BIOMETCHEM - WORK PACKAGE 2 - FINAL REPORT

BIOMETCHEM: Sustainable Production of Added Value Chemicals from SynGas-derived Methanol Through Systems and Synthetic Biology Approaches

WORK PACKAGE 2: RRI, Responsible Research and Innovation

FINAL REPORT, February 2021

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Summary

This report presents the work of WP2 of the BIOMETCHEM project, primarily comprising a series of Responsible Research and Innovation (RRI) workshops held over a one-year period (September 2018 - September 2019). The purpose of these was to facilitate creative reflection on values and ideas of 'responsibility' in BIOMETCHEM, beyond who has responsibility for risk or project management; to incorporate the bigger picture of 'Science with and for Society' (and society in science); and to explore and compare scientific and public perspectives and expectations about the project.

The workshops used a combination of factual presentations and LEGO® Serious Play® (LSP), a structured, facilitated methodology which uses a specialised set of LEGO bricks to stimulate creative reflection and surface tacit knowledge. The methodology is simple: the facilitator asks a question and participants build a model in response, tell the story of the model to each other in turn, and then reflect together on what has been revealed. It is interactive, allowing everyone to have an equal chance at meaningful input, rather than prioritizing those who tend to speak up, and helps to avoid 'tickboxing' or foreclosing of possibilities through using predetermined definitions which may limit the scope of response. Instead, it aims to produce information or outcomes which are relevant to the participants in a specific context. It also injects an element of fun which makes it easier to accept differing opinions and new concepts.

Overall, we found LSP to be a useful tool for the workshops. Rather than conventional presentation-based workshops, using the models helped to make 'responsibility' a tangible idea, and allowed the BIOMETCHEM partners time and space for reflection, exploring underlying values, and considering the interplay of external influences on the various elements of the project in a way which drew from everyone's experience. In the public workshop we also found that the LSP encouraged the participants' genuine curiosity and willingness to engage with an unfamiliar topic, and helped them describe a different set of perspectives which could then be returned to the project partners. These activities demonstrate the importance of incorporating a more creative approach to embedding RRI in scientific research, and of making sufficient space for RRI activities and findings to be integrated in meaningful ways.

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Introduction

Responsible Research and Innovation Frameworks

Responsible Research and Innovation (RRI) is considered to be both a process and an outcome,[1] in which both scientists and societal stakeholders are tasked (separately and together) with engaging in reflection about the benefits and risks of new technologies throughout their development. Deployed by the European Commission as a cross-cutting issue beginning in 2013 with the launch of Horizon 2020, RRI rests on keys or pillars derived from the goals of the Lisbon treaty; namely, new forms of governance of emerging technologies which enable attention to ethics, gender equality, societal engagement, science education and open access. It has been interpreted and implemented in a range of ways and contexts, in particular through the Science with and for Society (SwafS) programme, and in specific actions such as the European Research Area Co-Fund on Biotechnologies (ERA CoBioTech), which funded the BIOMETCHEM project.

The UK Engineering and Physical Sciences Research Council (EPSRC) also supports these ideas through its AREA (Anticipate, Reflect, Engage and Act) Framework[2] for Responsible Innovation, which encourages the incorporation of non-technical questions about underlying assumptions, motivations and dilemmas in the technical development process, as well as normative questions about ethics and impacts, in a way which has the capacity to influence the research and innovation process. The AREA framework has been influential in shaping engagement with responsible innovation (RI) in the UK and beyond, and has informed the work of the Nottingham Synthetic Biology Research Centre, the Coordinating Partner of BIOMETCHEM.

Neither framework lays out specifically how to do R/RI, and a broad range of methodologies drawing from various social sciences (sociology, psychology, marketing, etc.) and from more traditional formats such as technology assessment are being developed. For this project we used a framework drawing from both the EC and EPSRC formulations, developed by de Saille as ‘an ARIA in 6 Keys’. Our task was to integrate RRI into the BIOMETCHEM project through a series of workshops spread across the life of the project, involving PIs, postdocs and PhD students from the four teams in Nottingham, Toulouse, Ulm and Frankfurt, as well as members of the public.[3]

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1 Sutcliffe, H. (2017) *A report on Responsible Research & Innovation*. Prepared for DG Research and Innovation, European Commission. https://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf

2 https://epsrc.ukri.org/research/framework/

3 The phrase ‘members of the public’ is used as shorthand to refer to the lay participants recruited to participate in this research. The publics of research and innovation are multiple, diverse, contingent and dynamic (Mohr et al. 2013 https://nottingham-repository.worktribe.com/OutputFile/1005123). The lay perspectives analysed in this research do not represent the views of ‘the general public’ but the emergent perspectives of a convened group of particular participants.

The BIOMETCHEM approach to RRI

Rather than rely on a more top-down instructive approach, we chose a strategy which combines social scientist-led introductions to RRI concepts and frameworks with hands-on exploration of the underlying values and knowledge(s) brought to the project by members of the team, considering how these might be operationalised in order to craft an approach which would be specific to this specific project's parameters, goals, talents and expectations. To do this we used LEGO® Serious Play® (LSP), a well-known methodology for corporate strategising, team-building and product development, in which a certified facilitator uses a bespoke set of bricks in order to guide the participants through exploration of a problem,[4] in this case, how 'responsibility' could be enacted within the BIOMETCHEM project. The workshops were facilitated by Dr Stevienna de Saille (University of Sheffield) who is a trained LSP facilitator and an experienced RRI consultant, and organised by Dr Carmen McLeod, with facilitation support from Dr Eleanor Hadley Kershaw, and administrative support from Louise Dynes and Nathan Dixon.

A number of studies suggest that taking a constructionist (used literally in this context) approach can improve concentration on, and deeper engagement with, issues which are difficult to articulate or grasp, simultaneously promoting both individual reflection, and group interaction and knowledge-building.[5] LSP follows a four-step method in which 1) a question is posed; 2) a model is built to support a narrative response to the question, 3) each person shares their story with the group and 4) the group together builds on that knowledge. The methodology thus encourages sustained attention and 100% participation, allowing everyone a chance to speak and be heard,[6] and is particularly good for creating a shared language amongst groups with diverse cultures, experiences and backgrounds,[7] a key concern in operationalising RRI in international, multi- or inter-disciplinary scientific projects. LSP workshops are adaptable and bespoke, and the outcome will depend upon the needs of the client, or in this case, the research leaders. It can be aimed at providing an actionable plan, finding commonalities amongst a diverse group, exploring a particular terrain, or simply to support a learning experience; most often it is a combination of all of the above.

In order to help the project team explore how RRI might be applied specifically in BIOMETCHEM, we held three workshops with different aims and outcomes, developed to support the project as it evolved. The first took place in Nottingham at the start of the project in September 2018, combining a formal, presentational introduction to RRI with a chance for the project leaders and postdocs to explore their ideas about stakeholders in the bioeconomy

4 https://seriousplay.training/lego-serious-play/
5 Rasmussen R. (2006) When You Build in the World, You Build in Your Mind. *Design Management Review*, 17(3):56-63.
6 Grienitz V, Schmidt A. (2012) Scenario Workshops for Strategic Management with Lego Serious Play. *Problems of Management in the 21st Century*, 1(3):26-35
7 Dempsey, M., Riedel, R., & Kelly, M. (2014). Serious Play as a Method for Process Design. In B. Grabot, B. Vallespir, S. Gomes, A. Bouras, & D. Kiritsis (Eds.), *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World*. Berlin: Springer, pp. 395–402.

through LSP, and think about how incorporating these might inform their specific approach to RRI (**Workshop A**). The second workshop was held with members of the public (**Workshop B**) in August 2019, applying a set of questions similar to those used in Workshop A with additional input from some of the scientists working on the project, in order to better understand what the project's aims looked like from an external point of view. The final workshop was held in Toulouse in September 2019, to map out the context in which the project was being deployed, and explore the opportunities and barriers for RRI team members were encountering as it evolved (**Workshop C**). This report presents the activities of the three workshops, along with reflections and recommendations for future endeavours.

The Workshops

WORKSHOP A: 'Developing a shared vision of RRI in BIOMETCHEM.'

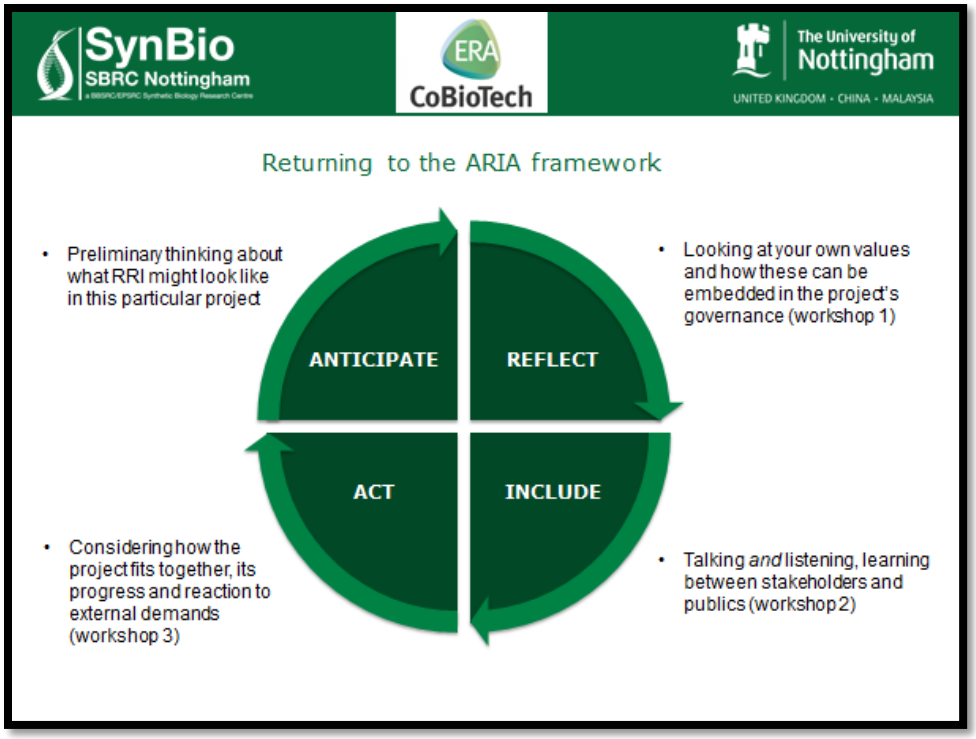
Nottingham, September 2018, attended by project team members.

The core of RRI as a framework for innovation tends towards public-facing activities, but there is also a corollary task of helping scientists and engineers productively engage with the idea that technoscience already embodies certain values, and that these can be shaped towards actions and decisions which support 'responsibility', however that may be defined within the particular project (or more widely). Dr. McLeod introduced these ideas through a presentation outlining the various approaches to responsible innovation developed within the EU and the EPSRC. Key to this is an adaptation of the iterative approach favoured by the EPSRC, which was introduced as the overall framework for the BIOMETCHEM RRI programme, and would take place in several stages over the life of the project.

Our approach includes a slight adaptation to the AREA framework (anticipate, reflect, engage, act),[8] modifying 'engage' to 'include', to represent a shift from a one-way, scientist-to-publics approach towards a more reciprocal, iterative approach which incorporates stakeholder and public knowledge produced through reflective engagement into the actions of the project. We therefore call this framework *ARIA*, and have developed it through our own work as social scientists anticipating the RRI needs of various projects, and innovating ways to productively address them.

The slide below illustrates how the ARIA framework was used as a basis for thinking through the focus of each of the workshops, encouraging the project partners to continue to travel around the circle as each stage of their work develops. Furthermore, the ARIA dimensions are not discrete processes and may overlap; for example, reflecting on values may also involve anticipating the desired or unintended futures of research, etc.

8 https://epsrc.ukri.org/research/framework/area/



The hands-on part of this workshop was thus framed around an anticipatory set of key tasks which built upon each other through the reflective process enabled by LSP: visualising what is meant by "the bioeconomy"[9] (Task 1), identifying potential stakeholders within the bioeconomy (Task 2), and developing guiding *principles* (rather than guidelines) for what, besides delivering their part of the project and avoiding lab accidents, the partners felt constituted a responsible approach to the project's goals (Tasks 3-5).

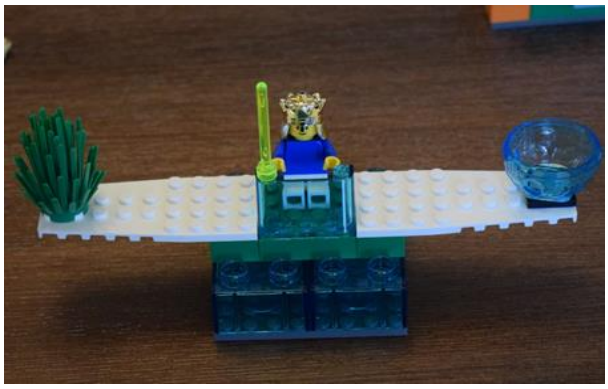
Task 1) 'Build a model to help describe how *you* see the bioeconomy'.

The first aim of the workshop was to take some time for the participants to examine their underlying assumptions about the larger field in which the project is embedded, and go beyond the natural tendency to assume that one's own perspective is not only shared by others, but represents the only logical answer to a particular question. Becoming familiar with the perspectives of other members of the team is essential for RRI, as each will be in a position within the project where some aspects are clearly seen and others are obscured, and each person brings to the project their own personal values and experiences. These are usually tacit and unexamined, and so bringing them forward for discussion increases awareness amongst

9 The overarching framing of "bioeconomy" was chosen given the centrality of bioeconomy to ERA CoBioTech's mission: its early calls and launch events featured the strapline 'Biotechnology for a sustainable bioeconomy' (https://www.cobiotech.eu/call-information/first-call). Focusing on and around this broad, interpretively flexible concept had the potential to widen consideration beyond immediate research practices and environments to include broader sociotechnical and ecological systems and contexts, including normative goals, impacts and visions.

the project members of the perspectives of others, which in turn improves the ability to incorporate the social and ethical aspects of the endeavour into the technical decision-making process, rather than leaving these questions to be pursued in a separate sphere.

Overall, most of the participants took a birds-eye view of the term “bioeconomy” and did not place themselves within the models or the stories, suggesting it was seen as something produced by external forces, a feeling that, “we all kind of have an idea what needs to happen, but we seem to be not able to control it. Other things control what’s going on.”



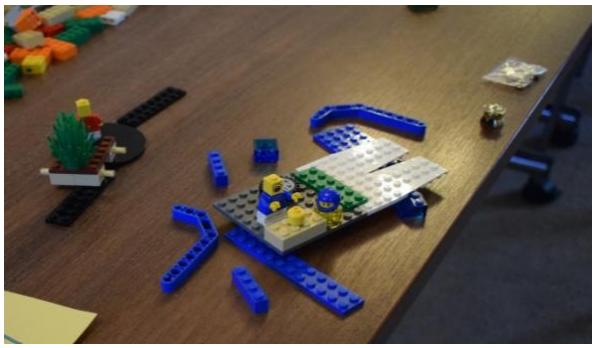
…when you first look at it, it looks like it might be reasonably familiar, like a plane or something, but then when you look at it a bit more, you realise it’s a bit confusing, and it’s not quite clear what all the bits are for and whether they are useful or not. Some parts of it are quite transparent, and some aren’t. Then, there’s someone in charge, but I’m not quite sure who it is, and where it’s going.

This sense of disconnection from the external demands placed upon researchers versus the reality of where the bioeconomy is as a field of knowledge was evident in many of the narrative responses to the question, particularly in relation to the stress which is being placed on the *economy* part of the concept (generally framed as money, i.e. ‘he’s only got one plan, and that’s to get to the money’). This could explain why ‘bioeconomy’ was often regarded as synonymous with ‘circular economy’, as this is receiving increasing policy attention at the moment.

So, this is supposed to represent the circular economy, this wheel. And these are the wheels of industry… here’s your biomass, these are the headless chickens and the scientists trying to do it; this is the politician on high; he’s not blind, but he’s got his helmet on the wrong way round so he can’t see.

In particular, the effect of economic competition on the scientific norms of knowledge exchange was seen by many as a significant impediment to deriving real benefit from the field:

> ...they're all vaguely going in the same direction, but with different goals along the way, and not looking at each other because they don't talk to one another very much. But they do have the tools to help each other...if he shared his wheels, he'd help this guy get to the end goal of the green future faster, but he wouldn't necessarily get to his money, so he doesn't feel like he's got an incentive to help at the moment, because his short term goal is before the long term goal, which they share. That's my bioeconomy picture, a bleak future.



Overall, the group's ambivalence about the bioeconomy was summed up by a participant who noted, "we should focus on the economy and the gain of money, because that's the incentive that drives us all, but we should also think about what happens when we're only thinking about the money."

The final discussion for this question focussed quite strongly on the idea of lack of control, and its implications for the bioeconomy as a whole:

> I think it's basically the economy that you cannot control. But, otherwise, in terms of science, technology or whatever, we can deliver whatever we want. It has no limitation, but [you can't] control the price of oil; you don't control the price of raw material, and so on, so this depends on that, and unfortunately you cannot control that. We are dependent on external factors. If someone decides to increase the price of oil, then the bioeconomy, for a lot of applications, will not be economically feasible.

These responses also reflect some of the inherent limitations of enacting RRI within an emergent field. Without funding (which is often subject to external factors, particularly government priorities) there is no project, but funding for emerging technology is always predicated on the sector's expected contribution to GDP and national 'competitiveness'. Thus 'responsibility' within the bioeconomy will always be mitigated by what is a) marketable, b) economically feasible, and/or c) considered by funders to be a valuable use of their money at the time. The economic imperative was seen by the group as simultaneously a driver of, and an impediment to, acting responsibly, depending upon *to whom* the project was meant to be responsible, and *for what*. This discussion segued nicely into the next task.

T2) Using the model from T1, who are the stakeholders in that bioeconomy?

Using the same models encourages participants to go beyond simply listing the usual categories of stakeholders and think more clearly about who these might be within the scenario already envisioned and how they are important to, or can change, the story the participants

were already telling. The purpose is to think about specifics, and in particular to help in grappling with the complexities of ‘to whom/for what’ revealed by the first task.

In contrast to the ambivalence expressed in the stories told for T1, which surfaced tensions between economic expectations and reality, the general vision of the bioeconomy once stakeholders were added was positive. The idea of the ultimate stakeholder being ‘the planet’ or ‘everyone’ was a strong theme. Most models had something representing 'member(s) of the public', somewhat confused about the science but happy with the way things had turned out:

Well, you’ve got this guy with the spade; he’s just a regular member of the public... He’s benefitted from this new green economy. He’s got a job doing something, and the old man there, maybe he was someone who invested back in the day, kind of looking with a smile on his face at this nice world he lives in. Maybe he grew up hearing all the doomsaying, thinking everything’s going to go bad in the future, and he’s thinking, well, I made the right decision, and yes, he’s happy about that.

While generally positive about the potential contribution of the bioeconomy to planetary health, some narratives did still grapple with the contradictory effects of economic imperatives, and how this could drive stakeholders to be *irresponsible* if the chief interest was monetary gain:

I got three people, the blue ones and the white one, which represent scientists for me. There’s one guy that’s climbing up the ladder trying to make the best of it, and get into the riches, so to say, and the two guys on the bottom of the ladder with the money beside them are fighting each other. Those guys are fighting for the resources, let’s say it’s grant money, or something … There are some skeletons who tried to climb the ladder but failed miserably, and fell down. Some got part of their money, but they didn’t survive it. There’s another one … he’s got a whip and he’s whipping the guy that is trying to dig the foundation of that tower, so one could probably say those are the people that are not thinking about the general picture, and are just in for the short term stuff, or for the fast gain.

Where the political environment was the dominant part of the T1 model, this disparity of goals was also reflected as the stakeholders ‘just going around in circles trying to achieve an impossible task' or ‘all looking in different directions’. But the importance of identifying and trying to work through the contradictions was clearly reflected in statements such as ‘...the stakeholders are what will determine whether we get to the final conclusion, and maybe

identifying who the important ones are, in terms of getting towards the goal, is the important thing for everything to go forward.' This discussion led directly into the third task, which was to counter the birds-eye view by asking the participant to place his/herself somewhere in the model (and therefore personally into the narrative), which almost no one had yet done.

T3 - How do you see your own responsibility within the bioeconomy?

These were new models, not built upon T2. The purpose was to explore how the team members saw their own responsibility within the bioeconomy, beyond their specific job-related responsibilities. However, most people did explore this in relation to their job in the larger sense of what they, as scientists, were being asked to do in terms of societal expectations. Responsibility in this sense was generally framed as responsibility to 'the world' or 'the planet', reflecting the underlying values of the individuals in the group, expressed as a genuine desire to 'make the world a better place', despite the impediments previously discussed:

...on my model, on top of it, it's our planet, that I think I'm kind of responsible for, and the project's responsible for. Here on the bottom, again, there's me on a hill of waste and biomass, which I want to use to make the planet better, and to keep it there, up on the top.

In general, the theme of circularity came up in a number of ways -- wheels turning round, the circular economy, etc. For example, one person saw the bioeconomy as a circle and himself as responsible for optimising the whole circle. However, there were clearly different senses of responsibility towards the *building* of the bioeconomy itself, with several participants declaring that to be the main goal; however, it was not always clear whether they were thinking of the processes or the money. For some it was probably both, as T2 showed some participants were acutely aware that these are entwined, but could reflect opposing goals.

In terms of the project itself, the general consensus seemed to be that *this* particular contribution to the bioeconomy was *already* responsible because of the materials and methods employed:

> ...we're part of a project that wants to make the world better. Of course there's money in it, of course, and of course there are risks involved in it, it couldn't work, and of course, there are things that could go as planned, like the genetics, or whatever, but we're all doing this for

> money, and for the end goal that we're using something that is essentially waste, to make something better for everyone. So, this process isn't decoupled from making something better for everyone.

In this, there was also an attempt at differentiation, placing the perceptions of the field of synthetic biology as a whole at a distance from the specifics of this particular project:

> I think what we aim to achieve is good and responsible, and it's difficult to imagine what the dangers are in it ... Not like other types of synthetic biology projects that might be going on.

T4 - Identify the most important part of the model in T3

In these last steps, we moved away from the broader visions and tried to focus on specifics, on what makes a project responsible or irresponsible, and examine the most crucial components of the narratives developed in T3. In this task, the participants simply had to place a flag on the part of the model which represented its most important aspect, the thing it could not be responsible without.

> Yes, so I obviously put the little pink flag on the fruit of all our work, the outcome of our work, that we can use to persuade everyone that what we are doing is a good thing, that we're doing something that benefits everyone, even if some people might say in the beginning that it's a waste of space, and that we can, yes, produce something that is of value for everyone.

The importance of the outcome was echoed by several, and seen as validating the project as responsible if it could get there (which did not seem to be a thing of certainty), as seen in this exchange:

> Participant: …the end goal is the most important thing, really. All the other stuff's nice, but at the end of the day, if you don't get to the end goal, it's not…
>
> Facilitator: What is the end goal?
>
> Participant: Well, developing whatever we develop at the end of it, getting close to that goal of bioeconomy, small steps towards it. If we can get our organisms more viable than they are now, then that's a small step in that direction.

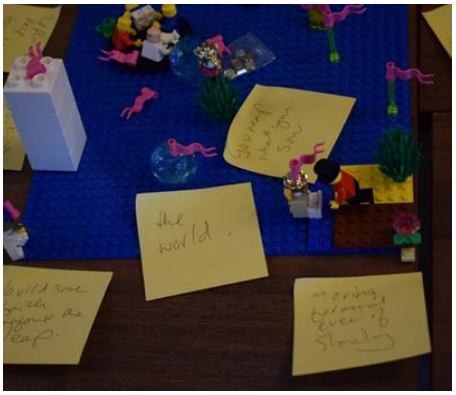
While the focus on outcome in this task was not surprising, or in and of itself problematic, RRI conceives of itself as both outcome and *process*. Therefore, the last task focussed on how processes might be shaped, and what principles could be used to develop a shared idea of responsible innovation which emerges organically from all the members of the group, rather than something that is imposed top-down.

T5 - Come up with a catchphrase to represent the most important part of your model

The purpose of the final task is to summarise the ideas which had been put forward through the previous questions, in a way that is both memorable and specific. Each of the pieces from the T3 model identified as crucial in T4 are separated from the original model and placed together as a model representing the whole group.

In this process, the placement and meaning of each model fragment is refined until each individual modeller is happy with the catchphrase s/he has assigned to their particular fragment, and the group is happy with how the different elements are positioned in relation to each other and the story they tell when considered as a whole. Each phrase thus represents an element of RRI seen by the participants as critical to the development of the project, but does not require that every member of the group agrees with the choice of element itself, leaving space for different values to be expressed and everyone's key concern to be represented. These are then the guiding principles of the project:

- We can't keep rolling without the wheel
- Achieving environmental cost efficiency
- Exploring Responsibility together
- Working synergistically to develop a bioprocess
- You reap what you sow
- Knowledge for education
- Build some faith before the leap
- The world
- Moving forward even if slowly
- From light saber to spade
- Wissen ist macht (both "the power of knowledge" and "knowledge is power")



Taken together, we can see themes of **collectivity** (together, synergistically, the world), **momentum** (keep rolling, even if slowly), **knowledge** (as power, for education, building faith), **practicality** (cost efficiency, bioprocess) and **caution** (before the leap, reap what you sow), all of which reflect a distillation of the more complex conversations which have taken place through the previous tasks. These five qualities can then be embedded in the project through a range of methods, discussions, protocols, etc. By making visible common values and qualities, this exercise aimed to sensitise the group to how responsibility might be embedded as the project develops, in ways which are not solely focused on risk management. The specificities of how this might inform project practice is then left to the group and individual researchers to determine as the project evolves.

WORKSHOP B: 'Public views on using bacteria to make chemicals from waste gases.'

Manchester, August 2019

This workshop was held in a hotel conference centre in Manchester. Sixteen members of the public were recruited via a market research company, DJS Research, with most coming from the Manchester area. The selection criteria looked for an interest in science and technology issues, a range of ages and an even split between genders. The groups were pre-assigned to two tables of 8, each half male and half female.

The format of the workshop also used LSP, split into two sessions with a break for lunch. Task 1 was intended to probe a 'naive'[10] response to the same question about the bioeconomy as had been posed to the scientists. However, we made it clear that we did not expect them to know anything about it; we were interested only in what they *thought* the term meant. Two members of the BIOMETCHEM (and associated) project(s) (James Millard and Beth Redfern) then presented their work focussing on modifying bacteria in order to make useful chemicals from waste gases, including a screening of the Carbon Recycling Network video which introduces the goals and processes of carbon recycling through gas fermentation. The participants were free to ask questions during and after the presentation, which made for a relaxed and lively discussion. The second half of the LSP workshop then explored how being 'informed' did (or did not) alter their ideas about the bioeconomy (Task 2), and what message they would like to relay back to the project team (Task 3).

Overall, the participants' idea of the 'bioeconomy' was not dissimilar to the scientists' views, but the two lay groups did have different responses, with much less focus on the *economy* part in Group 1. Instead, the focus there tended towards the *bio*, with more discussion of research aspects such as "a laboratory where they're testing different things like biodegradable fuels, fossils, all different things associated with biodegradable" and "a scientist coming up with ideas in a lab and challenges that they face in the future". Energy also figured strongly:

> this fella is a farmer and he's digging, it's called biomass crops, biofuels, whatever you want to call them. This bloke owns a power plant and instead of burning coal or natural gas or whatever they burn he's buying these biofuels off this chap to burn.

The dynamic of Group 2, however, was much more aligned with practical applications and the possibility of financial benefit. Circularity and connection were also themes in the discussion at this table, but the main themes were about sustainable fuel, a sense of movement and/or change, and potential wealth:

- So, here is almost a safe space, land, money, economy, things that are moving, a beacon and then the bio side of it is how it's fuelled but it's an empty space because it could be anything I guess. But it is connected, so we do have our normal kind of economy, ways of

10 Here 'naive' describes a response prior to hearing about the specifics of the BIOMETCHEM project and the visions and interpretations of bioeconomy therein, not a more general ignorance or lack of knowledge. Participants may or may not have previously engaged with ideas or practices relating to bioeconomy.

living and the bio side is something new, undefined but it is connected.

- Mine is nature and biology, and industry and economy out, productivity, gross domestic product and all that… it's all connected.

- I didn't really know what bio-economy means, in my head it was renewable energy sources ... And just money because it was bio-economy.

- I'm seeing it as a transition from the old ways to the new ways with various arrows… It's moving towards sustainable living and a rich bio using bio fuel and elements to drive this… and the money is there, it's going to be big.

From the start, therefore, 'the bioeconomy' was seen as something positive. This was only reinforced after the presentation from James and Beth, which gave clarity to one particular approach, but fit well within the imaginary which the participants had created in Task 1. At this point the participants began to take more control over their own knowledge processes, offering ideas, asking questions to gain greater detail and to test their understanding.

This was reflected in the response for Task 2, which asked them to modify or rebuild their original model of the bioeconomy based on what they had just heard, and particularly in the discussion afterward. Almost everyone attempted to modify the model to reflect a hybrid of their original story and the one Beth and James had just told about the project's goals:

So, this is still a factory. I'd say it's making, well it's a factory anyway, it's making stuff and the waste product is now coming down this piece of string into this sphere thing and the process you guys just described produces some kind of product which is used to make cement which built this chap's house...

In the third and final task, participants were asked to build a model to tell a story about a message they would like to convey back to the scientists working on this project. Here the participants seemed to shift to a much bigger picture of the world and how biotechnology might fit into existing systems:

> I was worried when you were talking that maybe this process has the potential to produce products that might be used in destructive ways. And so this is a bomb blowing up this woman's house and so the message I suppose would be maybe when you have a big change like this to think through second order effects or unintended consequences that could be harmful.

In particular, money was envisioned by some in a very different way. Whereas in Workshop A it was seen as both an enabler (through funding) and a desirable outcome (IP, profits from marketable products), here it was seen as a potential impediment as rich, powerful interests might be motivated to forestall competition from cleaner methods:

Are we prepared to overcome obstacles? This is the scientist at the end of the cog to represent all the good thoughts going on and this is the guy at the end who's got the bags of money who is representing industries who are going to object to anything like this, and literally it looks a bit of a mess because that's what it's supposed to be … straight away he's going to be worried that anything like that is going to be a threat … because there is a lot of financial power.

Asked whether they felt any other reservations, some doubts were expressed about the limitations of anticipatory or predictive knowledge ("you can never know what you're going to produce and how it's going to react with nature"), and other concerns, such as "it's always dangerous changing nature in my opinion" and "keep the military out". However, the messages were in general of positive encouragement:

- Take the politicians out of it, and like I said it might be a bit easier.
- I just think we need to move forward from the fossil fuels. Something has got to be done and it's a good job there's clever people around to do it.
- The message is that I can see where it's going. It's going to benefit the world basically.

For the most part, therefore, potential environmental and social benefits were seen as outweighing any other reservations, and this may in some aspect have been influenced by the workshop taking place in the middle of an unusually long and intense heat wave. Overall, however, the environmental goal was seen as adequate justification for the project. 'Responsibility' was clearly interpreted as 'save the planet', but also as something existing outside themselves, i.e. it was the scientists' responsibility to save the world, and their own potential contribution to that goal did not form part of the discussion. In terms of iterative learning about RRI as a process, this might be a lacunae to be addressed in future public engagement activities for this or other projects (e.g. by posing specific questions about how participants see themselves in relation to the innovations or processes under discussion).

WORKSHOP C: 'Mapping the innovation system for incorporating principles of Responsible Innovation in BIOMETCHEM.'

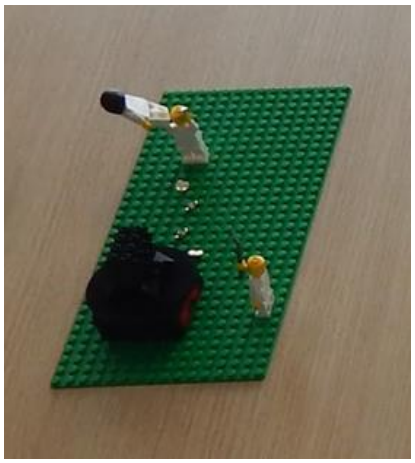
Toulouse, September 2019, attended by project team members.

This workshop took place one year after the first and followed a different format, using a much wider selection of bricks to help participants visualise the various aspects of the project as part of an interconnected system. With the project now well underway, the intention was to provide a space to reflect, discuss, and adjust if needed, aided by physical representations of the project and how it was situated within the larger bioeconomy at this point in time.

In **Task 1**, team members were asked to build a model to tell the story of their own part in the project and where it was at that point. They were then asked to fit the models together to create a landscape representing the whole BIOMETCHEM project (missing members were represented by models built by the group).

- Enzymes (Frankfurt, not present)
- Engineered bacterium
- Tools for systems biology
- Metabolism characterisation
- Strain development
- Successful knockouts
- Steps to success
- Reaching the goal of the project
- Industry (not present)

Task 2 aimed to explore which other agents (a person, place or thing with the capacity to affect the project or a part of it) might have an influence on their part of the project. These could represent barriers or opportunities, something that could either help or hinder. An agent can be something tangible (like funding or a bacterium), but does not have to be. For example:



So my agent is this black box, which I think is quite right for science in general, so it's a level of complexity that you don't really understand at the start of a project, otherwise it wouldn't be science. It would be engineering. So to convince people to give you money to throw at the project, you need to convince them you've got the tools to do this, but because it's science, apparently you don't know that you're going to have all the tools that you need at the start...but the project starts with a defined amount of money, and that's the way the government works. So you don't get any more money to throw at it, you don't get any more people to throw at it. And the tool that you have at the start might be a spade and you need a pickaxe.

The agents thus give a sense of context to the project, mapping out the landscape in which it is taking place, and the major influences which might affect findings, methodologies and outcomes. By creating the landscape together, and then determining how the agents connect to various elements of the project and to each other, a comprehensive map is built, creating a visual reference which can be manipulated to deepen reflection about risks and mitigation.

There were two rounds of building of the agents, with each being placed in the landscape after its story is told, according to where the builder saw it best fitting. Thus, the landscape evolves and changes as the exercise progresses. At the end of each round, participants work together to re-evaluate the landscape, and agree the movement of any models that appear to be out of place. As seen below, after the first round, the various elements of the project remained at the centre of the landscape, with the other agents placed in concentric rings according to their perceived relationship with those project elements.

FIRST ROUND

In the second round, some rearrangement of the project components did occur, with new ideas being placed in the centre, moving some of the project components towards the periphery where they were surrounded by agents. As one participant described it, this ended with:

> The ring of science brought together by all of the communications and successes and problems within it. I think, all of the agents that you've described are all contained within that ring of science that we first built, that's been pushed out and surrounded in equal measure.

SECOND ROUND

Discussion revealed that most of the agents had the capacity to be both obstacle and opportunity, depending upon the circumstances (reflected in their relationship to the closest models). In the final landscape, the agents represented were:

• Government funding • Public demonstration for more funding • Complexity of the science • Success despite complexity • Diversity of organisms • ABFD doesn't do what we want • CRISPR-Cas9 • Scientific community • Slow progress • Unforeseen obstacles to progress • Project progress supervised by funding agencies • PI's supervision	• Industry watching/learning/waiting • Internet, information, communication • Internal communication • Knowledge (collection and dissemination) • Report and grant writing • Time (in general) • Running out of time • Imbalance between success and failure • Sickness leading to failure • Influence of results on mood • Solutions to problems • Ideas to improve the project • Money for extra equipment

Task 3 then asked each participant to build two connections from the model of their own part of the project to the two most influential agents. The agents chosen did not need to be one of the ones the participant had built. As the discussion for Task 2 showed a general agreement that time (in general) and money (government funding) would exert a strong influence on most, if not all, of the project elements, these models were now removed from the table so they did not become the focus of everyone's connections.

As with the other bricks, the nature of the connecting material chosen also has meaning. One might use the string connectors to demonstrate a more tenuous connection, whereas the red vacuum hose might indicate a strong and continuous flow. Through explaining the form and substance of the connections, it becomes possible to more clearly envision the relationships between the different elements of the project and the agents which could exert the most influence over them, consider the strength of those relationships, and identify those agents which seemed to exert the most and least overall effect on the project as a whole (i.e. those with more or fewer connections). For example:

> ...to get successful knockouts, I have to use the CRISPR-Cas9 system. And the slow progress was actually getting that system to work in the first place … [I used the chains because] they're stronger connections. More flexible. And maybe, I don't know, it's an iron clad essentiality, you know, without the CRISPR system working I'm not getting my knockouts, which I need.

In the second part of this task, agents with no connections are taken off the table in order to increase the focus on those which do appear to have the most potential to influence the project, for better or worse. This allows a deeper understanding of the system within which the project is developing, and can reveal ambiguities or areas where there are tensions between differing meanings even where there is apparent agreement as to what the model represents.

The discussion can also clarify the need for more attention to be paid to elements which were taken off the table. In Round 1, there were models representing government funding and the public, which was initially described as the public protesting for *more funding* for biotech, rather than against it. Neither had been connected to any other part of the model so they were removed. In discussing whether these should be returned to the table, the conversation showed a distinct uncertainty about what was being represented in the "public" model, and the effect of having initially positioned it face-to-face with the model for government funding:

> Facilitator: So how do people feel, do people agree that [the model of the public] should go back on the table or not?
>
> Respondent 2: Well, without the [model of the] government, they are just rioters.
>
> Facilitator: Are they still protesting, or is it just now representing the public who is supportive?
>
> Respondent 2: But it's public opinion, isn't it? And how else can we get it across without demonstrating?
>
> Facilitator: Okay, so can that go back on its own or does it need government funding to go back on the table as well?
>
> Respondent 2: Well, I think they go together.

This exchange shows quite clearly how the meaning of 'the public' is dependent upon its perceived proximity to other agents, but also revealed an interesting assumption, which is that protest (whether for or against biotechnology) is the only way for public opinion to be heard (i.e. to effect change). RRI can be used to counter this by creating spaces for deeper and more meaningful possibilities for public influence over research priorities (for example, Workshop 2 showed strong support for biotech aimed at fossil fuel replacement); however, it requires responsive action on the part not just of scientists, but other players in the research ecosystem, in particular those who decide on the size and distribution of grants.

Conclusions and Reflections

An overview and evaluation of the three workshops was presented at the BIOMETCHEM team meeting in February 2020, giving the whole team (including the RRI team) a chance for further reflection. Aspects of this discussion are summarised below.

Conclusions

Overall, we found both the ARIA framework and LSP to be useful tools around which to organise the trajectory of the workshops, although the limited time and spacing of these meant it was not always possible to maximise the potential benefit. Rather than a conventional presentation-based workshop, using the models made 'responsibility' a tangible idea, and allowed the BIOMETCHEM partners to reflect on how that was interpreted by the different project partners, and to explore some of the underlying values and tensions between the project's economic and environmental goals. For the second, public workshop we found that LSP encouraged the participants' genuine curiosity and willingness to engage with an unfamiliar topic, and that they took real pleasure at being involved with the scientists directly. This workshop also showed that biotechnology projects need not fear public engagements, and that they can provide a different perspective on the tensions identified in Workshop 1. Overall, the field would benefit from much more of these kinds of engagements, with different kinds of publics as well as with other stakeholders. In the final workshop, held a year after the first, we were able to demonstrate the need to take a systemic approach to RRI early on, something which has been a thorny question for the field and for RRI practitioners. However, even at the mid-stage, mapping out the relationships between the various agents and components and the landscape in which the project is unfolding was able to reinforce the learning from the first workshop, and gave valuable space for reflection on how the project is progressing, and what actions might be needed next.

Reflections on the RRI Work Package

As a team, we felt that there were successful elements to the RRI work on this project, much of which was enabled by the LSP approach. The dedicated Work Package and resources gave both opportunities for and validation to the need to incorporate RRI within the project. We found that using LSP created space for all participants to reflect and share ideas, and it helped to make values and assumptions (that are often unspoken or difficult to articulate) more explicit, particularly when contextualising the project within the broader system. Because the workshops took place over the course of a year it was possible to observe some benefit to taking time for critical reflection through LSP in terms of creating greater cohesion within a research team which was geographically dispersed, and met only infrequently and usually under time constraints. It also demonstrated that there could be enjoyable mutual learning between

researchers and public participants, which would not be derived from a more top-down approach.

Overall, however, while the structure and activities of the work package did allow participants some space to consider their own values and ideas about 'responsibility' and how these might be embedded in the project's governance, there was difficulty in translating this into practice (the Action component of the ARIA framework). These are not limitations specific to BIOMETCHEM, but are rather well-worn challenges in the field, and are mainly a result of the way RRI is (or rather, is not) integrated into large projects with multiple and often geographically distant partners, such as EU consortia. This includes limited funding for staff time (meaning that it is challenging to maintain integration between workshops), and infrequent, short meetings rather than more intensive ongoing collaboration and integration which is necessary to overcome interdisciplinary communication challenges and the tendency to relegate the social scientific aspects of emerging technologies to a separate sphere mainly tasked with managing public acceptance. This long-standing division of labour creates differing expectations regarding the purpose of RRI, differing levels of ownership of RRI-related work, as well as limiting opportunities to feed back findings, which itself creates barriers to integration and real responsive action.

In short, we found that LSP is a very promising method for RRI, but it must be accompanied by mechanisms for early and ongoing integration and responsiveness.

To support this claim, we draw attention to the following overarching recommendation and four lessons for best-practice RRI summarised in the Agenda for RRI in ERA CoBioTech (published in April 2019, after the call that funded BIOMETCHEM).[11] While primarily targeted at funding bodies, these lessons entail important implications for research consortia too, with the potential to increase the use and value of RRI to future projects in emergent fields:

Overarching recommendation: Treat Responsible Research and Innovation components as research. 'This means that RRI components ... are not primarily about demonstrating a project's benefits for stakeholders. Ideally RRI components and the wider project will work towards an important issue of shared interest.'[12] At present, RRI activities are generally carried out by social scientists engaging with (rather than as full Co-Investigators on) science and engineering projects. However, research on RRI itself – its meanings, techniques and contributions to understanding the interplay between science and society – is an important and growing subfield in its own right. Deeper integration in scientific research has the capacity both to advance the social scientific study of innovation, and enable the kind of interdisciplinarity that research funders are seeking to encourage.

11 Smith, R.D.J., Scott, D., Kamwendo, Z.T., Calvert, J. (2019) *An Agenda for Responsible Research and Innovation in ERA CoBioTech*. Swindon, UK: Biotechnology and Biological Sciences Research Council and ERA CoFund on Biotechnology. https://bbsrc.ukri.org/documents/eracobiotech-rri-framework-pdf/, pp. 11-15.
12 Ibid. p. 13.

Lessons for best-practice RRI:

1. **Commit to and value responsible research and innovation.** The literature suggests that 'there is an onus on research funders to incentivise, make visible, and value the time and effort for critical thinking about science-society relationships',[13] but this also needs support from PIs, as they set the research agenda and priorities, and from entire project teams as they enact agendas, make day-to-day decisions and participate in collaboration.

2. **Support tailored approaches.** Ensure any RRI components are context-specific and detailed, developed in association with the core project proposal and together with the core project work (rather than on the periphery), and that resources are adequate to build a 'conception to grave' work package with staff funded for this purpose.

3. **Find an appropriate form of integration.** This includes treating RRI components as valuable social science research, allowing researcher equivalence and sufficient time, resources and opportunities for close interaction with the scientific and engineering aspects of the project.

4. **Go beyond projects**. Funding for RRI practices is usually time-limited, discrete, and at the project level, making it challenging to address systemic or institutional issues (e.g. funding priorities, incentive systems, or Intellectual Property regimes).

13 Ibid. p. 11.