is expected to be further amplified within the post-COVID era and the relevant familiarisation with digital services, but nevertheless raises questions as to how much inclusive the engagement can actually be (e.g., taking into consideration the digital divide among different geographical areas). As for the 'nature' of CS, the examined practices and the differentiated CS use in each case indicated the following: (a) CS is indeed an aspect most often 'coupled' with PE (Craglia and Shanley, as quoted in Guimarães Pereira et al. 2016), by allowing the public to become actively engaged with scientific processes (Martin 2017) and combining PE with scientific research (and vice versa) (Riesch et al. 2013) for ultimately initiating human-centric epistemic scientific practices(Kasperowski and Kullenberg 2019); (b) CS aims at raising scientific awareness on specific scientific fields, either as a main or supplementary activity (for example, on food security, PV energy, and pollution), thus being more successful in terms of science communication and scientific literacy rather than human-centric and inclusive R&I implementation. In particular, the latter observation verifies previous arguments on the exploitation of CS (Nascimento et al. 2014) for scientific literacy, but also contradicts the basic 'definition' of CS having to do with two-way, active collaboration. Overall, the aforementioned CS manifestations enhance the Guimarães Pereira et al. (2016) arguments on CS, based on which it is occasionally challenging to classify CS activities either as an acknowledged PE form, or as a means to support and enhance inclusive PE. However, no additional major insights on the relation between CS and PE, and on the implementation patterns of CS for inclusive and human-centric R&I can be drawn due to the few relevant instances in the data. For overall avoiding relevant confusion on PE, CS, and their in-between relation, suggestions made for improved RRI-related implementation in Horizon Europe can be considered; investment efforts could address training, education, and publicity for circulating a common idea to the key stakeholders (Braun and Griessler 2018).

The next concluding observation refers to PE practices abiding by equality and diversity principles. Implementing PE practices based on diversity and equality principles was usually a means to develop partnerships with different and diverse actors, thus verifying that the Quadruple Helix approach is a vital part of co-creation (Fagerberg 2018; Foray 2014; Wittrock and Forsberg 2019). The integration of such principles in the various PE implementation stages was also a significant driver for ensuring the integration of multiple perspectives and needs in accordance with the ISO standards for a human-centric approach. Then, diverse actors' inclusion also seemed to enhance the transferability of the examined practices, since they reached a broader audience by addressing a broader spectrum of needs. In particular, the equal (and non-biased) treatment of engaged actors further acknowledges and verifies the importance of fairness being a vital aspect of all responsible and inclusive R&I activities (Gerber et al. 2020). Finally, the prominent consideration of diversity and equality in the implementation of the PE practices further verifies multiple arguments on the overlapping nature of the RRI keys, and on their in-between interdependency (Wittrock and Forsberg 2019). The PE practices examined suggested that PE can heavily capitalise on principles of other RRI keys; gender equality, where the QH actors are 'recruited' without any bias; open access/open innovation/open to the world (the '3 Os'), where the open and social dimension of science is enhanced and all stakeholders are equally informed concerning R&I outputs; ethics, where engaged stakeholders equally co-contribute to an agenda, fostering a holistic vision and shared responsibility (ethics). As for the effect of the RRI keys' overlapping on the effectiveness of PE implementation, it seemed to have beneficial effects in terms of impact both inside and outside the ecosystem (EC project goals, and inclusive human-centric R&I implementation accordingly). It is finally worth highlighting that the overall and frequent overlapping among the RRI keys (Wittrock and Forsberg 2019) further enhances arguments on the concept of separate RRI keys being more relevant to the EC funding activities (Pellé and Reber 2015), SwafS and the horizontal RRI enhancement (Rip 2016), rather than to the conceptual foundation of it as articulated in (Stilgoe et al. 2013).

Proceeding further, PE practices examined further spelled out considerable *results* and 'justify' in this way their worthwhile capitalisation. Successful outcomes can be demonstrated through newly developed tools, functioning as an enabler for PE and enriching the existing collection of practical contributions to RRI (Mejlgaard et al. 2018). Based on the PE practices examined, successful outcomes in terms of external impact and inclusive, human-centric R&I implementation can then be 'confirmed' when (a) both individual citizens and broader (European) communities become recipients of a new knowledge and adopt new behaviours tailored to their needs, and (b) all the aforementioned context-based changes and the emerging state of affairs become 'anchored' and sustained. In particular, the importance of achieving sustainability for the achieved changes has been highlighted by previous literature as well (Wittrock and Forsberg 2019).

Returning to the diffusion of new knowledge as an outcome of the inclusive human-centric PE implementation, it is related to societal challenges, scientific concepts, and their in-between relation—as also suggested by Jasanoff (2003) and Marschalek (2017) and their arguments on PE-driven knowledge fostering the development of a new science–society 'contract'. Challenges addressed are firstly listed among the EC grand challenges. Then, the diffused scientific knowledge alludes to RRI and scientific fields that provide inclusive and context-based solutions to the aforementioned societal concerns. A knowledge flux of this nature thus suggests the frequent co-existence of scientific and societal elements in the PE-driven knowledge production process—an aspect further enhancing arguments on the importance of 'hybrid forums' that ameliorate scientific knowledge (Barthe et al. 2001) and the interaction between the public and experts. In particular, this interactive and hybrid problem-solving space between science and society can prevent the 'over-ruling' of the experts and mitigate concerns about the creation of new expert elites (Thorpe and Gregory 2010; Voß and Amelung 2016), potentially emerging out of the systematic application of downstream activities.

Based on the theme of *social impact*, it is verified that the inclusive implementation (and results) of PE practices reach broader communities when the latter ones acquire the capacity to be response-able (Meissner 2017) by adopting a more sustainable way of living (individual level) and contributing to addressing major goals, including the SDGs (collective level). The integration of a socially oriented narrative in R&I both verifies and strengthens the adoption of a human-centric approach; it further results in a relevant social impact that affects both (a) the experts and citizen communities, and (b) the fields of innovation and technology. Social effects on STI and R&I could, however, have been described in more detail in the data collected since, as mentioned, they contribute to having human-centic R&I systems that truly undergo changes through PE implementation and even acquire the ability to address their own internal R&I 'wicked' problems. Such argumentation has been missing by the description of the PE practices, even if this is a vital issue that was put forward several years ago, and should be entailed by PE integration in R&I procedures (Rittel and Webber 1973). What could be argued here is that, probably owing to the EC indications to achieve enhanced and inclusive citizen participation, there is a bigger emphasis on demonstrating such results. Nevertheless, RRI and PE-driven R&I can lead to a multi-layered social impact, enhancing the collaborative knowledge production that is tailored to public views and needs. Such collaborative knowledge production overall has the potential to exceed the Foucauldian sense where citizenship is often combined with techno-science advancements only for legitimating the latter—thus once again mitigating risks and criticisms referring to the dominance of expert elites (Barthe et al. 2001).

6. Conclusions

The present study identified and critically interpreted the core implementation patterns of RRI-driven PE practices, which evolve during the lifespan of EC-funded projects and attempt to foster an inclusive and human-centric R&I implementation. The qualitative approach adopted and the examination of the deliverables of five EC projects based on a set of pre-defined criteria led to primarily identifying seventeen PE practices. The thematic analysis applied to these seventeen practices led to identifying and interpreting their implementation patterns, thus gaining insights as to how RRI-driven PE practices aiming to foster an inclusive and human-centric R&I approach are usually put in practice. Some of the identified implementation patterns were indicated as more 'effective' than others in terms of genuinely facilitating the inclusive and human-centric R&I implementation, thus also constituting the basis for the study's suggestions. Overall, the insights provided by this study should not be seen as standpoints but rather as learning points, since the contextualisation of future R&I and PE initiatives cannot be overlooked.

PE practices usually evolve in forms already acknowledged both by the EC and by previous scholarly literature, particularly in a downstream way and by capitalising on co-creation and the Quadruple Helix approach. The strong consideration of these two latter approaches verifies the importance of cooperation with different and diverse actors in hybrid, democratic, and open (transparent) spaces, resulting in enhancing the inclusive and human-centric R&I implementation. As for the frequent implementation of downstream rather than upstream and midstream activities, it raises some concerns concerning the genuine participation of the public and the experts' interests concerning ensuring legitimacy for their actions. Similar concerns on the genuine and inclusive PE implementation are raised due to the frequent implementation of CS through digital means and/or in the form of awareness-raising, resembling to efforts to ameliorate the recipients' scientific literacy. The present study could thus suggest that while the co-creation and quadruple helix approach are major facilitating factors for inclusive and human-centric R&I implementation, the systematic realisation of exclusively downstream and one-way CS activities mostly proves to be a hindering factor.

Proceeding to the overall RRI context surrounding the PE practices, it affects the overall PE implementation in an undoubtedly beneficial way. A fruitful interdependency and overlapping between the different RRI keys and PE highly enhances the fairness, diversity, and inclusiveness of PE implementation. It further verifies a few more holistic arguments on RRI, having to do with the fact that the differentiated keys mostly serve EC funding purposes rather that RRI implementation. It is therefore recommended that PE practitioners could look for synergies among the different RRI keys in order to maximise the effectiveness and inclusiveness of their actions.

Finally, the inclusive and human-centric PE implementation enhances the exploitation of scientific knowledge for addressing major societal challenges, leading to the emergence of a social impact at both individual and collective levels. This multi-layered social impact can be further enhanced through a sustainability agenda, and can even mitigate the risk of (unintentionally) promoting expert elites. Such impact certainly has the ability to affect lay citizens, overall communities, and experts, as well as the field of STI and R&I per se (even if primary emphasis is usually placed on the former). Therefore, the development of a sustainability agenda accompanying the implementation of PE practices is highly recommended, so as to avoid PE agendas being 'hijacked' by elites, and maximise the impact per se of such agendas.

Along with showcasing the implementation patterns for achieving an inclusive and human-centric PE and its emerging benefits, it is equally important to highlight potential difficulties. Generally acknowledged difficulties have been mentioned in the literature review section, for instance, public reluctance, and the difficulty of genuinely integrating the public input in decision-making) (for a more detailed account of prominent difficulties in PE initiatives see Krabbenborg and Mulder 2015 and Marschalek 2017). The major and specific risk—or even occasionally back-firing effect—indicated by the present study refers to having a mechanistic rather that genuine public participation (Frahm et al. 2021) irrespective of good intentions. Still and as already argued, in spite of prominent challenges it is advised to opt for PE-driven practices and consequent results in the light of RRI to be sustainable. Sustainability can enhance the potential for socio-scientific transformations to be functioning as learning points (Wittrock and Forsberg 2019), rather than as tokenistic activities or short-term goals in a series of 'imposed' EU changes.

A few limitations of the present study should be finally acknowledged. Transferring RRI as an academic theory into innovative European practices can produce several implications, particularly when combined with the simultaneous attention that PE concentrates on scholarly analysis, EU policy lines, and social perspectives. EC-funded projects and the implementation patterns detected in them encompass these implications, when they have to apply sound, scientifically robust, and socially beneficial PE practices, which concurrently need to be context-based. Therefore, the examination of PE implementation patterns detected in EC projects could be supplemented by additional data in future research attempts. In addition, PE impact is challenging to measure, since it is open-ended due to the progressive information flow in society, and is often dependant on the 'sponsor' aims (i.e., the EC 'commands') and the time limitations of the EC projects. In a similar vein, it should be highlighted that in order to avoid misinterpretations in terms of impact achieved, the internal and external impact of the PE practices being analysed and mentioned in the present study draws exclusively to the implementers' arguments found in the project deliverables. It thus constitutes an additional limitation of the present study due to the lack of a more 'formal' evaluation.

In terms of future research, studies could address more extensively and based on a bigger sample the implementation patterns of RRI-driven PE and their impact for enhancing the inclusive stakeholder involvement and human-centric approaches. Triangulation of data from multiple sources could also take place to enrich the insights gained, as mentioned above. PE practices initiated in a different context other than the one of EC projects could similarly yield interesting insights—and even enable comparisons per type of 'change agent' and 'sponsor' initiating the PE practices. For example, companies nowadays are increasingly attempting to systematise stakeholder engagement through corporate social responsibility (CSR) policies, thus providing a rich ground for relevant research. Finally, capitalising on theories of change (ToC) for examining PE implementation in the R&I field is potentially worth exploring, since such theories provide a basis for 'planning' desired outcomes and necessary conditions for change in an incremental way. Future studies can overall enrich the insights gained by the present study, and deliver their own contribution in terms of how (RRI-driven) PE implementation can address the 'wicked' dilemma between the 'technocratic option (leaving it to the experts) and the ethical option (leaving it to the conscience of individual users)' (Bucchi and Neresini 2008), and which PE implementation patterns can be genuinely beneficial.

By identifying and critically analysing the implementation patterns of past RRI-driven PE initiatives, this study suggests what can be included in the PE implementation agenda and which aspects (actions) can enhance the ability of future R&I systems to inclusively co-shape science and innovation with society under a human-centric approach (results). The target groups addressed by the study can exploit the information found under each theme, and become informed on which implementation patterns and implementation sub-steps can foster (and to what degree) inclusive public engagement and socio-scientific collaboration. The concluding recommendations summarising the patterns that either enhance/facilitate inclusive PE implementation or end up mostly hindering it, can prove valuable notably for policy-makers and PE practitioners organising future PE activities. Such hints on facilitating and 'hindering' factors concerning inclusive PE implementation can similarly be exploited for mitigating some prominent perils in the upcoming years, referring to: (1) RRI-driven PE being marginalised as a non-efficient and past scientific trend; (2) PE being framed as a concept *on top* of what EU researchers and innovators already include in their action plans; (3) the possible wearing-away of 'pressures' for having democratised and inclusive practices in science and technology processes.

Ultimately, the study's target groups consisting of PE practitioners, citizens, policy-makers, and researchers can exploit the study's concluding and theme-based recommendations for: (a) putting in practice inclusive and two-way public engagement in the first place, and (b) gaining insights on how to achieve the highest possible results in terms of inclusive and human-centric R&I implementation. The PE implementation patterns and the corresponding concluding observations finally indicate that a decade of RRI can offer a number of legitimate agendas and lessons regarding responsible engagement, and consequently responsible research and innovation under a human-centric perspective. As repeatedly highlighted, these insights and recommendations constitute learning points and not standpoints; they provide a robust basis that is nevertheless open to a further context-based application by the study's target groups, always in alignment to the fact that RRI needs tailored and not normative implementation approaches. Therefore, these concluding remarks will always be open to further interpretation depending on context, as well as on the need to achieve 'a reconciliation between the EC RRI keys approach and an integrated broader RRI vision' for science, technology, and innovation (Owen and Pansera 2019).

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Notes

1. The authors of this paper have not been part of the consortium of the projects examined. The mapping exercise and consequent examination of these five projects took place during the tasks of another project, where authors were members of the consortium and the main implementing team.
2. RRI projects are EC-funded projects implemented under FP7 and H2020, and address Responsible Research Innovation (RRI) through specific interventions that build on the six RRI keys. For more details on RRI projects, please see the database of RRI tools (https://rri-tools.eu/, accessed on 10 June 2022).
3. Within the context of H2020, the EC defined the following major societal challenges: (1) Health, demographic change and wellbeing; (2) Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy; (3) Secure, clean and efficient energy; (4) Smart, green and integrated transport; (5) Climate action, environment, resource efficiency, and raw materials; (6) Europe in a changing world—inclusive, innovative, and reflective societies; (7) Secure societies-protecting freedom and security of Europe and its citizens.

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