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An appraisal of responsible research & innovation in ERA CoBioTech

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Monitoring & Evaluation

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Executive Summary

There have been many calls for life scientists to be socially responsible and conduct research in ways that will deliver clear public benefit. Accompanying these calls come attempts to develop indicators or evaluate what socially responsible research would look like in the life sciences. However, there are multiple competing understandings of social responsibility and public benefit, and any evaluative framework must first trace the different understandings at play.

Here, therefore, we develop an analysis of a cohort of 22 projects in synthetic biology, systems biology and industrial biology, funded by the ERA CoBioTech programme. The programme asked funded projects to incorporate research and reflection on the social, political, environmental, economic and ethical dimensions of developing and deploying biotechnologies under the aegis of Responsible Research and Innovation (RRI).

Using interpretative social scientific methodologies, we examine the way that project teams in ERA CoBioTech's first co-funded cohort situate their projects in relation to responsible research and innovation (RRI). Our analysis centres on three dimensions: the **concerns** researchers talk about; the **enactments** researchers use to act on these concerns; and the **organisational arrangements** within projects that distribute the labour associated with RRI.

Our analysis identifies nine distinct concerns, twenty different activities and seven modes of organisation relevant to RRI. This mapping offers an inventory for researchers and funders to work with when thinking about social responsibility in the life sciences. It also allows funders to reflect on the adequacy of different organisational approaches and consider how to incentivise some rather than others.

Unpacking the content of these three dimensions and making comparisons across the cohort shows us that the cohort divides roughly into two parts. One part adopts ideas, language, and activities that aim to make the project responsive to its wider societal, environmental and political context. The other part, in contrast, treats the project as a protected space, free from external input. Accompanying each major cluster was a minor cluster with projects that initially tacked closely to the ideas of the major cluster but with actions that did not match their initial rhetoric.

These two parts draw on a different idea of an appropriate science-society relationship. The distinctions between these clusters are important because they contain different ideas about how concerns should be addressed. The first cluster aims to 'open-up' concerns for debate, analysis and reflection whereas the second cluster aims to 'close-down' concerns, instead prioritising clear messaging and compliance. The two clusters also contain different ideas about whether the research project is a site for governance: Only in the first cluster — with projects that apportioned significant resources to research activities — is the answer to this question a clear 'yes'. Thus, this analysis highlights a potential gap between the request of funders to operationalise RRI at the level of the project, and researchers willingness or capacity to do so.

Having mapped and analysed the ways in which RRI is given meaning by researchers in ERA CoBioTech's first cohort, it would now be possible to develop a normative framework that allows researchers to actively design RRI processes, track progress and be accountable for their claims. Such a framework would need to consider whether all concerns are best addressed at the level of the research project.

Introduction

The ERA CoBioTech programme has asked funded projects to incorporate research and reflection on the social, political, environmental, economic and ethical dimensions of developing and deploying biotechnologies. This requirement became commonplace around the turn of the 21st Century as funders became concerned with the potential consequences of investing into a range of new scientific fields (e.g. genomics, nanoscience, synthetic biology) and emerging technologies (e.g. biofuels, geoengineering). It represents both a recognition that new scientific discoveries and technological inventions can be socially or politically disruptive, and that work is needed to legitimate large public investments, often in the hundreds of millions of euros, into these highly promissory scientific fields. While common, the rationale behind this requirement is rarely articulated coherently, and the precise goals are often elusive. Instead, it is common to see quite nebulous references to 'Responsible Research & Innovation' (RRI), 'Ethical, Legal and Social Issues' (ELSI) or 'Sustainability', without clear articulations of how these terms should be operationalised and what value will be placed on them by the funding programme.

Recognising this gap, in late 2017, ERA CoBioTech commissioned a study to survey past articulations of RRI in research policy and explain how the funding programme should improve its work on RRI and ELSI. The resulting RRI Agenda (Smith et al., 2019) defined the problem space for RRI as one concerned with the relationship between science, technology and public value — given our knowledge of the contingencies, time-lags, and lock-in that shape the way science and technology develop in society, it suggested RRI could help administrators address three longstanding questions in science policy:

1. *A question of choice:* Where should finite resources (people, money, infrastructure etc.) be allocated and where not?
2. *A question of care:* How should scientists, industrialists, policy makers, stakeholders and citizens foster science, technology and innovation to be more beneficial for people and the environment than they have been historically?
3. *A question of democracy:* Under what conditions should decision making power be devolved to relatively small groups and under what conditions would they be improved by opening them up to broad groups of citizens, stakeholders and experts?

ERA CoBioTech's RRI Agenda frames RRI as a process of knowledge production that aims to develop responses to these three questions. To translate this idea into action, and build on prior experiences with RRI, the Agenda then specified four targets to focus attention toward: Agenda Setting; Research Consortia; Cohorts and Monitoring & Evaluation.

In light of these suggestions, ERA CoBioTech has outlined its expectations toward different actors in the funding programme, including funding partners. Funders have developed guidelines for applicants and reviewers explaining how projects could work within the contours of ERA CoBioTech's RRI Agenda. New processes have been developed that offer training and guidance for applicants and reviewers, and the application review process has been modified to more clearly locate consideration of RRI within the scoring system (Smith et al., 2021b). Programme administrators have also begun to convene spaces for researchers to share experiences of research on the social, political, economic, ethical and environmental dimensions of biotechnology.[1]

[1] https://international.fnr.de/eu-activities/european-projects/european-biotechnology-and-society-online-seminar-series/

The analysis in this report is part of a larger piece of work that pilots monitoring and evaluation techniques as tools for RRI. The aim of this work is thus to ask whether and, if so, how processes of monitoring and evaluation central to the governance of science can be used to investigate, reflect and instigate discussion of (a) the kinds of bio-based economy being built by the programme and possible alternatives; and (b) the kinds of science-society relationships embedded within these trajectories.

The present report focuses on the latter of these two goals and asks two overarching questions:

1. How is the requirement to address RRI and related dimensions interpreted by funded projects?
2. What are the implications of these interpretations for the governance of science, technology and innovation?

The next section details the methodological approach taken, explaining why we draw on theory from the interpretative social sciences and how the analysis was developed. We then present an analysis of funded researchers' talk about responsible research and innovation. Focusing on three key dimensions — concerns, enactments and organisation — we show how three meanings of RRI are in play in ERA CoBioTech's co-funded cohort. Each meaning embeds different ideas about what constitutes an appropriate science-society relationship and how social responsibility in science should be distributed amongst people and organisations. The final section considers the implications of this finding for the governance of science, technology and innovation and explores what it means for a funding programme like ERA CoBioTech.

An interpretative approach to research evaluation

We develop a qualitative analysis of ERA CoBioTech-funded researchers' written submissions as part of the programme's application and mid-term phases. The analytic approach we adopt is *interpretive* — that is, it explores the way different actors generate meanings in social life — and *inductive* — that is, it was developed 'bottom-up' by exploring patterns in the data and drawing them into conversation with theory from the sociology of science. This is a significant break from common approaches to research evaluation, which usually draws on quantitative data and adopt a positivistic approach to their analysis. As explained below, these choices were both pragmatic and made to ensure conceptual coherence with recent scholarship on responsible research and innovation.

It is of course usual for an evaluation to be normative: to track progress against a set of goals, objectives or values. In the case of RRI, these goals could in theory be derived from the context of ERA CoBioTech's Agenda (Smith et al., 2019), from externally-produced lists of indicators by expert panels (European Commission, 2015) or bottom-up in workshops with people involved in the programme (Wickson and Carew, 2014). The first step in any such analysis is to define such normative criteria. However, this is challenging because many ideas in science policy effectively exhibit homonymy — they are vaguely specified and different groups bring their own experiences and assumptions to define them. National and disciplinary norms, as well as different assumptions about appropriate science-society relationships mean that multiple competing meanings circulate around ideas like RRI (Doezema et al., 2019; Glerup and Horst, 2014).

What RRI is meant to do is therefore a topic of considerable debate. Much of the academic literature on responsible innovation talks about creating space to debate the goals of science and technology, and generating democratic systems for governance of science, technology and innovation 'in the mak-

ing' (rather than ex post systems; Ribeiro et al., 2017). However, this literature needs to be set against a raft of competing understandings of what the salient concerns are in relation to science and technology. Some see RRI as a method to help science 'step outside of politics' to solve societal grand challenges, whereas others intend to act as a kind of capacity building exercise that enables scientists to reflect on the politics of science (Hilgartner et al., 2016). We also know that there are likely to be gaps between ideas of responsibility espoused by research funders and managers on the one hand and working scientists on the other (Davies and Horst, 2015; Davies and Lindvig, 2021). Here, an interpretative analytic approach can help — indeed may even be necessary — to unpack these variations and expose them to interrogation (Åm, 2019). This is a stronger and more democratic approach to governance than the alternative of papering over difference.

The realities of the funding programme also pose problems for a straightforwardly normative approach to monitoring and evaluation. It would be inappropriate to evaluate the first, and largest, cohort solely using the framing and objectives of the RRI Agenda, which was developed after the first cohort was funded, meaning the guidance developed was available neither to this cohort of researchers nor peer reviewers. Expectations about which research approaches would align with RRI were not clearly articulated, and nor were applications evaluated using the approach of later cohorts. While this is a methodological complication, the situation is common to funding programmes, which frequently specify that projects should adopt 'responsible research and innovation', 'Human Practices', 'ELSA', 'LCA' approaches without specifying what this means or how they will be assessed (Fisher and Maricle, 2015; Novitzky et al., 2020; Smith et al., 2021a). In such settings, interpretative methodologies offer a way of generating knowledge about the kind of understandings and practices in play, from which programme administrators can build normative frameworks that will actively guide practice.

If interpretative methodologies can help unpack meanings associated with concepts, what aspects of meaning-making should we focus on? In their study of senior managers within a research-intensive university Hartley et al. (2017) identify four different meanings of responsible innovation in play in the university. Each meaning emerges through a discrete fusing of practices and concerns. For instance, the practice of interdisciplinary is concerned with "allow[ing] a broader range of experts to participate in shaping the research and delivering potential benefits" whereas public outreach is "is concerned with impassioning future scientists, raising the reputation of science and increasing scientific literacy" (Hartley et al., 2017, 367). As we will see, these distinctions matter because they help to define the problem space in which science, technology and innovation operates, and begin to frame what an appropriate response within this space would be (Latour, 2004; Wynne, 2016).

In addition to concerns and practices, we might also focus specifically on responsibility and its connotations. For one, taking responsibility for something usually entails labour (Rip, 2014). If projects employ particular methodologies or approaches in association with their concerns, somebody will be doing this work. Prior studies have identified that the people responsible for it are often young, precariously employed researchers (Lyle, 2016; Viseu, 2015). While this may be for structural and epistemic reasons, and is not inherently problematic, it does begin to expose the power differentials at play within research projects. With questions of responsibility, then, it is worth paying attention to how different kinds of labour are distributed, by which actors, to whom. Projects that are organised to put the bulk of the responsibility work onto individual, junior researchers are likely working with a different understanding or responsible innovation to ones that are distributing labour amongst the project (Stilgoe et al., 2013). And projects that place the labour associated with responsible innovation in sites beyond the project may point to a gap between funders' and researchers' ideas of where governance of science, technology and innovation should happen.

Method

This research was conducted in summer 2020. We analysed 88 documents written by the 22 co-funded project teams between 2017 and 2019. As a cohort, the projects are international in nature, with between 4 and 7 partners, and representing 95 organisations from 18 countries[2]. For each project, documents included (i) a project proposal, (ii) a kick-off presentation, (iii) responses to a mid-term survey and (iv) a mid-term presentation.

The funding call required that projects adopt one or more approaches to consider the ethical, social, environmental, economic or political dimensions of their research. Funders highlighted ELSA, LCA, and RRI in the call text, presenting them as discrete methodological approaches. There was no elaboration on funders' rationales for mandating them. At both application and mid-term, projects were asked to provide a technical and lay summary of their research, as well as a statement on how they were operationalising RRI in their project. For instance, at mid-term the specific question relating to RRI read, "Please provide a short summary of your project members' research and other activities relating to Responsible Research and Innovation (RRI)." Where further information was required, for instance about the project's focus or the team's distribution, we drew on information provided on their websites.

The boundary between responsible innovation and scientific practice is porous. Much of the academic literature on responsible innovation emphasises that there should not be a clear separation between 'science' and 'RRI', instead seeing such boundaries as strategically drawn to separate science from scrutiny (Burchell, 2007; Levidow and Carr, 1997). Consequently, for ideas relating to responsible innovation, we cannot look solely at previously demarcated spaces for RRI, ELSI or some other equivalent concept. Instead, it is important to look for both explicit and implicit references to the ideas behind RRI at multiple parts of project teams' texts, i.e. in the lay and technical summaries, statements of goals, descriptions of work, description of project organisation, summaries of collaborative activities and summaries of major achievements provided in the mid-term review.

Using 'meanings of RRI' as a sensitising concept (Blumer, 1969), we coded inductively for emergent and coherent categories that would first reduce and then structure data (Coffey and Atkinson, 1996). Simultaneously, we iterated with literature in the sociology of science that would help to explain what was going on in researchers' text. We were looking for explicit and implicit interaction between project text and broader theories of science, technology and society. As described above, our analysis formed around three dimensions, each animated by a question:

Concerns. What ethical, social, environmental or political issues do researchers explicitly state or implicitly suggest are relevant to their projects?

Enactments. How do researchers' concerns map to practices in their projects?

Organisation. How do researchers organise their projects to distribute the work associated with RRI?

Subsequent sections present the results of this analysis, first showing the range of concerns, enactments and modes of organisation within the portfolio. We then zoom in on the content of the texts and compare results across the cohort. Finally we integrate the three dimensions of our analysis to assemble an overall picture of the meanings of RRI in play within the cohort. Quotes, where used, are exemplars of broader themes and patterns within the corpus.

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[2] Argentina, Belgium, Denmark, Estonia, France, Germany, Israel, Italy, Latvia, Netherlands, Norway, Russia, Slovenia, South Africa, Spain, Sweden, Turkey, United Kingdom.

Mapping the portfolio

Here, we present our mapping work, taking each dimension in turn. The aim is simply to overview the kinds of concerns researchers talk about in their text, the kinds of activities they associate with them, and the ways in which they allocate labour in light of these concerns and enactments.

What are researchers concerned with?

Our analysis identified nine concerns: alignment; data; diversity; GMOs; inclusivity; openness; reflexivity; relevance; and sustainability. Each represents a topic that researchers identified as societally, economically, politically, ethically or environmentally salient for their project. Table 1 defines each concern with a question indicating researchers' focus. For instance, concern about 'relevance' is characterised by the question, "Does the project address an environmental or societal problem?" Table 1 is supplemented by Figure 1, which offers a project-by-project breakdown of concerns within the cohort and also shows the total occurrence of each concern within the cohort.

Collectively, the concerns raised closely mirror prominent policy debates in the life sciences:

- **Sustainability** concerns were prominent around the development of biofuels in the mid-2000s and 2010s, since they have the potential to significantly impact on land use. Similar dynamics will be in play for many new technologies that create increased demand for biomass. This concern was also highlighted by ERA CoBioTech funders of being particular salience with their reference to Life Cycle Analysis within the funding call.
- **Gender and diversity**, and **openness**, as well as some aspects of inclusivity are prominent within the European Commission's RRI policy framework, and latterly its vision for 'Open Science'.
- **Alignment**, **inclusivity**, and **reflexivity** are each key concerns present with academic debates on responsible research and innovation. But the notion of 'alignment' between scientists, technologies and the citizenry, has long-been viewed as important by some corners of science policy and is, for instance, prominent within recent notions of mission-oriented research espoused by the European Commission.
- The use of techniques for **genetic modification** has been a longstanding topic of concern, arising initially with the use of recombinant DNA in the 1960s and 70s, with later attempts to bring genetically modified crops to market at the turn of the century, and again more recently with genome editing techniques. Some readings of Europe's settlement over the use of GM techniques paint it as the enduring illustration of a failure of social and scientific alignment. It is, unsurprising, therefore that concern with GMOs animate some projects.

This first, simple, analytic step highlights some key similarities and differences with respect to the way researchers in the cohort give colour to RRI. It shows that researchers cohere around three particular concerns: (i) **societal, environmental or industrial relevance**; (ii) **environmental, economic and social sustainability**; and (iii) **alignment** between scientific and societal values. However, beyond these three concerns, there is not one dominant concern that carries from project to project. Thus, while each of the three main clusters will be familiar, our analysis highlights a high degree of plurality in the concerns researchers position as relevant to RRI. This spread of issues suggests that rather than drawing from a single, coherent or stable definition of RRI, project members are drawing together concerns from a range of venues to give meaning to RRI within their own local context.

Concern	Illustrative question and key contours
Alignment	*Is the project aligned with societal goals and values?* There was a strong narrative in the cohort that science must align with societal values. One might position regulatory compliance and market choice as the primary ways in which this happens but here researchers suggest a need to go beyond such processes. Consumer rejection of genetically modified products was sometimes offered as an experience to learn from but the narratives are also pragmatic; a technology may be most useful if fits the values and needs of its users.
Data	*Are data collected, stored and managed appropriately?* This numerically small concern is uniform. Each project suggests the collection, storage and availability of data is relevant to the concept of RRI and procedural steps are proposed to account for them.
Diversity	*How diverse is the project team?* Similar to data concern, projects each locate diversity as relevant to RRI and propose procedural steps to account for it. The focus of diversity varies, ranging from gender, to ethnicity, to career-stage.
GMOs	*Is the use of GMOs accounted for in the project?* While most projects in the cohort use genetic modification techniques, some identify them as specific objects of concern and propose responses. One project advocates debate about the use of GMOs and five others suggest specific technical choices have been made regarding GMO use.
Inclusivity	*Are citizens and stakeholders included the project?* Here, drawing citizens and stakeholders into the scientific project is seen as an important facet of scientific practice in its own right. As explored later, the forms of inclusion vary with regard to timing and goals, with implications for the kinds of inclusivity fostered.
Openness	*How accessible are data, findings, and outputs?* Openness differs from inclusivity because researchers do not emphasise the inclusion of external actors in science; the central concern is the extent to which data, findings and outputs are readily accessible. Also included within this concern are questions of patenting and intellectual property.
Reflexivity	*Are implicit or explicit motivations and futures considered?* Reflexivity is an established concept within the social sciences. It has been suggested that explicit moments for reflection about prior assumptions and future consequences is important for the development of responsible science. Here, all projects refer to reflexivity in this way.
Relevance	*Does the project address an environmental or societal problem?* All but one projects claim they are addressing an environmental, societal or industrial need, which is central to the notion of RRI. However, projects define needs with varying degrees of breadth, ranging from general contributions to the bioeconomy, to sectoral challenges, to very discrete and distinct local challenges.
Sustainability	*Is the project concerned with its own environmental and sustainability dimensions?* This is the second most pervasive concern, and one that is quite homogenous. The major bifurcation is whether projects argue they are inherently sustainable (for instance because they replace a fossil fuel alternative) or whether they aim to evaluate sustainability over time.

Table 1: Summary of concerns identified through inductive coding of application and midterm text.

Figure 1: Overview of concerns identified by each of the 22 projects.

What do researchers do?

We examined, characterised and documented the methods and activities associated with particular concerns (table 2, figure 2, figure 3). We also captured points where it was unclear how a concern was acted upon by the project, i.e. where a project stated that a concern was important but offered no clear indication of what would be done about it.

Our analysis identifies a diversity of activities being associated with RRI: a total of 20 activities were identified within the cohort (table 2). They range from specific, quite-standardised methodologies, such as life cycle analysis (LCA), through general clusters of action, such as outreach, to processes that are part the project's organisation, such as the use of advisory boards. As with concerns, activities collect around a core set that includes (i) **life cycle analysis**, (ii) **humanities and social science research**, (iii) **completion of the project**, and (iv) **communication, dissemination and outreach activities**. These four activities account for over half of all instances within the cohort. As a whole, this distribution of activities strengthens our earlier suggestion that multiple interpretations of RRI are in play, but perhaps centred around a consistent core.

We coded these activities at 82 different points, meaning that the same activity or method could be invoked in relation to more than one concern. Perhaps the clearest example of this is **humanities and social science research**, which overall was coupled to concerns of alignment, reflexivity, relevance and sustainability (figure 2) and was frequently associated with two or three concerns simultaneously (figure 3). Conversely, **life cycle analysis** is the clearest singular enactment, being associated only with the concern of sustainability.

Table 3 makes the connection between activities and particular concerns more explicit by presenting a breakdown of activities per concern. If the number in the rightmost column is larger than the number in the leftmost column, projects are invoking multiple activities in relation to a single concern. For instance, in sustainability, some projects adopt **stage-gating**, **LCA** and **humanities and social science research** (again, specific project-by-project breakdowns are offered in figure 3).

Table 3 also shows whether particular activities are emerging in relation to particular concerns — a pink circle indicates that the activity makes up over 40% of the total for the concern, although some are much higher. This consolidation is clearest with concerns of diversity (monitoring recruitment & employment), data (the use of Fairdom, a data management platform), relevance (the completion of the project), inclusivity (through science communication, dissemination of findings, and outreach activities), and sustainability (through life cycle analysis). Other concerns, such as alignment, reflexivity, and openness coalesce to a much lesser extent, suggesting projects may be working with different underpinning assumptions that shape what would be a salient enactment in their context.

Activity	Description
Advisory Group	Inclusion of social scientists, external stakeholders or citizens as representatives on advisory board.
Citizen Science Project	An increasingly common and somewhat standardised approach to 'opening science' in the 21st Century. Generally, but not exclusively, refers to enrolment of members of the public in data collection and gathering.
Communication, dissemination and outreach	A range of, usually one-way, activities in which project members speak to external parties. Note that all projects were required to submit a 'communication and dissemination' plan by the funding programme.
Completion of project	Success of the project is positioned as key to ensuring responsible innovation.
Contained Use of GMO only	Used to code when project frames a particular research choice as response to concern about GM use. Discrete from ‘technological trajectory’ code because the technology may ultimately require deliberate release.
Data Sharing Plan	Production of a document and/or agreement detailing how data will be shared internally within the project and with external parties. Note that all projects were required to produce this plan as part of the funding programme.
Eco-toxicity Study	Approach within the field of ecotoxicology to appraise the potential impact of a product/process on organisms, especially at the population or ecosystem level.
Education (Postgraduate)	Lecture given to junior scientists associated with the project. The sole coding related to the topic of intellectual property (e.g. patenting).
Education (School Level)	Presentation of science to school children.
Environmental Fingerprinting	Also known as ecological fingerprinting. An approach that aims to capture the specific ecological characteristics of a product.
Humanities and Social Science Research	Inclusion of social scientists or humanities scholars as part of the research project.
Life Cycle Analysis	Somewhat standardised methodology aiming to quantify the environmental impacts of a product or process within a system of production and use. Various decisions can be made about the bounds of the system.
Monitoring employment diversity	Capturing employment data that includes gender, ethnicity breakdown. Note all projects are required to do this.
Open Access Publishing	Pursuit of one particular publishing approach to 'make science available'.
Risk Assessment	A specific approach to appraising the likelihood of undesirable consequences as a result of a particular intervention. Is the de facto standard for appraising release evaluation of GM organisms into the environment.
Stage Gating	Common approach within technology management that creates a specific decision-point through which a project must pass.
Stakeholder Engagement / Workshop	Activities aiming to engage with external parties, the most common format being a workshop. Distinct from communication, dissemination and outreach in that the actors were often identified groups (industry, policy, NGOs, consumers) and communication was viewed as two-way, although the timing of the activity within the project lifecycle varied.

Activity	Description
Techno-Economic Analysis	Methodology that appraises the technological and economic credentials of a product / process. Often incorporates modelling, engineering/technology design and economic evaluation.
Technological Trajectory	Decisions about the project's approach and the technologies it aims to produce have been made in response to the concern.
Use of Fairdom	Fairdom is a data management platform commonly used in systems and synthetic biology. It offers a standardised and open way of making data accessible to other scientific parties.
Unclear	Code used to capture an apparent gap between 'concern' and 'activity'

Table 2: Actions associated with responsible innovation in ERA CoBioTech's cohort with associated description.

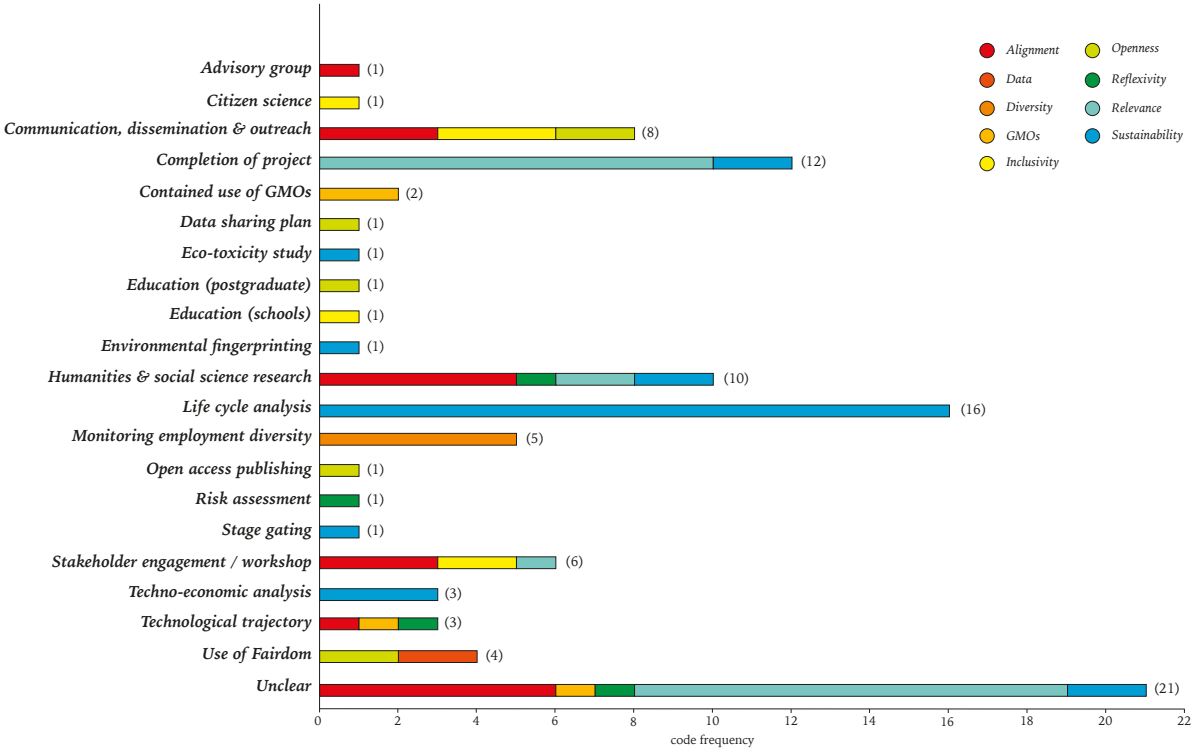
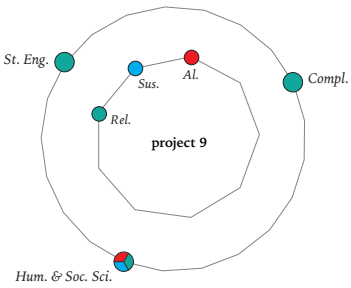


Figure 2: Frequency distribution of activity codes across the portfolio, sub-divided by concern (colour coded). Note that an activity can be coded to more than one concern by a project.

Figure 3: Overview of actions mapped to the concerns identified by each project.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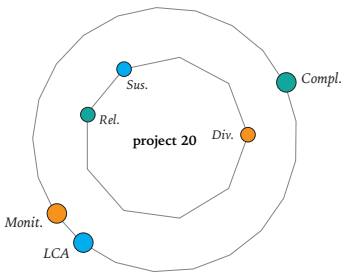
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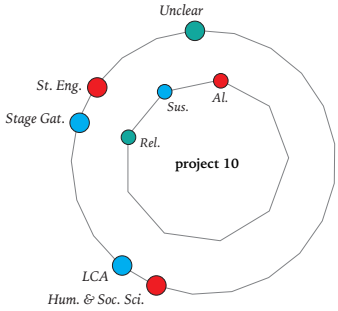
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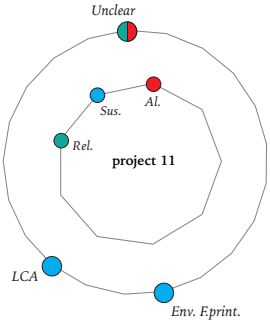
Hum. & Soc. Sci.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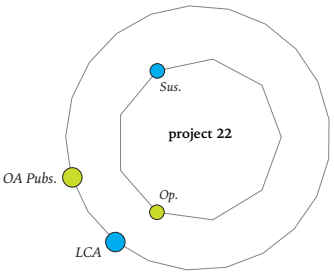
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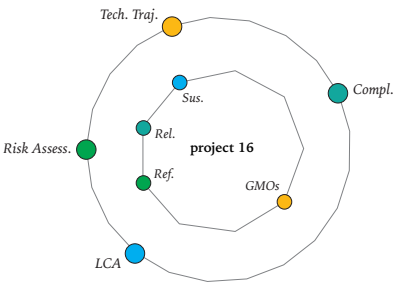
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Risk Assess.
project 16
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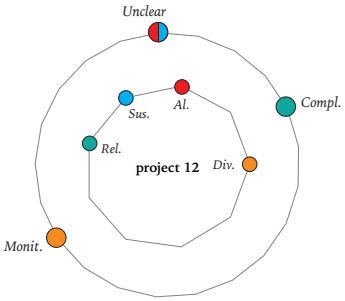
GMOs
LCA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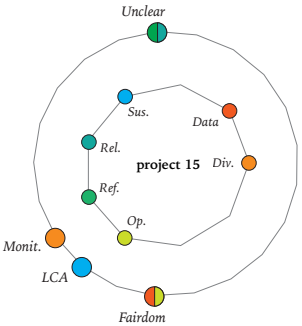
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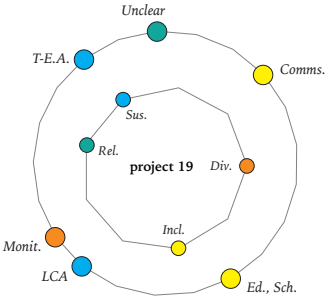
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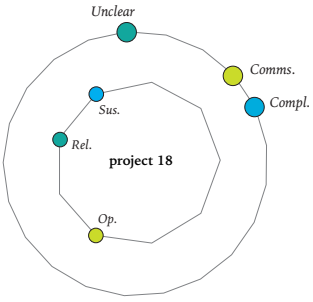
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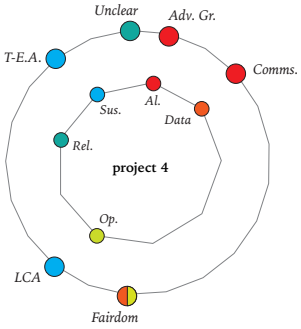
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project 4
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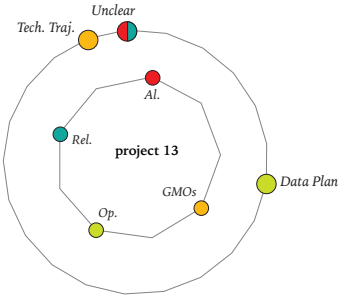
Unclear
Tech. Traj.
Al.
Rel.
project 13
Data Plan
GMOs
Op.

Concern (no. of projects)	Approach	Times coded	(total)
Alignment (14)	Unclear	6	(19)
	Advisory Group	1	
	Communication, Dissemination and Outreach	3	
	Humanities and Social Science Research	5	
	Stakeholder Engagement / Workshop	3	
	Technological Trajectory	1	
Data (2)	● Use of Fairdom Data Management Platform	2	(2)
Diversity (5)	● Monitoring employment diversity	5	(5)
GMOs (6)	Unclear	1	(6)
	Contained Use of GMO only	2	
	● Technological Trajectory	3	
Inclusivity (5)	Citizen Science Project	1	(7)
	● Communication, dissemination and outreach	3	
	Education, Science (School Level)	1	
	Stakeholder Engagement / Workshop	2	
Openness (7)	Communication, Dissemination and Outreach	2	(7)
	Data Sharing Plan	1	
	Education, Intellectual Property (Postgraduate)	1	
	Open Access Publishing	1	
	Use of Fairdom Data Management Platform	2	
Reflexivity (4)	Unclear	1	(4)
	Humanities and Social Science Research	1	
	Risk Assessment	1	
	Technological Trajectory	1	
Relevance (21)	● Unclear	10	(25)
	Communication, dissemination and outreach	1	
	● Completion of project	11	
	Humanities and Social Science Research	2	
	Stakeholder Engagement / Workshop	1	
Sustainability (20)	Unclear	2	(27)
	Completion of project	2	
	Eco-toxicity Study	1	
	Environmental Fingerprinting	1	
	Humanities and Social Science Research	2	
	● Life Cycle Analysis	16	
	Stage Gating	1	
	Techno-Economic Analysis	3	

Table 3: Distribution of actions amongst concerns within ERA CoBioTech's cohort. Circles indicate relatively prominent approaches within a given concern — pink circles mark activities occupying >40% of the total per concern.

How are projects organised to address RRI?

By extracting references to project organisation, we identified seven ways of organising the work related to RRI. Table 5 presents each category with a brief description and its prevalence within the cohort. As with activities, we also coded for situations where is was unclear what actions are actually happening in relation to RRI. Generally, this was used when projects made a claim that something would be done in the application stage and failed to mention it in the mid-term review. This initial mapping shows two dominant ways of organising work in relation to RRI — either as a discrete work package or through a series of individual activities that may or may not be tightly integrated into the project's core content.

Organisational Feature/ Form	Description	Times coded
Studentship	Associated studentship to examine defined aspects of the project.	1
Discrete LCA	Specifically defined LCA conducted by members of the research project. This mode of organising LCA tends to function as a form of research.	1
Outsourced LCA	LCA conducted through sub-contract by external party. Here LCA functions as an appraisal of the project/product/process.	4
Work package	Use of the work-package organisational structure to locate activities relating to responsible innovation. May vary with regards to whether the WP is 'management' focused or 'research' focused. May also vary regarding the level of cross-project input.	9
Unclear practice	Used to capture points where it is unclear what action is actually happening under the banner of responsible innovation. Most commonly used to capture a disjuncture between claims made in the application and activities reported in the mid-term review.	4
Multiple individual activities	Projects list a range of activities and attribute them to individual partners. Distinct from Work Package in that no clear organisational structure is offered; activities also tend to be additional to the core research.	7
Collective success	Project organisation is presented as a collective endeavour, with all partners responsible. Because the project is inherently responsible, responsible innovation depends on its success.	3

Table 5: Different organisational arrangements for RRI within the cohort.

Comparing projects in the portfolio

In this section we look into the content of researcher's text and compare projects with one another. We take each analytic dimension in turn before considering what the analysis as a whole tells us. As a whole, our analysis identifies common approaches around which mutual learning may occur, examines divergences within approaches, and examines potential gaps or blockages between the ambitions and reality of RRI-in practice (c.f. Rabinow and Bennett, 2012).

Understanding the differences between concerns

By examining the content of researchers' responses, we can unpack the kinds of meaning being given to RRI by ERA CoBioTech researchers and unearth embedded assumptions. This shows that some concerns are quite homogenous whereas others are heterogeneous.

Relatively homogenous concerns include **data**, **diversity**, **reflexivity**, **relevance** and **sustainability**. Diversity is always presented in terms of gender balance to be monitored:

> "it will be ensured that gender issues in recruitment, decision-making, research and dissemination will be considered and equally balanced." (Project 20, application)

Or take this archetypal quote about reflexivity:

> "Scientists should increasingly reflect on their visions and presumptions, including positive and negative impacts of their work on society. An effective process of learning about making research and innovation responsible to the needs of society is supposed to emerge through processes of anticipation, reflection, and inclusion." (Project 1, application)

Relevance is a large, homogeneous, concern incorporating statements from all but one project. It turns around an understanding that research should be driven by and contribute to a meaningful societal or environmental need. Sustainability, a similarly large concern, is frequently framed in terms of a product or process that will be assessed and quantified through life cycle analysis. The three projects (Projects 3, 12, 18) that depart from this framing do so in ways that state the importance of sustainability and then move to claim their products will be inherently sustainable, e.g.:

> "The new processes can achieve a significant environmental impact by replacing more energy and resource intensive processes, leading to reduced environmental footprints and lowering our dependence on fossil raw materials." (Project 18, application)

The more heterogeneous clusters are **alignment**, **inclusivity** and **GMOs**. With each, a salient distinction relates to the way in which concerns are framed and then acted upon. For instance, some frame GMOs as a settled political concern and modulate their research project in response to avoid their use. Others position the concern as one of continued public rejection that must be rectified.

Thus, we can see that while each concern represents a shared target, in some instances researchers' discourse frames concerns in varying and distinct ways, drawing on different logics and embedding distinct assumptions, with a key faultline being whether the project is organised to inherently address it, or whether some kind of action will be required in response.

Comparing enactments

The activities we identified have differing relationships to the actual research projects being conducted (table 4). Some, such as humanities and social science research, some forms of life cycle analysis and other appraisals, as well as citizen science projects are forms of **research** in their own right. They are part of the scientific research process. Other activities, such as communication dissemination and outreach activities, or educational exercises, and — if it occurs at the end of the project — life cycle analysis, are best thought of as **adjuncts**, that is 'bolt-ons' to the core scientific activity. Finally others, such as the use of advisory groups, pursuing particular technological trajectories, and stage-gating are concerned with the **operational** dimensions of science, that is the ways in which it is developed and amongst which constituencies.

An activity's relative position within a project is likely to affect whether researchers consider it essential or a luxury/imposition. It is also likely to affect whether the activity serves to 'open-up' the project and foster substantive engagement with the related concerns or whether it is more likely to 'close-down' discussion of the concerns (Stirling, 2008). Because they require inquiry, analysis, resources and time, research activities will generally open-up concerns. Because they are treated as something distinct from the scientific research and are often lightly resourced, adjuncts are likely to close-down concerns. Interesting distinctions happen with operational activities. Stage-gating and advisory groups are likely to open-up concerns, because they embed explicit deliberation and decision making structures into the project. In contrast, enactments such as completion of the project, and open access publishing are likely to close down discussion of the concerns because they do not create such deliberative structures; the decisions have already been made.

Opening-up could be seen as an attempt by researchers to 'care for the concern', whereas closing-down could be seen as an attempt to 'take care of' the concern (Evans and Frow, 2016). These distinctions are significant because they have different implications for where governance should occur: In the former, the research project is an active site of governance, whereas in the latter the research project is a subject of governance — debate and decision making is something that happens elsewhere and impacts the project. If responsible innovation is about creating space for active forms of governance and debating the shared trajectories of science, technology and society, but the methods adopted by researchers do not create this space, then there is a need for funders to engage substantively and open-up the tools of governance that projects defer to when they try to take care of the concerns.

In addition to examining what different enactments are likely to do, we can also examine how substantively concerns appear to be treated by researchers in projects. To do so we compare the framing of the concern and its associated enactments with the range of debate beyond ERA CoBioTech. In doing so, three concerns in particular seem to receive a relatively 'thin' level of engagement: data, gender and intellectual property. Data, how it is produced and used, has become a central concern within science policy and contemporary societies more broadly. This concern is visible in policy reports such as the Royal Society and British Academy's (Royal Society and British Academy, 2017) Data Management and Use: Governance in the 21st Century, which examined the role of data in the context of RRI, prominent European legislation such as Directive 95/46/EC (Data Protection Directive), as well as in narrower debates about the appropriate ways for scientists to 'care' for the data they create and make claims from (Fortun, 2005). But within this cohort, the ways in which researchers' claim to act upon this concern is to defer to institutional structures such as data sharing plans and open access repositories. Similarly, concerns about gender and diversity — more broadly construed — are salient in contemporary science. There are rich theoretical traditions within feminist studies and post-colonial studies of science from which to draw. However in this cohort gender

and diversity when it is identified as a concern is enacted primarily through employment monitoring, an extremely limited approach to the concern. Similar points can be made about the cohort's engagement with intellectual property.

Type	**Activity**
Adjunct	Communication, dissemination and outreach
	Education & Training
	Life Cycle Analysis (Final-Product/Outsourced)
	Stakeholder Engagement (End of project)
Operational	Advisory Group
	Completion of project
	Contained Use of GMO only
	Data Sharing Plan
	Monitoring employment diversity
	Open Access Publishing
	Stage Gating
	Technological Trajectory
	Use of Fairdom
Research	Citizen Science Project
	Environmental Fingerprinting
	Eco-toxicity Study
	Humanities and Social Science Research
	Life Cycle Analysis (Real-Time)
	Risk Assessment
	Stakeholder Engagement (On-going throughout project)
	Techno-Economic Analysis

Table 4: Activities categorised according to their position in relation to the research project.

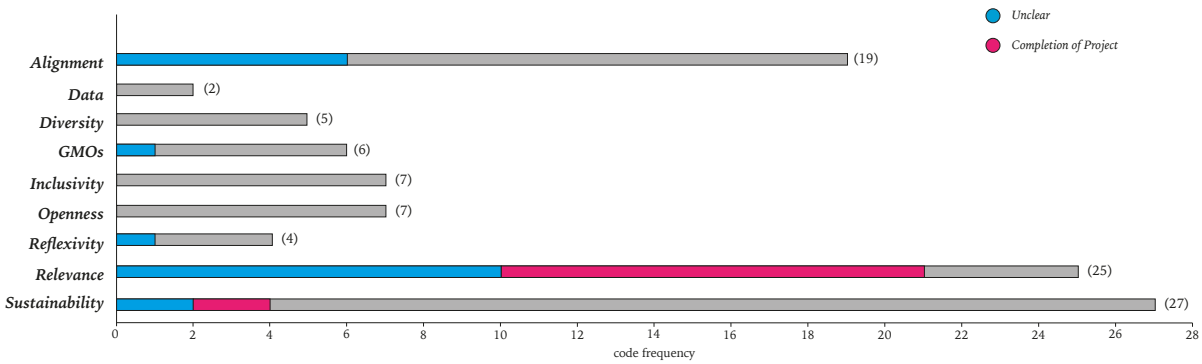

Figure 4: Distribution of 'unclear' and 'completion of project' enactment codes within the cohort, backgrounded by the overall frequency of enactment codes per concern.

Finally, our use of the 'unclear' code highlights 20 instances (figure 4) where it was not apparent how the concerns identified by researchers in their applications translated into any tangible activities. What can this tell us about governance? The figure emphasises that the majority of unclear codings are attached to two concerns, alignment and relevance, but each tells a slightly different story.

Fourteen projects identify alignment as a salient concern but six offer no explanation of how the concern will be engaged with. Here, the relative distribution of activities follows the faultline outlined in the earlier sections of the report - there are two subsets turning around the question, '*how should the project respond to societal concern and stakeholder values?*' The first subset adopts a passive approach to alignment, either explicitly or implicitly suggesting that the concern will be addressed by completing the research, i.e. the research project is inherently aligned with public values or addresses a meaningful societal need. The second subset tends to adopt an active approach to alignment and relevance, by locating quite resource-intensive activities — stakeholder workshops, and humanities and social science research — as central to ensuring the project addresses a meaningful societal need and is aligned with public values.

Twenty-one projects — that is, all but one — identify relevance within their salient concerns but almost half of them offer no explanation of how the concern will be engaged with. Here, the high concentration of the unclear code, highlights a similar but slightly different set of dynamics. Every project that identifies relevance as a salient concern within the cohort is coded with either 'unclear' code or the activity 'completion of the project'. Only three projects — 7, 2 and 9 — include activities beyond these codes. Relevance in this cohort, thus tends to be positioned in the following manner:

> "Rapid advances in biotechnological engineering combined with increased environmental awareness among consumers and increased number of new environmental legislations, has led to serious consideration of biological surfactants as possible alternatives to their chemical/ synthetic counterparts. Therefore, the […] project aims at producing novel and eco-friendly biosurfactants in a cost-effective manner through lab-scale validation, to a bio-process demonstrator within a real environment." (Project 8, application)

Rather than relevance being presented as a concern for researchers to address, the project is presented as being wholly driven by a societal and environmental need. Thus, relevance tended to act as an overarching narrative for the entirety of the project's text. Aspects such as 'directionality' and the ability of public research to address meaningful societal and environmental challenges are central to all mainstream conceptions of responsible innovation (Stilgoe et al., 2013; Stilgoe and Guston, 2016; von Schomberg, 2013) but the vast majority of research projects suggest these questions should be

addressed elsewhere in the research process. There are, then, significant questions as to where within the funding programme such aspects should be addressed. We now turn to a final analytic dimension, which examines the ways that projects distribute responsibility.

Distributing responsibility

Understanding how projects ascribe moral labour will further allow us to understand where they 'place' concerns — whether they place them as things to be addressed within the project, or whether they position them elsewhere within the research landscape. We can achieve this analysis by using insights from the social sciences to establish a two-by-two matrix (figure 5).

The X-axis maps whether responsibility is **delegated** or **embraced**. It draws on the fact that there are different kinds of responsibility and corresponding forms of labour. We might, for instance, distinguish between general responsibilities versus narrow role responsibilities (Douglas, 2003; Douglas, 2014). General responsibilities may be those we have as citizens or responsibilities to society (Wilsdon et al., 2005) whereas role responsibilities are specific to, for instance, a given profession. Wholesale rejections of responsibility are rare but delegations of responsibility are common. The phrase 'it's not my responsibility' is a simple example of this practice — this isn't a refutation of the responsibility but a delegation to an 'other'. Social studies of science have shown how certain kinds of responsibility are likely to be embraced while others are more likely to be delegated to others (Kerr et al., 1997). This is visible in scientists' talk about animal experimentation — narrow role responsibilities about care for individual animals are embraced as part of good science, whereas broader questions about the use of animals in science are delegated to others (McLeod and Hartley, 2018).

The Y-axis maps who responsibility is ascribed to — is it **individual** or **collective**? In liberal democracies, the most common way of ascribing responsibility is to an individual with a mechanism of accountability or liability. However, it has been argued that less common ideas of collective responsibility may be better suited to science and technology (Pellizzoni, 2004). Despite the myth of the individual inventor, transformative innovations commonly emerge from particular cultures, constrained circumstances and through processes of technological convergence, making it difficult to assign responsibility for success or failure to a single individual (Spruit et al., 2015; Stilgoe et al., 2013).

While some of the studies above express preferences toward one form or another, here the goal is to use the matrix as a heuristic to see which tasks are attributed to which groups of people, and consider the potential tensions therein. This is important because past research has pointed potential gaps between the ways that researchers conceptualise responsibility and the way that policy organisations do (Davies and Lindvig, 2021). The four quadrants are:

- **Individual and Delegated** (**Blue**) — RRI activities are discrete and delegated to an individual entity (individual or organisation) outside the project.
- **Individual and Embraced** (**Green**) — RRI activities are embedded within the project, and assigned to an individual through a specific task or, most commonly, a work package.
- **Collective and Delegated** (**Pink**) — RRI activities are claimed as collective but it is unclear who has ownership of them, or they are actively outsourced.
- **Collective and Embraced** (**Yellow**) — RRI activities are owned broadly, either as a series of inter-related individual activities or through collective engagement in a work package.

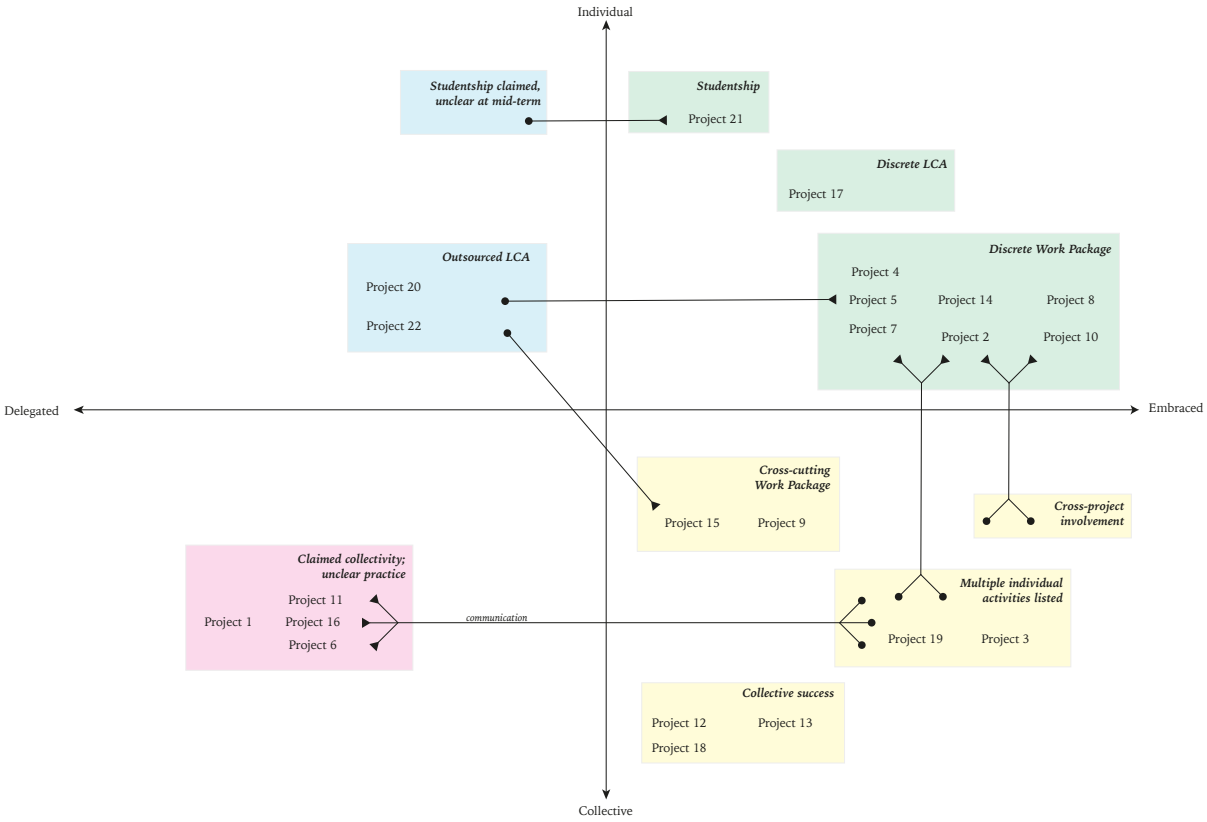

Figure 5: Distribution of projects according to whether their organisation of responsible innovation approaches delegates responsibility or embraces it, and whether they ascribe individuals or take a collective approach. Connecting lines identify extensions from the dominant approach (triangles) to additional aspects (circles) For example, a project may have a discrete programme of research but outsource the completion of an LCA to a third party.

The seven ways of organising work from table 5 are mapped onto the two-by-two matrix in figure 5. Projects including multiple dimensions are indicated with the black lines tracking from the major form (triangle) to the minor form (circle). For instance, project 5 (in the top right quadrant) organises its work into a discrete work package but the LCA is outsourced to a third party. The matrix thus shows a range of contrasting approaches to distributing labour for RRI. We examine this below, moving across the matrix from left to right.

The most likely activity to be outsourced is the conducting of LCAs. LCAs that have been outsourced to third parties are included with four projects: Projects 20, 22, 5 and 15. This dynamic is visible because LCA has become a discrete and increasingly standardised methodology, requiring specific expertise, and is widespread within industrial settings. It is therefore easy to bound and outsource. In itself outsourcing responsibility for this task is not inherently problematic. However, the practice does raise questions about the ways in which this information can be used by researchers to shape practice and make decisions. For the two projects for which LCA is the only active component of work on responsible innovation (Projects 10 and 22) this outsourcing also suggests the projects operate within a framework that largely delegates responsibilities to outside parties while the project team focuses on pursuing technology development.

A second form of delegation is also visible. Here, claims were made in project applications but failed to translate into tangible activities. Perhaps the most important instance of this to flag is the approach of Project 21, which initially effectively delegated responsibility for appraising the environmental dimensions of the project to a Masters student but has not subsequently discussed this work. Other projects (Projects 1, 11, 16 and 6) use discourse that closely mirrored academic literature on responsible innovation in the application stage but fail to translate into any tangible activities. Instead, what seem to emerge in practice are a series of individual communication and monitoring activities.

The majority of projects (n=15) embrace responsibility by distributing specific tasks to individual partners, a range of individuals, or the project collectively. The most common approach (n=8) is to collect responsible innovation activities in as a standalone work package that one partner is responsible for leading. For the majority of these projects (n=6) this is a discrete activity, conducted independently from other partners. However, two projects (9 and 15) frame the work package as being collectively owned by all partners, and two others (10 and 2) frame the work package as being led by humanities and social science researchers, with participation of all other project members through interview, workshops and reflexive exercises.

Two projects (7 and 2) collect work into a discrete work package but supplement this by distributing distinct, additional, activities to individual partners. This approach is adopted by project 3 and 19 but without a discrete work package, and is also adopted by the four projects that delegate labour, discussed above. As previously discussed, the activities within this cluster tend to be discrete management activities, such as oversight of data sharing, diversity monitoring and science communication, which is widely embraced. Less clear within this category are the audiences being communicated with and the forms that communication takes. Preliminary analysis of other parts of the mid-term report suggests these are primarily academic and industry audiences through talks rather than engagement with stakeholders and policy audiences.

Finally, we see that some projects (12, 18 and 13) frame responsibility as collective. However, this framing is only possible because the projects are framed as inherently responsible, meaning that success is collective and, because it depends on all partners, the responsibility is also collective. This framing is notable because it applies to all other projects but isn't mobilised by them. The next section integrates each part of our analysis to date.

Three understandings of RRI in ERA CoBioTech

Having considered three dimensions (concerns, enactments and organisation) through which responsible research and innovation is given meaning, we can now look holistically at each project's position within the three dimensions of the analysis. This gives an overarching picture of the first ERA CoBioTech cohort. It shows that when the three analytic dimensions are overlaid the cohort divides into three clusters through which RRI is given meaning (Table 6). The clusters are salient because they have different implications for governance and the allocation of responsibility within the research programme.

Cluster 1 - Active engagement

These projects stabilise around a meaning of RRI that treats the research project as an active site in the governance of science, technology and innovation. The primary, unifying, concern is one of

Model of responsibility	Projects	Concern	Enactments	Organisation of labour
Active Negotiation (8)	Projects 2, 4, 5, 7, 8, 9, 10,14	Alignment (7) Data (1) GMOs (2) Inclusivity (2) Openness (1) Reflexivity (1) Relevance (5) Sustainability (6)	Advisory Group (1) Citizen Science (1) Communication & Dissemination (3) Completion of Project (5) Contained Use of GMOs (1) Eco-toxicity Studies (1) Humanities & Social Science Research (5) Life Cycle Analysis (Final Product; 2) Life Cycle Analysis (Real Time; 3) Modulation of Technological Trajectory (2) Stage Gating (1) Stakeholder Engagement (5) Techno-Economic Assessment (1) Use of Fairdom (1)	Work Package, Discrete (5) Work Package, Discrete w/Cross Project Involvement (2) Work Package, Cross-Cutting (1)
Linear Model (8)	Projects 6, 11, 12, 13, 16, 17, 18, 20, 22, 22	Alignment (1) Diversity (2) GMOs (2) Inclusivity (2) Openness (4) Relevance (5) Sustainability (7)	Communication & Dissemination (3) Completion of Project (5) Contained Use of GMOs (1) Data Sharing Plan (1) Environmental Fingerprinting (1) Life Cycle Analysis (Final Product; 6) Modulation of Technological Trajectory (1) Monitoring (3) Open Access Publications (1) Techno-Economic Assessment (1)	Claimed Collectivity (2) Claimed Studentship (1) Collective Success (3) Outsourced LCA (2)
Patchworks of Responsibility (5)	Projects 1, 3, 15, 16, 19	Data (1) Diversity (3) GMOs (1) Inclusivity (1) Openness (2) Reflexivity (1) Relevance (2) Sustainability (4)	Communication & Dissemination (1) Completion of Project (2) Education of Postgraduates (1) Education of School Children (1) Life Cycle Analysis (Final Product; 3) Life Cycle Analysis (Real Time; 2) Modulation of Technological Trajectory (1) Monitoring (3) Risk Assessment (1) Techno-Economic Assessment (1)	Claimed Collectivity (2) Discrete LCA (1) Multiple Individual Activities (2) Work Package, Cross-Cutting (1)

alignment of scientific and societal values, which is addressed through research and/or two-way dialogue with various groups, and organised into a work-package. Most frequently, the research involves collaboration across the natural sciences, humanities and social sciences. The majority of projects (e.g. 5, 7, 20, 14) position methods such as citizen science and stakeholder workshops to draw people into conversation about the project's purposes, goals and uses. A minority (e.g. 9, 4) mobilise social and environmental assessment methodologies, suggesting that this will help to make decisions about particular technological trajectories at a given in the future. Others mobilise eco-toxicology work to understand the ecological impacts of their work (e.g. 8). In effect, the consortia in this cluster function as multidisciplinary research projects with specific methodologies employed to draw consideration of the concerns into the project.

Cluster 2 - Linear model

These eight projects emphasise either that the research is already sustainable and responsible, or that these concerns will be addressed at a point later in the research process, at the end of the project. The methods articulated by these projects do not aim to open-up research and instead locate the salient sites of governance away from the core research. Their use of Life Cycle Analysis here is instructive. In contrast to cluster one, LCA is treated not as a form of research that can help direct the project's development but instead targets a final product and is usually conducted by an outsourced third party. Other activities take the form of 'adjuncts', such as outreach activities, or 'compliance' with existing governance procedures, such as gender monitoring and open access publishing.

Cluster 3 - Patchworks of responsibility practices

The two clusters above are well-established within the literature. They track largely with distinctions between 'realist' and 'constructivist' ideas of science and society that became established in the 20th Century. In the realist camp, science is something special to be defended from social influence, with politics occurring elsewhere. In the constructivist camp, science is inherently social and full of value laden choices; rather than disavow this, the task is to make the value judgements explicit. Projects in cluster three in contrast, offer a complicating set of narratives that can be best described as 'patchworks of responsibility practices'. As a whole, the projects in this third cluster start by articulating their work in ways that closely mirror one of the two major clusters but at mid-term review shift to report different sets of individual, somewhat piecemeal, activities.

Three of these projects' discourse (1, 15, 16) is similar to that of cluster 1. The concerns centre around reflexivity, uncertainty and the need for 'active work' to understand the trade-offs around the development and use of biotechnology. At the research proposal stage they suggest, for instance, that LCA-compliant data will be collected throughout the project and then be used to inform decision making in a stage gate decision point, or that they will develop novel risk assessment methodologies to explore the unintended consequences of research. But at the mid-term review stage it is unclear how these claims have been translated into practice. Instead, what seems to be clearly acted upon are concerns and actions around gender monitoring, open access and data sharing.

The two remaining projects in this cluster (3 and 19) closely track cluster 2 in their application discourse but at the mid-term they report extensive lists of individual 'responsibility practices' from each partner organisation. These projects coalesce around scientists taking active responsibility for their work but the ways in which this happens are ambiguously connected to the funded research project. Instead what is alluded to is closer to an ecology of spaces for responsibility practices, which are distinct from the project but part of the landscape in which it is situated. As a whole, the projects

in this third cluster start by articulating their work in ways that closely mirror one of the two major clusters but at mid-term review shift to report different sets of individual, somewhat piecemeal, activities. Here, it is notable that four of the five projects include researchers in institutions with existing significant social scientific, sustainability sciences, or RRI work and researchers point to this capacity in their responses (NTNU, Wageningen University, TU Delft, and Leuphana University of Lüneberg). As discussed, the clusters have specific consequences for the governance of biotechnology, to which we now turn.

Implications of the analysis for governance

Any evaluation offers the potential for both accountability and learning. Here, we are aiming to use the data generated as part of monitoring and evaluation processes to understand the kinds of science-society relationship being imagined and constructed within ERA CoBioTech's portfolio. The purpose of this analysis is provide evidence on which existing institutional features, such as monitoring and evaluation processes, can be used as tools for innovation governance (the active steering of science). We adopted this perspective because it aligns with broader idea of responsible innovation — which aims to create space to reflect on the different ideas and assumptions embedded within science, technology and innovation — and because it allowed us to complete a robust analysis in this particular policy setting. It would have been inappropriate to retroactively impose a normative understanding of RRI to evaluate a cohort that was not provided with it.

As a whole, the report has been guided by two broad questions. First, how is the requirement to address RRI and related dimensions interpreted by funded projects? Second, what are the implications of these interpretations for the governance of science, technology and innovation? In moving through the discussion, we iterate between these two questions, first summarising the major findings of this analysis, exploring tensions in the different meanings of RRI within the cohort, and articulating why they might require further consideration by research funders.

Key findings

To understand what ideas researchers associate with RRI, we examined three dimensions relevant to the concept — concerns, enactments and organisation. We saw:

1. Nine concerns were identified across the cohort with a core of three concerns — alignment, relevance and sustainability. These concerns offer an inventory for future life science researchers and funders to work with when thinking about the social responsibility of science.

2. Twenty types of activity were coupled to RRI, ranging from completion of the project through to humanities and social science research. Activities varied in the amount of resource they required, their position in relation to the rest of the project, and in their capacity to 'open up' concerns to reflection, analysis and debate or their tendency to 'close down' debate through compliance. This list of activities offers a *starting point* for an inventory of activities associated with RRI in the life sciences.

3. Seven different ways that projects organised and distributed the work associated with RRI, the two poles being a discrete and substantive work package, and delegation to third parties. Funders can now see how researchers organise their project in response to requests for RRI.

Funders should reflect on the adequacy of different organisational approaches and consider how to incentivise some rather than others.

4. Sometimes researchers framed the same concern in different ways and a key distinction was whether the project would respond to the concern over its lifespan. This distinction often carried through into the activities researchers prioritised and the way they organised their projects. As discussed below, it is now possible to consider how comfortable funders are with these different approaches to RRI.

5. Certain concerns are addressed in more substantive ways than others. Questions about sustainability and reflexivity are frequently associated with research activity, whereas questions of data and gender are addressed in superficial ways that reduce the concern to rudimentary monitoring exercises. The adequacy of these approaches should be considered and additional guidance on how to address them in more substantive ways can be developed.

6. Potential gaps between rhetoric and practice were captured. Looking across the portfolio makes it possible to bridge such gaps, e.g. by drawing on the experiences of different projects, and consider whether certain concerns are the responsibility of funders rather than researchers.

7. Different ideas of responsibility are at play in the cohort. Notably, some projects — either through preference or circumstance — have chosen to delegate responsibility to third parties. The connection between organisation and the overall meaning of RRI developed by projects suggests that organisation is potentially a strong policy lever for funders to use.

The brief integrative analysis, which overlaid the three dimensions and considered each project's position within them, identified:

1. The cohort divides roughly into two parts. Each part draws on a different idea of an appropriate science-society relationship. Accompanying each major cluster was a minor cluster with projects that initially tacked closely to the ideas of the major cluster but with actions that did not match their initial rhetoric.

2. The distinctions between these clusters are important because they contain different ideas about whether the research project is a site for governance: Only in the first cluster — with projects that apportioned significant resources to research activities — is the answer to this question a clear 'yes'. **Thus, this analysis highlights a potential gap between the request of funders to operationalise RRI at the level of the project, and researchers willingness or capacity to do so.** Funders should reflect on the adequacy of their existing approaches to mandate and support RRI at the level of the research project.

3. The distinctions between clusters highlights the methods and approaches required to pursue an 'active' approach to governance. These include research components that transect the life of the project (rather than just kick-in at the end), stakeholder engagement exercises, stage-gating and advisory boards. If funders wish to prioritise an 'active approaches' to RRI, measures may be needed to more actively encourage, support and sustain them.

4. Finally, the distinctions highlight that there are different visions of governance to pursue with different allocations of responsibility. Funders should reflect on their comfort with this heterogeneity, the extent to which different approaches are mutually exclusive, and what the consequences of these different modes of governance are.

Future actions

In addition to these individual points, our analysis enables three broader actions:

Accountability and learning. It is now possible for funders to ask researchers to be accountable for some of their claims. Several projects made specific claims about RRI at the application stage and have removed reference to these claims in the mid-term reporting. In their application Project 21, claimed they would collaborate with the Leiden Institute of Environmental Sciences and would "perform an LCA to model impacts of [their] research", using comparators to try and understand the potential future impacts. Instead, the text of this project's midterm review suggested that the project was inherently sustainable and responsible because it was committed to the development of the bioeconomy. There are other projects with similar 'discursive breaks' between application and mid-term reporting. Funders should follow-up with this limited number of projects to understand how and whether the claims made at application stage have been or will be be pursued, and if not why not. This is both an issue of accountability but also valuation, because it will signal the programme's commitment to RRI. Understanding why such claims were made, why they may or may not have been referred to later, and what the reasons for this change will help to improve the design of funding guidance in the future.

Quality criteria. It is now possible to develop an evaluative framework for responsible innovation in the life sciences. Our mapping of concerns, enactments and organisation provides an inventory of approaches to RRI within ERA CoBioTech's first cohort. This, paired with the heuristic of opening-up and closing-down enables development of a substantive evaluative framework, grounded in the specificities of the programme. One approach would be to collaboratively develop 'quality criteria' for responsible research and innovation in the life sciences. This approach has been taken by Wickson and Carew (2014) as part of a nanoscience research programme, and would allow this funding programme to develop legitimate normative criteria for the research it funds.

Who is asking the big questions? It is important to consider whether some concerns are best addressed at particular points in the funding programme. For two of the most common concerns in the portfolio, alignment and relevance, it was often unclear what projects were actually doing. Relevance, for example, was present in 21 projects' discourse but in all of these projects it was either unclear how it would be addressed or was framed as being addressed through completion of the project. Both of these concerns are concerned with questions of directionality — the kinds of problems the funding programme is trying to address, and the kinds of value it is trying to create. Directionality is a longstanding concern within science policy throughout the 20th and 21st Century and is most clearly visible in the rhetoric around grand challenges and mission-oriented research, and explicit policy instruments such as the European Green Deal.

Arguably, one of the reasons projects raised but did not act upon them is because they saw the concern as being addressed at the funding call stage: in being funded, with one criteria for funding being impact, the question of relevance had already been determined. By far the most common line of reasoning here is to assume that projects are inherently beneficial because they mirror the framing established by ERA CoBioTech regarding the contribution of the bioeconomy. In effect the logic is as follows: ERA CoBioTech intends to foster the bioeconomy; this project is worth funding because it also aims to foster the bioeconomy. What is absent from the logic is consideration of *which* kind of bioeconomy is produced; the status of ERA CoBioTech's call has been to adopt a broad church in which all projects are welcome.

In framing their research as inherently societally, environmentally or industrially relevant, researchers are responding to a prior framing established by ERA CoBioTech funding programme. However, as we have shown, not all projects are created equally. They have been designed with different ideas of science-society relationship and different ideas of sustainability in mind. As funders are already mobilising the idea of grand challenges and mission-oriented research — and implicitly framing scientists' research projects — they should reflect on the adequacy of this situation as well as whether methods to more actively respond to questions of alignment and relevance are needed.

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