Collaborative research strategies in energy and sustainability related Social Sciences and Humanities

A literature review and practical guide

SHAPEENERGY

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Executive summary

One ambition of SHAPE ENERGY is to bring together the energy-SSH knowledge available, and create opportunities for energy-SSH researchers and 'users' of research (e.g. practitioners, policy-makers) to reflect on the co-production of knowledge in different settings. SHAPE ENERGY also aims at getting to know what is needed to make different archetypes of collaborative research successful (i.e. multidisciplinary, interdisciplinary, cross-sectoral and transdisciplinary or even transformative ways of working), and what their potential contribution and needs with respect to shaping the European energy agenda could be. The aim of this report is to discuss the need for and contribution of a better integration of SSH in the energy field, including integration and or collaboration with other types of knowledge, to discuss what type of integration might be needed in different settings, how to best organize these processes and how to measure the impact and quality of these types of collaborative research. In other words: if and what type of integration is useful, feasible (e.g. methodology, epistemology, procedures) to address complex energy related issues, and why and how.

To answer the above question, we first conducted literature research with the aim to gain conceptual clarity. Based on our study, chapter 2 provides a brief overview of the various archetypes of collaborative research, that is: multidisciplinarity, interdisciplinarity, transdisciplinarity and transformative science. Building on the overview of the various archetypes and their strengths and weaknesses, we then discuss the conditions that have an influence on the feasibility and desirability of working collaboratively in chapter 3. In addition, we will address the gap that often exists between the ideal type or archetype of collaborative research, and the actual practice. In chapter 4 we then present Building Blocks for a framework to design, monitor and evaluate collaborative research. We finish with recommendations for the European Commission and other funding bodies, the main target group for this report. Concluding remarks mark the end of the report.

Key findings

SSH-energy research is concerned with both researching and intervening in a multitude of relevant energy issues with respect to climate change. A lot of these challenges are fundamentally social (such as energy behaviour or practices, but also the systems around the practice of energy provision or understanding energy policy) thus SSH should be at the core of problem formulation. This type of research cannot lead to successful interventions without collaboration with the involved institutions, technologies and infrastructure that shape energy (Schuitema and Sintov, 2017). The validity of SSH-energy research furthermore increases through collaborations with other disciplines, experts, stakeholders, and end-users, because these engagements help to expose 'errors and irregularities' in commonly shared assumptions, norms and values (Schuitema and Sintov, 2017). We can also conclude that there is not yet a broad base of literature available reflecting on how to translate this need into practice in the field of energy-SSH research (e.g. proposed frameworks, quality standards).

Integration has become a Gold Standard in research and policy. However, especially given the difficulty in setting up functioning collaborative processes, especially those aimed at integration, we have to remain critical regarding the usefulness, the need and relevance of any form of integration and or collaboration in relation to the quality of the outcome. We also have to remain aware of the political process of inclusion and exclusion of disciplines and types of knowledge that will influence output/ results. What can be concluded is that knowing what type of integration or collaboration is needed, how many stakeholders need to be involved, if and how iteration is necessary is closely connected to the question why a certain collaborative research format is required. And this question and its answer is so context specific that we cannot provide an a priori answer. Asking what type of integration or collaboration is needed (e.g. methodology, epistemology, procedures) to tackle the energy challenges we are facing, is thus not fruitful. Although, an archetype matrix connecting each type of collaborative research with certain energy challenges is a valuable addition (to be found in the full background document), because both the circumstances in which the research is conducted (context, time, funding, organisational level, et cetera) as well as what is required for the specific

research question/ problem influences the usability of that collaborative form for the specific question. This is a question that can only be answered in situ.

What we have seen in the literature is that the term multidisciplinary and interdisciplinary are often used almost interchangeably, although there is great difference. In practice interdisciplinarity is already quite a challenge to do because many conditions need to be in place to allow for a good collaborative process. Another issue is that it is relatively difficult to measure some impacts; e.g. capacity building and learning among the public, private and civil society actors that participate in the research. Measuring the impact of deliberation: change in people's perspectives, ideas and convictions and the creation of shared goals and meaning is equally challenging, and efforts should be directed in creating effective monitoring and evaluation of these intangibles. This also applies to intangible impacts such as a sense of shared ownership, the creation of a more egalitarian work method, feeling of having a shared goal and real meaning, institutional investment and personal commitment (Thompson 2017). Many of the impacts of collaborative research only become apparent after a certain time frame, such as the formation of new consortia (Schneidewind, 2016) and cannot be monitored directly.

Recommendations

As discussed, the necessarily experimental nature of integration focused collaborative research requires a reflexive and continuous iterative learning process. This means that the management of projects should be reflective, iterative and open for change and failing should be allowed, as long as learning from failures is facilitated. This is however not the usual approach in H2020 and similar types of funded research programmes in which payment depends on concrete results and not lessons learned. This paradigm of efficiency and effectiveness hampers real learning curves and underscores the uncertainty and contingency of (innovative) experimentation. The review processes could allow for more experimentation with the use and usefulness of SSH in projects by valuing 'successful failures', as long as a reflexive learning documents based on internal process evaluations are produced. This is also important to guarantee a self-critical, reflexive and independent attitude of researchers in light of their dependence on subsidies/funding that should lead to useable and practical results.

Project proposals should therefore be explicitly invited to discuss exactly what type of collaborative working they seek, and why, and how they are going to set this up, and also why they exclude other types of collaborative working, so that they really need to make an effort at reflexive thinking about the collaborative research processes they set up. This includes also an explicit statement on process requirements with respect to the inclusion or exclusion of diverse perspectives at the beginning of the process and during the process and how a level playing field will be guaranteed as to ensure a safe space in which relationships of trust can be built to negotiate and deliberate ideas and perspectives. This should be part both of the concept and impact and implementation sections of proposals.

We recommend that more attention is paid to these necessary conditions in the design of the management of projects in particular those related to create a safe learning environment necessary to create relations of trust. This means for example that the project coordinator and WP leaders need to demonstrate expertise and skills of working with conflict laden and reflexive processes and internal evaluation structures should be in place (e.g. supervision) Time and resources should be available to create positive learning experiences in a safe setting. The uptake and usage of the outputs of collaborative research, especially in policy-making, is another important issue that needs further discussion. Often responsibility for the uptake of this knowledge and output is put on the researchers. However, Rau, Goggins and Fahy (2018) asks the legitimate question if more time and resources should be spent on evidence-based policies rather than placing the responsibility solely on academia. Hence, more research is needed to map the social, cultural and political barriers for access and usage of scientific knowledge by policy-makers, practitioners and other diverse publics.

Contents

1. Introduction[1]

SHAPE ENERGY (*Social Sciences and Humanities for Advancing Policy in European Energy*) is a European platform for energy-related social sciences and humanities (energy-SSH) funded by the EU Horizon 2020 programme[2]. The project started the 1st of February 2017 with a project duration of two years. SHAPE ENERGY aims to improve the uptake of SSH disciplines in Energy policy (in Europe), which until now has mainly been shaped by Science, Technology, Engineering and Mathematics (STEM) disciplines. The European Commission supports a better integration of energy-SSH into the policy process and has committed to use the project's output to shape the future policy strategy and plans of the European Commission.

The main focus of SHAPE ENERGY is the transition towards a sustainable system of energy provision. This transition is a challenging and complex issue as it entails not only techno-economic but also social, political, ecological and other challenges. Therefore, it is widely discussed that innovative research is needed to address the varied dimensions and to some extent that this research needs to inform and be informed by societal dynamics as well. It is also argued that research needs to bring together a diverse range of disciplines, whereby the largest challenges probably are to bring together STEM disciplines and sectors with energy-SSH, to highlight the value of SSH to potential users such as policy makers, and to bring together the individual SSH disciplines in collaborative research. The latter is increasingly acknowledged as essential (e.g. by the European Commission (European Commission, 2018) to enhance our understanding of the 'human' factor in the energy transition.

One ambition of SHAPE ENERGY is to bring together the energy-SSH knowledge available, and create opportunities for energy-SSH researchers and 'users' of research (e.g. practitioners, policy-makers) to reflect on the co-production of knowledge in different settings. SHAPE ENERGY also aims at getting to know what is needed to make different archetypes of collaborative research[3] successful (i.e. multidisciplinary, interdisciplinary, cross-sectoral and transdisciplinary or even transformative ways of working), and what their potential contribution and needs with respect to shaping the European energy agenda could be.

To better understand the need and contribution of a better collaboration between different disciplines, and potentially also other types of knowledge, it is important to develop explicit and concrete ideas explaining if and what type of integration is needed (e.g. methodology, epistemology, procedures), and why and how. There is a rich body of academic literature on collaborative research in general, discussing a wide range of issues related to the definition, quality, usability and impact of collaborative work. The literature focusing on collaborative research usually discuss a (single) aspect of that research, and there is no consensus on what these different types of research formats entail, what their boundaries are and thus how to evaluate them and claim successes. Furthermore, some of these archetypes are used interchangeably without making clear what type of research is referred to exactly. These archetypes however, are distinct in terms of epistemology (the origin, nature, methods, and limits of the disciplinary knowledge), work processes, involvement of internal and external participants, ambitions and output. In addition, often, these research papers start from the assumption that collaboration is a necessary requirement, a view that is becoming more evident in policy circles as well, and that what we need to figure out is how to best organise these processes and find new ways to measure the impact and quality of these types of research. A reflexive discussion of the actual contribution of collaborative research in the energy field or the wider sustainability field seems to be a closed chapter, and there are few case studies focusing on how the archetypes of collaborative working actually work out in practice. What is also understudied is an integral and comparative review of the various types of collaborative research focused explicitly on the energy research field, especially in relation to the question if and what type of integration is useful, feasible (e.g. methodology, epistemology,

1 A shorter version of this report has been published in: Sumpf, P., et al., 2018. *SHAPE ENERGY reflexive review of interdisciplinary Working. Cambridge: SHAPE ENERGY.*

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3 We use the concept 'collaborative' rather than 'integrative' because multidisciplinary research is not characterized as integrative form.

procedures) to address complex energy related issues, and why and how. In this report we seek to find an answer to this question.

To answer the above question, we first aim to gain conceptual clarity. Based on a literature review we briefly identify the various archetypes of collaborative research, multidisciplinarity, interdisciplinarity, transdisciplinarity and transformative science and their strengths and weaknesses, and briefly explain the origins and development of the archetypes within the field of sustainable research (chapter 2).[4] We also focus on why a specific form of the collaborative research approach (the integral approach) has become the dominant paradigm in the field of sustainable research. Building on the overview of the various archetypes and their strengths and weaknesses, and based on the literature review, we discuss the conditions that have an influence on the feasibility and desirability of working collaboratively in chapter 3. We also address the gap that often exists between the ideal type or archetype of collaboration, and the actual practice. Based on the literature review we developed Building Blocks for a framework to design, monitor and evaluate collaborative research which will be presented in chapter 4. Following up with recommendations for the European Commission and other funding bodies, the main target group for this report. Concluding remarks mark the end of the report.

4 Initially we aimed for a review of collaborative research in the energy field, but soon had to expand our search to include sustainability research for lack of material focused solely on the energy field.

2. Collaborative research archetypes and context

In this chapter we will briefly explore the origins and development of collaborative research within the field of sustainable research and explain why integrated research has become the dominant paradigm in the field of sustainable research. This discussion is followed by identifying the main archetypes, multidisciplinary, interdisciplinary, transdisciplinary research and transformative science, also referred to as MITT-research[5]. At the end of the chapter the constitutive elements of these various archetypes will be presented in a matrix.

2.1. Collaborative research in sustainable science and energy research

Collaborative research has become a common focus of research projects, funding opportunities and policy developments. This development is due to a change of perspective on the role of science and its relation to society. Whereas in the past it was commonly acceptable for researchers to produce highly specialised (fundamental) knowledge, nowadays, the pressure to produce knowledge relevant to societal challenges we are facing is growing. Several broader societal processes as well as academic debates and developments have shaped this changing perspective on the role of science and academic responsibilities and duties.

To understand this changing perspective, and the increased focus, or even paradigm shift towards interdisciplinary working, a brief discussion on the role of climate research is necessary. In the 1960's meteorologists and geophysics discovered the phenomenon of 'global warming'. Their highly specialised research outcomes all pointed in the same direction, but their models and methods weren't sufficient to fully understand the phenomenon and grasp the scope and impact. They were aware that collaboration with and perhaps even integration of their disciplines with other disciplines was urgently needed to gain a better understanding of global warming and map the potential (serious) risks. The early efforts of the researchers involved eventually led to the establishment of the Intergovernmental Panel on Climate Change (IPCC), which publishes reports every six year that contain 'a single authoritative assessment' from top researchers on the impact and risks of global warming (Waert, 2013). Although there was already a broader trend towards interdisciplinary working in academia, the size and scope of these new archetypes of interdisciplinary climate research were incomparable[6]. However, although the field of climate research is interdisciplinary, it is mainly dominated by natural scientists focused on understanding, measuring and mapping the complexity of global warming. This body of knowledge however, resulted more recently in the field of 'sustainability research', a scientific field characterised by its problem-oriented approach bridging knowledge and action to deal with global earth challenges such as climate change[7]. This academic field can be characterised by its normatively motivated agenda and an ambition to produce 'usable' research output which motivates researchers to work on a better integration of not only the natural but also the social sciences and the adoption of a systemic view.

The field of energy focused research, although often perceived as part of the field of sustainable research, is however still predominantly characterised by a sharp division between STEM and SSH. Not until recently have efforts to integrate natural and social sciences been undertaken[8]. There is a growing awareness that the field of energy research is in need of further collaboration of knowledge and disciplines to understand the complex challenges and develop knowledge and strategies to tackle them[9]. But the drive to integrate diverse disciplines within energy research is not as broadly shared as within climate and sustainable

5 Stock and Burton (2011) refer to this as MIT-research, that is: multidisciplinary, interdisciplinary and transdisciplinary. Their comprehensive comparative research didn't include transformative science, and we therefore changed the acronym into MITT.

6 For a detailed discussion on the history of climate research we refer to Waert (2013).

7 Source: https://en.wikipedia.org/wiki/Sustainability_science, [accessed 10-09-2018]

8 E.g. FP7 and FP8 programmes from the European Commission https://publications.europa.eu/en/publication-detail/-/publication/4365f75a-5efe-11e8-ab9c-01aa75ed71a1/language-en [accessed online 12-11-2018] and SHAPE ENERGY

9 E.g. transformative science has emerged around the UN Decade of Education for Sustainable Development (ESD, 2005-2014) which has been launched with the overall objective of integrating ESD in all fields of education worldwide. In the final report of this UN event, it was found that internationally progress has been made with regard to the institutionalisation of ESD in universities. However, it was also found that many countries are lacking pro-active leadership for a more substantial change in universities. Since 2015 efforts of strengthening ESD internationally are continued in the form of a UN World Program of Action (Schneidewind, 2016).

research and a natural synergy between STEM and SSH is lacking. To stimulate better integration, it is therefore important to develop explicit and concrete ideas explaining what type of integration is needed (e.g. methodology, epistemology, procedures), and why and how? To answer this first question, we will now continue first with a description of the definition of the different archetypes common to collaborative research. The why and how different types can be useful will be answered in the following chapter.

2.2. MITT-definitions

This paragraph discusses various archetypes of collaborative research, that is: interdisciplinary, multidisciplinary, transdisciplinary and transformative science (MITT). We map these different definitions by discussing issues such as their perspective on what valid knowledge is (i.e. epistemology, methodology), the involvement of, or integration of multiple disciplines and stakeholders into the research process, the research coordination, the research outputs and usability. In addition, we discuss the strengths and weaknesses of the different modes of collaboration and how the collaborative research deals with issues of inclusion, exclusion and knowledge creation processes (Stock and Burton, 2011).

2.2.1. Multidisciplinary research

Multidisciplinary research is the most common work-mode in academia, especially in temporary work-setting such as project funded research (e.g. Horizon2020). In theory and in practice "*Multidisciplinary research arises when multiple researchers investigate a single problem, but do so as if each were working within their own disciplinary setting*." (Miller et al., 2008, p.5). Multidisciplinary research is thus characterised by gathering knowledge from various disciplines, enriching the knowledge about that problem by adding multiple views, but without crossing disciplinary boundaries (Klein, 1990; Stock and Burton, 2011). The organisation of multidisciplinary research (projects) is usually build around an overarching theme and allows for the co-existence of multiple goals relevant to different disciplines within one project. Research output can be characterised as a bundling of expert opinions offering a kaleidoscopic perspective on a specific topic, which is a clear improvement compared to single discipline research. By its nature, the collaborative effort is not focused on confronting different expert opinions, nor on creating a shared language or a common problem definition (Miller et al., 2008). does not offer a coherent picture of how societal challenges can be dealt with.

A process of inclusion and exclusion is clearly present in the selection of disciplines and perspectives that are invited to multidisciplinary projects, consortia and research groups, but in general such negotiations take place beforehand and not during the course of the research process, and reflexive discussions on the value of different disciplines are thus not occurring during the research. Multidisciplinary research is probably the most common collaborative approach because it requires less organisational effort compared to collaborative research that aims at integration of disciplines such as interdisciplinary and transdisciplinary research, and transformative science. Multidisciplinary research still fits well with the organisational rationality of academia (which is biased towards disciplinary research, e.g. opportunities for funding, publications, tenure tracks), which as such is a conducive factor in facilitating the popularity of multidisciplinary working.

Research output in multidisciplinary projects is usually published in academic journals, with academics as main audience. This does require a practical translation for practitioners ('users' of scientific knowledge) because the output, although thematic, does not present an integrated or more holistic problem-solving focus, a coherent picture of how societal challenges can be dealt with. Instead of offering an integrated approach or solution, the 'user' needs to put the pieces of the puzzle together. For some challenges this may not be problematic (e.g. when research highlight several aspects of a problem that can be tackled independently), but for issues that concern sustainability and energy, multidisciplinary research is insufficiently capable to capture the complexity and interrelatedness of problems. A certain level of integration is needed. As such it can be concluded that multidisciplinary modes of working are not the best combination with climate change and or energy transition related issues.

2.2.2. Interdisciplinary research

Interdisciplinary research is distinctively different from multidisciplinary research, in the sense that there is a certain level of disciplinary integration which requires more extensive academic cooperation than is common to multidisciplinary research (Stock and Burton, 2011). Interdisciplinary research is, according to the widely supported definition of interdisciplinarity by Klein and Newell: "*a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession. Interdisciplinarity studies and draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective*" (Klein and Newell, 1996, pp.395). Interdisciplinarity ideally involves openness to the inclusion of theories and methods to any set of phenomena within academia. The degrees of collaboration result in 'different kinds of interdisciplinarity' (Bammer, 2015) that can be characterised by "*the nature of the problem under investigation, the number of disciplines involved, whether these are closely aligned or disparate, whether the interdisciplinary research is undertaken by an individual or a team, and whether it is engaged with policy and end-user practice*" (Bammer, 2015, p.506).

One of the biggest challenges in interdisciplinary research is achieving effective communication between experts from different disciplines. Misunderstanding and misconception will endanger the quality of research output. Common understanding derived from shared languages furthermore plays a vital role in enhancing the relations of trust that are necessary for effective interdisciplinary working (Bracken and Oughton, 2006). Bridging these vocabulary differences is however particularly challenging in project settings because such collaborations are usually temporary and often there are not enough opportunities nor enough time to organise face-to-face exchanges that could help to overcome problems related to this. Interdisciplinary projects must therefore explicitly be able allocate time to the development of shared vocabularies[10] and understandings. This negotiation between disciplines is the core of the development of more integrated research perspectives on the problem, thus providing a more comprehensive perspective on the societal challenge to be solved. The degree in which interdisciplinary research is able to find answers to complex and systemic issues depends both on the attempt to integrate diverse disciplines and perspective, as well as on the actual integration and cooperation.

The output of multidisciplinary research and interdisciplinary research is knowledge, targeted at academic audiences, and measured along academic evaluation standards (e.g. articles in peer-reviewed journals) but recipients are also to be found in public administration and society.

Stock and Burton (2011) cite several researchers that have evaluated case examples of 'interdisciplinary research' and conclude that researchers often claim (or aim) to work interdisciplinary, but when one takes a closer look, these projects can better be characterised as multidisciplinary because often integration of disciplines is not occurring, and the cooperation is limited to providing different disciplinary perspective on the problem.

The field of energy focused research, is predominantly characterised by a sharp division between STEM and SSH. Not until recently have efforts to integrate natural and social sciences been undertaken. There is a growing awareness that the field of energy research is in need of further collaboration of knowledge and disciplines to understand the complex challenges and develop knowledge and strategies to tackle them. Depending on the research topic and problems that need to be tackled, interdisciplinary research can be a suitable approach.

2.2.3. Transdisciplinary research

At first sight it is difficult to clearly distinguish between interdisciplinary and transdisciplinary research because "*The boundaries between interdisciplinary and transdisciplinary projects are thus diffuse and dependent more on a subjective judgment on the level of holism applied than on the presence of clear boundary markers.*" (Stock and Burton, 2011 p.1102). However, there are a number of characteristics that make transdisciplinary research

10 Note that this does not imply developing a new vocabulary but to create conceptual clarity regarding disciplinary use of archetypes and perspectives.

distinctively different from interdisciplinary research. Similarly, to interdisciplinarity, transdisciplinary research seeks to collaborate with multiple disciplines. Transdisciplinary research however, seeks to restructure the nature of disciplinary knowledge by crossing disciplinary boundaries and synthesising new disciplines through collaboration (Luederitz et al., 2016; Stock and Burton, 2011; Thompson et al., 2017). In addition, transdisciplinarians adopt a holistic approach that does not single out certain research elements but looks at phenomena in their context and their relation to other phenomena or elements. Moreover, the research design of transdisciplinary research, and the definition of relevant knowledge and problem definition involves a participatory process in which non-academic actors (e.g. policy makers, end users, practitioners, citizens) are invited to co-creation and co-produce knowledge (De Boer et al., 2006) such as through the creation of real-world laboratories (field labs, social labs) in which experiments take place. The participation of non-academics may vary case-by-case, from defining a shared problem definition to having influence on the research design and/ or what is considered as relevant (and irrelevant) knowledge (Klenk and Meehan, 2017). The contribution of non-academics ideally results in the inclusion of diverse ideas and perspectives.

The co-creation of knowledge furthermore results in more diverse output than interdisciplinary research, for the exchange of knowledge not only feeds into research papers and scientific reports but also influence the decision-making capacity (when policy makers are included) or the actions of other stakeholders (Stock and Burton 2011; Walter et al., 2007). Although common, there is however no explicit requirement for transdisciplinary research to produce results that can be implemented. (Höchtl et al., 2006; Jackson, 2006).

The need and usefulness of transdisciplinary research receives widespread support[11] [12], especially in the field of sustainable research, its holistic perspective and participatory approach is crucial in learning to understand how humanity can transition towards a more sustainable system of provision. The holistic perspective and the inclusion of multiple stakeholders create a better understanding of energy issues, especially when social aspects are at the core of the problem formulation, which makes transdisciplinary research highly suitable for these types of energy research.

2.2.4. Transformative science

Transformative science is a concept that delineates a new role of science and the scientific system, which goes beyond observing and analysing, and co-creating, but rather takes an active role in initiating and catalysing change processes e.g. through fields labs and social labs, with the aim to achieve a deeper (in the sense of including all relevant forms of knowledge, not only academic, but also sectoral and lay) understanding of ongoing transformations and increase societal capacity for reflexivity with regard to these fundamental change processes. In order to increase this reflexivity in dealing with great societal challenges and to re-integrate societal sub-systems, science needs to transcend its descriptive analytical functions and cooperate with non-academic actors to achieve shared, normative goals (Schneidewind, 2016).

Simultaneously however, transformative science reflects on the role of science on society and the need for change of the scientific practice itself. The development towards transformative science has been catalysed

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11 Developments preceding the transdisciplinary approach include post-normal science (early nineties of last century), which accounts for systemic uncertainty by integrating different and often conflicting interests and interest groups in an 'extended peer community' (Funtowicz and Ravetz, 1993). Similarly, approaches of a 'mode-2 science' (at the turn of the century) build on the assumption that in modern knowledge societies, relevant knowledge is produced by a variety of actors in different settings (Nowotny, Scott and Gibbons, 2001). Transdisciplinary research added the normative elements to this co-creation of knowledge.

12 At the European level a similar call for more transdisciplinary research can be witnessed in the debate on the concept of 'Responsible Research and Innovation'. This concept describes a research paradigm that focuses on anticipating the potential societal impact of research, on the development of co-design and co-production in research design and on facilitating innovation and sustainable development (Schneidewind, 2016). This concept originates from the concepts of Technology Assessment and Constructive Technology Assessment - a scientific, interactive, and communicative process that aims to contribute to the formation of public and political opinion on societal aspects of science and technology (Rip, Misa and Schot, 1995). What Technology Assessment stresses is that a reflexive process is necessary that focusses on how research and knowledge production is taking place, and how certain forms of knowledge are included and other excluded. Reflexivity on the processes of research and knowledge production is therefore deemed a key mechanism for delivering a transformation in sustainability (Daedlow et al., 2016).

by the felt (negative) societal impact of technical innovations and scientific knowledge-production. Especially critical are those types of technological innovations that deeply interfere with natural and human systems and produce unintended and often irreversible ecological and social side effects (Beck, 1986).

Transformative science describes a concept of science as a social institution that also aims at reorganising the scientific system in order to achieve change where needed in society in a reflexive manner. Transformative science differs thus from transdisciplinary research in its aim to reform the scientific system as well as (a part of) the social system, and in its aim of societal capacity building. It furthermore facilitates processes of balancing societal power structures through the legitimising force of evidence-based arguments (Schneidewind, 2016). The concept and ambitions of transformative science thus have implications with regard to research and knowledge production, education and teaching and institutional change of the science system.

From a methodological point of view, transformative research builds on and makes use of a broad repertoire of research approaches, which focus on joint social learning of scientists and lay persons, such as transdisciplinary case studies, transdisciplinary research, participative action research, intervention research and transition research (Schneidewind, 2016).

The transition towards a sustainable system of provision requires not merely a better understanding of the dynamics between the social and the technical disciplines, and creating participatory research mechanisms for inclusion of non-academics, but is dependent on social empowerment and capacity building as well. Hence, for many energy transition issues, transformative science can result in better research outcomes because it targets the above issues.

2.3. Reflective conclusion

An extensive academic debate has taken place (resulting in numerous publications) discussing the definition of collaborative research archetypes and the rationality behind them. Based on the brief description of different collaborative approaches above, we can however conclude the following:

Multidisciplinary research is the least integrated and cooperative form of collaborative research. Research outcomes are usually disciplinary and there is hardly any confrontation between various methodologies, epistemologies and values and norms between disciplines. This type of research is sufficient and justified as long as the research topic does not require to look outside its discipline to look for solutions e.g. a confrontation between human and technological systems (Stock and Burton, 2011) When this outside look is needed, interdisciplinary research could help to build a bridge between various disciplines. The main focus of both multidisciplinary research and interdisciplinary research is academia, in the sense that output is usually targeted to academic communities using academic communication channels such as journals and research papers at conferences.

Transdisciplinary research seeks to go beyond interdisciplinary research by creating mechanisms that make it possible to include lay knowledge (e.g. tactical and strategic) and non-academic expert knowledge in their research. This may involve participatory approaches such as research dialogues and workshops. This type of research does not only allow to establish confrontations between different epistemologies, methods, norms and values and worldviews, it also allows to confront different systems with one another. By including lay persons, transdisciplinary research helps researchers for instance to understand the impact of technology on day to day (social) practices and how they shape one another. The output of transdisciplinary research is more diverse, while research oriented transdisciplinary research targets mainly academic communities, action-oriented transdisciplinary research – which is more common – also includes non-academic audiences.

The most important distinction between multidisciplinary and interdisciplinary research on the one hand, and transdisciplinary research and transformative science on the other hand has to do with its problem-solving focus. Whilst the first two types are concerned with a particular problem that can be understood and solved through setting up a pre-defined methodological procedure which is reliable and can be validated, such as

studying the number of animal species. The second set of inquiries (transdisciplinary and transformative) are not neutral, in the sense that their objectives are characterised as 'value-laden' and based on normative agenda, a 'transformational perspective' which implies a transition towards a more desirable situation (e.g. a more sustainable system of provision) (Popa, Guillermin, and Dedeurwaerdere, 2015). Whereas multidisciplinary research and interdisciplinary research is conducted by researchers, the output is targeted at academic audiences, and measured along academic evaluation standards (e.g. articles in peer-reviewed journals), transdisciplinary and transformative research is usually more diverse in terms of contributors, targeted audiences and impact.[13] Similar to transdisciplinary research, transformative science takes place in real-world laboratories (field labs, social labs) in which reflexivity plays a key role (Schneidewind, et al., 2018). Research is then conducted through, alongside and guided by the implementation of innovative interventions; research and experiment coincide.

There is however, no conceptual consensus regarding the exact definition and constitutive elements of these different archetypes and it is therefore difficult to define clear boundaries to clearly distinguish these various modes of collaborative research (Stock and Burton, 2011). It seems furthermore, that in fact the different archetypes of collaborative research are more part of a continuum than that they are very distinct archetypes. Moreover, talking about disciplines as single units might lead to the thought that there is epistemological, methodological and normative consensus within these disciplines, which is not the case. Hence, we can conclude that discussions about the integration, collaboration and confrontation takes place both within and between disciplines (Miller et al., 2008).

Nevertheless, to better understand at least the different shades of grey of different collaborative research archetypes, it is helpful to highlight distinctive elements of these different collaborative archetypes. Based on the literature we distinguish four types of distinctive elements: philosophical organisational, social and relational and finally, skills and competences. Together these elements form the context in which collaborative research is conducted in different ways. We aim to provide for a nuanced overview, that takes account of the different weight attributed to the distinctive elements, and the nuances in terms of their content. So rather than ticking boxes of labels, it might help to distinguish their constitutive elements on a continuum by adding degrees and then identify their relative importance for each archetypical collaboration. We depict these elements in the following tables below[14].

13 Note that this is a generalization for the sake of argument.

14 Note that these constitutive elements are distinguished for the sake of clarity. The measuring scale is from – (non-present) to +++ (distinctive element)

Philosophical

The philosophical elements refer to issues such as epistemology, methodology and at a deeper level the question of the role and responsibilities of sciences in and for society. These elements deliver a different kind of tension because confrontation between different disciplines challenges basic assumptions, norms and values within disciplines and require researchers to reflect on a meta-level on their research (position).

Table 1: Philosophical Elements

Philosophical	Multidisciplinary	Interdisciplinary	Transdisciplinary	Transformative science
User friendly results (for scientific knowledge users) / usability	Depends on complexity of questions	Depends on complexity of questions	++	+++
Whole system research	-	-	+++	+++
Experiments in practice (e.g. real-world project, field labs, social labs)	N/A	N/A, only as case studies, not with respect to action research with non-academic stakeholders	+++	+++
Iterative research process between science, disciplines, sectors and society	-	-	+++	+++
Reflexivity (reflecting on and changing existing way of doing thing)	-	+/-	+	+++
Academic output	+++	+++	++	++
Output geared to implementation	N/A	N/A	++	++
Confrontation between diverse methodologies	-	++	+++	+++
Attempts to create a shared language	-	+	++	+++
Working towards a common goal (normativity)	-	-	++	++
Synthesis new disciplines and society	-	++	++	+++
Confrontation between diverse epistemologies	-	++	+++	+++
Diverse group of targeted audiences	-	-	+++	+++

Organisational

The organisational elements refer to structural and operational elements of both the organisation of the academic community as well as the organisation of project funded research e.g. job requirements, status, nudges and rewards, financial opportunities. These elements are important for the ability to engage in collaborative research.

Table 2: Organisational Elements

Organisational	Multidisciplinary	Interdisciplinary	Transdisciplinary	Transformative science
Organisational complexity	-	+	++	+++
Existence of practical framework or research design	+	+/-	+/-	+/-
Organisational level of cooperation and exchanging ideas	-	+	+++	+++
Timing	+	+	+++	+++

Social and relational

The social and relational elements include the norms and values of academic communities and how these affect social relations and work processes e.g. in- and exclusion mechanisms (who is invited to join? And who isn't), is a diversity of perspectives represented? And how are ideas, interests and perspectives negotiated? These elements influence the motivation of researchers to engage in collaborative research projects.

Table 3: Social and Relational Elements

Social and relational	Multidisciplinary	Interdisciplinary	Transdisciplinary	Transformative science
Diversity of multiple academic disciplines	+	+	+	+
Diversity of multiple actors (including non-academics)	N/A	N/A	+++	+++
Negotiation and deliberation	N/A	++	+++	+++

Skills and competences

These elements refer to the qualities and capacity of researchers to engage in collaborative research. Besides the qualities one needs to be a good researcher, collaborative engagements require social competences (group dynamics). To have the right skills influences the willingness to engage in collaborative research.

Table 4: Skills and Competences

Skills and competences	Multidisciplinary	Interdisciplinary	Transdisciplinary	Transformative science
Social learning through monitoring and evaluation	+	+	+++	+++
Complex project coordination and moderation between participants	-	++	+++	+++
Societal Capacity Building	-	-	-	+++
Individual competence with relation to group dynamics, willingness to engage etc.	-	+	+++	+++

Recap

The overview we presented above aims to contribute to guiding researchers and project participants to question and reflect on what is ideally required for the type of research and/ or challenges they are working on, and learn how to better align their work with that ideal type. However, as mentioned before, the circumstances in which the research is conducted (e.g. context, time, funding, organisational level) creates contingency which is also very important to understand. We will further explore this issue in the following chapter.

3. Conditions influencing collaborative research in practice

In the previous chapter we provided an overview of the various archetypes of collaborative research, conferring their strengths and weaknesses. In addition, although the boundaries between the archetypes are gradual and there is no conceptual consensus regarding the definitions, we did draw some boundaries to allow for a pragmatic discussion on what these archetypes ideally have to offer in the field of energy related SSH. Translating these archetypes into practice however, all of these collaborative research archetypes are bound by contextual factors influencing their feasibility and desirability It may not be surprising that the gap between ideal type definitions of collaborative research and practice is wide. A gap between research intentions and the actual research effort may also arise because research practices are always conducted in a context which can inhibit or enable the intended practices. In addition, these conditions are interdependent and together they affect the opportunities for researchers to engage in collaborative research. Based on a literature review this chapter addresses the (pre-)conditions that influence the different archetypes of collaborative research and that need to translate into successful modes of working in practice, with output that meets the needs of the intended users.

3.1. Philosophical

There are philosophical conditions such as epistemology, methodology and at a deeper level the question of the role and responsibilities of sciences in and for society that affect collaborative archetypes of research. These elements deliver a tension because confrontation between different disciplines challenges basic assumptions, norms and values within disciplines and require researchers to reflect on a meta-level on their research (position). One aspect that is mentioned in the literature is that the integration between social and natural sciences suffers from "*disciplinary chauvinism*" from STEM disciplines in the sense that SSH "*is being treated as secondary and peripheral*" (Sovacool, 2015 in: Schuitema and Sintov, 2017, p.247). Critics consequently remark that in practice knowledge from one discipline is often merely used in service of another discipline and the genuine exchange of knowledge, ideas and perspectives (Thompson, 2017) which require dialogue, confrontation and negotiation is hardly undertaken. Moreover, researchers often have a bounded way of perceiving and understanding phenomena and consequently, open and deliberate discussions negotiating researchers' values stand in stark contrast to traditional approaches in which researchers endorse and value disciplinary assumptions (Miller et al., 2008). These academic biases are hard to overcome and often results in 'unidirectional integration', interdisciplinary research in which a single discipline dominates others (Stock and Burton, 2011). The valuing of different types of research affects how certain points of view, theories and perspectives are taken into account and confronted with one another. Take for example an interdisciplinary project in which both natural and social scientists cooperate to create an innovative energy management system. If the natural scientists won't accept the assumption that technological systems are always based on (implicit) scripts of human interaction with that system, or that these scripts are of no importance to the further development of the technology, there will be no effective confrontation of the underlying and often hidden assumptions. The lack of broadly accepted conceptual framework for various archetypes of collaborative research may furthermore result in these kinds of biases. Although multidisciplinary and interdisciplinary research is at least bound by academic standards that guide researchers with respect to the quality of their work, what these collaborations (especially interdisciplinary collaboration) face in practice is that there are no clear guidelines as to what is acceptable in terms of integration. For transdisciplinary research and transformative science there is no clearly defined and broadly accepted research framework available either, leaving room for interpretation and divergence in practice, and this also applies to quality standards. According to Stock and Burton (2011), the lack of a framework furthermore leads to 'goal-oriented' interdisciplinarity, which is issue-centric and mainly guided by the nature of the issue. The methodological bias towards quantitative research approaches and the preference for 'solid data' based on representative samples and replicable research designs (Rau, Goggins and Fahy, 2018) do not contribute to a level playing field in academia.

An important issue to mention is that the need to integrate research is sometimes overemphasised and has become a goal in itself, as Klenk and Meehan (2017) point out: "*transdisciplinary models of research*

are increasingly upheld as the gold standard of collaborative science to solve complex social and environmental problems, promising to 'close the gap' between knowledge and action, inject science with greater accountability, democratic participation, and include stakeholders as practitioners of research." (Klenk and Meehan, 2017, p.27). Klenk and Meehan argue that we should however remain critical because transdisciplinary research is not a panacea. The confrontation between a plurality of methodologies and epistemologies allows for critical reflection and will lead to potentially better research outcomes, especially for complex and controversial socio-ecological issues (Shove and others in Rau, Goggins and Fahy, 2018, p.267; Stock and Burton, 2011). The confrontation in itself may for, some types of research problems, be sufficient (Schuitema and Sintov, 2017; Stock and Burton, 2011). Luederitz et al. (2016) even state that the strong move towards integration of theories, terminology and methodology is potentially even counterproductive, and that "*... iteration, confrontation, evaluation and reflection are not just valuable tools, they are at the core of research projects*" (Luederitz et al., 2016, p.2).

Some of the conditions mentioned above are relatively easy to put in place, whilst others require long-term investments to change them. For example, with respect to transdisciplinary, and in particular transformative science, short and long-term changes and investments are necessary because for these types of research to succeed it is not simply a matter of "*assembling the 'right' object, method or team*" that will solve the organizational and epistemic issues (Klenk and Meehan, 2015, p.162). Rather, a more fundamental systemic change in academia will be necessary.

3.2. Organisational

The organisational conditions that influence the ability to engage in collaborative research are structural and operational elements of both the organisation of the academic community as well as the organisation of project funded research e.g. job requirements, status, nudges and rewards, financial opportunities. One important condition is the reward system. Because of the bias towards conventional performance standards researchers prefer to produce disciplinary research outputs such as publishing in disciplinary peer-to-peer journals (Klenk and Meehan, 2015; Rau, Goggins and Fahy, 2018; Stock and Burton, 2009). Publishing is at the core of a ranking system that determines career changes (such as tenure tracks) (Schuitema and Sintov, 2017). Higher impact scores, open up better career opportunities which is especially important for early-career academics. In addition, less tangible research outcomes and real-world impact are excluded from evaluations and rankings and this is also creating a bias towards disciplinary approaches (Schuitema and Sintov, 2017). An alternative approach to measure such impacts is lacking (Rau, Goggins and Fahy, 2018).

Another important condition is the funding system. Currently, funding opportunities and criteria are predominantly disciplinary (Rau, Goggins and Fahy, 2018) and not fit for measuring scientifically rigorous interdisciplinary research (Schuitema and Sintov, 2017)[15]. Academics are becoming more responsible to secure external funding (Rau, Goggins and Fahy, 2018). The limited funding opportunities for collaborative research will consequently maintain disciplinary and sectoral research silos. Moreover, reviewers for funding bodies usually have disciplinary expertise and are therefore not capable to review proposal on all aspects (Schuitema and Sintov, 2017). As a result, high quality collaborative research may not be recognised as such.

Another trend that is affecting research opportunities is the increasing outsourcing of 'policy-driven research' (Rau, Goggins and Fahy, 2018). Governance agencies are under financial pressure to reduce costs. Hiring external expertise to create more financial flexibility is more efficient than maintaining staff. This development creates opportunities to securing financial support but place more pressure on academics to demonstrate the value of their work (Rau, Goggins and Fahy, 2018). Together with the above-mentioned trend that academics need to secure external funding, the requirements of applied policy-relevant research have a profound impact on the independent position of academics, especially in case of controversial topics (Slaughter, Martin in: Rau, Goggins and Fahy, 2018). The increase of applied research furthermore

15 Note that recently funding opportunities are becoming more available (but are still limited).

has a weakening effect on opportunities to conduct more fundamental and experimental research. Applied research commissioned by governments are predominantly steered by the efficiency and effectivity frame; they want benefits of investments (Rau, Goggins and Fahy, 2018).

The question is if academics are responsible to contribute to applied-research and acquire corresponding skills and competences or should more time and resources be allocated to policy-makers for integral evidence-based policies (Rau, Goggins and Fahy, 2018). The answer to that question is probably dependent on the issue at stake, but generally speaking a bit of both is necessary because that would allow for a better synergy between research and policy. While the pressure is mounting, a supportive infrastructure to secure long-term investments in collaborative research is missing, hence a broader reorganisation of academia is necessary (Schuitema and Sintov, 2017) to support interdisciplinary and transdisciplinary research as well as transformative science.

Last but not least, the lack of a framework defining how to organise the research process, how to assess quality standards and to monitor and evaluate is lacking is potentially one of the biggest impeding conditions.

3.3. Social and relational

Social and relational conditions are the third set of influential elements. These include the norms and values of academic communities and how these affect social relations and work processes. There are inclusion and exclusion mechanisms at work that further affect the biases that are mentioned under philosophical conditions. These types of mechanisms are often implicit and become apparent when reflecting on questions such as: who is invited to join, and who isn't, is a diversity of perspectives represented? And how are ideas, interests and perspectives negotiated?

The diversity of research groups, both in academic settings as well as in project settings is often lacking, not just in terms of disciplines but also in terms of gender, ethnicity, and such. Current participation procedures can be discriminatory towards less visible groups, organisations and researchers, because invitations often happen through networks and befriended colleagues (Popa, Guillermin, and Dedeurwaerdere, 2015). The lack of a diversity of (research) perspectives which may negatively affect research outcomes (Rau, Goggins and Fahy, 2018). An important, and related, requirement is the need for building trust and shared understanding (Klenk and Meehan, 2015; Stock and Burton, 2011). Power mechanisms do not just occur beforehand, but continue throughout the research process as well. It is generally more challenging to build trust in heterogeneous research settings because power mechanisms are at work at different levels of the interactions (e.g. language, disciplinary values and norms, appearances, knowledge-levels).

Another issue that affects the interaction between academics and non-academics is that academic output is less accessible for non-academic knowledge users (e.g. practitioners, policymakers) who are (often) less capable of understanding and applying academic knowledge. Academics could make an effort to tailor their message towards the 'general public' but it is often not clear who these receivers and users in general audiences are. Moreover, non-academic audiences are generally less valued by academics, researchers publishing in non-academic journals and reports receive less academic prestige for their work, and it does not contribute to academic performance standards, as mentioned under organisational conditions (Rau, Goggins and Fahy, 2018). Hence, academics may lack motivation to engage in collaborative research efforts especially when it does not directly contribute to their academic career (Klenk and Meehan, 2015).

3.4. Skills and competences

A fourth category is that of skills and competences, which refer to the qualities and capacity of researchers to engage in collaborative research. Besides the qualities one needs to be a good researcher, collaborative engagements require social competences (group dynamics, communications skills). To have the right skills influences the willingness to engage in collaborative research. What can be concluded here is that for example in academia there are limited training opportunities with respect to acquiring relevant skills to participate in collaborative research, e.g. communication and outreach skills. But also, management

training to coordinate collaborative research seems to be lacking. Moderation skills to manage conflict laden group processes are crucial to deal with the confrontation between different conceptual, epistemic and practical challenges (Rau, Goggins and Fahy, 2018). As long as these skills and competences lag behind, collaborative research processes will negatively affect the appreciation of and the willingness to work in collaborative research settings.

3.5. To conclude

Based on the above we can conclude that collaborative research does not only depend on the motivation of individual researchers, but that there are many necessary conditions that need to be in place. Willingness and motivation are the basis, but collaborative practices are done within a specific context that influences the willingness and ability of researchers as well. Efforts from funding bodies such as the European Commission to stimulate collaborative research are highly important[16]. Yet, Winksel (2014; 2018) has shown for example, that simply opening up funding opportunities for interdisciplinary research in the energy field is not enough to establish a better synergy between natural and social sciences. Academics need a supporting system to create the right circumstances to conduct collaborative research, and this requires more a fundamental transition of the academic system – this is especially important to create better opportunities for transdisciplinary research and transformative sciences. Stock and Burton, having done an extensive literature research on collaborative archetypes of research remain critical as well, by raising the practical concern that "*transdisciplinary ... research is an exception, even interdisciplinarity is seldom reached*." (Stock and Burton, 2011, p.1098). Due to the lack of a supportive infrastructure, the lack of a suitable research approach and communication issues (Stock and Burton, 2011). Working towards a broadly accepted organisational and quality assessment framework is an important step in this process. In the following chapter we will give some ideas how to create a framework to conduct, monitor and evaluate collaborative research based on our literature research.

16 For example: https://publications.europa.eu/en/publication-detail/-/publication/4365f75a-5efe-11e8-ab9c-01aa75ed71a1/language-en, https://ec.europa.eu/futurium/en/digital4science/why-should-interdisciplinary-high-risk-research-disruptive-technologies-be-supported, https://ec.europa.eu/research/openvision/pdf/rise/allmendinger-interdisciplinarity.pdf, https://publications.europa.eu/en/publication-detail/-/publication/5b2811d1-16be-11e8-9253-01aa75ed71a1/language-en [accessed online 31-10-2018].

4. Towards actionable perspectives

There is an increasing amount of academic literature that seeks to offer quality assessment frameworks that allow for the monitoring and evaluation of transdisciplinary and transformative science. These frameworks are usually not unambiguous nor standardised. A consensus regarding a comprehensive quality assessment framework is currently lacking (Bark, Kragt, and Robson, 2016; Luederitz et al., 2016; Miller et al., 2008; Miller et al., 2010; Popa, Guillermin, and Dedeurwaerdere, 2015; Rau, Goggins and Fahy, 2018; Schneidewind, 2018). This hampers the ability to design an approach for different collaborative types of working that takes into account the necessary conditions for that collaboration, but it also hampers the ability to monitor and evaluate the collaboration process, and it hampers the ability to evaluate the quality of the outputs or outcomes. The fact that collaborative processes are also reflexive learning processes about the validity of knowledge, perspectives etc., increases the complexity of monitoring and evaluating of collaborative research. In this chapter we do not seek to offer a standardised framework that solves all these issues, rather we offer building blocks that could help to develop a framework suitable for the research issue at stake, and that fits in the circumstances in which the research will be conducted. We conclude this chapter with recommendations for the European Commission to facilitate better opportunities for collaborative research and create more flexibility for researchers to adapt to context and research specific requirements.

4.1. Deciding what type of collaborative research is necessary

When thinking about a framework to design, conduct, monitor and evaluate collaborative research, it is first of all important to consider that different archetypes of collaborative research have different objectives. The first step towards a framework thus is to reflect on a set of guiding questions (which we have derived from literature on quality assessment frameworks and monitoring and evaluating collaborative research) that can help to decide what type of research format is most suitable in light of the problem. These questions are depicted in figure 1:

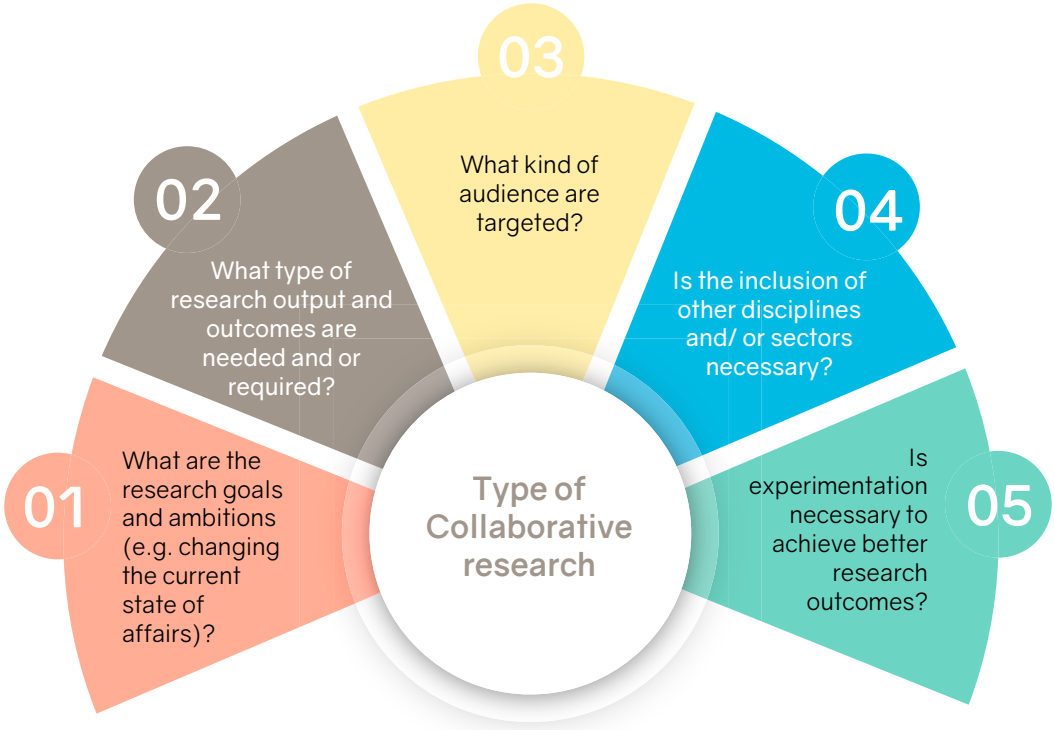

Figure 1: Selecting a Collaborative Research format

Answering these questions will help to identify what type of collaborative research is most suitable, but as argued in the above, the various types of collaborative research do not offer unambiguous guidelines for the practical organisation and research design. The following step is to identify and undergo a reflexive process focusing on the four constitutive elements of collaborative research: organisational, social and relational, skills and competences, and philosophical conditions, and determine if these conditions are needed and if yes, if they are sufficiently present. As mentioned before, reflexivity and a continuous learning process is a necessity for collaborative research types that aim at solving complex energy transition issues. Discussing what type of collaborative working is needed, why, and how this is to be set up, what inclusion mechanisms are at work would need to be included in any framework focused on interdisciplinary, transdisciplinary and transformative science.

Multidisciplinary and interdisciplinary types of research are concerned with a particular problem that can be understood and solved through setting up a pre-defined methodological procedure which is reliable and can be validated, and for which in a sense an unambiguous quality assessment framework is possible. Unfortunately, the quality of transdisciplinary and transformative research cannot be as easily determined by simply defining pre-set robust procedures, solid methodologies and predictions based on a quality assessment framework. Transdisciplinary and transformative research processes are too diverse (and open-ended) in terms of theory and method. The main challenge is therefore, to create a framework for reflective, iterative and open questioning of the quality of the research and the work process (Lemos and Morehouse, 2005). Iteration is key to sustain the research quality, accountability and relevance of collaborative research.

4.2. Building blocks for a framework to design, monitor and evaluate collaborative research

In this section we present a reflexive guide for developing a framework for collaborative research (building blocks). This research guide is developed along the lines of the four constitutive elements of collaborative research: organisational, social and relational, skills and competences, and philosophical. The importance of finding answers to these reflexive questions should not be underestimated. As mentioned earlier, the validity and legitimacy of especially trans- and transformative types of collaborative research cannot be determined by defining pre-set robust procedures, solid methodologies and predictions because of the complexity and uncertainty of socio-ecological systems (especially connected to the interventions types of research). Moreover, questions should be raised concerning the legitimacy of involving (or excluding) and legitimising certain points of view (e.g. of disciplines, sectors and stakeholders). Figure 2 depicts these Building Blocks of collaborative research (which are detailed in the next sections):

Figure 2: Building Blocks for a Reflexive framework Collaborative Research

Creating room and means for this reflexivity is potentially the most important condition for success. Unfortunately, the validity and legitimacy of transdisciplinary research and transformative sciences cannot be determined by defining pre-set robust procedures, solid methodologies and predictions. Whilst the multidisciplinary and interdisciplinary types of research are concerned with a particular problem that can be understood and solved through setting up a pre-defined methodological procedure which is reliable and can be validated, transdisciplinary and transformative research processes are more diverse (and open-ended) in terms of theory and method. The output and target audiences also impact how the different archetypes should be monitored and evaluated. Whereas the output of multidisciplinary research and interdisciplinary research is conducted by researchers, targeted at academic audiences, and measured along academic evaluation standards (e.g. articles in peer-reviewed journals), the output of transdisciplinary and transformative research is usually more diverse in terms of contributors, audiences and format.

Energy issues and sustainability transition challenges in the broader sense are often characterised as 'wicked problems' because a complete understanding of the problem(-s) is lacking, either more, a consensus regarding the potential solutions is challenging is well. It is a contested field in which (social-cultural) norms and values play a role as well as a wide range of diverse stakeholders, political-institutional arrangements and other factors (Mourik, Robison, and Breukers, 2017). The thus necessarily experimental nature of collaborative research which is "*embedded within structures and power relations*" (Avelino and Rotmans, 2009 in Luederitz et al., 2016, p.3) requires a reflexive and continuous iterative learning process as transversal aspect at the core of research projects (Luederitz et al., 2016; Popa, Guillermin, and Dedeurwaerdere, 2015). The need for such reflexivity as a condition that needs to be in place holds

especially for complex and controversial socio-ecological issues (Mourik et al., 2015; Shove and others in Rau, Goggins and Fahy, 2018; Stock and Burton, 2011).

According to Popa, Guillermin, and Dedeurwaerdere (2015) the validation is created in a deliberative, iterative process through a Community of Practice in which reflection and social learning are key (Popa, Guillermin, and Dedeurwaerdere, 2015). It should be noted that the need to place monitoring, evaluation and learning at the core is not an exclusive issue for transdisciplinary research and transformative sciences because each type of MITT-research can result in 'unstructured pluralism' in which there is still ambiguity regarding the theoretical commitments and underlying values and norms (Popa, Guillermin, and Dedeurwaerdere, 2015). Hence, the main challenge is to remain reflective and open to questioning the quality of the research and the work process with questions such as: are we on the right track? Is there enough room for each participant to reflect on the process and content? Is there an equal playing field? These are questions that require to go back and forth between the different aspects of doing research. Iteration is key to sustain research quality accountability and relevance of collaborative research. Triple loop learning can contribute to reach this kind of reflexivity at a deeper level. In Triple Loop Learning participants are not just invited to reflect on the challenges and potential solutions based on predefined goals, but also on their own underlying views, norms, and values which contribute to rethink assumptions and to redefine the goals. In addition, they are encouraged to reflect on the paradigmatic level and question the underlying (or overarching) systemic aspects (e.g. organisational rationality or governance regime) (Kraker, De, J., 2017). These questions are connected to of the issues raised in the other four building blocks. Consequently, monitoring, evaluation and learning should be regarded as transversal aspect of collaborative research and cannot be separated or side-lined.

The Building Blocks providing a framework to design, monitor and evaluate collaborative research are quite elaborate and may, at first hand, not seem to be practical at all. It is important to bear in mind that we work from the assumption that there is a necessary shift towards a more reflexive way of 'doing research', especially in the field of sustainable and energy research. Not just because there is an urgent demand for innovation to create a sustainable system of provision, but also it could create higher quality research output and outcomes. Developing a research framework applicable to the diverse types of collaborative research does no justice to practical research challenges (Mourik et al., 2015).

4.2.1. Monitoring, evaluation and learning building blocks

Table 5: Monitoring, evaluation and learning building blocks

Reflexive Learning	Reflective questions	How to best address it
Reflexivity (reflecting on and changing existing ways of doing thing)	Are participant open to and willing to exchange ideas and be confronted with their (research) limitations. Are they open to discuss various ideas and approaches and come to a general agreement with all parties?	Create a safe environment in which participants are reassured that their ideas, perspectives and feelings are taken into account
Iterative research process between science, disciplines, sectors and society	Does the collaborative effort contribute to a broader problem definition and research scope? And does this contribute to increased reflexivity?	Organise recurring meetings to reflect on the research scope and objective Evaluate if the societal capacity for reflexivity for collective social processes has increased Evaluate the (re-)organisation of the scientific system and didactics

Interventions / implementation	What kind of intervention are needed? Who can contribute and who are the beneficiaries? Is there potential to close the gap between knowledge and action, dissemination throughout practitioners' and policy-makers' networks	Create potential to help actors to initiate and support new constellations Create potential to inject science with greater accountability
Working towards a common goal (normativity)	What kind of societal impact is to expected and how can we observe it is met? To what goal does the knowledge integration and cooperation lead? What is the context of the work described, quality of the collaborative method used to arrive at the content that is presented, how collaborative is the output? Is single, double or triple loop learning explicitly used and if so how?	Measure the impact of both the output and the outcomes. Output are the (expected) and direct research (measurable) products. Outcomes are the (sometimes unexpected) effects and impacts of research interventions, which often become visible after a longer period of time Create flexible monitoring practices in which both qualitative and quantitative indicators are used Include all participants in monitoring and evaluation practices (not just the coordinator, (project) lead or management team) Evaluate if the outcomes are sustainable and how they fit in social system changes Evaluate if the research has contributed to a deeper understanding of transformations

4.2.2. Philosophical building blocks

The philosophical Building Block contribute to create an iterative process that enables participants to reflect on underlying and often hidden assumptions, values and norms.

Table 6: Philosophical building blocks

Philosophical	Reflective questions	How to best address it
User friendly results (for scientific knowledge users) / usability	Who are the targeted audiences and how to communicate to each of these audiences? Who is responsible for communication?	Make sure the information is user-friendly Find an intermediate (e.g. a 'boundary organisation' that is used to work between science and society) that can play a role in communication efforts
Whole system research	What kind of systemic aspects, actors and perspectives are included?	Make sure stakeholders of each of these domains represented and/ or able to participate

Experiments in practice (e.g. real-world project, field labs, social labs)	What type of experiments are needed to gain expected research outcomes? And who should be included in this process?	Determine in what form and at what stage of the process these participants should be involved (and if they agree upon their role)
Academic output	What kind of academic output is required/ desired? Where is the knowledge integration and collaboration leading to?	Create interesting research challenges by spending time to confront and discuss a wide range of topics and different points of view Try to identify common areas of interest Make sure that there are novel ideas and that there is potential to publish results in journals
Confrontation between diverse methodologies and epistemologies	What type of disciplinary methodologies and epistemologies can be identified and discussed?	See academic output
Creating a shared language	How to avoid misunderstandings and miscommunication? Is it possible to create conceptual clarity amongst participants?	Bear in mind that participants have different backgrounds, knowledge levels and language (e.g. jargon) and use dialogue techniques (such as storytelling) to overcome misconceptions and misinterpretations
Synthesis of new disciplines and society	To what extent is integration of perspectives/vocabularies/ normative goals visible?	Evaluate of integration of theories and methodologies is possible and to what extent

4.2.3. Organisational building blocks

The organisational Building Blocks concern the internal and external alignment of goals and ambitions. The research goals and ambitions may not converge with practical opportunities and possibilities. In some cases, this may concern practical hurdles that, once identified, can be overcome. Whilst in other situations there are more structural problems that inhibit opportunities. It is important to identify these organisational conditions and align expectations, because it will affect the research output and outcomes.

Table 7: Organisational building blocks

Organisational	Reflective questions	What does it entail or how to best address it
Organisational complexity	How high is the level of organisational complexity? Is there a supportive infrastructure?	The higher the level of complexity, the more important the skills and expertise of the coordinator are. Make sure the coordinator has the right qualifications Make sure that the researchers receive sufficient organisational backing to conduct their research If the organisational support system is lacking, evaluate how this will affect the research

Practical framework or research design	What should the overarching research framework look like?	Find 'Best Practices' that we can be used as inspiration Contact researchers from that research project or with similar research experience and exchange ideas and experiences If possible, organise (small) seminars to exchange ideas and experiences and to discuss potential research frameworks
Level of cooperation and exchanging ideas	What kind of interactions are required between the different research participants How does the project organise sufficient support for participating stakeholders?	Try to map these relationships and connect them to the type of output and outcomes Align expectations regarding the aim and the scope
Timing	How to better align differences in time-cycles (e.g. short-term policy cycles and long-term scientific processes)?	Map relevant ongoing processes and initiatives Identify windows of opportunities
Maintenance and long-term effects of intervention	How does the project ensure that an infrastructure is developed that continues to exist beyond the project? Who carries the responsibility for the long-term outcomes (if any)?	Create a plan and assign roles and responsibilities

4.2.4. Social and relational building blocks

One of the major pitfalls in collaborative research efforts has to do with how people work together. Even when participants share the same goals and aspirations, social interaction can become a barrier that hampers successful outcomes. It is therefore important to create social legitimacy through the inclusion of diverse participants and the creation of a level playing field.

Table 8: Social and relational building blocks

Social and relational	Reflective questions	What does it entail or how to best address it
Diversity of multiple academic disciplines	Which disciplines and are involved and how do they recognise and appreciate the added value of the others? How are differences in perspectives, vision, terminology, norms/values/ goals made explicit and clear?	Ensure sufficient time to invest in the creation of a diverse research network (identifying inhibitors and barriers) Ensure to invite diverse groups of participants and reflect on who else should be invited Ensure an inviting and safe-setting for a diverse group of participants Make sure that the coordinator has sufficient moderation skills and is sensitised in identifying power mechanism in group dynamics
Diversity of multiple actors (including non-academics)	Which disciplines and (societal) sectors are involved and how do they recognise and appreciate the added value of the others? How are differences in perspectives, vision, terminology, norms/values/ goals made explicit and clear?	Same as the above Ensure to invite diverse groups of participants and reflect on who else should be invited (this could involve both diverse types of researchers as well as diverse societal groups)
Negotiation and deliberation	At what stage do different participant need to engage? And what kind of encounters are necessary to create a sufficient setting for fruitful exchanges? From which roles and with which mandates are participants involved? What are the weaknesses of measuring the outcome, quality and 'success' of collaborative research (for each of the separate types of collaboration)? E.g.	Align roles and mandates within the collaboration Collaboration is not a neutral process, negotiations, trade-offs, power relations are all part of the process. Make sure to identify these mechanisms and to address them

4.2.5. Building blocks for skills and competences

In academia, there are disciplines in which research is conducted in research groups (which is more common in natural sciences) whereas other disciplines tend to be more individually organised (such is generally the case in social sciences). The experiences in research groups are however somewhat different than collaborations with participants outside academia. In homogenous settings, it is much easier to speak 'the same language' but when a research group is more diverse it requires specific skills and competences to be able to arrive at a shared understanding. The Building Blocks for skills and competences therefore focus on creating and facilitating engagements and encounters that allow social learning.

Table 9: Building blocks for skills and competences

Skills and competences	Reflective questions	What does it entail or how to best address it
Complexity project coordination	What type of interactions will take place? And what are the potential challenges in those interactions?	Identify the engagements that are necessary for the project, and the potential challenges Make sure to use methods and dialogue techniques that address these challenges
Social learning	Do the participants have previous experience working together? Do participants acquire new skills and competences throughout the duration of the research (project)? How is the scope for action affected through the collaboration? Is it leading to enhanced capacity for the longer term? Are processed developed that encourage participation and that balance power structures? Is this leading to enhanced reflexivity? Does it lead to increased capacity on the long-term? Do the processes contribute to increased participation?	Previous experiences (both negative and positive) will affect the collaboration. Make sure to address and learn from these experiences Evaluate if participants gained new skills in Systems thinking, anticipatory competence, normative competence, strategic competence, interpersonal competence, anchor and scale up transitions and to organise productive interaction in relevant fields in society for producing impact Are translation and mediation activities and or structures put in place Ensure more understanding for diverse aspects emerging through the participation of diverse disciplines/sectors

4.3. To conclude

Working in collaborative settings is challenging because the local circumstances in which this collaboration takes place are highly contingent. Moreover, the outcomes of a transition are uncertain hence the process steps, research objectives, participants (and their roles and responsibilities) may shift over time. Instead of offering a solid and fixed framework to conduct collaborative research, we think it is more appropriate (and adequate) to offer a tool that can help to improve the outcomes. The Building Blocks are developed to reflect on these contextual conditions and how they interact with the researchers and participants involved in the collaborative research (project), and how to best address the challenges that they meet in this process. The Building Blocks are not perfect nor complete because these operational environments in which research is conducted are too complex to capture in a framework. Nevertheless, we try to offer support and inspiration to those who are willing to take up responsibility for this challenging work.

4.4. Policy recommendations

In the previous sections we addressed the issues researchers are confronted with when they engage in collaborative archetypes of research. In chapter 3 we described the conditions that influence current practices in collaborative research (e.g. organisational, relational). Although the opportunities to conduct collaborative research is gradually increasing, there are still many challenges to overcome. In the previous

section we presented Building Blocks for a framework for collaborative research that could support researchers to reflect on their work and the research setting. In this section we address issues that are related to the research context (e.g. funding, diversity) offering recommendations for those responsible for research funding and funding policies.

Challenge integration, inclusion and exclusion

Integration has become a Gold Standard in research and policy. However, especially given the difficulty in setting up functioning collaborative processes, especially those aimed at integration, we have to remain critical regarding the usefulness, the need and relevance of any form of integration and or collaboration in relation to the quality of the outcome. We also have to remain aware of the political process of inclusion and exclusion of disciplines and types of knowledge that will influence output and or results.

Project proposals should therefore be explicitly invited to discuss exactly what type of collaborative working they seek, and why, and how they are going to set this up, and also why they exclude other types of collaborative working, so that they really need to make an effort at reflexive thinking about the collaborative research processes they set up. This includes also an explicit statement on process requirements with respect to the inclusion or exclusion of diverse perspectives at the beginning of the process and during the process and how a level playing field will be guaranteed as to ensure a safe space in which relationships of trust can be built to negotiate and deliberate ideas and perspectives. This should be part both of the concept and impact and implementation sections of research proposals, e.g. Horizon2020/ European proposals.

In practice collaborative research is already quite a challenge to do. Interdisciplinarity can be done, but many conditions need to be in place to allow for good collaborative research to take place. More attention to these necessary conditions in the design of the management of projects could be a recommendation to the commission, also to liven the management and coordination section which is rather a dull thing. This means for example that the coordinator or WP leaders responsible for the integration and interdisciplinarity need to demonstrate expertise and skills of working with conflict laden and reflexive processes.

Create room for reflexivity

As discussed, the necessarily experimental nature of integration focused collaborative research requires a reflexive and continuous iterative learning process. We recommend that more attention is paid to these necessary conditions in the design of the management of projects in particular those related to create a safe learning environment necessary to create relations of trust. This means for example that the project coordinator and WP leaders need to demonstrate expertise and skills of working with conflict laden and reflexive processes and internal evaluation structures should be in place. Supervision of research coordinator and intervision between the research coordinator and participants to evaluate the research process could be a valuable addition to the day-to-day experiences with collaborative research (projects). Instead of creating evaluations in an additional administrative burden, time and resources should be available to create positive learning experiences in a safe setting. In addition, there are hardly any (independent) case studies of collaborative research (projects) available in the field of sustainable and energy research. Hence, more research is needed to open these black boxes and see what we can learn from these experiences.

Create room for experimentation

This means that the management of projects should be reflective, iterative and open for change and failing should be allowed, as long as learning from failures is facilitated. This is however not the approach in Horizon2020 and similar types of funded research programmes. If you fail you don't get paid. This paradigm of efficiency and effectiveness hampers real learning curves and denies the uncertainty and contingency of (innovative) experimentation. The review processes could allow for more experimentation with the use and usefulness of SSH in projects by valuing successful failures, as long as a reflexive learning document based on internal process evaluations is produced. This is also important to guarantee a self-critical and reflexive and independent attitude of researchers in light of their dependence on subsidies/funding that should lead to useable and practical results.

A difficult issue is that in a way, learning from failures is not facilitated in H2020 and similar types of programmes. Payment is dependent on research output rather than failures. This hampers real learning curves and exchange. The review processes could perhaps allow for more experimentation with the use and usefulness of SSH in projects, and value instead of punish failed collaboration, as long as a reflexive learning document is produced.

Alternatives to standard impact assessment

Another issue is that it is relatively difficult to measure some of the impacts of collaborative research; e.g. capacity building and learning among the public, private and civil society actors that participate in the research. Some of these aspects can be quantified, such as the impact of research on policies (references and discussions), budget allocated to policy implementations. Another issue is that some qualitative outcomes such as the impact of deliberation is often not seen as research result and/ or evaluation tool for research processes. However, valuable experience with researching change in people's perspectives, ideas and convictions and the creation of shared goals and meanings has already been acquired in the field of Deliberative Democracy. Hence, although non-existent yet, it shouldn't be relatively easy to direct efforts in creating effective monitoring and evaluation of these intangibles. This also applies to intangible impacts such as a sense of shared ownership, the creation of a more egalitarian work method, feeling of having a shared goal and real meaning, institutional investment and personal commitment (Thompson, 2017). Another challenge is that many of the impacts of collaborative research only become apparent after a certain time frame, such as the formation of new consortia (Schneidewind, 2016). Monitoring and evaluation should does also come back to a project some time after its conclusion.

Allocating resources and responsibilities

The uptake and usage of the outputs of collaborative research, especially in policy-making, is another important issue that needs further discussion. Often responsibility for the uptake of this knowledge and output is put on the researchers. However, Rau, Goggins and Fahy (2018) asks the legitimate question if more time and resources should be spent on evidence-based policies rather than placing the responsibility solely on academia. Hence, more research is needed to map the social, cultural and political barriers for access and usage of scientific knowledge by policy-makers, practitioners and other diverse publics (Schuitema and Sintov, 2017).

Offer opportunities for more diverse and new engagements

Research consortia are often formed ad hoc and through formal and informal networks. Moreover, the formation of a consortium is time consuming, requires substantial organisational efforts whilst the chances of success are uncertain. Only organisations with substantial organisational and financial capacity are able to lead consortia. Obviously, this is a necessary requirement to ensure viability and credibility and make sure that the money is well-spend. However, these processes and requirements have an exclusionary effect. Either certain groups, disciplines and researchers with minority opinions or novel but experimental ideas are less visible or less viable as consortium partner. Or, if there is an explicit requirement to include certain perspectives or certain minorities (e.g. gender quota), some partners might be invited solely to match the requirements (e.g. end-of-pipe measures). The matchmaking Horizon days could be reorganised to facilitate meetings between different disciplines, sectors and societal groups, and perhaps also explicitly discuss for example the added value of different SSH disciplines to certain topics. Funding bodies can play an important role in making the contribution of SSH to societal challenges more visible and stimulate better synergies between diverse disciplines and sectors. Setting up a (continuous) dialogue with researchers and societal actors may contribute to creating an actionable vision on collaborative research[17].

Create room for boundary organisations

17 Such as the joint effort of Hera and Norface for SSH-research, http://heranet.info/2018/02/08/hera-and-norface-publish-research-beyond-borders/ [accessed 21-11-2018]

Boundary Organisations are organisations that mediate between sciences and practice. Often, they work in the field of applied research, conduct action-oriented research or other types of embedded and field research. The advantage of these types of organisations is that they are on the one hand familiar with the academic setting, language and organisation, but on the other hand, these organisations are also familiar with the demands and work settings of practitioners and/ or have experience with working in the field (with citizens, stakeholders and communities). Hence, these types of organizations could play a valuable role in communication and mediation between these diverse groups.

5. Conclusions

What we can conclude is that there is a both a need and a move towards more integrated approaches of 'doing research'. The demand for "*concrete, politically acceptable and directly implementable solutions to pressing socio-environmental problems*" (Rau, Goggins and Fahy, 2018, p.266) is ever more present in the field of sustainable research. This is due to a broad consensus that there is an urgent need to deal with environmental pollution and the impacts of climate change. SSH-energy research is concerned with both researching and intervening in a multitude of relevant energy issues with respect to climate change; such as energy behaviour or practices, but also the systems around the practice of energy provision. Moreover, it is concerned with the development and effectiveness of interventions that intend to change energy behaviour or the systems of provision. This type of research cannot lead to successful interventions without collaboration with the involved institutions, technologies and infrastructure that shape energy behaviour (Schuitema and Sintov 2017). The validity of SSH-energy research furthermore increases through collaborations with other disciplines, experts, stakeholders, and end-users, because these engagements help to expose 'errors and irregularities' in commonly shared assumptions, norms and values (Schuitema and Sintov 2017).

We can also conclude that there is not yet a broad base of literature available reflecting on how to translate this need into practice in the field of energy-SSH research (e.g. proposed frameworks, quality standards). Integration has become a Gold Standard in research and policy. However, especially given the difficulty in setting up functioning collaborative processes, especially those aimed at integration, we have to remain critical regarding the usefulness, the need and relevance of any form of integration and or collaboration in relation to the quality of the outcome. Moreover, we should also remain critical regarding the time and resources spend on evidence-based policies. Budget cuts in government spending have reduced time and resources for policy research. The financial pressure on academia is also mounting. These austerity policies should not affect research disproportionally by merely outsourcing the responsibility to deliver usable research output. Because this would affect research and policy quality standards negatively and endangers the independent position of researchers.

We also have to remain aware of the political process of inclusion and exclusion of disciplines and types of knowledge that will influence output/ results. Knowing what type of integration or collaboration is needed, how many stakeholders need to be involved, if and how iteration is necessary is closely connected to the question why a certain collaborative research format is required. And this question and its answer is so context specific that we cannot provide a definite answer. Asking what type of integration is needed (e.g. methodology, epistemology, procedures) to tackle the energy challenges we are facing, is thus not fruitful. The challenge is not necessarily to create an archetype matrix connecting each type of collaborative research with certain energy challenges, because both the circumstances in which the research is conducted (context, time, funding, organisational level, et cetera) as well as what is required for the specific research question/ problem influences the usability of that collaborative form for the specific question. This is a question that can only be answered in situ.

Instead of outlining a concrete set of guidelines for the diverse forms of collaborative research, we developed Building Blocks for a framework to design, monitor and evaluate collaborative research. These Building Blocks are developed to offer guidance and support to researchers responsible for, or involved in collaborative research (projects). In addition, we also presented a set of recommendations for those responsible for research funding and funding policies that may help to create better conditions for collaborative research (projects) to succeed.

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