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Responsible Research and Innovation applied to Renewable Energy Research. A theoretical contextualization and implementation proposals

Ruth Carbajo García

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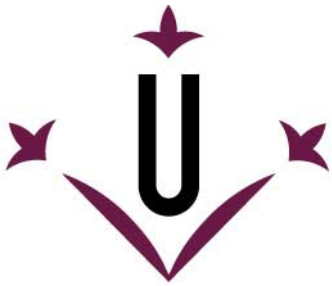

Universitat de Lleida

Responsible Research and Innovation applied to Renewable Energy Research. A theoretical contextualization and implementation proposals

Ruth Carbajo García

Memòria presentada per optar al grau de Doctor per la Universitat de Lleida

Programa de Doctorat: Enginyeria i tecnologies de la informació

Director

Prof. Dr. Luisa F. Cabeza (Universitat de Lleida, Spain)

2019

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Para Amanda y Ángel …. Ángel y Amanda.

Amor desordenado.

"Nothing is more powerful than an idea whose time has come"

Victor Hugo

"Antigonous exit pursued by a bear"

The winter's tale. Willian Shakespeare

Universitat de Lleida

Departament d'Informàtica i Enginyeria Industrial
Escola Politècnica Superior
Universitat de Lleida

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Lleida, Septembre 2019

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For what has been lived and are going to live.

And thanks to the books.

Summary

Envisioning outcomes of scientific research and innovation understood as an expression of human values, such as safety, justice, sustainability, and efficiency, recently inspired several new policy models of governance. One of them, the European Responsible Research and Innovation (RRI) policy approach aims to put social perspective at the core of research and innovation.

Similarly, the increasing challenge of transforming and governing energy systems taking into account social aspects became a priority in most global research agendas. New important work on research about the energy system is focusing on the development of reliable renewable energy systems, and on the transition to decentralized paths based in the integration of socio-technical, behavioural, and institutional capabilities
Thereby, this thesis examines the possibility of the combination of these capabilities under the socio-technical transitions theoretical approach, as a proposal for transforming energy systems research. For this purpose, considers to putting European RRI approach at the heart of energy transitions and proposes a methodology for its contextualization and implementation on the energy research domain. In this vein, proposes the construction of a state-of-the art and theoretical framework for the RRI contextualization along with an implementation methodology, which is also assessed via case studies proposals.

The initial focus of this study was on the application of RRI to the field of energy systems research, in particular to renewable energy systems and application research governance. A small area of research was chosen to be able to fully explore the implications of RRI application in the energy system governance.

Despite the small size of the setting, this research is now placed at the forefront of a current and vital debate on the integration of science and society. Moreover, delves in the open questions and challenges of how the creative process of research and innovation will develop in the coming years, how will the outcomes of this process be used, shared and preserved and, most importantly, how such insights can be vertebrate into regulatory frameworks.

Resumen

La consideración de que los resultados de la innovación pueden entenderse como la expresión de los valores humanos de seguridad, justica, sostenibilidad y eficiencia ha inspirado recientemente nuevos modelos de políticas de gobernanza. Uno de estos modelos es el marco europeo Responsable Research and Inovation (RRI)que surge con el objetivo de situar la perspectiva social en el centro de los procesos de investigación e innovación.

De forma similar, los retos de transformar y gobernar los sistemas energéticos teniendo en cuenta los aspectos sociales se han convertido en una prioridad en las agendas globales de investigación. En este sentido, los nuevos avances se enfocan en el desarrollo de sistemas energéticos basados en energías renovables seguros y confiables, así como en la transición hacia sistemas descentralizados basados en la integración de capacidades socio-técnicas, de comportamiento e institucionales.

Esta tesis examina la posibilidad de combinar estas capacidades teniendo en cuenta el enfoque teórico de las transiciones socio –técnicas, como propuesta para transformar la investigación en sistemas energéticos. Para ello, considera situar el marco europeo RRI en el corazón del concepto de transición energética proponiendo una metodología para su contextualización e implementación en este campo. En este sentido, este trabajo propone la construcción de un estado del arte y marco teórico, así como su implementación, junto con la evaluación de este proceso a través de la propuesta de casos de estudio.

El foco inicial de este estudio ha estado relacionado con la aplicación de RRI en el ámbito de la investigación en sistemas energéticos, para el caso particular de la gobernanza de la investigación en sistemas de energía renovable y sus aplicaciones. La selección de este pequeño aspecto de la disciplina se llevó a cabo con la intención de explorar de forma detallada las implicaciones. A pesar de lo concreto de esta propuesta, esta investigación a día de hoy ocupa un lugar preferente en el actual y vital debate acerca de la integración de la ciencia y la sociedad. Asimismo, ahonda en las cuestiones y retos de cómo el proceso creativo de la innovación va a ser desarrollado en los próximos años; en cómo los resultados de este proceso van a ser utilizados, compartidos y preservados y de forma más importante, en cómo estas ideas pueden vertebrase en marcos reguladores.

Resum

La consideració de que els resultats de la innovació i recerques científiques poden entendre's com l'expressió dels valors humans de seguretat, justícia, sostenibilitat i eficiència ha inspirat recentment nous models de polítiques de governança. Un d'aquests models és el marc europeu Responsable Research and Inovation (RRI) que sorgeix amb l'objectiu de situar la perspectiva social en el centre de la recerca i innovació.

De forma similar, els incessants reptes de transformar i governar els sistemes energètics tenint en compte els aspectes socials i tècnics s'han convertit en una prioritat en les agendes globals de recerca. En aquest sentit, els nous avanços i recerques s'enfoquen en el desenvolupament de sistemes energètics basats en renovables que siguin segurs i de confiança, així com en la transició a sistemes descentralitzats basats en la integració de capacitats soci-tècniques, de comportament i institucionals.

D'aquesta manera, aquesta tesi examina la possibilitat de combinar aquestes capacitats tenint en compte l'enfocament teòric de les transicions soci–tècniques, com a proposta per a transformar la recerca en sistemes energètics. Per a això, considera situar el marc europeu RRI en el cor del concepte de transició energètica proposant una metodologia per a la seva contextualització i implementació en aquest camp. Aquest treball proposa la construcció d'un estat de l'art i marc teòric així com la seva implementació, juntament amb l'avaluació d'aquest procés a través de la proposta de casos d'estudi.

El focus inicial d'aquest estudi ha estat relacionat amb l'aplicació de RRI en l'àmbit de la recerca en sistemes energètics, per al cas particular de la governança de la recerca en sistemes d'energia renovable i les seves aplicacions. La selecció d'aquest petit aspecte de la disciplina es va dur a terme amb la intenció d'explorar de forma detallada les implicacions. Malgrat el concret d'aquesta proposta, aquesta recerca avui dia ocupa un lloc preferent en l'actual i vital debat sobre la integració de la ciència i la societat. Així mateix, aprofundeix en les qüestions i reptes de com el procés creatiu de recerca i innovació serà desenvolupat en els pròxims anys; com els resultats d'aquest procés seran utilitzats, compartits i preservats i de forma més important, com aquestes idees poden vertebrar-se en marcs reguladors.

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Introduction, objectives and PhD thesis structure

1.1 Introduction

1.1.1 Background

The movement towards new models of research and innovation governance that create the possibility for alternative approaches in policy started along trends towards greater public engagement, the need to make scientific expertise and innovation more democratic, increasing the growth of bottom-up strategies for endorsing the social outcomes to the results of the innovation [1], and the decline in deference to authority, in general, and to expert authority in particular [2].

In contrast with traditional considerations of governance understood as the steering innovation through the establishment and verification of performance of goals and means [3], the disruptive nature of new models lies on the potential of replacing top-down control by the consensus. This process brings with it the underlying philosophy of distributed consensus, open source, transparency, and community based decision-making [4]. Moreover, it implies the transgression of the traditional boundaries regarding the provision and distribution of funding and the regulation of research and innovation activities through the inclusion of cultural and normative means understood as *soft* within laws and institutional understood as *hard* procedures [5–7] which lead to a holistic policy approach.

Furthermore, alternative approaches within new models are built upon the retrieval of the strength and importance of the ethical considerations devoted to addressing science and technology present and future controversies more efficiently. This makes that both goals and normative consideration are transformed into proposals to embody the dimensions

that are necessary to reflect a range of social and environmental needs and to bridge scientific, technological, and social domains resulting in a commitment to balance what is possible and what is desirable [8,9].

The consideration of ethical aspects within technological innovation was in the core of the search of governance since the early attention of this concept appears in the policy arena. Even though in alternative approaches, ethical aspects of new technologies are no longer seen as a constraint, but as a stimulus[10].This consideration is operationalized through the proposal of mechanisms that tackles societal challenges by aligning the values, needs and expectations of all actors involved. Moreover, it is driven by the use of an interactive process governed by the principles of ethical acceptability, sustainability, and societal desirability [11].

An example of a new model of governance that gained increasing attention and was aligned within the mentioned trends is the European policy Responsible Research and Innovation (RRI). RRI is a EU research and innovation initiative been put forward by the European Commission as a key element of the Horizon 2020 programme, in which the trifold ambition of excellent science, competitive industry, and a better society locates innovation in the spotlight to address a number of well-chosen societal challenges, for example, to contribute to a transition to a low carbon and inclusive economy [12].

Governance for RRI means attempting to shift science and innovation systems from a narrow focus on innovation towards democratically defined societal challenges. In its endeavour for a normative and comprehensive governance framework for research and innovation (R&I) [10,11,13], RRI calls to connect different aspects of the relationship between R&I and society [14]. In this vein, the principles of RRI emerged from the desire to pursuing '*citizen engagement and participation of societal actors in research and innovation', 'science literacy and scientific education', gender equality', 'open access to scientific knowledge, research results, and data', 'research and innovation governance' and 'research and innovation ethics*'[15].

Moreover, RRI insights construction [15] are embedded under the achievement of *good governance*, which is proposed to reach through the statement of research agendas , the use co-production of knowledge, and the implementation of alternative impacts measurement systems for scientific and innovation production [14].

Those aims, that are transformed into conceptual dimensions pooling analytical and empirical aspects, entail that RRI at policy level is structured in the fulfilment of two main fundamental missions: (1) the development of specific research agendas, and (2) the reformulation of the research and innovation process following the aforementioned principles and goals.

RRI research agendas are guided by the keys of science education, open access, engagement, ethics, gender, and governance; which were updated with two more areas of relevance, social justice and sustainability, included in RRI as an expression of the policy goals, since they were the backbone of the Europe 2020 strategy [16,17]. In addition, the process re-formulation is proposed to be carried out through the definition of attributes that the innovation needs to fulfil to be considered responsible, namely, anticipation, reflexivity, inclusion and deliberation, and responsiveness [8] or anticipation, reflexion, engagement, and action [18] depending on the approaches.

The discourse concerning RRI from the valorisations of its heterogenic theoretical background (ethics studies, radical innovation support, the changes in techno-economic paradigms, or the changes in technology systems, socio-technical transition approaches, technology assessment approaches, innovation theories, as well as philosophical and cultural imprints) to the enrichment of the approach due to the evolution of the surrounding rationales [19] (adapting technological revolutions approaches, anticipatory governance approach and the adoption of holistic perspectives of innovation) reached a significant level of sophistication [20] that goes beyond the umbrella of the search of *good governance* [21].

An overview to this sophistication (and growing in importance) process is shown in Figure 1.1 where the results of a bibliometric analysis on a comprehensive dataset of academic papers is conducted to show the umbrella of domains that currently RRI covers.

This bibliometric analysis provides the necessary metadata to identify trends and characteristics of this body of works and was conducted with VOS viewer domain visualization software [22]. This software allows to uncover the intellectual bases of each speciality being possible to visualize the different literature and epistemic domains.

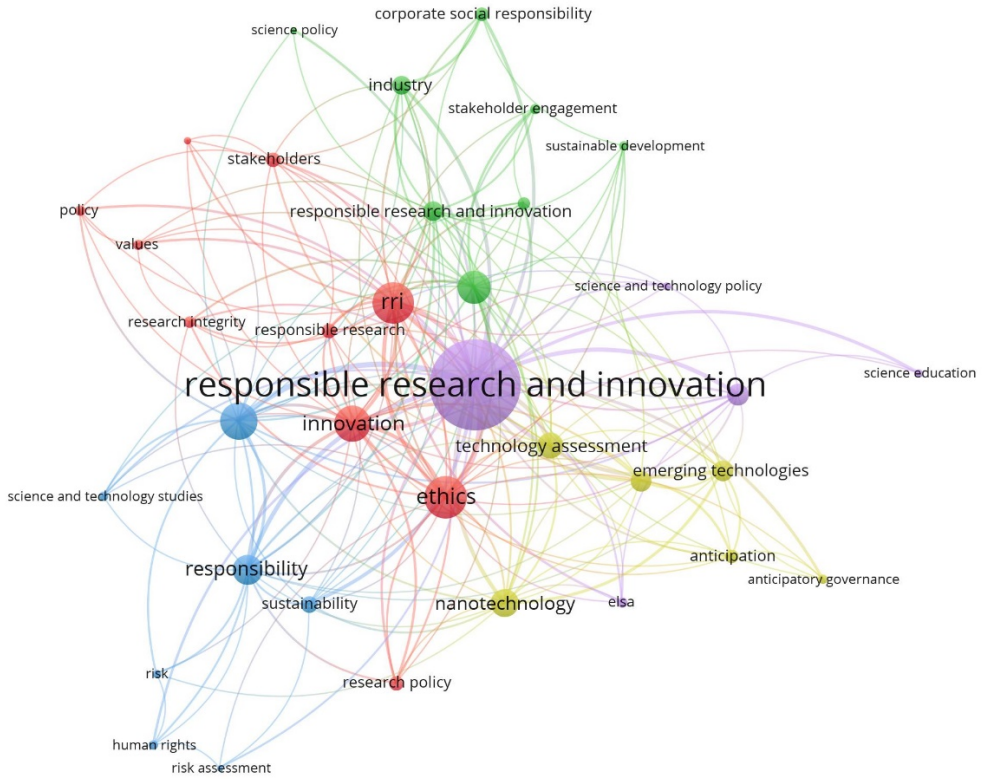

Figure 1.1: Bibliometric analysis of 654 documents from Scopus database with [“RRI”]as searching topic.The search was performed with exclusions related to heath and for the years ranging from 2011 to 2019.

As shown, RRI is linked with concepts that shape relatively recent epistemic domains, such as anticipatory governance and stakeholders engagement, even if it is also strongly related with innovation, ethics and technology assessment background approaches. Moreover, in the figure the size of the spheres indicated the weight of the related concepts, named items [23].

The colour represents the different clusters to which the items were grouped, for example, the consideration of yellow for the umbrella of concepts of technology assessment,

anticipation and emerging technologies. Furthermore, the lines represent links where the number of links and the distance between items is considered. The links indicates the relatedness and the distance indicate the level of the strengths in their relatedness.

1.1.2 The RRI discourse

The review of the discourse concerning RRI requires from the valorisation of its heterogenic theoretical background and the review of the enrichment of the approach due to the evolution of the surrounding rationale. This process, which is part of the hypothesis and theoretical proposal of this PhD, is presented in the following paragraphs, where (i) the review of the backgrounds, (ii)the evolution of surrounding rationales, and (iii) the review of the current discourse elements is outlined.

The theoretical background of RRI are the approaches science, technology and society studies (STS) and technology assessment (TA) [24]. These backgrounds are still present within the RRI approach, despite the process of sophistication. For example, in the case of the attributes of the process reformulation, they came from the Responsible Innovation approach (RI) a type of technology assessment approach [8,25]. This approach is focused on engaging the innovation process dimension with a set of norms or even virtues for practices related with both outcomes and options evaluation. Moreover, in RI, the enhancement of innovation, in terms of moral values, is essential, based in the fact that innovation are never neutral or value laden [26] thus, outcomes need to be the expression of human values [27].

An overview of the evolution of the surrounding rationales shows that the socio-technical transition approach and the evolution of innovation theories are the elements that have more weight in the current discourse. In this vein, socio –technical transition approaches converge within the idea of arranging changes that can be understood as socio-technical where innovation theories comprise a wide umbrella of considerations.

Current socio-technical transition approaches borrow concepts from a mix of disciplines, including history, evolutionary economics, institutional theory, and traditional socio-

technical studies (STS). Moreover, it can be framed under the transformative change approach consideration, linked to contemporary social and environmental challenges [28]. Under this contemporary view, the transformative change can be considered the core from where the transition approach emerges, aiming to address complex policy challenges of a long-term nature, such as sustainable transitions. In addition, the transformative change is related with the proposal of the creation of a space with the purpose of transforming general policy goals into concrete visions is proposed to achieve these challenges, which in turn it would be used to develop possible transition paths on how to connect the present with the future [29].

Current innovation theories, in contrast, are engaged in an evolution process towards the adoption of holistic perspectives. This perspectives are characterized by a problem- and solution-orientated approach to problem-solving, based on a systemic design, the adoption of collaborative research strategies and the co-production of knowledge proposals at policy level and the focus on demand factors upon supply factors [1].Moreover, holistic approaches, intended to mapping of contemporary long-range phenomena, in economic, social, environmental, political, and ecological domains using the paradigm of collaborative research strategies that are for example interdisciplinary, multidisciplinary, transdisciplinary, and transformative science (MITT) [30].

The background of socio-technical transitions and innovation theories is related and can be found reviewing the evolution of theoretical approaches of innovation. In this sense, this process can be threshed through a series of periods, steps, and milestones [31].

An approach to the different periods comprises a first step of innovation linear models prevalence, where innovation systems comprise actors, institutional conditions and networks, and were the systems were focussed on addressing the failures of the isolated elements, such as the market failures, ignoring the importance of wider failures [28]. This period was followed by a second step which includes induced innovation, evolutionary economics, and path dependency models considerations. This second step was capitalized by the early use of the systems theory and the statement of its drivers and trajectories, namely the *niches*, *regimes*, and *landscapes* [32].

Moreover, this period was characterized by a change in rationales moving towards a more complex, systems-based perspective, explainable by introducing a four-level taxonomy of innovation corresponding to incremental innovations, radical innovations, changes of technology system, and changes in the techno-economic paradigm [33].

In this vein, incremental innovations occur continuously where radical innovations come from outside current mainstream, as a result of R&D activities. Also, incremental innovations can bring a structural change, but their impact is relatively small. In contrast changes of the technology system and changes in the techno-economic paradigm known as technological revolutions are far-reaching changes in technology where, in the case of revolutions, go beyond engineering trajectories for specific process or product technologies [31].

Furthermore, within radical innovation, the drivers of niches serve to gain diffusion or adoption. The use of regimes is referring to the incumbent of socio-technical system where that the niche is potentially affecting [32]. In addition, the landscapes refer to exogenous developments or shocks (e.g. economic crises, demographic changes, ideological change, or major environmental disruption like climate change) that create pressures on the regime, which in turn create windows of opportunity for the diffusion of innovation [33].

A third step of the innovation theories evolution comprised the consideration of innovation system frameworks namely innovation for growth, national systems of innovation, and national innovative capacity considerations [12]. The fourth step comprises the implementation of systemic and hierarchic innovation, which includes the technical innovation systems, the re-envision of niches in terms of niches accumulation, the reformulation of radical and disruptive innovation and the proposal of transition innovation approaches. Technical innovation systems and niches accumulation are based in the application of a systems-style analysis of the innovation process. In contrast, radical innovation is based in the arrangement of a significant change that is not necessarily disruptive. In addition, disruptive innovations are innovations that eventually overturn the existing dominant technologies, products or processes [31].

The proposal of the transition approach is focused on the detailed process of a technological change (which is not simply incremental but represents radical, possibly even disruptive, shifts) including the main theoretical approaches of multi-level perspective, strategic niche management, and socio-technical scenarios.

Both innovation theories imprint and current discourses regarding socio-technical transition consideration are an important aspect of this PhD. Moreover, both approaches are linked sharing the consideration of the principia of the transition. This principia are built upon the acknowledge that diffusion (or transitions) occur through interactions among the levels of the niche, the regime, and the landscape [25].

This consideration is shown in Figure 1.2,where the results of a bibliometric analysis are presented.

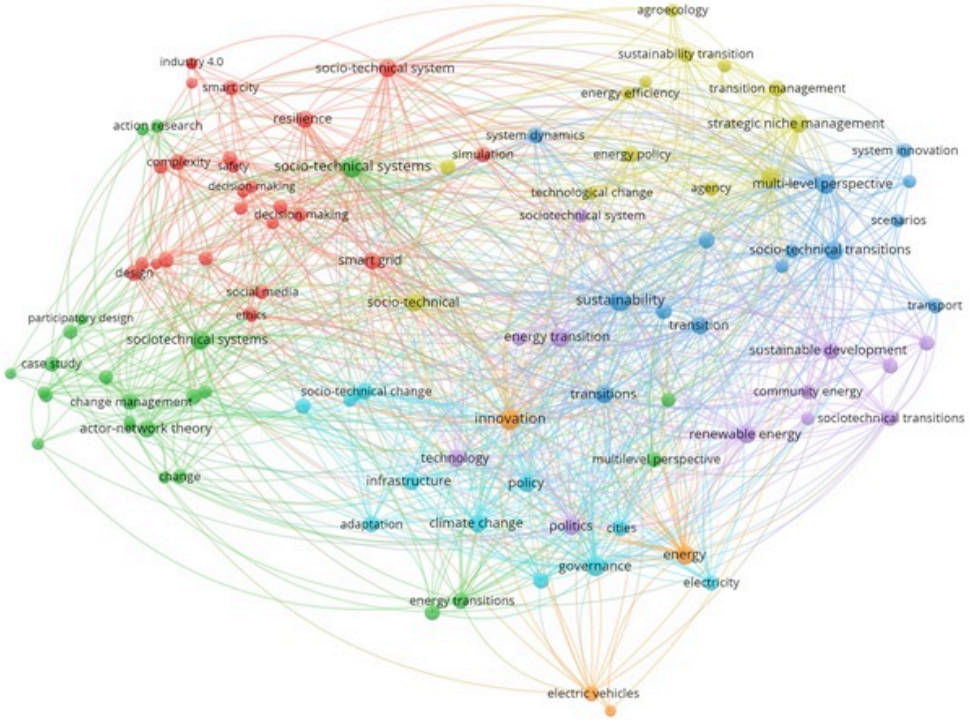

Figure 1.2: Bibliometric analysis of 2527 documents from Scopus database with [“socio-technical” or “sociotechnical” and “transition” or “change”] as searching topic. The search was for the years ranging from 2011 to 2019.

The bibliometric analysis was performed with the purpose of identifying specialities in literature uncovering the intellectual bases and epistemic domains of socio-technical transitions and their roots in innovation theories.

When the bibliometric map is centred on innovation, some of the milestones arising in the evolution of the theoretical consideration such as the technological change, socio-technical systems, or multi-level perspective appear (Figure 1.3). Moreover, the relations and subdomains arise shaping a distributed umbrella of related concepts.

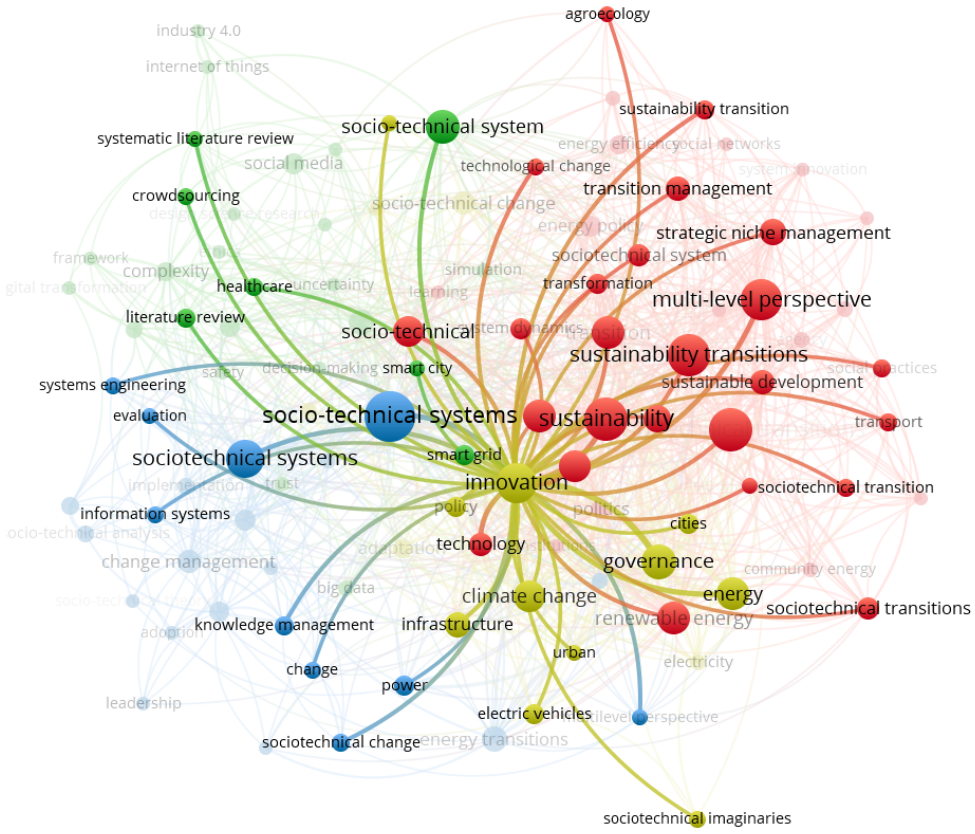

Figure 1.3: Bibliometric analysis of 2527 documents from Scopus database with [“socio-technical” or “sociotechnical” and “transition” or “change”] as searching topic. Within the search, the map is centred in the term“innovation”. The search was for the years ranging from 2011 to 2019.

In contrast, the map centred in the topic “socio-technical transition”, as shown in Figure 1.4, shows how the approach have been distanced from its innovation theory roots [31].

As shown in the figure, the socio-technical transition (in blue) comprises a cluster within domains, which is strongly linked with the specific subdomains (related to applied energy field) of sustainability transitions (in soft green) and energy transitions (in purple). Moreover, its links are also extended to the general subdomains (not related with applied fields or domains) of socio-technical systems and system approaches (in green) and overarching concepts considerations such as governance and the climate change (in light blue). This can be considered as a symthom of the the mainstreaming process.

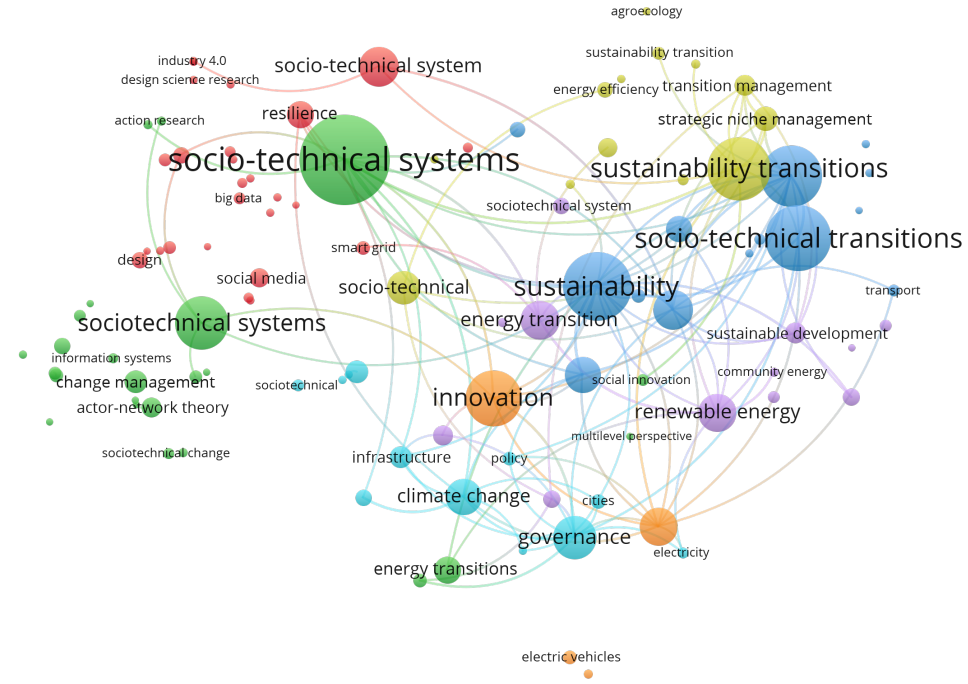

Figure 1.4: Bibliometric analysis of 2527 documents from Scopus database with [“socio-technical” or “sociotechnical” and “transition” or change”] as searching topic. Within the search, the map is centred in the term“socio-technical trasitions”. The search was for the years ranging from 2011 to 2019.

1.1.3 Socio-technical transitions in energy systems research: The paths towards transformation

The implementation of considerations of the socio-technical transition approach within research about energy systems is a long settled tendency, even if the current transformation ongoing on the energy system is asking for its application to this domain [34].Within the energy systems research, early insights of considerations of the socio-technical transition approach can be found in the sustainable development (SD) model, as an umbrella for multiple normative criteria used in the fields of development studies, economics, law, legal studies, and jurisprudence used to assess the pros and cons of the socio-technical change [33].

As an approach, sustainable development was normalized and mainstreamed at international level through the Sustainable Development Goals (SDG) [35], comprising

statements such as the achievement of sustainable low carbon energy systems and the enhancement of the affordability and equity of new innovations.

The evolution of the sustainable development approach shapes the energy transition consideration, which comprises an overall approach to tackle present and future energy system changes derivate from its urgent necessity of transformation. Moreover, energy transition, bridges socio-technical systems considerations along with the energy domain, as show in Figure 1.5 .

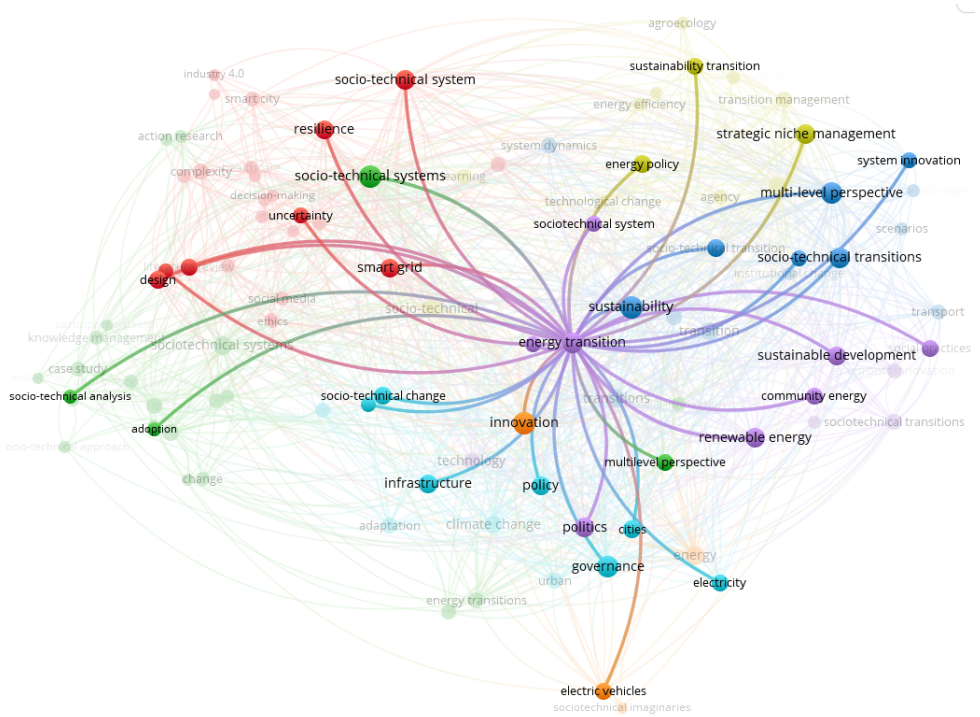

Figure 1.5: Bibliometric analysis of 2527 documents from Scopus database with [“socio-technical” or “sociotechnical” and “transition or change”] as searching topic. Within the search, the map is centred in the term “energy trasition”. The search was for the years ranging from 2011 to 2019.

This transformation steams from the necessity of decarbonisation and decentralisation, which were updated with digitalisation [36] and democratization [37], shaping the (4Ds) of the challenges of the energy systems transformation [38].The approach to an energy transformation can be considered both a new governance and a holistic innovation approach which provides a new series of principles that are designed to articulate normative and empirical assessments based in governance and policy proposals.

Traditional energy governance dimensions entails the policies, institutions, rules and incentives, and the underlying decision-making process, which establishes the guidelines and incentives rules for the energy system [28]. In contrast, the transition approach replaced these dimensions by drivers to ensure governance to suit the characteristics of a clean energy system based on renewable energy and energy efficiency that can also be considered secure, affordable and equitable.

In this vein, since the governance shapes structures driving the channels to how money flows through the system, enabling what products and services are available, and, ultimately, allowing the people to interact with the technological systems, the attention to transition brings an opportunity to channel change in a particular direction. However, the prospect of this transformation entails not only the achievement of the challenges such as 4Ds, but also the consideration of the relevance of the chosen goals and the transcendence of these decisions.

An example of the consideration of the relevance of the chosen goals and the transcendence of these decisions are the links between goals and the balance between them. For example, digitalisation and democratisation are related leading to implications for data protection regarding democratisation of the energy system. Moreover, the measure to what extent digital energy innovations will become dominated by existing companies is related with the balance.

In case of considering the transcendence of decisions, for example, it is well known that policies to support decarbonisation led to substantial reductions in the cost of decentralised renewables. However, these reductions seem to be not fast enough to energy transition targets.

Moreover, the uncertainty in relation to how democratic or equitable the energy system transformation will be related with the fact that customers are set to become central to the energy system, along with how the benefits of transformation will be balanced between the stakeholders of energy systems (citizens, researchers, policy makers, companies, etc.) in terms of those able and willing to be engaged and those who are not is an another example related with the balance.

This new governance rationales and models are focused in the energy system transformation and their proposals stem most of the energy policy approach. This consideration and concerns can be translated to the energy research arena, which opens the possibility of this study where the combination of socio-technical capabilities under the socio-technical transition approach and RRI runs along with the consideration of alternative approaches for transforming energy systems.

The current socio-technical transitions imprints, as shown in Figure 1.2 to Figure 1.5 are integrated within the energy domain in terms of governance, energy transitions, sustainability transitions, and sustainable development approaches. These considerations, that are also linked with concepts such as climate change, energy efficiency, and renewable energy will be developed in the following sections.

1.2 Responsible approach applied to energy research

1.2.1 Introduction to the approach

The greatest potential of RRI is the ability to unify and provide political momentum with a wide range of long-articulated ethical and policy issues [24]. In this vein, RRI has the potential as a transformative, critical and radical concept, to make research and innovation more efficient to solve global social problems and to help developing a more socially dimensioned research environment. For this reason, RRI can be proposed to approach the transformation of the energy systems research.

In this vein, the contextualization of governance approaches based in responsible science for energy systems research is the aim of this PhD. This aim requires the empirical construction of an approach, that for the purpose of this PhD is based in the process of opening up of approaches, rationales and understandings and the embracement and contextualization of new governance approaches within a selected scientific discipline.

Opening up of approaches, rationales and understandings, requires identifying the emerging dimensions and drivers of the concepts and moving the focus towards where the direction of the process runs alongside the implementation of measures to quantify its impact.

In addition, embracing and contextualizing a new governance approach within any scientific discipline requires from the consideration of how different regimes are operating and what measures are required in order to assess whether governance moves are successful [39].

Moreover, since governance is concerned with how knowledge is produced and how it is distributed, the realisation that much governance happens within and is done by the scientific community itself place researchers as relevant but not unique actors in the re-envision of the process.

This PhD proposes that the consideration of how different regimes are operating can be contemplated in terms of the contextualization of RRI for a specific scientific discipline and context. In this vein, translating the RRI approach to energy systems research transformation and focusing in the researchers participation is considered. Moreover, the use of a non-European context can be used to explore the implementation of new approaches taking into account the real characteristics of the countries [40]. This non-European projection can be considered as an attempt to an anticipatory governance approach which considers the importance of investigate how emerging countries are dealing with responsibility and the consideration of the main differences, difficulties and opportunities underlying anticipatory-like international governance dynamics [41–43].

For the purpose of this PhD, the concept to be extended is the governance regarding to the process of research and innovation and the considered new approach is Responsible Research and Innovation (RRI). Moreover, the scientific community and the researchers are the selected actors since governance is concerned with how knowledge is produced and how it is distributed.

1.2.2 The challenges of the approach

The overall challenges of the consideration of RRI are related with the fact that the greatest potential of RRI can be hindered regarding to practices, since the dynamism and resulting complexity may represent its biggest challenge [24]. Moreover, at operational level, it suffers from a lack of frameworks for assessing its impacts and it suffers from burdens regarding its practical applications and depletion in research institutions.

Furthermore, the consideration of an approach based in the process of opening up approaches, rationales and understandings and the embracement and contextualization of new governance approaches within a selected scientific discipline shows a series of challenges detailed in the following paragraphs.

A first overview of the process of opening up approaches, rationales and understandings shows that each discipline has its own considerations and dynamics and often they come into conflict. For this reason, the RRI and the energy systems transformation considerations of governance should be examined separately and then in terms of searching synergies.

In addition, embracing and contextualizing alternative approaches within any scientific discipline or context requires from the consideration of multiple trans-boundary and trans-disciplinary characteristics of the different research and innovations paths and actors, disciplines and global contexts which inevitably fall between the gaps of existing regulatory frameworks and instruments [44]. Moreover, these dynamics also affect the consideration of methodological proposals and the measures to quantify its impact. For example, in RRI governance dimensions are affected by the multiple connections between the other dimensions. This affects both, the agenda setting and process reformulation, and the further development of methodologies and assessment proposals.
As shown in Figure 1.6 both inclusion and governance dimensions are the core of the approach, since they provide the elements from where the rest of the dimensions and keys are generated.

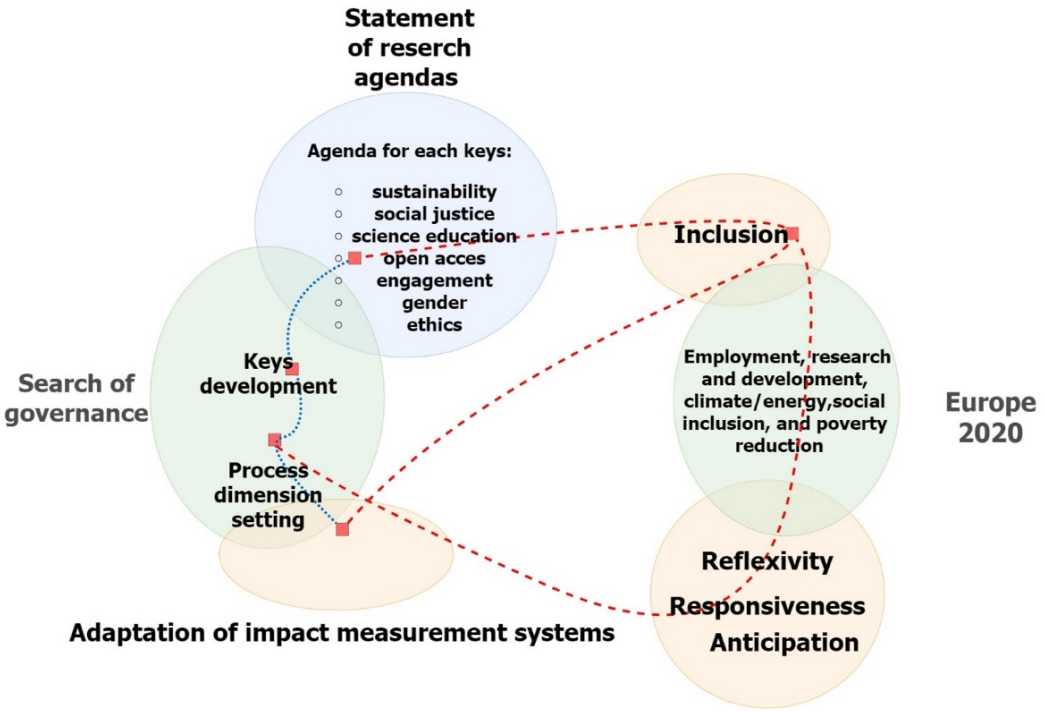

Figure 1.6: The insights of the connexions linking key and dimensions for RRI and Europe 2020 strategy goals in terms of agenda setting and process reformulation [45].

Moreover, they share the aim of promoting good governance. Furthermore, sustainability and social justice, which are included in RRI as an expression of the policy goals, are interconnected and related to some extent with aspects of inclusion.

The interlinkages and overlaps of RRI dimensions were considered since the approach was launched, as shown in Figure 1.7. These interlinks between the six dimensions, that affect the proposal of activities and indicators for the implementation of RRI, can be considered a burden, but it is also a strength of this approach. These relations act as an inhibitors and a facilitator of the policy integration [14], especially in the case of the indicators proposal. As show in the figure, for example, elements addressing the aspects within public engagement (PE) such as public communication aspects for instance, overlaps with the science literacy-science education (SLSE) which is a sub-category of science communication.

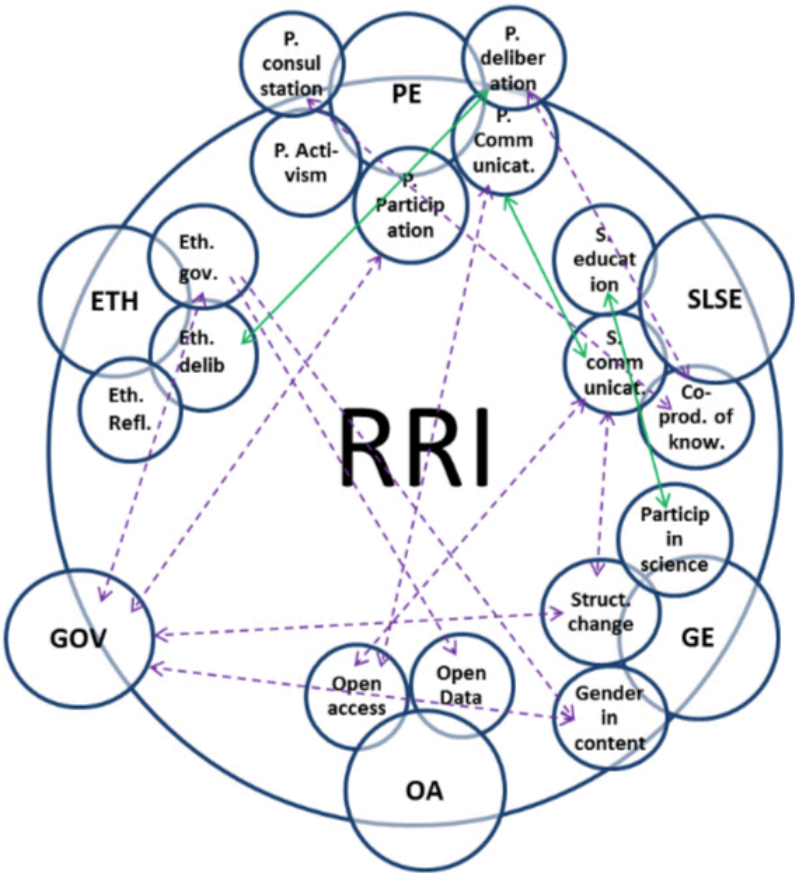

Figure 1.7: Existing and potential interlinkages/overlaps between RRI dimensions and sub- dimensions. Adapted from [15,21].

Similarly, within the energy systems transformation, the new models of governance locate the people in the core of the process along with legitimacy and transparent decision-making, the participation of customers in the decision process, and the changes in regulatory frameworks, as shown Figure 1.8.

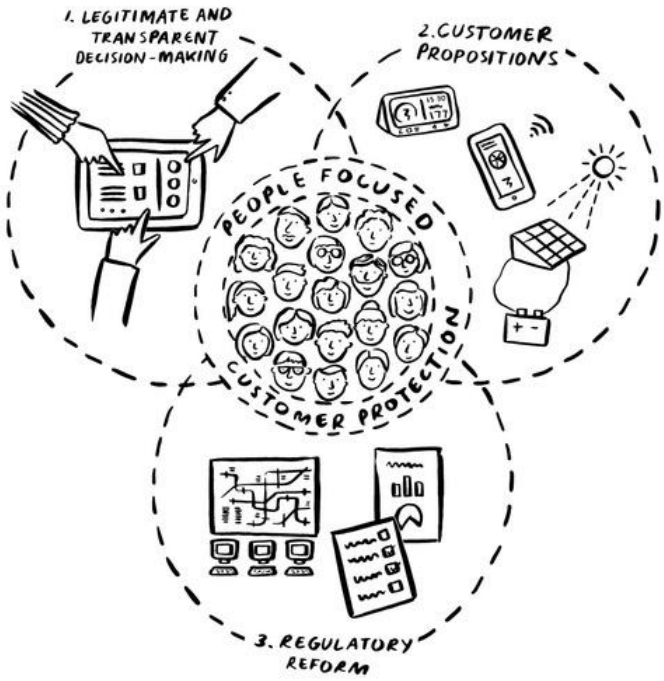

Figure 1.8: The four elements of governance [37,38]. © Illustrated by Melanie Chadwick

This dimension proposal is focused in the idea that the transformation require from dealing with incumbents and their assets along with the process of reforming regulation frameworks and, finally, leading to the transformation.

Building a system around people implies to transit from a largely perception as simply consumers playing a passive role to be put into the centre of thinking and governance. This, moreover, create new complications for customer protection and equity that needs to be addressed [37,38].

Furthermore, the proposal of a regulatory reformulation as a dimension of governance requires from better regulation and more legitimate and transparent decision-making process proposals. These efforts are largely political and will be influenced by stakeholders in different ways, such as through lobbying and arguing for a speed or direction of change that meets a particular actor business model or interests.

In addition, reforming regulation requires also decision-makers to confront the realities of the transformation in a transparent process to mitigate negative distributional effects of moving from one system to another.

1.3 PhD hypothesis

As mentioned in previous sections, the contextualization of governance approaches based in responsible science for energy systems research is the aim of this PhD. This endeavour requires from establishing the hypothesis of whereby these new models for governance share a general vision towards achieving, among others goals, the reformulation of the innovation process and the re-envision of the agenda setting, as well as the adoption of alternative approaches and paradigm changes regarding the decision-making processes.

The foundation of this hypothesis is the result of an extensive empirical investigation based in the review governance models and insights, the review of the discourse concerning RRI, and the consideration of the socio-technical transition imprints in the energy domain. The result of this empirical investigation is the consideration of socio-technical transition as a common language to vertebrate the search of correspondences between new modes of governance for responsible science and for the energy research transformation.

This consideration entails also the attention of a theoretical implication of the socio-technical transition approach in terms of the consideration of the background, the evolution of the surrounding rationales and the grade of deployment of these models within energy research and innovation.

The theoretical implications of the background are related with the shared imprints of transition approaches and innovation theories. This entails to acknowledge that the origin of the new trends in governance within these approaches came mainly from how the evolution of the innovation theories affects the construction of approaches. . Moreover, it entails the integration of other imprints such as ethics studies, that are positioned as highly pertinent in both research and energy policy current concerns.

The consideration of the evolution of the surrounding rationales is based in the fact that the approaches can be considered as an interpretation of innovation theories enriched by the synergies arising during their evolution process. This evolution process results in an

integration of a mix of disciplines, including history, evolutionary economics, institutional theory, and STS, as shown in Figure 1.1 and Figure 1.3. Moreover, the mentioned sophistication and mainstreaming processes aroused within the evolution and enrichment. In this vein, RRI sophistication entails transcending from the search of governance, where the socio-technical transition approach mainstreaming entails distancing from its theoretical background.

Finally, the implications of considering the grade of deployment of these models within energy research and innovation is related with the prevalence of traditional models versus the degree of depletion of new approaches. This deployment assessment needs from questioning if renewable energy research and innovation are still influenced by early linear concepts (where innovation systems comprise actors, institutional conditions and networks, and are focussed on addressing the failures of the isolated elements ignoring the importance of a wider system) and reflecting if alternative approaches encountered under a real era of transformative change or may be regarded as variants of a systemic approach.

1.4 Objectives

The objectives of this PhD within the requirements of the considered approach are considered in terms of empirical and operational objectives. In this vein, the empirical objectives steam from the consideration of how different regimes are operating and what measures are required in order to assess whether governance moves are successful. This first consideration is the inspiration to contextualize responsible science within energy systems governance and the exploration of which targeted stakeholders can be suitable within this process.

Moreover, reviewing what measures are required in order to assess whether governance moves are successful takes us to the consideration about the fact that RRI policies are themselves governance actions. Therefore, those actions can be assessed and tested. For

the purpose of this PhD, the meta-governance appraisal comprises a proposal of a RRI plan and the case studies.

In this vein, the empirical objectives of this PhD are:

- The identification of dimensions and drivers of governance emerged from the opening up of approaches, rationales and understandings.
- The proposal of a methodology to integrate this governance approach within any scientific discipline considering how different regimes are operating and what measures are required in order to assess governance.
- The enlightenment of the researchers role within the scientific community in the re-envision of the innovation process.

Where, the operational objectives entail:

1. Contextualizing the RRI approach within renewable energy research and innovation based in the:
    a. State-of-the-art construction based in the review of the discourse concerning RRI from its valorisation of theoretical background (radical innovation support, the changes in techno-economic paradigms or the changes in technology systems, the socio-technical transition approach, technology assessment approaches, ethics studies, innovation theories, as well as philosophical imprints).
    b. Enrichment of the approach due to the evolution of the surrounding rationales (adapting technological revolutions approaches, scientific and innovation governance, anticipatory governance, and the adoption of holistic perspectives of innovation) and the retrieval of the energy related social sciences and humanities (SSH) frameworks considerations.
2. Proposal of a theoretical framework to contextualize RRI within renewable energy research and innovation.
3. Proposal of a methodological framework for the assessment RRI implementation within renewable energy research and innovation based in a context and assessment levels. This proposal is focused in the RRI dimensions of sustainability and social justice.

4. Exploration of the stakeholder considerations regarding the concept of RRI through a participatory study, applied to the study of renewable energies and the role of the researchers.
5. Generation of methodologies for responsible research applied to the study of renewable energies, collected in the GREiA RRI plan.
6. Transnational projection of the study comprising:
    a. Proposal of a theoretical framework to contextualize RRI within renewable energy research and innovation, considering non-EU contexts.
    b. Chile-Europe case study on responsibility concerning R&D practices in selected innovation and business areas related with solar energy research and innovation.
    c. RRI plan for the project *Strengthening the lithium value chain* for the University of Antofagasta, Chile.

The description of the empirical and operational objectives and its interlinkages regarding the proposed approach is shown in Figure 1.9.

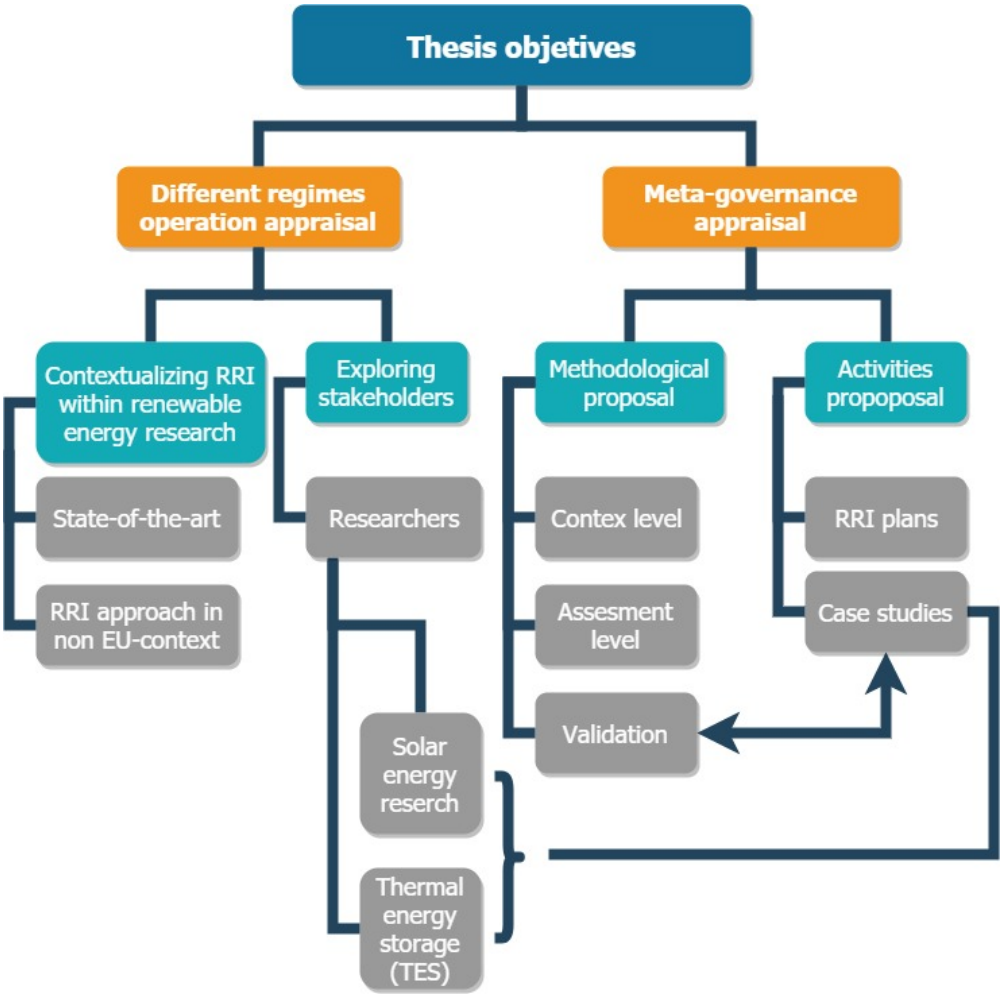

Figure 1.9: Empirical and operation objectives of this thesis.

1.5 Thesis structure

The present PhD thesis is based on four papers, of which two papers are already published in SCI journals while another two were submitted in July 2019, and on two RRI plans: the GREiA RRI plan [46] and the RRI plan for the technology transfer project *Strengthening the lithium value chain* for the University of Antofagasta, Chile.

This PhD thesis is divided into five chapters as shown in the scheme of the structure of the PhD presented in Figure 1.10.

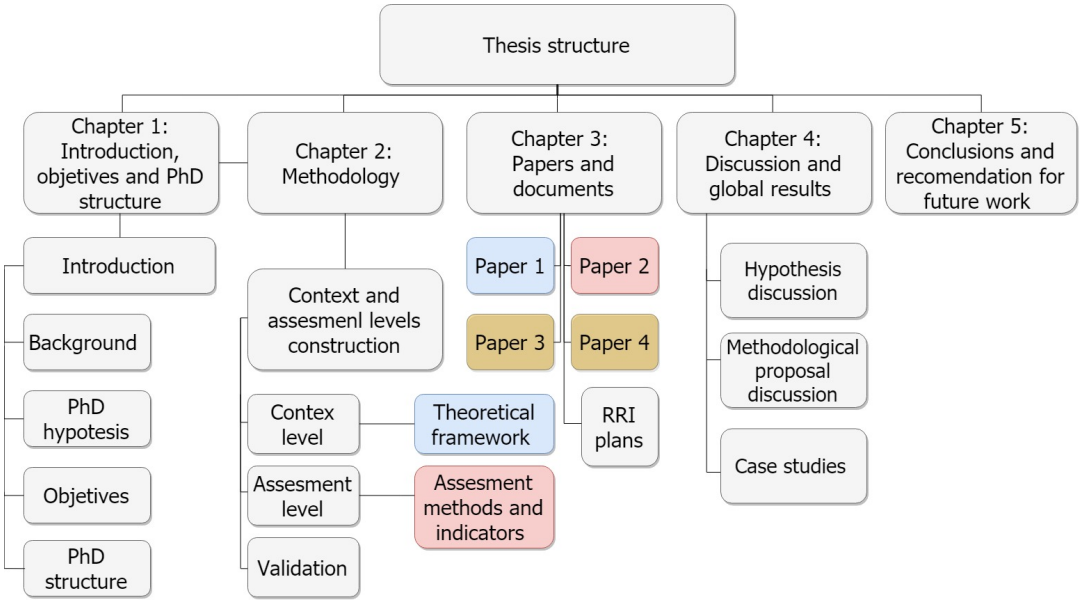

Figure 1.10: Scheme of the PhD thesis.

Chapter 1 starts with an introduction comprising the background to the new models of governance and a contextualization of the evolution of the innovation theories followed by a contextualization of the socio-technical change approach to energy systems research. It continues with the presentation of the responsible approach to applied to energy research, which considers the introduction and challenges of this proposal, followed by the hypothesis of this PhD thesis and the outline of the empirical and operational objectives. Then the PhD structure scheme ends chapter 1.

Chapter 2 presents a brief overview of methodology for the empirical objectives followed by the methodology for the construction of a theoretical framework for contextualizing the RRI approach within renewable energy research and innovation. Then it includes the explanation of the methodology of the assessment framework in terms of the context and assessment levels proposals and the exposition of a validation methodology.

Following, the consideration of the methodology for the case studies and RRI plans proposals is explained with attention to the participatory study, RRI plans, science shops, and transnational projection of the study.

Chapter 3 comprises the outline of the papers and RRI plans proposal. Paper 1 includes the theoretical contextualization of RRI for energy research while Paper 2 is related with

the proposal of a methodological framework for assessment RRI implementation within renewable energy research and innovation based in a context and assessment levels and focused in the dimensions of sustainability and social justice. Paper 3 comprises the case study applied to renewable energies and the role of the researchers within thermal energy storage (TES) community. Paper 4 includes the contextualization of RRI within the innovation theories evolution and the RRI consideration for the non-EU context as well as the exploration of the stakeholders consideration applied to a Chilean solar energy researchers community.

Chapter 4 embraces the global discussion of results. Finally, chapter 5 outlines the main conclusions of this PhD thesis and the recommendations for future work.

Chapter 2

Methodology

2.1 Methodology for the empirical objectives

The PhD objectives show that the contextualization endeavour comprises the construction of the state-of-the-art and motivate to study and understand landscapes and contours of divergence and commonalities regarding the applicability of the RRI approach in a EU and non-EU context. Moreover, from the consideration of the rationales and the evolution of the imprints the assumption that the energy research and policy have their own interpretation regarding the concept of responsibility and the fact that these approaches and interpretations are in a continuous process of change.

Within energy research and innovation, responsible considerations are related with the treatment of social issues and concerns, and in the socio-political impact approaches that are engaged with reframing energy decisions in terms of ethical concerns, such as justice and values [47,48]. In addition, they are related with tackling the effect of technology outcomes on society, the well-being of the community, the consequences that changes in norms, values and beliefs have on the society and in the enactment of government as well as policies and regulations [49].

Furthermore, the consideration of the evolution of rationales can be found, for example, regarding the engagement in the renewable energy innovations. Since the traditional focus of public engagement was focused on creating consensus around top-down engagement or traditional social acceptance, which assumes that the agreement between diverse stakeholders is desirable and possible [26], nowadays, bottom-up approaches consider that the engagement process needs to be upstream and mandatory, involving methods such as focus groups, citizen juries, and other forums for participatory discussions [8,50]. In addition, the envision of anchored goals and dimensions such as engagement or acceptance are no longer seen as an aim, but rather how decision-making process should contribute to progress along the path to such goal [51].

When it comes to extrapolating RRI rationales in a non-EU context, this process is conducted inspired by tackling different interpretations of the problem to be addressed for avoiding pre-existing institutional anchors and reference points appealed to, on how to understand and mobilise particular constituencies of actors, and what strategies and interventions were recommended to bring about the envisioned 'better world' of responsible governance [44].

The consideration of the importance of the variety of stakeholders opens up the responsible governance debate. In this vein, testing the different constituencies of stakeholders, arenas of engagement, orders, norms, forms of legitimacy, and histories of practice, separating challenges, issues, and concerns shape the exploration of the stakeholders within governance [44]. Moreover, this process includes questioning if RRI fold together ontologically distinct categories of science, technology, research, and innovation within governance.

Finally, to consider what measures are required in order to assess whether governance moves are successful requires the consideration of a meta-governance appraisal comprising methodological proposals endowed with robust context, assessment levels, and validation method as well as the consideration of a proposals of activities. The validation and the activities proposals are going to be related, since they provide case studies and roadmaps (RRI plans). The use of the activities proposal is based in the use of models to introduce changes in the systems intended to produce outcomes which are the essential elements for process assessment [45]. In this vein, activities are going to comprise all the practical actions proposed in this PhD to achieve the aim of embrace and contextualize RRI governance approach within energy research.

2.2 Theoretical framework construction

The policy implementation process requires shifting from a theoretical discussion to the operational level of a concept. However, theoretical approaches are necessary to shape the context that allows the construction of the ontologies.

Following the proposal of this PhD approach, the theoretical framework collects the review of the discourse concerning RRI through the valorisations of its theoretical backgrounds and the consideration of the enrichment of the approach due to the evolution of the surrounding rationales.

In this vein, the methodology for the construction of the theoretical framework is based in the assumption that a context can be built following the paths of the measurement of the differences aspects of the considered concepts and through the embracement of different perspectives [45]. The process of measuring the different aspects of sustainability and social justice concepts shapes the construction of the first block of the theoretical framework, which is built based in the insights obtained from the review of the overarching approaches under socio-technical transitions.

In contrast, the path of boarding the concept to embrace different perspectives and trends vertebrate the inclusion of the approaches for navigating through sustainability and social justice in terms of the inclusion of RRI, sustainability assessment body of works, and energy related social sciences, sustainable development approaches, and the energy justice approach.

Moreover, the theoretical framework incorporates the insight of the state-of-the-art based in the review of the discourse concerning RRI from the valorisations of the theoretical background to the enrichment of the approach due to the evolution of the surrounding rationales. Within this design, the contribution of the state-of-the-art, the overarching approaches, the measurement of the differences aspects of the considered concepts, and the embracement of different perspectives shape each domain which are separated in terms of conceptual frameworks and operational frameworks. In these terms, conceptual

frameworks are going to consider the theories shaping the context and the operational frameworks are going to consider the methods that provide tools for the construction of proposals. For example, energy related social sciences body of works, such as sustainable development approaches and the energy justice approach, are going to be considered conceptual frameworks, and sustainability assessment frameworks body of works along with RRI are going to be considered operational frameworks.

The detailed blocks of the theoretical framework are shown in Figure 2.1.

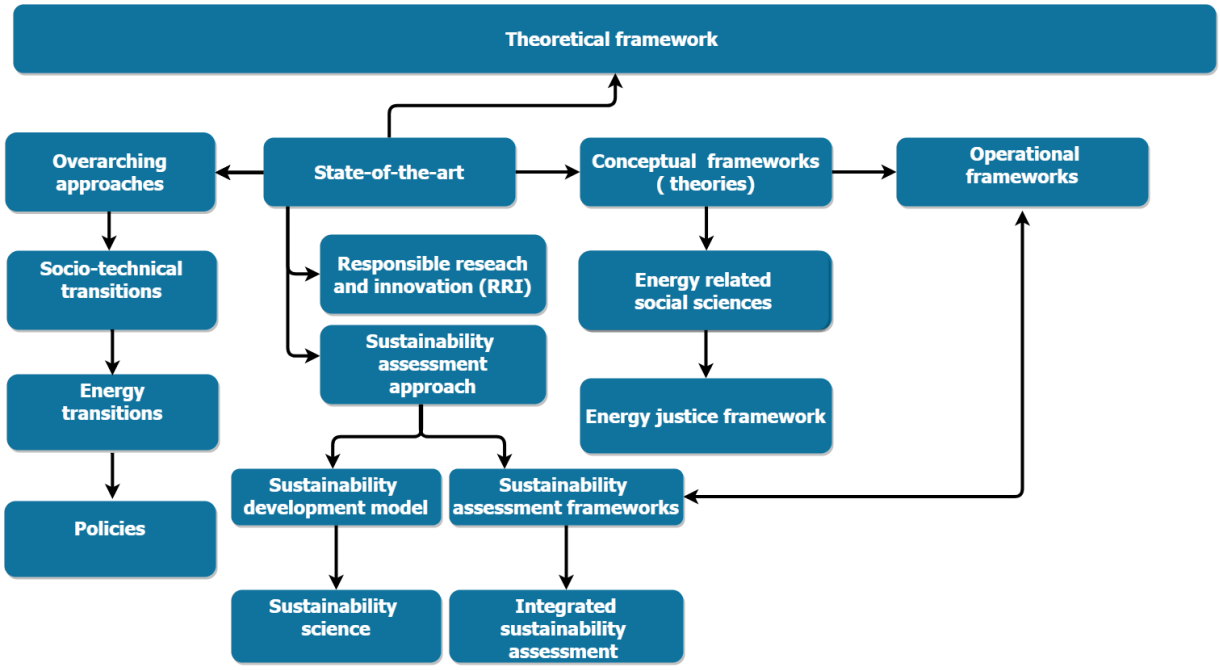

Figure 2.1: Building blocks of the theoretical framework proposal

2.3 Methodology for the assessment framework

2.3.1 Context and assessment levels

The methodological proposal entails gathering the inputs regarding the context for both sustainability and social justice dimensions and gathering the impacts for this assessment. For this purpose, the methodological proposal introduces two levels of context and assessments as shown in Figure 2.2. In this figure, context and assessment levels flow from the theoretical approach, since the assessment framework arises from the consideration of the approaches regarding context and assessment purposes.

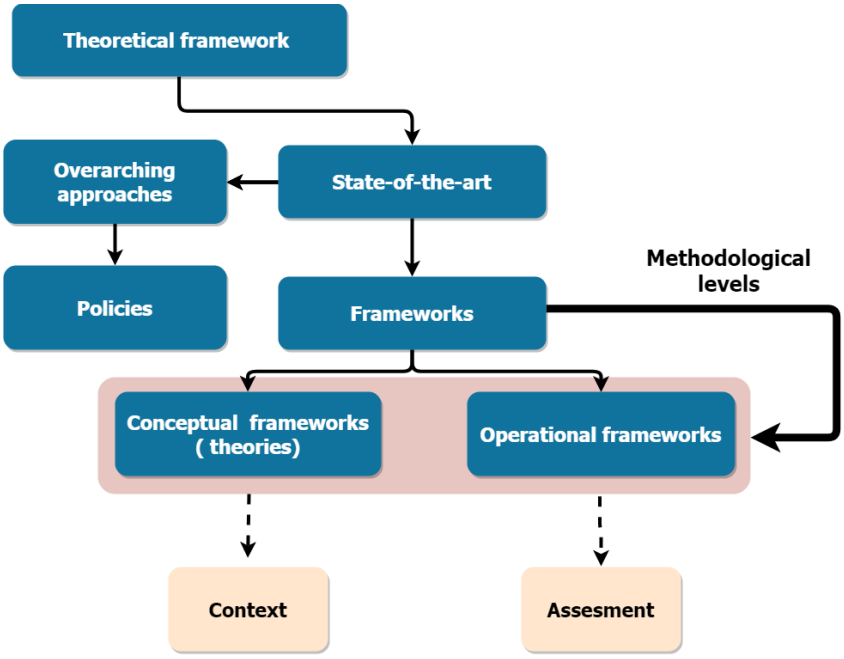

Figure 2.2: Steps for the construction of methodological proposal

In this vein, the context level is going to comprise the context insights along with assumptions built upon the concepts and understandings, and the assessment level is going to entail methodologies, indicators proposals along with tools on how to carry out the actions in terms of recommendations or activities for of both sustainability and social justice dimensions.

Moreover, the assessment level is going to comprise operational elements such as attributes, indicators, and drives of operational frameworks, such as technology assessment or sustainability assessment methods. The assessment level provides an indicators proposal which are considered following the RRI indicators constrictions and thresholds. In this vein, RRI have built a policy context in terms of an input–output models [52] and the process for monitoring is considered in terms of the outcome variables considered impacts [45].

Following these criteria, impacts measurement for both keys for agenda settings and dimensions of the process are subject to be measured by performance indicators divided in process indicators, outcome indicators, and perception indicators. RRI agendas and their deployment were considered as primary general indicator along with the definition of three scopes: performance, perception, and key actors.

A comprehensive step-by-step diagram of the indicators structure proposal emerging form the assessment level is shown in Figure 2.3. The figure shows the indicators in terms of outcomes, processes and perceptions.

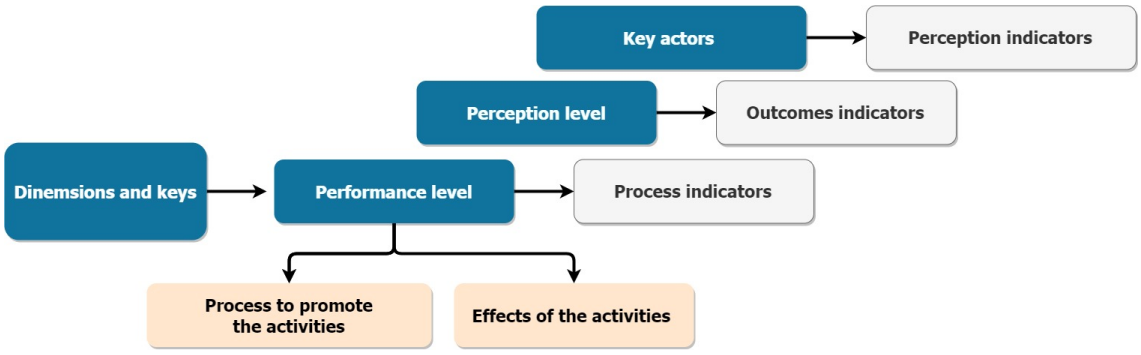

Figure 2.3: Indicators structure proposal to measure the impacts referring to outcomes, processes and perceptions of RRI and monitoring the development of RRI agendas, based on Strand et al. [16] , the insigths of EU MoRRI project [53], and the proposed assesment framework.

In the case of performance, it is dependant of both the processes that promote RRI activities and the effects that these processes own. In addition, performance yields the outcomes, thereby, acting with responsibility was presented as what defines who we are, along with the fact that acting in a certain manner results in the performance of this action.

Moreover, since responsibility covers the perception related with acting in a responsible manner [16], the definition of perception indicators arise from this consideration.

For instance, in the case of governance evaluated in terms of involvement with the wider public in RRI debates, national and supranational governments and stakeholders in science and society can be considered key actors and their interactions, measured for example through social media, can be considered as a perception indicator [16].

2.3.2 Validation method

The validation is the process of determining the degree to which a model is an accurate representation of reality and the method for validation implies testing the model results against real existing elements (technology, policies, approaches) meeting a series of requirements. For the purpose of this PhD, the validation process is going to be based on the validation of the principles, that needs to fulfil a series of requirements based in the accuracy of the context, the validation of the data, and the inclusion of the perception consideration in terms of stakeholders.

In this vein, the accuracy of the context it is proposed attached to three aspects:

- Being transferable to any discipline and global environments.
- Being innovative.
- Following RRI fundamentals.

Furthermore, the inclusion of the stakeholders perspective to transform performance indicators in key performance indicators (KPI) and perception indicators is based in RRI fundamentals, and at operative level it is based in a novel technology assessment method proposed for an integration of a technological system in a process where the stakeholder perspective forms a fundamental element of the analysis methodology [54].

The methodology proposed for validation is shown Figure 2.4.

In this vein the definition of boundary conditions is going to be linked with the definition of the context and state-of-the-art and the consideration of the operational elements from the assessment level.

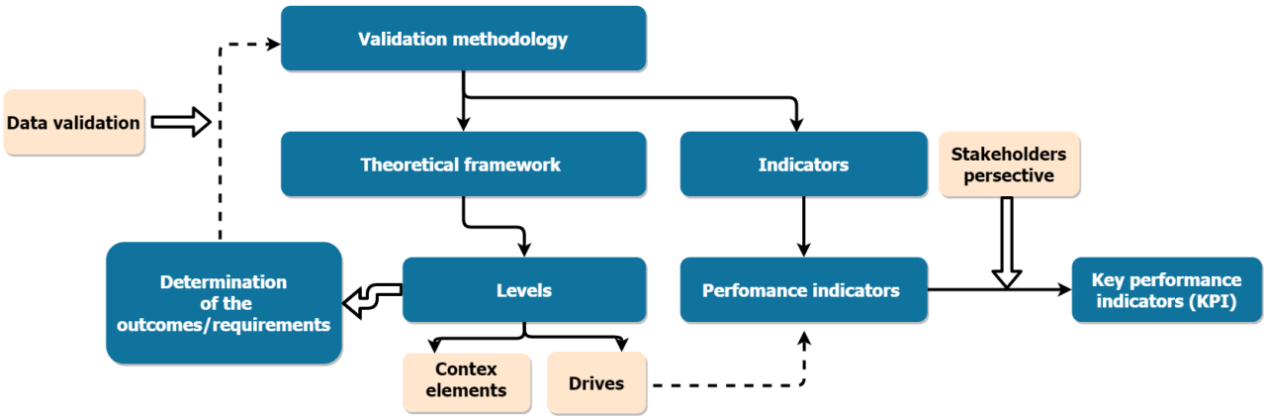

Figure 2.4: Structure of validation methodology.

2.4 Methodology for case studies

2.4.1 Methodological approach to participatory study

This PhD considers two case-study selection for the application. These case studies comprise the exploration of the stakeholders' consideration regarding the concept of RRI applied to the study of renewable energies and the role of the researchers. Case study 1 includes the analysis of a group of energy researchers within the field of thermal energy storage (TES) for the purpose of evaluating their perception regarding the inclusion of alternative policy and research approaches in their research. In addition, case study 2 comprise the analysis of a group of solar energy researchers from Chile for the purpose of evaluating their perception regarding the inclusion of alternative policy and research approaches.

In both cases, the methodology is based in the construction of an approach, a survey tool and the use of semi-structured interview process. The selection of these tools is based in the need to inform and be informed by societal dynamics, a dominant approach recommended in socio-technical transition approaches. In this vein, the use of human

centred research methods [55], such as focus groups and interview surveys, were reported to be useful to modulate the way in which research questions can be formed and interpreted by actors.

Moreover, within the renewable energy discipline, the use of qualitative methodologies employed for the appraisal of interacting energy and climate policies is not only confronted for their use within renewable energy innovation and policy development processes [56], but it also provides a descriptive explanatory analysis of the often non-quantifiable process in policy interactions and the description of the contextual implications [57].

Furthermore, the assumptions to choose qualitative participatory methods and the selection of researchers as a stakeholder of the energy system along with selected technological application are based in the following assumptions.

Regarding the implementation of alternative policy frameworks such as the RRI perspective, this selection entails the assumption that energy system actors and local communities should collaborate to share responsibility, to become mutually responsive, and to anticipate future developments to guarantee socially and technologically acceptable transformation towards an inclusive and sustainable energy system [14].

In the case of the consideration of the participative enquiring process in the design of proactive policies, within the discipline of energy, researchers are urged to ask what types of politics can make the energy and climate policies *achievable* [55]. In addition, how technologies for the renewable energy revolution can be can be socially framed in various ways taking into account the context construction and the communication in terms of transmission and participatory approaches reinforced the selection of these methodologies [58].

2.4.2 Survey for energy researchers within the field of thermal energy storage (TES)

The selection of storage technologies as a case study is supported since the adaptation of energy storage technologies is a hype in the global innovation policy trends world-wide [59–62]. Moreover, storage systems are considered a cross-cutting issue in terms of energy technology or infrastructure which can be used either to enhance the thermal energy output of a renewable energy system, or to enable a greater fraction of the output by the system to be used, or to allow the exploitation of renewable energy systems (RES) which would be difficult or impossible to use in specific applications [63–65].

Moreover, since storage provides value across different portions of the energy market (i.e. supply and demand sides) resulting in an inability to fit into existing regulatory frameworks, its inclusions in a prospect of a socio-energy system design [3,62] is essential.

The approach for the contextualization was considered in terms of a socio-technical transitions approach applied to storage technologies. This approach takes into account todays momentum where two trends are running in both research and energy policy arenas. In the case of research, RRI as an approach comprises the synergies between socio-technical transition approaches and holistic perspectives of innovation. In addition, within the focus on energy system transformation and energy transition socio-technical transition and innovation theories are the most extended representatives.

The found attempts to frame storage technologies within socio-technical transitions were based in the uses of the technological innovation systems (TIS) theory or systems innovation [66] and the co-evolutionary innovation framework for the energy transition [67]. TIS is focused on understanding the dynamics of innovation based on the performance of the surrounding technological system. Moreover, the key structural elements are actors, institutions, interactions, and infrastructures. Its key functions include knowledge development and diffusion, market formation, goal formation, resource mobilization, as well as, entrepreneurial activities assessment.

Co-evolutionary innovation in contrast, redefines technologies, institutions, ecological systems, business strategies, and user-practices, which co-evolve through mutual causal influences. Co-evolutionary innovation frameworks for energy storage evaluate the factors affecting its deployment. It states that energy storage innovation must, therefore, look beyond the traditional producer–user relationships, setting institutional environment, governance structures, and the willingness of users to engage with new technologies as key factor influencing innovations and the degree to which they are deployed across a system, upon cost and performance of technologies [68]. This framework is of the few representatives to by applied in the case of the research process.

The survey tool construction was based in the theoretical assumptions articulated in the previous sections. The survey tool was framed into four main areas (levels) representing: energy and society, communication, research and dissemination and outreach, participatory research or engaging research, and methodologies and regulatory framework awareness.

The levels were proposed for measuring the drivers of this dependent variables and their corresponding concepts as shown in Table 1.

The surveillance process was based in the use a survey tool and the performance of a qualitative approach to examine a phenomenon, to characterize it and differentiate it from other policy integration strategies. However, the survey was constructed taking into account the possibility of framing the results in indicators for subsequent statistical analysis. For this purpose, the consideration of a series of independent and dependent variables was made. The considered independent variables were gender, role, presence of absence of managements responsibilities within the institutions, and the years of expertise. And the dependent ones were organized in the four levels of the questionnaire:

The questions under the area of *energy and society* intended to elucidate the social approach to scientific research in general and then focus on renewable energy and TES. Within this area the first question was proposed in terms of *how researchers understand and describe energy research and TES social approach?*. This question intended to identify the drivers and the different weight in the rationales in the context of TES.

Potential drivers are the integration of social sciences increased acceptance, assessment of the context of the research, the consideration of participation either for pursuing social impacts or for drawing research questions across the society, and outcome innovation process reformulation.

Moreover, the questions under the area of *communication, research and dissemination and outreach* intended to elucidate the factors influencing the chosen transmission approach and the drivers of communication, divulgation, and engagement.

The level *participatory research or engaging research* indented to elucidate the drivers of the allocation of responsibility and elucidate the drivers of the extent to which scientific information meets the needs regarding collaborative research strategies and co-production of knowledge. Moreover, intended to unpack the awareness about the RRI conceptual and key dimensions and enquire the opinions regarding to responsibility, engagement, open access and open science.

Finally, the questions under the area of *methodologies and regulatory framework* intended to provide further insight into what factors are relevant in forming opinions and beliefs about RRI integration feasibility within renewable energy innovation and thermal energy storage (TES) research.

The questionnaire was designed following two different type of questions. The questions were enquiring with a semi-structured pattern of answers (give-one-view questions, multi-options, and yes or no questions) and open-ended response questions.

In the case of the give-one-view questions a five-point level was stabilised (1-strongly agree, 2-agree, 3-desagree , 4-strongly disagree, 5-indiferent) to evaluate responses following the case studies founded in the literature in similar areas [56,69–71]. Moreover, the approach of asking the enquires using additional related questions were included to provide further insight into what structural factors were relevant in forming opinions and beliefs. This strategy implies to, for example, enquiring similar questions changing some details.

Table 1. Questionnaire main levels

Level	Objective	Questions
Energy and society	To elucidate the drivers to social approach to scientific research in general and then focus on renewable energy study and (TES) applications	9-13
Communication, research and dissemination and outreach	To elucidate the factors influencing communication process and the drivers of the communication, divulgation, and engagement.	14-18
Participatory research or engaging research	- To elucidate the drivers of the extent to which scientific information meets the needs - To elucidate the drivers within the user-inspired innovations, collaborative research strategies, and co-production of knowledge - To unpack the drivers of RRI conceptual and key dimensions - To broad the opinion regarding to responsibility, engagement, open access and open science (citizen science, etc.)	19-35
Methodologies and regulatory frameworks	To provide insight into factors in forming opinions and beliefs about RRI and the feasibility of this integration within (TES) applications	36-40

2.4.3 Participatory process for the solar energy researchers from Chile

The proposal of a theoretical framework to contextualize RRI within renewable energy research and innovation, considering Chile is based in the fact that the two recurrent elements that have more weight in the surrounded rationales (when RRI is considered as an alternative science, technology and innovation governance approach) are the socio-technical transition approach and the current and traditional innovation theories and their synergies and evolution [45]. Moreover, the fact that, both approaches derived from the evolution of the theoretical approaches to innovation and the consideration that innovation theories approach are part of the RRI background, is used as a starting point to contextualize this approach for Latin America and Chile, acting as a common language.

Furthermore, the innovation theories consideration can be located within the efforts to promote renewable energy innovation in developing countries. These theories were used to deal with the renewable energy innovation challenges, the innovation and technology transfer and the proposals of alternative policy strategies. In this vein, the systemic approach is dominant in renewable technologies innovation rationales within the Latin American context. For example, the dominance of high carbon technologies is related with a 'locked-in effect' by the accumulation of knowledge, capital outlays, infrastructure, available skills, production routines, social norms, regulations and life styles, which developed around them [72]. This lock-in slows down low carbon technologies and disincentives radical, low-carbon innovation.

Within Latin America, systems of innovation are historically characterized by small scientific communities, with scarce financial resources and focused on research guided by curiosity [73]. Furthermore, the existence of little incentives to conduct research oriented to national priorities, the fact that the public sector is the main source of funding, the prevalence of an import-based industrialization model and a research imitation model, and a strong distortion in the incentive structure were considered the most remarkable prevailing burdens.

Chile as a country within Latin America that occupies a remarkable position in renewable energy research and innovation, specially within the international flows of solar investment [74]. Moreover, it is the forerunner of PV energy in the region [75] working in the prospect of turning the country into a solar superpower. The prospect of this endeavour is based in the developing and using solar energy extensively, not only at a domestic scale but also becoming exporter, adding all its generation capacity, and incorporating solar energy to industrial and productive processes to make them environmentally friendly [76].

Furthermore, Chile owns an extended trajectory regarding to the implementation and use of alternative models of innovation (such transdisciplinarity), and recently it embraced highly innovative approaches embedded in triple-, quadruple- and quintuple-innovation approaches [77].

In the case of this case study, a two–fold methodological approach was followed, based in a qualitative method consistent in the realization of a series of semi-structured interviews and the use of a survey tool designed in the previous studies. The interviews consisted in individual conversations organized with the purpose of reconstructing in detail and in a non-induced manner situation, opinions, judgments, and interpretations of the interviewee about certain events, problems or situations. The construction of the interview process was based in the previous studies conducted regarding RRI perception and implementation [78–80] piloted with researchers and in studies of researcher opinions regarding systems of innovation and innovation agencies in Chile [81].

The specific objective of the interview process was to outline the real characteristics of the country innovation system and within the solar energy research in Chile, avoiding the burden reported in the literature, the generalization and use of mainstreaming development, innovation and policy approaches [40].

In contrast, the survey tool was based in the survey for energy researchers within the field of thermal energy storage (TES) (section 2.4.1.1). This adapted survey explored researchers awareness and opinion regarding the questions of the social approach of energy studies, communication and divulgation aspects, the responsible methodologies and RRI dimensions, and keys and methodology awareness and pitfalls. These aspects were organized in four levels: (i) energy and society, (ii) communication, research, dissemination and outreach, (iii) participatory research or engaging research, and (iv) methodologies and regulatory frameworks.

The survey tool was adapted using the same levels but with the intention of contextualizing solar energy research within renewable energy research and innovation, following the case studies found in the literature in similar areas and for similar purposes [56,69–71].

The inclusion and adaptation of questions under the area of energy and society intended to elucidate the social approach to scientific research in general and then focus on renewable energy and solar energy research. Moreover, it also intended to introduce and grasp the first impressions regarding how researchers understand and describe energy

research relation with the social approach, to identify the drivers and the different weight in the rationales in the context of renewable energy research and innovation in Chile. The questions under the area of communication, research, dissemination and outreach intended to elucidate the drivers of this process taking into account the Chilean innovation ecosystem.

Furthermore, the level of participatory research or engaging research indented to elucidate the drivers of the extent to which scientific information meets the social needs. This is carried out considering collaborative research strategies and co-production of knowledge. In addition, participatory research level also intends to unpack the awareness about the RRI concept and its key dimensions and to enquire the opinion of participants regarding to responsibility, engagement, open access, and open science. In this sense, awareness regarding transdisciplinarity and its correlation within the Chilean context was expected.

The questions under the area of methodologies and the regulatory framework intended to provide insights into what factors are relevant in forming opinions and beliefs about the RRI integration feasibility within the renewable energy innovation framework in Chile.

2.5 Methodological approach for the RRI plans

The RRI plans are proposals of roadmaps to achieve the practical implementation of Responsible Research and Innovation. In the case of the proposal of RRI plans for the practical implementation to the study of renewable energy, the methodology is based in three steps:

- Step 1: A review and accumulation of elements obtained from the exploration process of the universe of the projects which were engaged with the RRI approach in EU and non-EU contexts.
- Step 2: A process of meta governance diagnosis.
- Step 3: A proposal of activities following the methodological proposals of the assessment framework.

Step 1 comprises the review and accumulation of elements obtained from the exploration process of the universe of the projects which were engaged with RRI approach in EU and non-EU contexts provides insights such as the levels of taxonomy that can be overview are among others, the projects intending to map RRI dimensions, aiming to foster the keys and attributes of RRI (focused in a selected area or in terms of mainstreaming the six plus two dimensions) and intentioned to mainstream the responsibility approach in different ambits and locations.

The second step comprise carrying out a meta governance diagnosis proposed in the project ReS-AGoRA [7,16] tested in many practical cases in research institutions. This meta governance analysis was conducted in the research groups and institutions for which the RRI plans proposals were designed, GREiA research group from the University of Lleida (Spain) and Centro de Desarrollo Energético de Antofagasta CDEA from the University of Antofagasta (Chile).

The Res-AGorA framework suggests that the success of any new RRI governance framework will depend on the way it relates to already existing governance practices or *de facto* governance. To translate this *de facto* to *de jure* in terms of governance arrangements, the suggested steps are to learn from the dynamics in *de facto* RRI governance, by using a meta-governance approach including the design of a series of research questions and model for the assessments of *de facto* governance and the operationalisation of the model for the pilot case studies.

The meta-governance approach analyses the *de facto* governance through a process of assessing *RRI in the making* [7]. This is proposed to be carried out through the use of a survey process based in two general concerns (which are further developed in a broader process enquiring through focus groups and surveys). These concerns are related with how is (i) *RRI in the making* conditioned and with (ii) the building components for a socio-normative governance framework regarding the selected institution or group.

As exposed in the introduction (Section 1.1.1), the driver *RRI in the making* is going to be conditioned by the proposal of new models of governance regarding the inclusion of cultural and normative means [5,6]. In this sense, RRI policies are characterised by

structural aspects such as a modes of regulation (e.g. hard/soft), type of responsibility (e.g. prospective/retrospective), the type of ethical principles and the relative position within the broader landscape of R&I and RRI governance arrangements [7].. In contrast, the building components are linked to the demonstrated success or failure of the selected case studies.

The third step for the methodology of the RRI plans proposals is based in the considerations exposed in the explanation of the methodological proposals of the context and assessments levels (Section 2.3.1) and the proposal of activities from the project MoRRI [16,17]. For the activities and assessment proposal, this project considers the theory of the intervention logic model based in the definition of a set of inputs which are applied to a series of activities to be developed; which generate outputs which lead to outcomes considered in the resolution of the problems [82,83].

Since, the activities are actions that will be produce tangible and measurable results in term of organisational process and structure inputs are translated into activities and the immediate results of those activities are going to become outputs, leading to outcomes for reaching long term achievements. Moreover, the selection of the activities needs to be arranged based on the RRI defined keys following the criteria expressed in background and to facilitate its later monitoring.

2.5.1 Methodology for the activities proposal in GREiA RRI plan

In this vein, the proposal of activities for GREiA RRI plan follows a structure based on the construction of a context or theoretical approach (that in this case entails the development of foundational issues of RRI), the key dimensions development, and the adaptation of the RRI approach to energy research, as shown in Table 2 were the development of the specific objectives in terms of foundational issues of the GREiA RRI Plan [46] is exposed.

Moreover, the activities are proposed to be carried out through the implementation of a science shop. A science shop allows to vertebrate initiatives to achieve the objectives of

the RRI plans and physically host and coordinate the activities. The methodological approaches proposed in the science shops considered for the purpose of the proposal of these RRI plans are the project-based learning (PBL) [84] and community- based research (CBR) [85].

Table 2. Development of the specific objectives in terms of foundational issues of the GREiA RRI Plan. Adapted from [16,82].

Activities scheme based in RRI plans objectives proposals	**Development of RRI foundational issues**	**Development of the eight key aspects of RRI**	**Adaptation of RRI methodology to energy research**
	Translate RRI into practice	Move forward RRI dimension significance	Frame RETs and TES innovation as a Responsible innovation
	Reinforce researchers awareness	Translate dimensions to research topics	Frame non-technological barriers for RETS and TES
	Foster interdisciplinarity	Reframe responsibility and social justice dimensions for energy research	Arrange users approach to technology transfer

2.5.2 Methodology for the activities proposal in *Strengthening the lithium value chain* RRI plan

In the case of the RRI plan for the project *Strengthening the lithium value chain,* the proposal of activities follows the same structure where the construction of a context or theoretical approach comprise the consideration of the Chilean context and the subject of the project is related with technology transference of energy research. Moreover, the key dimensions are considered open science and science education.

Furthermore, the methodology for the activities proposal in the case of *Strengthening the lithium value chain* project is based in the midstream modulation (MM) methodology, which lies on fostering knowledge transfer between actors from within and without the

science system, thus, evaluating and applying participatory foresight processes and user-oriented processes of technology transfer [6,86,87]. Moreover, it uses the interdisciplinary approach to ideas generation and evaluation to shape research agendas and to support spin offs resulting from those ideas.

2.6 Methodological considerations of the transnational projection

RRI as a policy approach settled within the context of the European research policy is an extended trend in several scientific disciplines and policy approaches, as well as in different countries. Thus, embracing and contextualizing alternative approaches within any scientific discipline or context requires from the consideration of the multiple trans-boundary and trans-disciplinary characteristics of the different research and innovations paths and actors, disciplines and global contexts which inevitably fall between the gaps of existing regulatory frameworks and instruments [44].

In this vein, case study 2 and the proposal of the development of a RRI plan for the technology transfer project for the University of Antofagasta, Chile (*Strengthening the lithium value chain* RRI plan) encompass the transnational projection of this study to Chile.

At methodological level, this transnational projection is based in the anticipatory governance approach proposal which embraces the postulates of the meaning and scope of anticipation and responsibility throughout the world, how emerging countries are dealing with this responsibility and the consideration of the main differences, difficulties and opportunities underlying anticipatory-like international governance dynamics [41–43].

Moreover, within the anticipatory governance consideration, a series of methodological approaches need to take into account postulates related with these. First, the meaning and the scope of anticipation is considered through the review of the evolution of systems of

innovation in Latin America and Chile. This evolution is considered the emergence in recent years of some changes that increased the productivity of research appeared in the Chilean research and innovation framework.

Second, the consideration of the different governance dynamics is advanced taking into account the different approaches to development paths in the Latin American context such as the imitation-based technological development [88]. This development is related with how innovation and international knowledge is integrated are considered. This imitation process is complex and is modulated by the factors affecting the extent to how national systems of innovation are able to grow and catch up with the technological frontier by means of international learning and imitation activities [89].

These factors are the innovative capacity and the absorptive capacity or imitation capability of a country [90]. These two factors constitute the technological capabilities (TC) of the countries from where technological capability accumulation (TCA) is defined [90]. TC are defined as the ability to make an effective use of technological knowledge for production, investment and innovation, and TCA comprises the levels of knowledge and advanced innovative capabilities which include capabilities for conducting R&D.

Chapter 3

Papers and other documents comprising this PhD

Figure 3.1 shows the papers and documents relation with the PhD objectives.

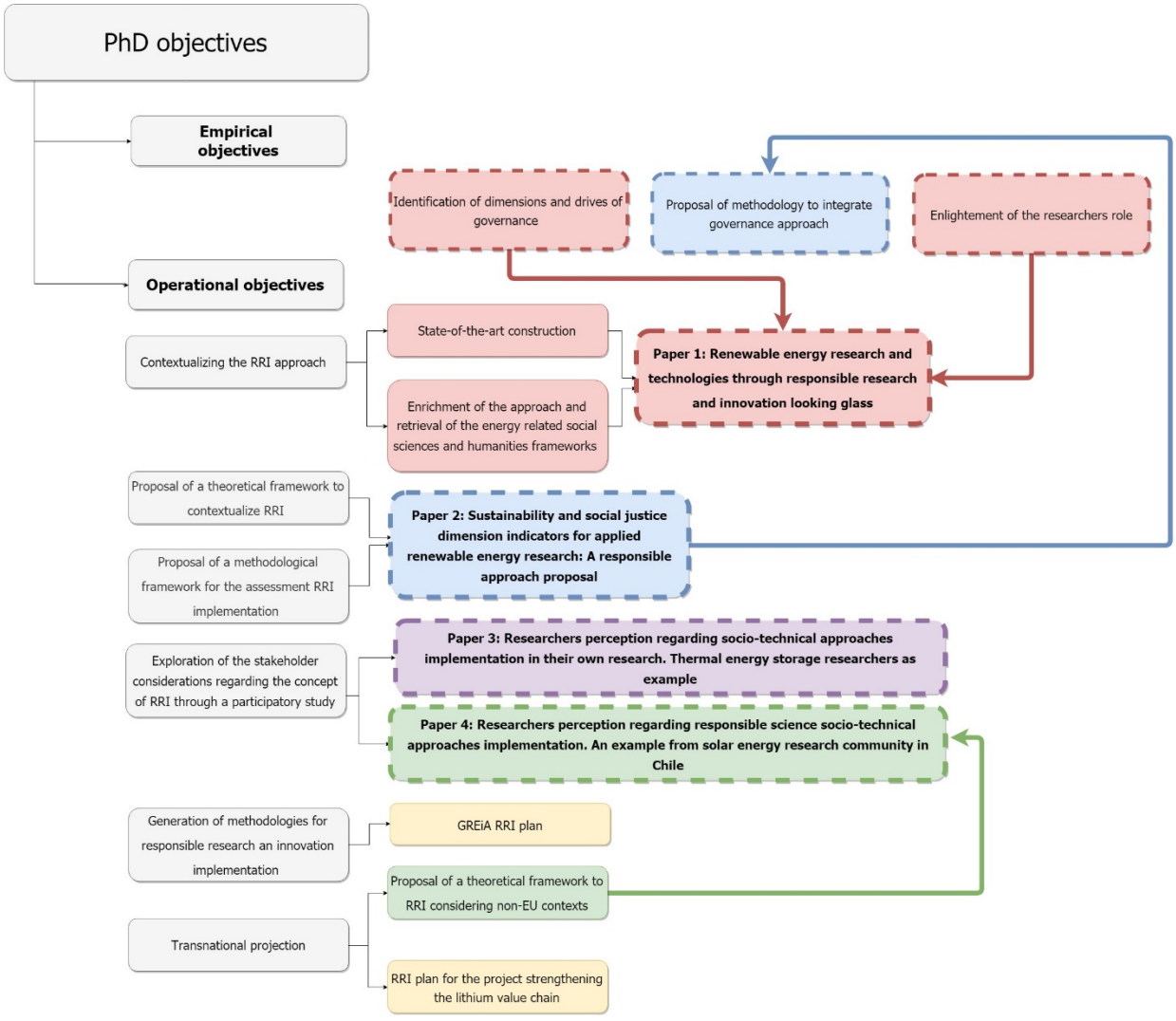

Figure 3.1: Papers and documents objectives relations chart

3.1 Paper 1: Renewable energy research and technologies through responsible research and innovation looking glass: Reflexions, theoretical approaches and contemporary discourses

3.1.1 Overview

The purpose of this paper is to present a reflexion regarding to a contextualization of Responsible Research and Innovation (RRI) and Open innovation European strategies which promote the development of social issues as core key of the research and innovation and the definition of the outcomes as the expression of human values such as safety, justice, sustainability and efficiency to energy research.

Moreover, these strategies are aligned with the purpose of this paper with the increasing challenges that energy research faces as a priority in most of the global research agendas, revealed both in terms of social and technical issues. In this vein, energy research highlights are set on the development of reliable renewable energy systems and applications; transition to decentralized systems and socio-technical, behavioural and institutional issues combination which requires the integration of both energy and research policies.

The proposal of contextualization considers a review of the range of theoretical backgrounds, meaning making processes, historical approaches, frameworks and contemporary discourses. The aim is to provide a detailed review of existing literature related to the key elements of Responsible Research and Innovation.

The results of this contextualization process show the existence of a common ground between responsible approaches and many concepts from energy research and social sciences frames. However, responsibility as understood in the RRI framework was found not deliberately represented, although, shifts towards responsible approach in social dimension treatment of renewable energy research appeared notable.

3.1.2 Contribution to the state-of-the-art

The innovation of this paper is focused in (1) the vision of RRI key elements applied to energy research, with particular reference to renewables, and (2) the outline of the many factors influencing the real field implementation.

The consideration of RRI dimensions of science education, gender, governance, ethics, open access, engagement, were treated in renewable energy research in different levels. Moreover, this paper emphasizes the consideration of sustainability and social justice, which is an innovation within the RRI body of works. Social justice and sustainability are endorsed in RRI as elements for transversal objectives of specific EU policies and dedicated in social sciences framework for energy.

Moreover, several interconnections between RRI and evolved and traditional social inputs from energy research heritage were found in the literature review process along with correlations between RRI dimensions in energy policy focused on the relationship with technology. Education, public engagement, gender and public participation, and new paradigms such as energy justice, are some of the most remarkable elements where correlations are notable.

In the case of sustainability and social justice dimensions, both can be located under the umbrella of the seeking for good governance in terms of the right to all people to have access to high-quality information about energy and the environment and pursue accountability and transparency.

When it comes to outlining the many factors influencing the real field implementation of RRI, the researchers perception, the existence of a time lag between obtaining research outcomes and the process of developing applications, and the difficulties of acknowledging contributions when innovation is the result of interactions between a variety of stakeholders and responsibility goals design dynamics can be considered.

In this sense, the researchers perception is related with the awareness and disaffection, convenience, lack of familiarity with the social sciences approaches, and the complexities

of the real practice of interdisciplinarity, as well as, the autonomy of the individual researcher activity and that of the research institution.

The responsibility goals design dynamics influences the application since these goals can be framed in a broad spectrum of expectations and suggested good practice. This consideration results that in some ways, the impact of responsibility actions can be relegated to a series of good intentions without actual materializing into specific actions.

3.1.3 Contribution to the objectives of the PhD

This paper contributes to the empirical objectives of the identification of dimensions and drivers of governance emerged from the opening up of approaches, rationales and understandings and the enlightenment of the researchers within the scientific community role in the re-envision of the innovation process. This contribution is show in Figure 3.1.

In this vein, the insights of this opening up of the approaches can be found in the development and outline process of the evolution of the responsibility approach. An example of the opening up of the approaches is the consideration of the top-down and bottom-up approaches, as well as upstream/downstream/mainstream strategies rationales.

The distinction between top-down and bottom-up technical approaches in energy innovation and energy research attends to distinct manners in which these two types of models treat the adoption of technologies, the decision-making of economic agents, and how markets and economic institutions actually operate. Participatory bottom-up approaches in renewables and energy studies are generally related with systems that ensure people participation at multiple stages of the process, starting from project selection by capturing people needs/desires and studying the existing practice to understand its importance in the local context.

In contrast, in responsible approaches, both top-down and bottom-up synergies are related with the introduction of policies, with top-down referring to initiatives coming from

policy makers and governance spheres, and bottom-up with the inclusion of represented researchers as well as involved stakeholders.

Moreover, the consideration of the shift towards responsibility detected in other approaches contribute to this objective. For example, the consideration of the ethics dimension treatment is an example of the shift towards responsibility. In the case of energy research, ethical frameworks were detected, transitioning from their use (trying to predict or anticipate social consequences and as a basis for moral and regulatory appraisal) towards their use for the introduction of new technologies.

In the case of the operational objectives, this paper contributes to fulfil objectives **1a** and **1b** of this PhD, entailing the contextualizing of the RRI approach. These objectives comprise (1) the state-of-the-art construction and (2) the enrichment of the approach due to the evolution of the surrounding rationales and the retrieval of the energy related social sciences and humanities frameworks considerations.

The state-of-the-art and the enrichment of the approach due to the evolution of the surrounding rationales insights can be found in Sections 1.1 and 1.2 of this PhD. Moreover, the review of social sciences and energy policy framework, in terms of RRI elements, is overviewed in the results chapter of this thesis.

3.1.4 Journal paper

The scientific contribution from the present research work was published in the journal Applied Energy in 2018.

Reference:

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Renewable energy research and technologies through responsible research and innovation looking glass: Reflexions, theoretical approaches and contemporary discourses

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HIGHLIGHTS

- Responsible Research and Innovation (RRI) and Open Innovation European strategies.
- RRI policy insights construction.
- RRI dimensions beyond significance.
- Social science frameworks for energy research.
- Operational elements of responsibility in energy research.

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Keywords:
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ABSTRACT

The increasing challenges that energy research faces as a priority in most of the global research agendas, are revealed both in terms of social and technical issues. Energy research highlights are set on the development of reliable renewable energy systems and applications; transition to decentralized systems and socio-technical, behavioural and institutional issues combination which requires the integration of both energy and research policies. Global trends in research policies showing an advocacy for responsible approaches are for example Responsible Research and Innovation (RRI) and Open Innovation European strategies which promote the development of social issues as core key of the research and innovation and the definition of the outcomes as the expression of human values such as safety, justice, sustainability and efficiency. The purpose of this article is to present a reflexion regarding to a contextualization of this approach in energy research. Therefore, a range of theoretical backgrounds, meaning making processes, historical approaches, frameworks and contemporary discourses, have been examined. Our aim is to provide a detailed review of existing literature related to the key elements of Responsible Research and Innovation. The innovative contribution is focused in the vision of these key elements applied to energy research, with particular reference to renewables and the outline of the many factors influencing the real field implementation. Results show the existence of a common ground between responsible approaches and many concepts from energy research and social sciences frames. Responsibility as understood in the RRI framework was found not deliberately represented, although, shifts towards responsible approach in social dimension treatment of renewable energy research appeared notable.

3.2 Paper 2: Sustainability and social justice dimension indicators for applied renewable energy research: A responsible approach proposal

3.2.1 Overview

This paper explores the importance of the aspects of sustainability and social justice within the research and innovation landscape in Europe in the context of the integration of the RRI approach to renewable energy research. For this purpose, this paper presents a review of approaches around sustainability and social justice dimensions and a proposal of theoretical and assessment frameworks.

Furthermore, the paper highlights the substantial efforts required to integrate the interactions between renewable energy research and energy and climate policies within responsible approaches. The thresholds of this endeavour are detailed in terms of the challenges for the integration, the identification of the inhibitors and facilitators of policy integration and the proposal of the levels for a methodology for this integration.

The results of this paper show that the different readings and understanding of the contexts and dimensions and the existence of knowledge gaps between policy targets and the outcomes of research and innovation can be considered inhibitors for the integration. In contrast, the interlinks between dimensional concepts, backgrounds and rationales appear as facilitators.

3.2.2 Contribution to the state-of-the-art

The innovation of this study lays in the construction of a robust and interdisciplinary methodological basis composed by a theoretical framework and methodological levels with the intention of illuminating the integration of responsible approach and RRI policy for sustainability and social justice dimensions.

In this vein, the importance of introducing a more holistic approach between social sciences and technological implementations supported by scientific data and experiments, which shall be emphasized in future studies, opens the possibility of the re-envision of the policy elements under the transition approach.

Moreover, this proposal contributes to the integration of the RRI policy taking into account the development of the agenda setting for sustainability and social justice dimensions, an option that was not explored in the literature before. Furthermore, the consideration of the synergies between the two missions of RRI along with the liaisons between conceptual dimensions and keys, represented in this paper by sustainability and social justice and the inclusion and governance, are considered.

The paper considers RRI under the perspective of the socio-technical transition approach with the intention of building a theoretical framework and generating operational tools for decision-making and the policy processes assessment.

Sustainability and social justice dimensions are framed in this paper regarding the process of transition and transformation of the renewable energy research and innovation in terms of facing the increasing complexity of moving from the sustainable development towards sustainable transitions. The drivers of this transition are, among others, the globalization and greater centralization coexisting with the fragmentation and decentralization of decision-making spheres, as well as the number of actors involved in the policy process. In addition, different energy research frameworks, such as sustainable development, sustainability assessment, and energy justice, are reviewed and framed under the socio-technical change approach.

Furthermore, the paper overviews the results of this integration of approaches in terms of the challenges for the integration, the identification of facilitator of inhibitors for this integration, and the pertinence of the use of the proposed methodological levels of context and assessment.

3.2.3 Contribution to the objectives of the PhD

This paper first contributes to the development of the PhD hypothesis in terms of the exploration of the importance of the aspects of sustainability and social justice. This exploration is conducted based in the hypothesis that the insights of the reviewed frameworks can build a methodological approach taking into account that they share a general vision towards achieving, among others goals, the reformulation of the innovation process and the re-envision of the policy agenda setting, as well as the paradigm change in decision-making. Moreover, this hypothesis was ascertained regarding the RRI approach providing a scenario to integrate interactions between renewable energy research and innovation and energy and climate policies.

In addition, the paper contributes to the operational objectives **2** and **3** of the proposal of a theoretical framework to contextualize RRI within renewable energy research and innovation and the proposal of a methodological framework for the assessment of RRI implementation based in context and assessment levels, focused in the RRI dimensions of sustainability and social justice (Figure 3.1).

This paper based its proposals in the consideration that the policy integration process requires from (1) shifting from a theoretical discussion to the operational level of a concept, and from (2) the ability to identify inhibitors and facilitators of the process. And also, in a methodological proposal for an assessment based in context and assessment levels and a proposal of indicators framework.

3.2.4 Journal paper

The scientific contribution from this research study was published in the journal Applied Energy in 2019.

Reference:

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Sustainability and social justice dimension indicators for applied renewable energy research: A responsible approach proposal

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HIGHLIGHTS

- Sustainability and social justice deserve attention in sustainable transitions.
- Responsible research and innovation is used for envision sustainable transitions.
- Responsible research and innovation offers tools for policy integration process.
- An understanding of the context is vital in terms of replicating an intervention.
- Context description must be considered as part of the validation methodology.

ARTICLE INFO

Keywords:
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Sustainability
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Sustainability assestment frameworks

ABSTRACT

Aspects of sustainability and social justice deserve special attention in the research and innovation landscape in Europe. In this vein, the inclusion of innovative research and innovation policies, such as Responsible Research and Innovation, devoted to mainstream social outcomes, to deploy democratic governance of science, and to drive innovation into a direction that is ethically acceptable, societally desirable and sustainable are noteworthy. However, substantial efforts are required when it comes to integrate the interactions between renewable energy research and energy and climate policies within responsible approaches. In order to adapt responsible research and innovation approach for the purpose of building an alternative context and assessment approach for sustainable transitions, this paper presents a review of approaches around sustainability and social justice dimensions. The thresholds of this endeavour are detailed in terms of the challenges for the integration, the identification of the inhibitors and facilitators of policy integration and the proposal of the levels for a methodology for this integration. The results show that the different readings and understanding of the contexts and dimensions and the existence of knowledge gaps between policy targets and the outcomes of research and innovation can be considered inhibitors for the integration. In contrast the interlinks between dimensional concepts, backgrounds and rationales appear as facilitators. The innovative contribution of this paper is focused on the contextualization of the dimensions through the use of socio-technical and multi/inter/trans and cross-disciplinary approaches. The authors conclude that the process of introducing a more holistic and alternative approach opens the re-envision of policy elements. Moreover, RRI offers an innovative perspective to the transition approach as well as tools for decision-making and policy processes assessment, in an arena where constant innovation is taking place and new structures, processes and metrics are necessary to guide this process.

3.3 Paper 3: Researchers perception regarding socio-technical approaches implementation in their own research. TES researchers as example

3.3.1 Overview

This paper enriches the literature in two significant directions. First, it presents the state-of-the-art of the socio-technical integration in energy storage research considering three aspects, social science integration, the new approach of communication of research results to society and other stakeholders, and opportunities of collaborative research strategies and co-production of knowledge. This highlights the literature gaps in considering researchers as stakeholders of this process, which brings the second part of the paper, which shares in-depth the survey results about the researchers perception towards the prospect of the use of the RRI approach in their research, with a specific researchers community (thermal energy storage).

Findings show willingness to include citizens as beneficiaries but not as participants of research decisions. In addition, the use of social sciences to increase the acceptance of technology prevails. Moreover, divulgation and communication were considered the same and ignorance regarding collaborative research strategies was found. Finally, researchers considered not significant efforts for the implementation of socio-technical approaches but acknowledged the need of a change in research governance.

3.3.2 Contribution to the state-of-the-art

This paper intended to reveal how multiple elements influence the energy researchers belief about the RRI integration in their day to day work for the sake of the transformation of energy systems. This process was conducted in the case of thermal energy storage research considering the levels of energy and society, communication, research and

dissemination and outreach, participatory research or engaging research, and methodologies and regulatory frameworks.

The innovation of this paper is related with the fact that the given literature was focused on the social approach of the technologies, not in the research process. In this vein, the review of the literature trends on the inclusion of social approaches on storage technologies and the case study of thermal energy storage shows increasing trends of research papers on the topics of renewable energy as well as thermal energy storage containing references to social aspects and social approaches. However, studies on perception of alternative policy frames and responsible policies in researchers remain sparse, and towards renewable energy applications such as thermal energy storage are non-existent.

The survey data was collected from a representative group of researchers working on TES (33 countries, 215 targeted researches completing the surveys at 31% with a final N=72) that were part of institutions throughout the world. Moreover, a query in Scopus shows that around 160 researchers publish in TES, showing that the sample is indeed representative of the topic assessed [91].

3.3.3 Contribution to the objectives of the PhD

This paper contributes to the operational objective **4** entailing the exploration of the stakeholder considerations regarding the concept of RRI through a participatory study, applied to the study of renewable energies and the role of the researchers (Figure 3.1).

Within the objectives of this PhD, this paper comprises a case study. This case study is built on (1) the selection of the technology, (2) the elaboration of an approach, and (3) the survey process. The selection of the technology assessment is detailed in the methodology section related with this paper (Section 2.4.1.1).

3.3.4 Journal paper

The scientific contribution from the present research work was submitted to the journal Renewable and Sustainable Energy Reviews in July 2019.

Reference:

Carbajo R, Cabeza LF. Researchers perception regarding socio-technical approaches implementation in their own research. Thermal energy storage researchers as example. Submitted to Renewable and Sustainable Energy Reviews, 2019.

Elsevier Editorial System(tm) for Renewable & Sustainable Energy Reviews
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Title: Researchers perception regarding socio-technical approaches implementation in their own research. Thermal energy storage researchers as example

Article Type: Original Research Article

Section/Category: Society

Keywords: Researcher acceptance; responsible research and innovation (RRI); thermal energy storage (TES); collaborative research strategies

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3.4 Paper 4: Researchers perception regarding responsible science socio-technical approaches implementation. An example from solar energy research community in Chile

3.4.1 Overview

This paper deals with the question of how to incorporate the RRI approach into the discipline of renewable energy innovations in a non-European context. This endeavour requires from considerate the different research and innovations paths and actors, disciplines and global contexts. The researchers for the survey process were selected from the Chilean Solar Research Centre (SERC-Chile) and the approach to RRI was considering coming from the overall consideration of the social approach of the research activity and the social approach of energy studies.

As a result, the participants account the social approach in terms of economic, institutional and regulatory features, but they also listed engagement with community, real appropriation, cultural integration, social licence to operate, and the valorisation of methodologies, such as transdisciplinatiry and co-construction.

3.4.2 Contribution to the state-of-the-art

The innovation is based in the proposal of the use of the socio-technical transition approach and the evolution of the innovation theories acting as a common language to consider the integration of RRI in a non-EU context. In this vein, this approach outlines the real characteristics of the countries in terms of socio-economic concerns and politics necessary to generalize and use mainstreaming innovation and policy approaches.

The participatory process presented in this paper confirms the trends reported in literature in terms of the incorporation of changes in Chilean innovation systems to increase the productivity of research, the commitment to innovation in terms of acquiring internal

knowledge, the change in the assessment process and the appearance of new actors, and their impact on the reconfiguration of the innovation system which allows the integration of alternative policy approaches.

Moreover, the paper examines the researchers opinion from a renewable energy discipline through the realization of a series of semi-structured interviews and the use of a survey tool. The interview process brings a series of consideration that cannot be obtained by a systematized survey process.

Furthermore, the survey data was collected from SERC researchers which comprise a representative group working on the solar field and renewables in Chile (78 targeted researches, with 44 answering to request and between 34 to 44 completing the surveys).

3.4.3 Contribution to the objectives of the PhD

This paper contributes to the operational objective **6a** and **6b** entailing a transnational projection of this PhD. This objective is comprised by (1) the proposal of a theoretical framework to contextualize RRI within renewable energy research and innovation, considering non-EU contexts, (2) the contextualization for Chile, and (3) the arrangement of a Chile-Europe case study on responsibility concerning R&D practices in selected innovation and business areas related with solar energy research and innovation (Figure 3.1).

3.4.4 Journal paper

The scientific contribution from the present research study was submitted to the journal Renewable and Sustainable Energy Reviews in July 2019.

Reference:

Carbajo R, Cabeza LF. Researchers perception regarding responsible science socio-technical approaches implementation. An example from solar energy research community in Chile. Submitted to Renewable and Sustainable Energy, 2019.

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Title: Researchers perception regarding responsible science socio-technical approaches implementation. An example from solar energy research community in Chile

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Keywords: Researcher acceptance; responsible research and innovation (RRI); solar energy research; Chile

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3.5 GREiA RRI plan

3.5.1 Introduction

The construction of the RRI plan for GREiA (former GREA) was based on the idea of pursuing excellence beyond standards in terms of research and innovation attached to social relevance with particular attention to improve the ways that different aspects of science and technological change are governed. It was also motivated by the idea of transcending beyond RRI dimensions and attributes, implement responsibility and open

innovation approaches in renewable energy research and applications and to be able to monitor this implementation.

The international partnership of GREiA, the participation in research projects, and the specific levels of governance offers the opportunity to transcend from local to global and use RRI dimensions to vertebrate partnerships and future research towards more social outcomes. In this sense, the plan aims to develop and implement a RRI Plan to promote institutional change and to foster the uptake of the RRI approach by researchers and participants.

At disciplinary level, the recognition of the interdisciplinarity and cross-cutting nature of the field of energy and its applications is also the motivation to start the implementation of RRI in a research institution (research centres, universities and the research departments, as well as in industry partnerships) by the implementation around one research area, to set common strategies and tools giving answer to common working methods, problems and approaches, as well as to reinforce the culture of responsibility within the research group.

The plan is launched with the ambition of allowing GREiA to manage research and innovation to be more efficient to solve social problems regarding energy research through the integration of eight key aspects of RRI in research to arrange structural changes in our research organization as well as to vertebrate partnerships towards more socially outcomes and encourage awareness in researches.

3.5.2 Contribution to the-state-of-the-art

The innovation of this document is related with the fact that even if the implementation of considerations of the socio-technical transition approach within research about energy systems is a long-settled tendency, the specific use of RRI approach to energy systems is an emergent field of study.

Moreover, this plan considers the application of the RRI approach taking into account the overarching considerations of the framework upon the established agendas and processes. In this vein, this is considered as an innovation since the attempts to implement RRI were related with the application of the conceptual dimensions [92,93], but were not based in the development of the keys of the agenda setting.
Furthermore, regarding this monitoring process, since there is an absence of assessment and monitoring methods for RRI, the proposals of this document are an innovation.

Regarding activities, the commissioning of a science shop is proposed, named GREiA science shop, focused in fostering RRI dimensions with core activities for public engagement, science education and open science keys. The GREiA science shop is proposed to represent a physical place for researchers and citizens interchanges and the *home* of the RRI plan. Moreover, the innovative consideration of a science shop is proposed to be structured in five lines of action comprising five labs:

- Users lab (UL)
- Responsibility lab
- Communication, culture and transmedia lab
- Science education lab
- Open science lab

3.5.3 Objectives of the GREiA RRI plan

The aim of the plan is to develop, adopt and assess a RRI Plan around the topic of energy research and applications such as RETs and Thermal energy storage (TES) at national level within the GREiA research group. For this purpose, a number of general and specific objectives are defined.

General objectives are related with the outputs of the RRI plan and specific objectives are linked with the measurement of the appropriateness of this methodology for GREiA research purposes; the overcoming of barriers both related with implementations of the

framework and deployment of RRI that we shall call foundational issues as well as unravelling research issues of GREiA related disciplines.

In this sense the general objectives of this plan are:

- To develop a RRI plan for the GREiA research group.
- The adoption of the plan by the researchers at GREiA.
- Monitoring and assessing the implementation of the plan to evaluate the results in terms of changes within the GREiA research structures and its international partnerships.

The ccomplexities regarding the implementation in terms of adopting this new label and the observance of how far RRI methodology allows to achieve research and innovation goals, shape the specific objectives, that are focused in three elements:

- Development of RRI foundational issues.
- Development of the *eight* key aspects of RRI beyond significance and focused on research and researchers.
- Adaptation of RRI methodology to energy research.

The process of the development of foundational issues consists in the consideration of the theoretical and practical concerns related with the dimension interpretation and the barriers for the implantation coming from a literature review process and from the review of the insights of the RRI previous experiences. Moreover, this development comprises the review of the responsibility frameworks such as the ethical framework for experimental technology, the review of the RRI importance for the European Commission, and review of the related rationales affected by RRI such as open innovation strategies.

The development of the eight key aspects of RRI beyond significance is focused in transcending from the keys to research topics and the integration of RRI dimension and attributes in the objectives of the projects. This process is going to be focused in expansion of the attributes of RRI with frameworks of ethics in technologies and value approaches trying to broaden the responsibility approach. Regarding the RRI dimension, GREiA is going to focus in translating the RRI dimension in research topics, reframe

dimensions for their adaptation to energy research such as sustainability and social justice, and to reinforce the interlinkages between dimensions.

The dimensions (and actions) with special interest for this reframing process are:

- Gender: With actions focused in ensuring the effective promotion of both gender equability and gender dimension in research topics.
- Sustainability: With actions focused in assessment and developments of performance indicators.
- Social justice: With actions focused transcend to research topics, such as energy poverty and assessment and developments of performance indicators.
- Science education: With special dedication to arrange and monitoring non-conventional methodologies and alternative approaches.

In the case of the adaptation of the RRI methodology to energy research, three elements are going to be considered:

- To explore the possibility of reframing renewable energy technologies (RETs) and innovation and thermal energy storage (TES) innovation as Responsible innovation.
- To use RRI to frame non-technological barriers framework for RETs and TES.
- To arrange users approach to technology transfer.

3.5.4 Contribution to the objectives of the PhD

This document contributes to the operational objective **5** entailing the generation of methodologies for responsible research applied to the study of renewable energies (Figure 3.1).The RRI plan contributions are related with the contextualization of barriers for the arrangement of methodologies for RRI implementation, the development of the foundational issues, and the review of the indicators proposal considered for the eight key dimensions of RRI.

The barriers for the GREiA RRI plan emerged from the review and accumulation of elements obtained from the exploration process of the universe of the projects. This

process is part of the Step 1 mentioned in the methodology section. The contextualization of these barriers can be found in the discussion of the results section related with RRI plans (Section 4.5.4).

In contrast, the review of the existing indicators is focused in evaluating the continuity of the plan implementation. The main source of theoretic indicators for the RRI eight key areas are EC RRI process indicators which depends both on the processes that promote RRI activities and on the effects that these processes have (outcome). Those EC RRI indicators are distributed in processes indicators, their outcomes, and how such processes and outcomes are perceived (perception).

3.5.5 GREiA RRI plan

The GREiA RRI plan is an open resource located in the GREiA group web page since 2018.

Reference:

Carbajo R, Cabeza LF. GREiA Responsible Research and Innovation plan (RRI PLAN). http://www.greia.udl.cat/rri.html

GREiA Home People Research Finished Research Publications RRI Plan

RRI Plan

GREiA RESPONSIBLE RESEARCH AND INNOVATION PLAN (RRI PLAN)

INTRODUCTION

Over the last decades many efforts have tried to reduce the distance between science and society, leading to a European-wide approach in Horizon 2020 called **Responsible Research and Innovation**. RRI seeks to bring issues related to research and innovation into the open, to anticipate their consequences, and to involve society in discussing how science and technology can help create the kind of world and society we want for generations to come.

A normative framework for RRI includes eight normative policy keys/agendas:

- **Ethics**: focuses on (1) research integrity: the prevention of unacceptable research and research practices; and (2) science and society: the ethical acceptability of scientific and technological developments.
- Gender Equality: is about promoting gender balanced teams, ensuring gender balance in decision-making bodies, and considering always the gender dimension in R&I to improve the quality and social relevance of the results.
- **Governance**: arrangements that lead to acceptable and desirable futures have to (1) be robust and adaptable to the unpredictable development of R&I (de facto governance); (2) be familiar enough to align with existing practices in R&I; (3) share responsibility and accountability among all actors; and (4) provide governance instruments to actually foster this shared responsibility.

3.6 *Strengthening the lithium value chain* for the University of Antofagasta, Chile RRI plan

3.6.1 Introduction

The objectives of this proposal are the optimization of the lithium production chain through a scaled study of the thermal properties of solar storage of $LiNO_3$, as well as to propose innovative solutions to support the process of technological transfer for the creation of a processing local industry focused on obtaining and supplying this product. Likewise, one of its strategic objectives is the development and implementation of initiatives for Energy Education and/or Energy Culture to promote changes in the society towards a more sustainable and equitable Chilean society aligned with the efforts that are being carried out in the Chilean higher education institutions, such as the University of Antofagasta.

For the integration of the strategic objectives of this project, the use of RRI is proposed. In this vein, although RRI is a European policy, primarily addressed to policy makers of

the European Commission and Member States, the significance of this framework to global public and private markets is considered [94].

The starting point of this proposal is the fact that as a tool, RRI addresses the social challenges of research and technology transfer, by aligning the values, needs and expectations of all actors involved in the R&D process. Moreover, it is being used successfully in the EU and the US, Brazil and China, especially in research and innovation activities financed with public funds, framing the backbone of technology transfer processes in industries and SMEs. Furthermore, it was used in the creation of companies with the participation of institutions such as start-ups and spin-offs based on the open, fair and equitable use of research results.

3.6.2 Responsible insights in Chilean context

The examples of the RRI application within the Chilean context can be separated in the specific use of the approach and in the case of the use of the overall considerations of RRI. This option merges the initiatives that without using the RRI specific approach, they are inspired by their rationales in terms of the use of alternative approaches, participatory methodologies, as well as the consideration of the RRI key elements.

In this sense, regarding the specific application and consideration of RRI, a project related with the responsible mining within the scope of the European project RESPONSIBILITY and the Global Model and Observatory for International Responsible Research and Innovation Coordination can be found. The project was based in the RRI application to the mining industry was carried out in 2015. This project was also based in the results of "Responsible Research and Innovation in Mining", a previous workshop that toke place in Santiago de Chile on March 19th, 2015.

In the case of the initiatives where the rationales and inspiration of RRI can be found, some of the energy policy proposal and the process for its construction can be highlighted. In this sense, for example, the roadmap ENERGY 2050 (ENERGÍA 2050 in Spanish) can be considered. The elements of responsibility in this policy construction can be found in

the use of the *Backcasting* methodology based on the processes of balancing economic efficiency, environmental protection, and alternative governance. It has been used for the development of the Canada Water Strategy and National Solar Energy Strategy for Chile. Furthermore, within the policy, the consideration of the key elements of the community engagement and the scientific education along can be highlighted.

Another example can be found in the educational innovation and promotion project Engineering 2030 (INGENIERÍA 2030 in Spanish) operating in engineering schools and science faculties at the University of Chile, Technical University Federico Santamaría, and Universidad de Concepción, among others.

In the case of the Engineering 2030 initiative, it seeks to transform engineering schools into leading organizations to achieve the country objectives and to promote multidisciplinary research and education, to restructure the teaching methodology and to solve social challenges by encouraging student training world class with related improved skills. It is an integrated strategy based on the promotion of economic development and international networks and alliances and the search for new strategies and mechanisms for technology transfer based on the commitment to society managed by economic promotion agency CORFO.

3.6.3 Project policy context

The project is typified as a technology transfer project in the energy production sector and it is applied to the following areas of the regional innovation strategy (*Estrategia regional de innovación* in Spanish (ERI)) of the Antofagasta Region. This strategy is aligned with the Chilean national strategies (*Estrategias regionales* in Spanish (ER)) and the National energetic policy (Política energética en Chile, ENERGÍA 2050 in Spanish) [95].Moreover, it refers to the objectives of the 2015 roadmap (*HOJA DE RUTA 2015, Hacia una energía sustentable e inclusiva para Chile en 2015* in Spanish) from the energy consulting committee (*Comité Consultivo de Energía 2050* in Spanish) regarding the key of promoting behavioural changes in society about sustainable energy production and

consumption and the key of developing professional and technical human capital for sustainable energy management.

The goals of both keys are based in allowing a transition of citizens towards a more active role in terms of the production of goods and services they consume and the minimization of the impacts that they generate, as well as the incorporation of the transversal content on the energy development, such as awareness and dissemination programs on sustainable energy, with a macro-zonal approach, that collects the particularities of the territories and their communities.

In this vein, the indicators of outcomes of the project following the region innovation strategy of Antofagasta are shown in Table 3, where the indicators and results of the proposal of the University of Antofagasta regarding the objectives of the Regional Innovation Strategies of the Antofagasta Region are shown.

Table 3. Indicators and results of the proposal of the University of Antofagasta regarding the objectives of the Regional Innovation Strategies of the Antofagasta Region.

Regional strategy objectives (RSO/ERI)	**Valorisation of the natural resources of the region process**	**Grade of innovation generation in the valorisation process**	**Pilot test and prove of concepts applied to regional SMEs**
University of Antofagasta proposals	Lithium nitrate application in solar thermal energy storage process	Thermal characterization of industrial molten salts with lithium nitrate content	Pilot scale tests with the designed solar storage fluid with lithium nitrate
RSO/ERI	**Innovation for sustainability of the regional economy**	**Reduction of the production cost of the non-conventional renewable energies in the Region**	**Innovation for the economic diversification of the Region**
SMEs outcomes	Lithium nitrate production on an industrial scale in Chile	Elimination of the costs derived from the importation of these products and an	Positioning of the Antofagasta region as a world leader in the

Regional strategy objectives (RSO/ERI)	Valorisation of the natural resources of the region process	Grade of innovation generation in the valorisation process	Pilot test and prove of concepts applied to regional SMEs
		valorisation of the lithium production chain	production of lithium nitrate storage fluids

3.6.4 Proposal of a RRI plan

In view of the policy context of the project, the application of the RRI framework for RRI focuses on the reformulation of research and innovation processes to support responsibility objectives, as well as the establishment of priority dimensions such as participation, governance, and scientific education.

The proposal is based in three main actions:

1. The systematic review of the current discourse on RRI, both academic and public policy-oriented, to assess its usefulness for the industry, especially in the case of SMEs, and the identification of sub-areas represented in the discourse that could potentially help its applicability in the industry.
2. The design of a RRI program focused on the technological transfer of research results and the development of communication and scientific dissemination initiatives.
3. The development of tools to collect the appropriate information to measure and monitor the impact of these initiatives.

The first action is focused in the consideration of the process reformulation mission of the RRI approach. The second action is based in this proposal of a responsible framework considering the context of energy studies and storage along with the overall consideration of the strategic nature of the lithium products for the region of Antofagasta. Furthermore, the consideration of the strategic dimensions of science education and energetic culture merging the insights of sustainability, social justice and engagement are taken into account for this proposal.

The third action is related with the development of tools to collect the appropriate information to measure and monitor the impact of these initiatives that is going to comprise a work plan based in the researcher capitation and the proposal of practical actions.
The development of these purposes is outlined in the next section related with the contribution of this RRI to the objectives of this PhD.

3.6.5 Contribution to the state-of-the-art

The innovation of this document, in addition to those listed in the case of the GREiA RRI plan in Section 3.5.2, are related with the opportunity of the transational projection of this study. In this vein, despite that RRI is a policy approach settled within the context of the European research, the possibility of overviewing its application in a non-EU country can be considered an innovation. Therefore, this document outlines the meaning and scope of anticipation and responsibility in Chile and overviews how emerging countries are dealing with this responsibility.

3.6.6 Contribution to the objectives of the PhD

This document contributes to the operational objective **6c** entailing the construction of a RRI plan for the project *Strengthening the lithium value chain* for the University of Antofagasta, Chile (Figure 3.1).This process comprises the achievement of the proposed objectives based in three main actions: (1) reviewing of the current discourse on RRI to assess its usefulness for the industry; (2) the design of a RRI program focused on the technological transfer of research results and the development of communication and scientific dissemination initiatives, and (3) the development of tools to collect the appropriate information to measure and monitor the impact of these initiatives.

3.6.7 Document characteristics

This document was presented as a part of an advisory report for the technology transfer and Responsible Research and Innovation for project for the University of Antofagasta in Chile on 25 July 2017.

Moreover, the document is a proposal for advice for the project *Strengthening the Lithium value chain* related with the proposal of $LiNO_3$ as solar thermal storage material in the Antofagasta region (Fortalecimiento de la cadena de valor del Litio, in Spanish) awarded to the University of Antofagasta, Chile in the call for Innovation Funds for the Competitiveness FIC Region of Antofagasta 2015, to be executed during the period of March 2016-July 2017.

The original document is in Spanish.

Reference:

Carbajo R, Cabeza LF. Asesoría para la Transferencia tecnológica e Investigación Responsable en el proyecto: Fortalecimiento de la cadena de valor del Litio en la Región de Antofagasta, Chile. 25 de julio de 2017.

Asesoría para la Transferencia tecnológica e Investigación Responsable en el proyecto: Fortalecimiento de la cadena de valor del Litio en la Región de Antofagasta

25/07/2017

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Chapter 4

Global discussion of results

4.1 Contextualizing the RRI approach within renewable energy research and innovation

The responsibility approach evolved from encompassing socially considered aspects of disciplines towards more specific approaches. Therefore, the multifaceted nature of the responsible approach seems to be taking place in the case of social dimension treatment of energy research and policy, as a natural and contemporary evolution of approaches. However, in renewable energy research, as well as in the general energy studies field, contemporary discourses coexist with traditional socio-technical approaches and it is difficult to separate the effects of the temporal evolution of the methodological approaches from deliberate responsible trends due to the social footprint of the discipline.

Despite the strong social dimension of renewable energy research, the integration of RRI can trigger misunderstandings in the definition of terms and approximations, obstructing the translation into practice. Likewise, the integration may be possible due to the fact that both, socio-technical dimension and responsible approaches, share the same theoretical background.

An in deep consideration of these statements shows that renewable energy research does not seem very influenced by the RRI approach when considered globally. Furthermore, the policy debate surrounding renewable energy is still influenced by linear concepts, in this vein, the consideration of the grade of the deployment of these models within energy research and innovation is low.

However, when each dimension of RRI is observed separately, finding more correspondences is possible. The RRI dimensions of science education, gender, governance, sustainability, ethics, open access, engagement, and social justice were

treated in renewable energy research in varying levels, emphasizing engagement, education, sustainability, and social justice.

In this vein, traditional and current social aspect considerations from energy research were found connected with RRI in the literature review process. Moreover, correlations between RRI dimensions in energy policy were found focused on education, public engagement, gender and public participation, and new paradigms such as energy justice.

A special attention has to be taken in the case of sustainability and social justice dimensions. Both can be located under the umbrella of seeking for good governance in terms of the right of all people to have access to high-quality information about energy and the environment.

An important part of the contextualization process of the RRI approach within renewable energy research and innovation is based in (1) the enrichment of the approach due to the evolution of the surrounding rationales and (2) the retrieval of the energy related social sciences and humanities (SSH) framework considerations.

Within the evolution of the surrounding rationales, the presence of the operational elements related with the use of technology assessment methods for the re-interpretation of the attributes that research process needs to fulfil for being considered responsible arises. In this vein, attributes of anticipation and reflexion can be achieved with the application of technology assessments and participatory research among others. These methods are also widely being used in energy policy.

In the RRI attributes translation to energy research, for example, anticipation is related to issues such as a techno-economic feasibility and topics such as pricing selection, forecasting, feasibility, and renewable energy markets, as well as efficiency and cost-benefits. Consumption topics appear to be related with reflexivity and inclusion, with the participation of the behavioural sciences approach and the participation of topics such as consumer acceptance, sustainability and energy futures. In the case of renewable energy research, this behavioural point of view was reinforced since the challenge of addressing global climate change. It can therefore be concluded that for the reviewed elements,

attributes are related with topics and subtopics of specific research and not related with the reformulation of the research and innovation process, and the operational elements are related with socio-technical considerations to approach the topics.

In contrast, the review of the social sciences energy policy frameworks in terms of RRI elements yields the consideration that (1) the application of social sciences to the technical disciplines is perceived as an expression of responsible approach, (2) the fact that even if the same terms are used in the RRI discourse and in social sciences framework, the concepts and contexts embodied are not exactly the same leading to burdens in the implementation of this approach, and (3) the consideration of the conceptual dimensions as operational dimensions.

In this vein, the consideration of the expression of responsible approach is related with the most unanimously recognized interpretation and the contributions of social sciences in the development of energy policies for the inclusion of divergent voices and topics. Moreover, in the case of the use of the same terms in the RRI discourse and in social sciences framework, the concepts and contexts embodied are not exactly the same as mentioned in the above paragraph listing the attributes translation to energy research.

Furthermore, the attributes of RRI can be considered as a conceptual dimension or as an operational dimension. The conceptual consideration is related with the translation of the attributes to energy research. For example, the anticipation is related to issues such as a techno-economic feasibility and topics such as pricing selection, forecasting, feasibility, and renewable energy markets, as well as efficiency and cost-benefits.

These considerations are especially notable in responsibility bias, found when attributes of the research process of RRI considerations and responsibility in terms of the consequences of environmental degradation, responsibility for climate change and the recognition of values are compared. Despite this bias, an overall shift towards responsibility is detected in alternative approaches in the process of investigation conducting to this PhD.

4.2 Towards a policy integration

The challenges to pursue a responsible policy integration are related with the integration of interactions between renewable energy research and energy and climate policies within sustainable transitions. Moreover, they comprise the understanding of the mission and objectives of the policies. Furthermore, the importance of gaining knowledge about the context within the integration produced results in the fact that the context must be considered as part of the validation of the proposed methodology.

However, prior to building a theoretical framework with the purpose of gathering the concepts and the understandings, acknowledging the context importance, the process of shifting from a theoretical discussion to the operational level of a concept needs to be taken into account. This process can be achieved by different paths of characterising and measuring the different aspects of the concept and boarding the concept to embrace different perspectives and trends.

In this sense, the selection of each path implies a series of consequences. For example, the process of characterising and measuring the different aspects of the concepts requires accepting that the impact of the implemented process cannot be determined with any degree of confidence if there is no knowledge about the context within which they have taken place. Furthermore, since an understanding of the context is vital in terms of replicating the intervention, the context must be considered as part of the evaluation and is key when it comes to uncovering the circumstances in which, and the reasons why, a particular intervention works.

In contrast, the path of boarding the concept to embrace different perspectives and trends is the path that is proposed in the transitions approach, which requires from a concept reformulation. Under this approach, the proposals are not anchored in the concepts which are no longer seen as goals, but rather how the system needs to be changed to contribute to progress along the path to such goals. An example of this approach can be found in the case of the sustainability dimension, in terms of not to sustain but to change [96].

Moreover, when the process of broadening the concepts is considered, not only a diversity of approaches is taken into account, but the different inputs, new trends and perspectives that, over time, the frameworks integrate and embody [97].
The results of translating these considerations to energy research show that the path to measure the different aspects of the concepts was widely reported in this field dealing with social aspects related literature, for example for the case of social acceptance [98–100]. Moreover, an in depth consideration shows that both the measurement of the different aspects of a concept and the alternative of broadening the concepts within energy research entails the consideration of a series of concerns.

In this sense, the measurement of the different aspects of a concept considers rationales such as the responsibility to assume the effects and to minimize the environmental degradation and climate change; the recognition of the importance of more people-centric approaches for energy use; the understanding the human dimensions of energy as promise of generating valuable insights about energy culture; and the process of individuals sharing resources with those who have less. In addition, broadening the concepts resulted in the inclusion of alternative rationales such as the effective mechanisms for transforming how people, organizations and societies use of energy in terms of historical and future shifts in energy practices and the processes of variation of energy-use patterns.

Moreover the embracement of different prespectives allows to the retrieval of social sustainability approaches or the consideration of the aspects of resilience of the systems. Both considerations, comprise sustainability and social justice insights, where social sustainability is related with the pursuit of the properties of the system and the consideration of these, as a final objective to undertake the reformulation of the process and resilience is related with the capacity of system to recover from changes. Furthermore, enables the integration of innovative perspectives outlooks under energy transitions such as energy democracy, energy citizenship or new envisions of community energy science.

The benefits of the consideration of these two paths (the measurement of the different aspects of a concept and the embracement of different perspectives),brings an opportunity to consider the grade or level of integration of the approaches in terms of the different

inputs that, over time, frameworks were adapting and embodying. Moreover, enables also the coexistence of approaches and the possibility to overcome the consideration of the approaches anchored in linear or systemic models.

This conclusion is vital for propose options for overcome the findings related the fact that renewable energy research does not seem very influenced by the RRI approach when considered globally, due to the linear concepts prevalence in the case of energy research and innovation, mentioned in the section 4.1. In this sense, since when the re-envision of the innovation process inspired by responsible approaches coexist with the system approach, where systems disruption and response along with the reflexion and responsiveness is considered, the proposals of this PhD can be used to increase the grade of the deployment of these models within energy research and innovation.

In this vein, taking into consideration the theoretical implications of the hypothesis of this PhD, the integration and proposals inspired by responsible approaches understands the achievement of transformative change in terms of the level of integration of the frameworks and the coexistence of thereof, without the necessity of neglect approaches influenced by early linear concepts or regarded as variants of a systemic approach.

4.3 Inhibitors and facilitators of integration

The challenge of the policy integration lays in the identification of inhibitors and facilitators of the process which arise when it comes to transcending from policy to practice. In this vein, the identification of the facilitators and inhibitors shows that the integration was trapped in the fact that different understanding of responsibility, sustainability and social justice for each specific discipline was found. In addition, an inhibitor related with the operational level of the frameworks was the fact that each framework has its own driver considerations.

The considered inhibitors were the different understanding of responsibility, sustainability and social justice for energy research, the underdevelopment of the

methodologies, and the fact that both sustainability and social justice dimensions were linked at the context and assessments levels.

The inhibitor effect of context consideration was found modulated by two factors: The importance of the context consideration within the interventions and the existence of a knowledge gap between policy goals and the outcomes of the processes represented by accurate indicators. The importance of the context consideration within the intervention makes necessary to build a robust theoretical framework. In the case of the existence of a knowledge gap, this fact was reified since RRI as a cross-cutting principle throughout Horizon 2020 was intended to be operationalized through the implementation of agenda setting dimensions which are related with the headline targets of smart, sustainable and inclusive growth guidelines. But they were not represented by the accurate indicators, since the development for these dimensions cannot be obtained directly enquiring at what extent does a research field, a research programme, or a RRI initiative contribute to these goals, and moreover, how can this be assessed and monitored.

The multiple connections between the two missions of RRI was found acting as a facilitator and an inhibitor. The facilitator effect of the interlinks was related with the sharing of the theoretical backgrounds. This fact allowed to construct common rationales. In contrast, the inhibition effect was related with the fact that, since there is an absence of consensus regarding the ingredients that comprise each element, the consideration of various definitions and concepts may result in the lack of accuracy in the proposals.

4.4 Methodological proposal discussion

The methodological proposal was based in the consideration of a series of levels of context (considering the context insights along with assumptions) and assessment (entailing the used methodologies and indicator proposals, along with tools on how to carry out the actions).

The context level was built upon the concepts and understandings of both sustainability and social justice dimensions. Furthermore, it was found that it was also affected by the different understanding that for each framework the concerned dimensions had. In contrast, the assessment level was found strained by factors affecting each framework understanding in terms of policy goals.

The levels of context (considering the context insights along with assumptions) and assessment (entailing the used methodologies, indicators proposals along with tools on how to carry out the actions) were found useful to arrange a methodological basis of an integration proposal. However, in some of the considered approaches, both context and assessment spheres were found interrelated and affected by the level of integration of the frameworks exposed in section 4.2.

Thus, despite of the utility of the context and assessment levels proposal, the consideration of the grade of integration as an alternative methodological level brings the opportunity to avoid the burdens of the context and assessment levels construction, related with the differences between the normative sphere or the conflicts between the understandings.

The consideration of this alternative methodological level requires from the re-envision of the meaning of the normative sphere for each framework used for building these proposals. In this vein, in RRI, the normative sphere was built on considering ethical and societal concerns in terms of values giving place to an innovation process reformulation. In contrast, in the sustainability assessment framework, normative elements were found located under the methodological aspects dimension, where sustainability was placed, along within goals, impacts, undesirable futures, etc. Moreover, this normative sphere is also settled with the representation of sustainability in terms of indicators of how sustainability was represented in the decision-making process.

Thereby, these consideration needs to be changed from the dimensions of the systems or process to the identification of the solutions towards achieving strong links with the specific social/local context and institutional setting from where sustainability and social justice issues originate.

4.5 Case studies

4.5.1 Building the approaches for the case studies

The attempts of considering the socio-technical transitions approach applied to storage technologies and research is based in the fact that the approaches share the acknowledgement of the non-linear nature of socio-technical innovation, giving an adequate importance to key elements such as actor networks, institutions, social practices, businesses, as well as socioeconomic and technological characteristics of the technologies. Moreover, the socio-technical transition was successfully applied to the storage technology in the case of community energy approaches as well as sustainability transition research, because practices are not based on a single discipline but draw concepts and insights from multiple disciplines and practices.
In contrast, in the case of the proposal to contextualize RRI within renewable energy research and innovation in Chile, the use of innovation theories can be located within the efforts to promote renewable energy innovation in developing countries. These theories were used to deal with the renewable energy innovation challenges, the innovation and technology transfer and the proposals of alternative policy strategies. In this vein, the systemic approach is dominant in renewable technologies innovation rationales within the Latin American context. For example, the dominance of high carbon technologies is related with a 'locked-in effect' by the accumulation of knowledge, capital outlays, infrastructure, available skills, production routines, social norms, regulations, and life styles, which developed around them.

Moreover, within Latin America, the recent changes financed by some countries that increased the productivity of research are transforming the perception of the systems of innovation historically characterized by small scientific communities, with scarce financial resources and focused on research guided by curiosity. Those changes are the commitment to innovation in terms of acquiring internal knowledge; the change in the assessment process to include not only the input needed to innovate (R&D funding) but also the output of the process itself (improving the Chilean researcher positioning in international rankings and the successful performance in specific research areas); the

appearance of new actors and their impact on the reconfiguration of the innovation system; the increase in the amount of R&D financed by the business sector (private funding); and the integration of alternative policy approaches.

4.5.2 Researchers perception regarding socio-technical approaches implementation. A comparative between surveys

In the case of the arrangement of a Chile-Europe case study, this endeavour was based in (i) a survey process and (ii) an interview process. Both survey and interview process were based in the idea of the reflection around the concept of the social approach to energy research applied to the researchers activity, the policy, and the use of the methodologies.

In this vein, social approach consideration flows around the idea that when a social focus or approach is to be included in energy research results, it varies considerably depending on the considered approach. The majority of the selected participants considered the following factors as relevant: real impacts for society in the research targets and the inclusion of the citizens as direct beneficiaries, followed by the use of social sciences to increase acceptance of renewable energy technology, and the participation of society in scientific advances and in the processes leading to such technological advances.

4.5.2.1 Energy and society level

The respondents engaged with EU research context first oncoming to the approach of the energy and society was found related with the integration of social sciences in energy studies. Likewise, the majority agree that energy studies need social sciences and the majority stress the benefits of the insights of social sciences to energy studies. In the case of Chilean researches, they also acknowledge the importance of the integration of social sciences in energy studies.

Moreover, the most significate differences can found regarding the consideration of a more disruptive social approach, such as the participation process whereby the researcher includes the society when setting research questions and the inclusion of social research topics such as gender. In this case, the EU context researchers considered these approaches marginal whereas Chilean researchers considered it with a more important amount of the attention of the respondents, as shown in Figure 4.1.

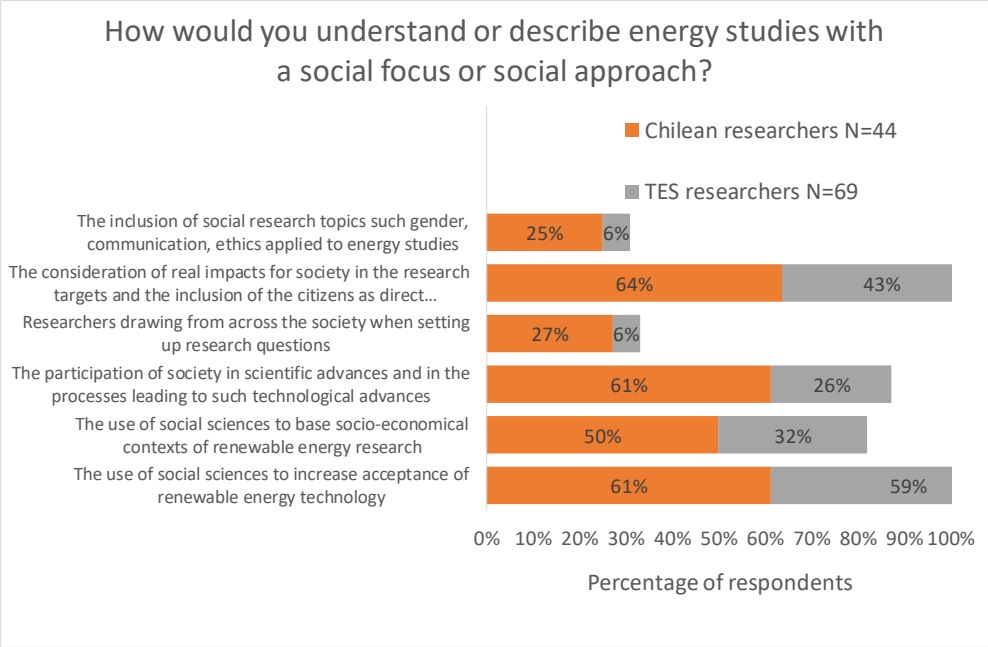

Figure 4.1: Drivers of the social approach considerations comparative between TES and Chilean researcher surveys.

When enquiring the particular condition of research with social approach within the TES field in an open-ended question and with reference to the participant, institution, country, and region role, the responses were found divided between considerations such as the social acceptability of the technology (the integration of social sciences, broadening the scope of the TES research for the purpose of overcoming barriers, and fostering technology depletion), the consideration of education and outreach activities, and the inclusion of topics dealing with social aspects such as sustainability, waste management, and the study of environmental impacts (development of sustainable cities, the implementation of TES in rural and poor communities, and life cycle assessment).

In the case of the Chilean researchers, when enquiring as an open-ended question their thoughts regarding the social approach within the context of their field and with reference to the participant, institution, country, and region role, the responses were diverse. On one hand, 25% did not answer this question or directly specified that there is no relationship between the social approach and their field of research. On the other hand, the consideration of the rest of the respondents yield interesting rationales such as the social acceptability of the technology (the integration of social sciences, broadening the scope of the research for the purpose of overcoming barriers, fostering technology depletion, and the consideration of socio-technical impact assessment), the consideration of training, education and outreach activities, and the consideration of participatory research strategies such as participatory models for the design of energy projects with active participation of people in all stages.

Within the case of acceptability, the drivers given by the respondents within an EU context were the social acceptance of TES in terms rejection or adoption and the search of the social impacts (either through considering the needs of the population to then determine best research approaches, or through the involvement of the end-users). This last consideration, the involvement of end-users, was specially highlighted in the case of TES research for buildings energy efficiency applications, where the consideration of the influence of the social context in the actual energy use of building occupants and their attitude towards the use of new technologies to improve the efficiency of their house or working place was included by the participants in the survey.

In contrast, in the case of the integration of social sciences, the use of socio-technical approaches, the purpose of improving business models, or economic benefits and the understanding of the benefit of TES in society was found to shape this integration. Moreover, the recognition of social sciences was found to be a driver to help science and technological advances to reach society.

Regarding these approaches, the acceptance within the Chilean context were found within the context of the community and more related with the concept of appropriation and empowerment instead of adoption or opposition. In this sense, the inclusion of the communities in the decisions was considered as a direct path to achieve the understanding

and use (the community feels part of the benefits of the technology and loses the role of being a simple observer). Moreover, this approach of acceptance is linked with the consideration of the role of local culture for the sustainability of technological projects associated with renewable natural resources. In addition, a re-envision of acceptance in terms of the social licence or social licence to operate (SLO) was reported.

Participatory research was found highly supported by participants, either because they were previously involved in participatory projects or because they recognised its relevance. The reported methodologies were co-construction processes. The co-construction model was based in the mainstreaming use of interdisciplinary and transdisciplinary approaches in terms of the integration and supporting social science approaches and the participation of the indigenous communities (in Spanish *Pueblos originarios*). The interdisciplinary approach was proposed to merge the anthropological, environmental and technological concerns, and to be able to draw the interpretation of the local culture. Co-construction was reported based in a process of co-management, first, and then of self-management, where ethnographic methods and participatory models were considered as tools for working with communities, in order to achieve their empowerment with energy projects.

Moreover, and regarding the Chilean context, a series of important reflexions arise. The first one is the fact that when implementing the social approach with a too wide perspective, the real needs of the communities are neglected (i.e. considering a high penetration of renewables while the communities suffer of a lack of supply).

4.5.2.2 Communication, research and dissemination and outreach level

A detailed assessment of results of the EU context researchers shows that there was a balance of respondents which identified training students and public in TES and participation in science education activities under the umbrella of divulgation. In the case of aspects under the context of communication, the majority of respondents considered the presentation of papers and conference assistance. In addition, other communication activities listed in the question options and selected by the respondents were the internal

communication of the research results for the purpose of promoting synergies and interdisciplinarity and the engagement in scientific education activities. Furthermore, the less considered elements within divulgation were the actions aimed at commercializing a product or a research result and within communication of the content generation.

Regarding communication, outreach and dissemination, Chilean participants considered the publication of papers and conference assistance as the most relevant aspect from both divulgation and communication.

4.5.2.3 Participatory research or engaging research level

EU and non-EU context researchers largely considered themselves aware about the concept of participatory research or engagement research. Regarding awareness of responsibility within EU researchers, the idea of the responsible behaviour of the researchers as individuals prevails, followed by the consequences of innovation is selected, the assessment of risks and the management of intellectual propriety.

Regarding awareness of responsibility within research, within Chilean researchers the idea of the responsible behaviour of the researchers as individuals prevails followed by the philosophical regarding the consequences of innovation. The comparative of the drivers of responsibility between TES researchers and Chilean researchers is shown in Figure 4.2.

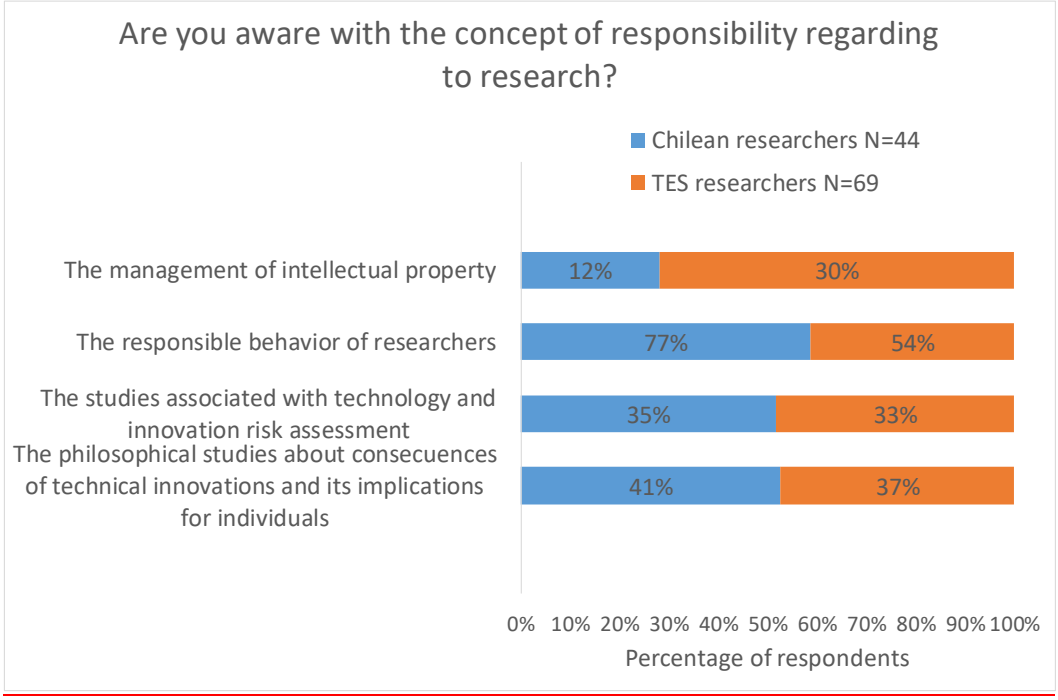

Figure 4.2: Comparative of the drivers of responsibility between TES and Chilean researchers surveys.

Moreover, EU-researchers awareness about the different conceptual dimensions and keys of RRI, responsiveness and inclusion were the options chosen by more participants, while scientific education and open access were the more known RRI keys. In the case of Chilean researchers and regarding the researchers awareness about the different conceptual dimensions and keys of RRI, responsiveness and reflexivity were the options chosen by more participants regarding the conceptual dimensions, while open access and ethics were the more known RRI keys.

Furthermore, when it comes to broadening considerations regarding with specific keys, in the case of TES researchers for the engagement, although a high percentage of participants state lack of knowledge, those answering included concepts under the umbrella of the social use of technology. Within the social use of technology, respondents included, in an open-ended question, meaningful incorporation of public inputs in the innovation process and using knowledge for society amelioration. The elements related with the accurate dedication and self-responsibility were commitment, motivation, and passion. The development of topics with social imprints included sustainability of the energy systems, being this one listed by several participants. And finally, the integration

of diverse stakeholders such as industry, community and society, and the consideration of outreach and educational activities emerged translated with engagement.

In contrast, Chilean researchers considered questions such as the participation of different stakeholders within the different stages of the research and innovation projects, in terms of a first stage of definition of the objectives and methodologies selection and second step of efforts towards appropriation and sustainability of the project. This approach was reported linked with the researchers working with communities, in terms of establishing participation through a commitment to the beneficiaries.

In addition, this engagement approach included concepts under the umbrella of the social use of technology. Within the social use of technology, respondents include in an open-ended question meaningful incorporation of public inputs in the innovation process and using knowledge for society amelioration. The elements related with the accurate dedication and self-responsibility were commitment, motivation, and passion. The development of topics with social imprints include sustainability of the energy systems, being this one listed by several participants. And finally, the integration of diverse stakeholders such as industry, community and society, and the consideration of outreach and educational activities emerged translated with engagement.

In the case of science education considerations, the majority of the TES researchers reported awareness. Moreover, the open-ended question showed reflexions that can be merged in technology transfer activities, promotion of scientific interest in student communities, the arrangement of courses or training schools, and teaching activities strongly focussed within academia in the field of TES, mostly their own master or PhD students (teaching, PhD supervision, etc.).

In contrast, science education was founded related with teaching activities (teaching, PhD supervision, etc.), outreach activities and community acceptance strategies in the case of Chilean researchers. It is important to point out that regarding teaching activities, the reflexion of the importance of the capacitation of human capital to increase Chilean research community and the necessity of change the transmission models to embrace real

holistic scientific education where the multifaceted dimension of research practice is explained.

Moving towards the integration of the open science concept, the participants were inquired about their understandings of the concept, the gaps, challenges and trends in today momentum and the near future.

In the case of TES researchers, regarding definitions, the majority of respondents considered that open science belongs to an approach where researchers, citizens and multiple actors participate, share and draw upon the results of scientific activity, followed by the research communication in open access journals. Moreover, actions to increase transparency in the institutions and the regulation of intellectual propriety were considered less representative. Chilean researchers, in contrast, considered open science as an approach where researchers, citizens and multiple actors participate, share and draw upon the results of scientific activity, followed by the open access publications initiatives. Regulation of intellectual property initiatives and the actions to increase transparency in institutions was less considered.

Regarding the assessment of open science, in an open-ended question TES researchers participants reported an initial enthusiasm considering that more open science would lead to better achievements. Moreover, the social appraisal of innovation and the open accessibility of the outcome of research is seen as an opportunity of the open science effect on society. However, the necessity of a new approach was indicated as the main gap. Regarding the critical issues and the burdens of open science, TES respondents reported four main issues. The first one was intellectual propriety concerns. The second one was the concern of researchers vs. their influence in their research, since freedom of researcher was always considered essential. This is presented within two main perspectives, that of the lack of knowledge of some stakeholders (such as the society) not having the skills to understand the advances and that of biased interest of others (such as industry or policy-makers). The third one was the regulations of the open access in terms of the role of the journals as a profitable organisation.

In the case of the Chilean researchers, the majority of respondents of an open-ended question about open science considered institutional constraints, ineffective policy guidelines, lack of standards for sharing research materials, lack of legal clarity, and the financial aspects of openness as the most important barriers for open access diffusion of their research. In addition, institutional constrains were considered related mostly with the intellectual property and the balance of power (that sometimes make knowledge so linked to power that it is not disseminated).

Furthermore, questions such as the existence of commercial interests regarding the research founded by companies, the loss of research competitiveness (not sharing the results to maintain the institutional or personal rankings), the lack of the scientific knowledge in terms of not everyone having the ability to understand the meaning of that development, neither share a scientific language were the main constraints. In this sense, endowing the resources for an inclusive approach and the homogenization of a language to generate this open science was considered a solution.

Regarding the grade of support to publish in open access, the TES community raised burdens such as the risk of the low quality of results, the increase of publications with less content, and the factice possibility of buying a position to publish whatever, limitations related to lack of funding, and the no-recognition or improvements in the CV were also highlighted. In the case of Chilean researchers, most respondents support publications in open access in terms of benefits for researchers, institutions, nations, and society as a whole. For researchers, it brings increased visibility, usage and impact for their work. Institutions enjoy the same benefits in an aggregated form. Society as a whole benefit because research is more efficient and more effective, delivering better and faster outcomes for all. On the other hand, Chilean researchers considered the necessity of the re-envision of peer review process within open access and the limitations related to lack of funding.

Finally, when enquiring the opinion regarding citizens contribution to scientific research and the relation of society with TES research, the majority of respondents considered that citizens can contribute to scientific research and the majority reported awareness of the concept of citizen science. When asked about examples, participants reported low

awareness except for examples of projects related with observation of the ecosystems, the measurement of the air pollution, initiatives to bring technology incomes to communities, and energy consumption surveillance projects. Within the Chilean community, the majority of the respondents considered that citizens can contribute to scientific research. Regarding the description of their relationship with the society, the arrangement of educational activities in their community was the most considered drive followed by the consideration of communities and citizens as users technology and a valuable source of data on consumption, demographics and habits being fundamental. An important representation reported having worked with communities in renewable energy implementation programmes and considered citizens for the evaluation process of the research proposals. In addition, less researchers reported awareness of the concept of citizen science and projects related with environmental rescue of flora and fauna.

4.5.2.4 Methodologies and regulatory frameworks level

When participants are asked about the awareness of the methodologies and regulatory framework that seek to integrate social approaches in scientific research, the majority of the TES researchers reported non-awareness. This non-awareness was extended to the methodologies applied to renewable energy research and methodologies to integrate social approaches.

In the case of the Chilean researchers, the consideration of participatory innovation models, epistemological knowledge dialogues, and co-construction were considered. In regard these methodologies applied to renewable energy research, the co-construction and human-scale-development approach were considered.

Regarding the integration of alternative approaches and collaborative research strategies, multi- and interdisciplinarity were the most known for the majority of the participants of both communities.

In the case of the specific framework, for TES researchers, RRI was reported acquainted by the majority of respondents, followed by technology assessments, while social

innovation and participatory action research were the less acquainted. In the case of Chilean researchers, technology assessments were reported as the most acquainted, followed by participatory action research. Social innovation and RRI were reported acquainted by 25% respondents.

Regarding to the measures considered necessary to carry out an integration of methodologies to integrate the social approach in TES research, strategies such as the identification of potential researchers in the field with the aim of collaboration, policy developments for integration of these methodologies, and the need of funding were considered by the respondents. In the case of the impact of the implementation of these methodologies and regulatory framework within the institutions for targeted researchers, participants considered that would bring more dedication to research, more economical resources for their research, followed by a renewal of the governance structures.

Moreover, when enquired regarding the measures considered necessary to carry out an integration of these methodologies, strategies such as fostering interdisciplinary and multidisciplinary work, training researchers regarding these approaches and the benefits of their implementation, the valorisation of this researcher efforts by his/her institution and the mainstreaming integration of social outcomes in research design were reported.

In this vein, regarding multi- and transdisciplinary strategies integration, the necessity of a real practice and professionalization of this MITTSs was reported in terms of valuing the interdisciplinary dialogue but also the synergies and retro-feeds from all the stakeholders, along to having a clear consideration of the context of the local realities in term of indigenous knowledge, tradition and customs, imaginaries, etc.

Regarding the capacitation of researchers and the valorisation by their institutions, an awareness campaign for researchers and the necessity of changes in the professional evaluation mechanisms incorporating indicators associated with participation, training, dissemination, and sponsorship of projects taking into account these approaches was considered. In contrast, regarding the mainstreaming integration of social outcomes in the research design, the transversal consideration of the social approach, social licence and

social impacts were considered, but not only in terms of detecting the social approach, but of truly integrating it.

4.5.3 Transnational projection of the study: Insights from the semi-structured interviews

The interview questions were inspired by the survey even if the use of the levels was blurred being replaced by a general approach to the social approach to scientific research in general and then focused on renewable energy, the awareness and factors influencing communication and divulgation and engagement, the drivers of responsibility in terms of the extent to which scientific information meets the needs, and the awareness about the RRI conceptual and key dimensions and RRI integration feasibility within renewable energy innovation in Chile.

4.5.3.1 Social approach considerations

The first overview to the question of the social approach to scientific research in general and then focusing on renewable energy shows to distinctive paths. The first path is represented by the overall point of view regarding the social approach, and it is related with the features framed under the umbrella of social aspects such as the economic, institutional and regulatory features. In this vein, the use of social sciences to increase acceptance of the renewable energy technology and its use to establish the socio-economic context was reported. The interviewed experts recognize that social aspects are an important concern within environmental issues and agree that environmental concern are now socio-environmental challenges such as the challenge to provide safe and sustainable energy and boost economic development. Moreover, interviewed experts considered the opposition from the communities as the most relevant social concern and the challenges of the self-generation and aspects such as inequity and energy poverty due to the aspects such the territorial distribution and the presence of cross-border and isolated territories.

Within this path, the early participation in the innovation projects and the integration of alternative business models where a valorisation of the innovation projects rung along the value to the community holding the project and the participation of the communities in the territorial planning of the policies and in the decision making scopes spheres. Furthermore, the reflexion regarding the fact that the capitation/capture of social elements to achieve the acceptance does not establish real appropriation of the benefits of the innovation, but a particular achievement of the project emerges a very prominent deliberation.

The second reported path related with the social approach was related with the evolution of this concept and the consideration of the social aspect of the innovation practice in terms of the socialisation, the embracement of the inclusive processes, the agglutination of diverse actors and voices for facing multifaceted concerns, and the generation of impacts and achieving success. Within this path, also questions such as the consideration that the technological change can be only successful and sustained by the time if it is culturally integrated, if it produces a social benefit, and if improves the quality of life. These considerations shape the idea of a more inclusive energy, where power is not only an energy culture, but a process also inclusive for decision-making.

Furthermore, regarding the prospective of the social approach, interviewed experts considered that part of the scientific questions could be gestated in the community for therefore go through researchers. This flow and iterative process linking scientific community with society is a valuable exercise in which the change can be based in the transformation of the generation of knowledge and the search for universality, since this iteration causes the results to be universalized.

4.5.3.2 Communication, divulgation and engagement

An outline of the considerations regarding communication, divulgation and engagement shows that the first approach to these concepts within interviewed experts was related with the fact of understanding communication as the process of the presentation of research results in congresses and conferences. Within the umbrella of divulgation, the

process compressing outreach activities such as the participation in education activities was considered. The consideration of outreach actions (*actividades de extension* in Spanish) aimed at commercialising a result or research product where also considered within communication. It is important to point out that a certain mix of concepts were detected, since communication, divulgation and extension concepts were used indifferently.

Regarding the use of alternative and social tools for the arrangement of communication and divulgation, most of the interviewed researchers considered the necessity of having a professional such as a community manager or outreach specialist to manage the social communication and to generate communication content, considering that these tasks are not competence of the researchers. It is important to point out that the existence of responsibility and fear within the use of social platforms was remarked in a sector of the interviewed experts. In addition, most of the interviewed experts participate in social platforms such as ResearchGate even if they did not consider its use as a priority tool to communicate their research.

Within engagement, the majority of the participants reflected the consideration of the communities either in the innovation development or in the case of staying engaged organizing and taking part in community activities (education, advisory actions, etc.). Moreover, engagement through the collaboration with different research groups was considered. Moreover, engagement is unanimously approached from the point of view of the associativity (*asociatividad* in Spanish) since it is a requirement imposed by innovation and funding agencies.

Furthermore, within the aspects of communication, the consideration of the open science was enquired. In this vein, the awareness regarding the fact that open science is a very broad term was approached. The aspects coming under the umbrella of open science were the democratization of knowledge and the growing interest of this concept from the academia, the empowerment of the knowledge community (researchers, stakeholders, innovators, etc.), and the consideration of the social outcomes mainstreaming within the innovation and research process. Regarding the degree of democratization of knowledge,

the burdens were considered in terms of the internal constrains governing the generation of knowledge that often do not allow the participation yielding open science projects.

4.5.3.3 Responsible approach and methodologies

Regarding responsibility concepts, correspondences between philosophical studies concerning the consequences of the emerging technologies along with the researchers behaviour and intellectual propriety rights (IPR) were considered. Moreover, regarding renewable research, the interviewed experts reported that the responsibility approach was related with the ability to make judgments and to take decisions with the adequate support and consciousness to the implications in the people live. Moreover, although the interviewed experts reported awareness regarding a more disruptive participatory research strategy, such as the search and contrast of research questions in society, they did not consider the possibility of its use within their work and within the Chilean context, despite recognizing that it is going to be a future trend.

Moreover, within the Chilean context the existence of alternative methodologies used for the case of renewable energy research and innovation were enquired, yielding the use of transdisciplinatiry and co-construction. Transdisciplinatiry endeavours were related with the use of interdisciplinary methods and teams in the development of energy research projects and the participation of the results and the integration of communities knowledge in the projects.

In the case of co-construction, it was reported as a participatory methodology based in applying the consideration of the communities in the early planning of the objectives and project outcomes as well as ensuring their participation in the implementation and operation stages of the project. The use of this approach is based in the consideration of the sustainability of the energy project, and it is modulated by the appropriation of the hosting community requiring the adaptation technical requirements to social aspects that go beyond the objectives such as the existence of the social opposition.

4.5.3.4 Awareness about RRI conceptual and key dimensions and integration feasibility

RRI as an approach or policy was found unfamiliar to the interviewed experts. Even if the concepts under the umbrella of socio-technical change and evolution of the innovation models and approaches allow to thresh the consideration of responsible approach within the Chilean researchers community. A first approach to the conceptual and key dimensions show that the consideration of the democratization of knowledge and the mainstreaming of the social outcomes was considered as an expression of these dimensions. Within the reformulation of keys for agenda developments, scientific education, governance, engagement, and ethics were the most acknowledged in the detriment of gender. In the case of open access and open science, the reflexions are collected in the previous sections and were more widely addressed in the survey process.

The consideration of gender was taken into account in terms of the arrangement of positive actions, not so much in terms of mainstreaming the gender perspective. However, the commitment with science education as a strategy was not only to change how research and innovation was performed but in terms of an engine of change of the Chilean socio-economic transformation. In these terms, strategies such as *Ingeniería 2030 Innovación tecnológica para la sociedad* (in Spanish) was mentioned.

4.5.4 GREiA RRI plan

The main results of the GREiA plan regarding a global contribution to this PhD are the contextualization of barriers for RRI implementation. In this vein, the literature review of RRI barriers unveil a series of issues not only related with the practice of RRI, but with the implementation of the theoretical background of RRI such as a general complexities regarding with real practice of the interdisciplinarity, especially when the collaboration is between social scientist and energy scholars and social sciences frameworks [101].

Moreover, when developments are focus in issues which appear to be more manageable than societal and ethical issues, or when upstream interaction arrangements are made with society to avoid to be blamed for what happens afterwards, this can be considered a barrier [9].

In this sense, the first considerations are related with the hegemony of the institutions in the assignation of responsibility issued in the division of moral labour philosophical backgrounds that may hinder the application and achievements of attributes such as anticipation, reflexivity, inclusion, and responsibility as keys recognised in RRI [8]. In line with these considerations, the fact that research organizations are currently undergoing a process of debating and discussing questions of responsibility results in a situation where is too early to make any statements regarding *responsibilisation* and deep institutionalisation of RRI [102].

Moreover, the issues regarding with reinterpretation of the objectives of RRI in terms of shared theoretical backgrounds can occur. For example, regarding justice/social justice (RRI dimension) most of the approaches dealing with science, technology and innovation interpretations are in terms of realising distributive justice [103].

Furthermore, the lack of optimization of the assessment frameworks for RRI and the complexities to develop indicators that are dependant of primary (non-existing) and secondary (existing) data for monitoring RRI practices is considered one of the largest operational barriers.

A remarkable insight of the review of the barriers are the considerations related with researchers. In this sense, how RRI will translate into institutional pathways and arrangements remains to be an open question [5], this uncertainty affects to researches. Moreover, R&D policies often suffer from a certain amount of disaffection and doubts regarding to the extent the research groups involved had really 'internalised' the label. In addition, the consideration that the use of RRI in designing research is not adequately rewarded in the researchers careers and the fact that policies were introduced in a top-down manner, namely, by funding agencies rather than by the research communities arises [101].

Furthermore, the implementation of RRI faces the freedom of individual research activity consideration and the autonomy of the research organizations. This is a great concern for scientists, who claim that their commitment is to make excellent, trustworthy and reliable research, to diffuse, transmit and circulate knowledge, and to calculate how the results coming from research would produce an impact on science. In addition, convenience, in terms of adopting this new label that the research in question to be recognised as 'eligible for funding', arises [101].

Regarding the specific keys of RRI, some of these keys themselves emerged as a critical issue for practical implementation. For instance, public/stakeholder engagement emerge as prominent and cross-cutting practical dimensions of RRI [24]. Moreover, the drivers of engagement in terms of public acceptance can, for example, suffer reductionism when efforts are focused on an upstream approach to ensure acceptance while the real challenges might be downstream [9]. Furthermore, the preference to develop some RRI keys upon others is considered.

A review of the barriers can be found in the Table 4.

Table 4: Review of the barriers for RRI implementation.

Barriers	**Type**
Culture of responsibility Hegemony of the institutions in the assignation of responsibility Philosophical backgrounds Absence of common ground Reinterpretations	**Foundational issues**
Public/stakeholder engagement Novel policy and governance mechanisms Reductionism of upstream approach *Responsibilisation* and deep institutionalisation Disengagement with top-down approaches Freedom of individual research activity consideration /autonomy of the research organizations.	**Practical implementation**

4.5.5 *Strengthening the lithium value chain* for the University of Antofagasta, Chile RRI plan

The most important contribution of the *Strengthening the lithium value chain* RRI plan is based in the review of the current discourse on RRI to assess its usefulness for industry. Moreover, this is based in the relationship between RRI and economic development.

This relationship is reflected in its integration with public research and innovation policies. In this vein, the EU policy strategy is settled in the belief that for the achievement of the success, the goals of the research and innovation must be oriented towards the needs of society. Moreover, it fosters the idea that the satisfaction of such needs cannot be left exclusively to the market. This results in a normative consideration where both companies and innovators and researchers must integrate these practices to achieve the objectives of smart, inclusive and innovative economic growth. Furthermore, the EU strategy supports innovation through alternative systems such as start-ups and spin-offs as well as through SMEs that promote local and regional industries.

Under this view, RRI is focused in promoting a change in the governance of the R&D process to avoid negative impacts, foster an integrated, participatory, reflective and sensitive deliberation process on uncertainties and possible unwanted consequences of innovation and to extend the notion of responsibility in research and innovation processes beyond researchers practice.

In the case of the RRI program proposal, it develops a responsible framework considering the context of energy studies and storage along with the overall consideration of the strategic nature of the lithium products for the region of Antofagasta. Furthermore, a series of strategic dimensions are considered in terms of science education and energetic culture merging the insights of sustainability, social justice and engagement.

Regarding the practical activities, for the achievement of the objectives, a work plan is proposed based in the researcher capitation based in the use of practical actions. This training proposal for researchers will be carried out with the intention of reinforcing

researchers skills regarding the competences of the methodologies used in the RRI approach.

An overview of the proposed practical actions and activities for *Strengthening the lithium value chain* RRI plan is shown in Table 5.

Table 5: Training actions and activities for *Strengthening the lithium value chain* RRI plan

Stakeholders	**Researchers**	**Students, academics and citizens**
Training activities	- Engagement with science education activities - Open access content generation and engagement with open science activities - Engagement with outreach activities such as guided visits to research installations - Capacitation in RRI	- Use of material and contents - Assistance to science education and outreach activities - Open labs and pilot plants use - Engagement with science education projects

Chapter 5

Final conclusions

5.1 Conclusions

5.1.1 Sharing a general vision towards achieving the reformulation of the innovation process and the re-envision of the agenda setting

In this PhD, the proposal of putting the European RRI approach at the heart of the energy transition considering the socio-technical transition approach was revealed as a usefully exercise of policy approaches integration along with the consideration of a research hypothesis based on whereby new models for governance that can founded in RRI and energy transformations approaches share a general vision towards achieving, among others goals, the reformulation of the innovation process and the re-envision of the agenda setting was settled.

The assessment of the hypothesis was considered two-fold in terms of the validation of the consideration of socio-technical transition as a common language and in terms of the measurement of the grade of deployment of responsible –based approaches within energy research and innovation. **First,** considering the socio-technical transition approach as a common language was revealed to be a valuable to vertebrate the search of correspondences between new models of governance for responsible science and for the energy research transformation. **Second,** the assessment of the grade of deployment of these models within energy research and innovation concludes that renewable energy research is very much inclined by socio-technical change imprints, specially being focused on change processes related to socio-technical systems. Moreover, does not seem very influenced by the RRI approach when considered globally, despite the existence of correspondences in some dimensions such as engagement, sustainability or social justice. The reason for this lack of influence can be associated with the fact that the policy debate surrounding energy systems and renewable energy innovations are still influenced by linear concepts yielding to a low grade of the deployment, that when it is found is probable

regarded as a variants of a systemic approach not being encountered under transformative change consideration.

An in deep consideration of this systemic approach prevalence can be found in the assessment of the case studies. In both cases, for build an approach to consider a responsible –based methodologies, the background founded in the review of the literature shows the prevalence of the technological innovation systems theory or systems innovation for the case of the contextualization of thermal energy storage applications, and socio –technical transition and innovation theories in the case of the contextualization for Chilean solar researchers. The marginal presence of alternative approaches was found in the consideration of co-evolutionary innovation frameworks and transdisciplinarity.

The reason for this prevalence can be found since in the case of thermal energy storage applications, the approaches give more importance to the technology, where in the case of the Chilean approach, they are focused in the socio-political context of renewable energy innovation.

5.1.2 Contextualization of RRI within energy research towards socio-technical integration

The process of contextualization of RRI within energy research can be considered as an input for the sake of the achievement of the transformation of energy system research with significant implications specially within policy and research spheres. These implications are related with the approaches background and the existence of synergies and transmissions between surrounding rationales. **First,** background importance concludes in the retrieval of approaches such as ethics, that are no longer seen as a constraint, but as a stimulus within technological innovation or the socio technical transition. **Second,** the synergies, transmissions and the evolution allows the consideration of a space of integration were approaches from outside as well as the new envisions are welcome. This integration (in terms of the possibility of modulation, cognitive interactions with their social and ethical contexts in combination with intervention-oriented interdisciplinary collaboration) is highly pertinent in both research

and energy policy and results in a policy strategy which brings alternative envision to both problems and solutions approaches.

5.1.3 Examining RRI as a socio-technical integration

Taking into account the proposal of a socio-technical integration, RRI can be considered an attempt in this direction where responsible innovation and ethics enacts as a transition approach, focused on achieving democratic and anticipatory governance. Socio-technical integration consideration requires from re-envision the understanding of the dichotomies of theory/empirical research, as well as the how the normative sphere (comprising the normative functions, elements and contents) consideration can change between approaches and over the time. In this vein, the empirical research conducted in this PhD conclude that the normative sphere, which comprises the function of the frameworks, in the case of RRI is related with the capability to provide direction through visions and goals and with the ability to drive methodologies towards the definition of tools and the achievement of solutions. Moreover, in RRI, the normative sphere was built on considering ethical and societal concerns in terms of values giving place to an innovation process reformulation. In this PhD the consideration of socio-technical integration using RRI and energy systems research approaches for the dimensions of sustainability and social justice implies to consider that the normative sphere can change between approaches and over the time, and the fact that these changes need to be take into account. In this sense two type of normativity have been detected. **First,** the narrow normativity related with normative directions of policy governance framework that are often competing and contradictory and related with the fact that the concrete realisation of the goals its currently found being contested in the context of pluralistic, empowered and participatory societies. **Second**, the flexible normativity related with the fluid and disputed new understandings of the policy goals such as responsibility, sustainability or values. These last normative elements are enough elastic to shape new structures, consider the scope where action is located and change how these elements can be settle and assessed, for example, in terms of negotiated the normative values content with the actors. Moreover, this flexible normativity implies to transform the policy proposals to change towards a prescription where concepts which are no longer seen as a goal, but rather how the system needs to be changed to contribute to progress along the path to such goals.

The examples of flexible normativity can be found in energy research in re-envisions of sustainability assessment frameworks such as sustainability science within the transition approaches. In this case the flexibility is not related with the change in the nature of the goals, rather than in the change in the process itself to be fewer normative. To be less normative can be materialized in terms of being focused in dealing with uncertainties instead of being focusing in sustainability goal per se and through the deployment of social learning and co-production of knowledge. In specific manner an example of this change in the normative sphere can be found in sustainability science approach to sustainability dimension. In this approach normativity transits from the dimensions of the systems or process to the identification of the solutions towards achieving strong links with the specific social/local context and institutional setting.

5.1.4 Assessing methodological proposals: Building a framework for socio technical integration systematization

Leaving theoretical implications, the methodological proposal lays in the construction of a robust and interdisciplinary basis composed by a theoretical framework and methodological levels with the intention of illuminating the systematization of the integration of RRI policy for sustainability and social justice dimensions. The implication of this systematization lies in the possibility of introducing a more holistic approach between social sciences and technological implementations, concluding that this introduction opens the possibility of the re-envision of the policy elements under the transition approach and transformative change envisions. Moreover, this PhD agrees in the consideration of new science-society interactions, which lead to multiple forms of knowledge and the synthesis of theory and practice as a drive to intended to resolve societal problems through collaboration among scientists from different academic disciplines and with other stakeholder groups.

The methodological choices (inclusion of frameworks, levels considerations...) implication lies in the envision of the clear commitment with the necessity of built new frameworks both in terms of context descriptions and measurement proposals. This endeavour is full of complexities. **First,** regarding context complexities features, this proposal recognizes the richness and complexity of the concepts, which transcends from

a disciplinary perspective and expands the subject-object traditional relationship. New and integrative envisions can contribute to shed a light regarding epistemic uncertainty of some concepts, such as sustainability or justice which entails scepticism about the use, not only because of its underlying theoretical understandings and changing normativity, but mainly due to the intrinsic difficulties of measuring it. **Second,** new proposals can be alternatives to the approaches which are questioned in terms of whether are really adequate to evaluate concepts such as governance, responsibility, sustainability or social justice in terms of measurement.

5.1.5 Case studies

The implications of the proposal of a participatory process with researchers is based in the generation of a knowledge domain focused on the social approach of the research process not in the technologies. This domain emerges intending to cover the consideration of the emerging alternative policy frames such as responsible policies. In these terms, this PhD can be considered an example of a first approach for renewable energy applications such as thermal energy storage.

In this vein, participatory process shed light about the theories, approaches and understanding related with each surveyed communities along with multiple elements that influence the energy researchers belief. In this sense, the alternative approaches such co-construction and transdiciplinarity emerge as the theories or concepts for the goal of explaining the adoption, use, acceptance, diffusion or rejection of new technology within the socio-technical change. In contrast, the multiple elements that influence the energy researchers belief about the RRI integration shows that in the case of the thermal energy storage researchers community, open access and open science consequences implementation capitalize the concerns. In the case of Chilean researches, the real implementation and achievement of participation and the integration of the communities shape their concerns.

The drivers of this change within RRI were examined empirically in this PhD considering the relations and links between the principles (engagement, science literacy and scientific education, gender equality, open access to scientific knowledge, research results, and data, research and innovation ethics and research and innovation governance), its construction from the idea the seeking of good governance and from the point of view of

take into account the grade o deployment of this principles within energy research and innovations.

The first implication of the links between keys in RRI affect the proposal of activities and indicators for the implementation of RRI. **The second one,** entails the changes in how the search of good governance is proposed. In this vein, this PhD proposes to reinforce the strategy of the use co-production of knowledge upon the implementation of alternative impacts measurement systems or the statement of research agendas.

The conclusions regarding the grade of deployment of RRI dimensions within energy research, explored empirically in this PhD conclude that the presence of RRI dimensions to achieve certain objectives does not necessarily imply subscribing responsible research policies. Although understanding of energy research in terms of the RRI dimensions shows correspondences with other responsible approach insights, such as the duty to assume the effects and the participation of stakeholders needs.

The process arranged with researchers conclude the great importance that researchers give to dimensions of open access, especially in the case of thermal energy storage community. Moreover, shows the little presence of the gender awareness and importance and the circumstance of not knowing where to fit science education. In the case of science education considerations, researchers reported awareness but ideas that can be merged in technology transfer activities, promotion of scientific interest in student communities, the arrangement of courses or training schools.

Furthermore, the engagement concepts were considered under the umbrella of the social use of technology, the participation of different stakeholders and the appropriation and commitment to the beneficiaries.

The proposal of an RRI implementation strategies or RRI plans have enlighten the transcendence of the process of search of governance in terms of the empirical implications and practical proposals of meta governance analysis.

5.2 Future work

This PhD proposed that the future studies related with the conclusions will be driven by the envision of the necessity of an overarching reformulation or proposal of new frameworks.

Moreover, the full development of the fuzziness of the concepts for the case of the social justice implication regarding to the energy systems research and governance is considered since it is key when it comes to address environmental, economic and social issues and their interactions with robust measures taking into account concepts such as resilience.

Furthermore, delves in the consideration of the emerging field of the RRI for energy systems as a starting instrumental point for initiating a dialogue among researchers working within scholarly traditions is considered. This field is calling for a conceptual clarification on the meaning of values and attempts to synthetize social psychological and ethical approaches to value in RRI for energy system, developing and using new approaches to identify and assess values related to the design and transformation of energy systems and analysing the current role of values in the governance of energy systems for proposing approaches to integrate values in the responsible governance of energy systems to which consider that this PhD contributed significantly.

Other research activities

Contributions to international conferences

The PhD candidate contributed to different international conferences:

1. **Carbajo R**, Cabeza LF. Reflections on the social approach of renewable energy studies using TES as case study. A responsible and participatory overview for researchers. INNOSTORAGE - Advances in Thermal Energy Storage 2016, Beer Sheva (Israel). Oral presentation.
2. **Carbajo R**, Cabeza LF. Keep Calm and Go Social: Responsible Research and innovation for Renewable Energy Research. ESOF -European Science open forum 2016, Manchester (England). Poster presentation.
3. **Carbajo R**, Cabeza LF. Transcending traditional non-technological barriers frameworks- Insights from thermal energy storage and citizen awareness. ERSS - Energy research and social sciences 2017, Sitges (Spain). Oral presentation.
4. **Carbajo R,** Cabeza LF. Social dimension of renewable energy research through Responsible Research and Innovation looking glass: From social aspects to a social dimension. IRES - 11th International Renewable Energy Storage Conference 2017, Düsseldorf (Germany). Poster presentation.
5. **Carbajo R**, Cabeza LF. Boosting responsibility in engineering: Challenges for national and global initiatives. 10CNIT - 10º Congreso Internacional de Ingeniería Temodinámica 2017, Lleida (Spain). Oral presentation.
6. **Carbajo R**, Cabeza LF. Monitoring Sustainability and social justice in applied renewable energy research: A proposal of indicators. ICAE2017 - The 9th International Conference on Applied Energy 2017, Cardiff (England). Oral presentation.

International meetings and workshops

The PhD candidate assisted to international into international meetings and conferences:

1. 1th HERRI Conference- Higher education institutions and RRI 2016, Barcelona (Spain).
2. Joint Meeting ECES-IAE-Annex 30 and Open workshop with Spanish Stakeholders EERA subprogramme on TES, 2017, Lleida, (Spain).

Scientific foreign exchange

The PhD candidate did one stay in Chile during the development of this PhD thesis hosted by two institutions, Centro de Desarrollo Energético de Antofagasta (CDEA) and SERC-Chile from Chile.

In this research stay, the candidate worked on the contextualization and trasnational projection of RRI within the Chilean innovation system and in the participatory study conducted with researchers of Solar energy research SERC-Chile, performing interviews and the survey which is presented within the framework of this PhD thesis.

Other activities

Projects participation

- Identificación de barreras y oportunidades sostenibles en los materiales y aplicaciones del almacenamiento de energía térmica (SOPPORTES). Ministerio de Ciencia e Innovación, ENE2015-64117-C5-1-R, 2016-2018.
- Use of innovative thermal energy storage for marked energy savings and significant lowering of CO2 emissions (INNOSTORAGE). European Commission Seventh Framework Programme (FP/2007-2013), Nº PIRSES-GA-2013-610692, 2013-2017.
- PhD on Innovation Pathways for TES (INPATH-TES). European Union's Horizon 2020 research and innovation programme under grant agreement No 657466, 2015-2018.

Organizing committee participation

- Eurotherm Seminar #112 – Advances in thermal energy storage 2019. Lleida, Spain.
- INNOSTORAGE Third Training School - Experimental Apparatus for Measurement 2018. Lleida, Spain.

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