Responsible research and innovation

(A chapter for the Handbook of Science and Technology Studies)

Jack Stilgoe and David H. Guston

Introduction: Caring for the future

'Responsible innovation' and 'responsible research and innovation' are topical themes of twenty-first century science governance. But the ideas that sit behind these terms are perennial ones for the internal workings of the scientific community and its relationships with the outside world. Indeed, one of the reasons why these terms, which may seem like truisms, need to be re-articulated now is that discussions of social responsibility in science have fallen out of fashion. Following the publication of Rachel Carson's Silent Spring in 1962, the birth of US environmental consciousness, prompting the creation of important regulatory bodies like the Environmental Protection Agency in 1970, coincided with soul-searching during the Vietnam War to lead to new movements for social responsibility in science. The British Society for Social Responsibility in Science the Union of Concerned Scientists in the US and were both created in 1969. Post-war recognition of the power of science and technology forced reconsideration of the responsibilities that should follow. With the growth of Science and Technology Studies as a body of scholarship, understandings of the responsible governance of science and innovation have advanced considerably, blending with and occasionally challenging the discussions taking place among scientists.

In this chapter, our aim is to explore and draw connections between current discussions of responsible innovation and scholarship in science and technology studies (STS). We begin by observing the emergence of the term as a response to perceived governance crises before retracing the STS concern with the politics of technology that provides a starting point for so much productive research. Our aim, however, is not purely analytical. Work taking place around responsible innovation is not just interested in asking what counts as responsible or irresponsible; it is also pointing to ways in which things could be improved, building on a normative interest in democratizing and pluralising the voices engaged in debates about science and technology.

In the sections that follow, we chart the relationship between responsible innovation and public engagement with science, an earlier debate in which STS had taken an interest and become similarly implicated in complicated ways. We look at the laboratory as a site for the conventional discussion of scientific controversy and at attempts to broaden the notions of responsibility being discussed there. We then look beyond, to the sociotechnical complexity of innovation in the world, to see new challenges to our understanding of responsible innovation and new challenges to STS. Finally, we observe some of the ways in which the language of responsible innovation has enabled STS researchers to play new roles in real-time discussions of emerging science and technology. Our conclusion is that these new, co-constructive relationships are necessary even if they are often neither straightforward nor comfortable.

The (Re-)emergence of responsible innovation

During the 1970s, as debates about social responsibility grew among US scientists, the infamous Tuskegee syphilis experiments were drawing to a close and lessons from this scandal were being inscribed into the Belmont report and the Common Rule for the ethical treatment of human research subjects. The Technology Assessment Act was finalized in 1972, with the Office of Technology Assessment (OTA) of the US Congress emerging a couple of years afterwards. In 1975, molecular biologists would descend on Asilomar in California, in a major attempt at self-described self-regulation. Their hope was they could improve upon the physicists' response to the bomb as they sought to control the potential of new techniques of genetic modification (see Kaiser and Moreno 2012). Elsewhere, human subjects protection and technology assessment trailed by many years, even in Northern and Western Europe.

Precedents such as Asilomar and Tuskegee were in mind when one of us proposed in 2002 that universities, as hubs of knowledge-based innovation, should establish 'centers for responsible innovation' to serve as a counter-weight to growing commercial norms in the university context and extend the concept of responsibility beyond contributing to the economy and not abusing research subjects (see Guston 2004). While the term 'responsible innovation' had been in modest circulation, it had not yet been thematized in STS or in practice. Towards the end of the 20th Century, ethics scholarship had begun an 'empirical turn', in which the realities and constraints of scientific practice had provided new research questions (Borry et al 2005; Kroes and Meijers 2000). And technology studies had explored questions such as how artefacts can produce 'a specific geography of responsibilities' in allowing or constraining particular actions (Akrich, 1992, 207). But links with governance and institutions had not yet been clearly drawn.

Since the mid-2000s, the terms 'responsible innovation' (RI) and 'responsible research and innovation' (RRI) – which, for the purposes of this chapter, we take to be synonymous – have entered intellectual and institutional discourse rapidly, if sometimes surreptitiously. STS researchers have variously been involved in encouraging the term's uptake, studying its usage, making sense of it in policy and pedagogical terms, critiquing its myriad simplistic or instrumental invocations, and catalysing the creation of communities to perform all these functions by organizing large, international research and networking projects and even founding, in 2014, the *Journal of Responsible Innovation*.

This process of scholarly and rhetorical blossoming has meant, inevitably, that various actors have attached multiple meanings to responsible innovation. Before offering our own definition, it is important to note some of the motivations behind its usage. In Europe, where its use is most developed, RRI has become a theme that cuts across the various programmes of Horizon 2020, the European Commission's (EC) latest and largest funding programme. De Saille (2015) catalogues the spread of RRI at the European level through the commissioning of various research and coordination projects attempting to clarify and encourage its uptake, explaining it as part of larger European Union concern with getting what it wants from investments in science and innovation.[1] There are also on-going attempts to mainstream considerations of RRI across other EC-funded research and innovation projects.

The concern De Saille describes stems at least in part from the desire of European policymakers to avoid such surprising and costly crises of public confidence as occurred with Europeans' rejection of genetically modified crops (see Wynne 2001 for an STS analysis of this controversy). More recently, the Dutch experience with the aborted rollout of smart energy meters, undermined by concerns about privacy that were realised too late, has given policymakers further cause for concern (EC 2013). RRI is also connected with the growing prominence of 'grand challenges'[2], which can be seen as policy recognition of three key pressures: first, the need to demonstrate and increase the external value of science; second, anxiety among scientists and engineers that the utility of their work is perceived in purely economic terms; and third, recognition that past efforts to increase impact through policies that emphasize the supply side of innovation have been a failure (see ERA expert group, 2008; Lund declaration, 2009).

Rene von Schomberg's (2011) characterisation of RRI in the European context anchors the approach explicitly to the values that drive EU policy: scientific and technological advancement; the promotion of social justice, equality, solidarity and fundamental rights; a competitive social market economy; sustainable development and quality of life. Von Schomberg (2013) defines RRI as:

> 'a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products in order to allow a proper embedding of scientific and technological advances in our society'.

In the US, responsible innovation received an early but indirect push with the inclusion of 'responsible development' as one of the four strategic goals of the

---

[1] For projects, see for example, the Governance for Responsible Innovation (GREAT) based in Belgium, the Global Model and Observatory for International Responsible Research and Innovation Coordination (Project Responsibility) based in Germany, the Governance Framework for Responsible Research and Innovation (RES-AGORA) also based in Germany, ProGReSS based in the United Kingdom, and the RRI-TOOLS initiative to develop a 'toolkit' for responsible research and innovation (for which Stilgoe is a project partner). In the US, NSF has also funded a Virtual Institute for Responsible Innovation, where Guston is PI at Arizona State University.

[2] The Lund Declaration, 2009, Europe must focus on the grand challenges of our time, July 009. In the US in 2008, the National Academy of Engineering also articulated a set of 14 "grand challenges for engineering in the 21st century."

2001 US National Nanotechnology Initiative (NNI), which was launched in 2001. The NNI rhetoric on responsible development was informed by the successes and failures of the Human Genome Initiative's more distanced ethical, legal and social implications (ELSI) program (Cook-Deegan 1994 and the chapter by Hilgartner in this Handbook). The NNI's post-ELSI orientation meant focusing responsible development in two ways: first, on the environmental implications and applications of nanotechnology, and second on integrating social science, as a way of divining and making sense of societal concerns, into the nano-scale science and engineering research itself (see Fisher et al 2006).

Ideas about responsible innovation flourished in this domain, in part as an attempt to broaden the deterministic language of responsible 'development'. This led to the articulation of a vision for the 'anticipatory governance' (Barben et al 2008) of nanotechnology and other emerging technologies that, in turn, promoted the further development of RI (Guston 2014b). Drawing upon earlier work in STS, particularly a normative framework derived from Winner (1977; 323) – who reasoned that because 'technology in a true sense *is* legislation' it required elements of public participation akin to legislation to make it legitimate – as well as more recent STS scholarship surveyed below, anticipatory governance proposes the development of three inter-related capacities of *foresight*, *engagement* and *integration* as a response to various pathologies of innovation that are conventionally realised only with hindsight.

Consistent with the vision of extending these capacities more broadly through society, Stilgoe and colleagues (2013) articulate a framework in which the covering concept of responsible innovation builds on anticipatory governance to enhance a similarly inspired set of capacities – *anticipation*, *inclusion*, *reflexivity* and *responsiveness* – in research and innovation systems. Their emphasis is on the need to take the more experimental work of anticipatory governance, which has often occurred with the voluntary participation of a more narrow set of actors in the innovation system such as academic scientists and engineers, and better connect its findings with the practice, institutions and cultures of the broader innovation system. One specific manifestation of this effort is with the UK Engineering and Physical Sciences Research Council, which adopted a version of this framework called 'AREA', emphasizing anticipation, reflection, engagement, and action (Owen 2014). Elsewhere, national research funders in Norway and the Netherlands have created programmes of research and engagement under the heading of responsible innovation.

The idea of responsibility being enacted here is not a legalistic and retrospective one but rather a prospective one, recognizing profound uncertainties and encouraging researchers to join intellectual forces to explore them. In terms yet broad enough to capture the range of possible issues and targets of responsible innovation, a still more concise definition of responsible innovation holds it as 'care for the future through collective stewardship of science and innovation in the present' (Owen et al, 2013). This definition not only embodies the idea of anticipation that flows through most of these efforts, but it also implies the scrutiny of the societal goals to which emerging innovations are commonly offered as a response. The point is not just to ask what emerging technologies can do to help us, but rather to ask what we can do to help, or not, emerging technologies.

One important research agenda for STS is in continuing the study of the emergence of responsible innovation as a hybrid construction at the interface of science and policy. But this kind of approach has not been and, we would argue, should not be the only contribution made by STS researchers. As seen in the US experience related above and as we describe later in this chapter, STS people are more than just researchers here. In the STS tradition of what might be called 'constructive constructivism' (Rip 1994), they are often aiming to ameliorate as well as analyse, to help reconstruct as well as deconstruct. The roots of this engagement go back to the STS diagnosis of the problems to which responsible innovation might offer some remediation. Indeed, this idea of the depth of the STS agenda motivates much of the remainder of our discussion.

Technology as means and ends

The conventional approach to questions of technology governance (Wynne 2001; Macnaghten and Chilvers 2013), as developed over the second half of the twentieth century, has been one of technology assessment, risk assessment and risk management, coupled with ethical attention to questions of implications and research practices. The growth of institutions of risk and ethics governance follows a narrative of responsibility with which the scientific community has grown comfortable. There have been controversies and crises in the governance of science, including prominent examples such as the Manhattan Project, the Nuremberg trials, the Tuskegee experiment and accidents involving nuclear power, pharmaceuticals and other technologies, which have produced regulatory responses. Scientific cultures can justifiably claim some ability to self-correct in matters of ethics, even if lessons are often learnt slowly and travel across cultures and scientific domains glacially (Briggle and Mitcham 2012).

The 1975 Asilomar conference, at which early recombinant DNA researchers met to draw up guidelines for an attempt at self-governance, is more than a case in point, as the heritage of Asilomar is being held up by some scientists, such as those involved with research on mutant influenza viruses, as a paradigmatic demonstration of the capacity of the scientific community to take care of an emerging issue (Kaiser and Moreno 2012), and those involved in emerging technologies from synthetic biology to geoengineering are constituting new, self-consciously Asilomar-style meetings (Hurlbut 2015). Yet STS scholars have explained how Asilomar failed to capture the full range of public concerns as they were expressed at the time or would emerge in the future (Wright 2001; Nelkin 2001). Jasanoff (2013) discusses the Asilomar meeting in terms of 'containment'. The participants sought to contain not just the technical artefacts – using physical and biological means to stop new organisms from entering the environment – but also the scope of public debate. The debate was cast as one of health and safety, with questions of political economy overlooked. For Krimsky (2005), the reductionism of the Asilomar debate failed to prepare either scientists or policymakers for impending controversies over industrial biotechnology. Moreover, as Guston (2006) has shown, the very idea of 'self'-governance is irreparably problematic and scientists with diverse opinions invariably need something other than science – we might call it politics as shorthand – to aid in decision-making.

STS has thus helped to articulate the need to escape simple distinctions between self-governance and top-down regulation and between 'good' and 'bad' uses of a technology – even if it has not fully penetrated the veil around the scientific community. The field has built up historically and sociologically rich accounts of the plurality of the motivations for research and the sources of innovation. Just as the linear model of innovation is flawed for its presumption that science is the wellspring of technology, so we know also that necessity is not necessarily the mother of invention (see Williams and Edge 1996 for a survey). STS instead reads such "simple stories" of innovation as performances emanating from traditional assumptions about scientific authority, autonomy and responsibility, and STS scholars have developed new frameworks of governance that get past a fixation on 'risk' (Wynne 2002) to concentrate instead on 'the governance of innovation itself' (Felt et al 2007).

Responsible research and innovation directs attention not only to the well-rehearsed risks, uncertainties and unintended consequences of technology, but more importantly to an innovation system and the problems to which it offers technology as a solution. Furthering Winner's technology-as-legislation, STS has discussed the 'social constitution' of emerging technologies, the social and political arrangements that particular technologies demand (Grove-White et al 2000, Kearnes et al 2006, Szerszynski et al 2013). We can see, without resorting to technological determinism (the idea that social change is driven by technical change), how technologies variously open up or narrow choices. As Latour (2008, p. 5) describes when discussing tools of genetic modification,

> Science, technology, markets, etc. have amplified, for at least the last two centuries, not only the scale at which humans and nonhumans are connecting with one another in larger and larger assemblies, but also the intimacy with which such connections are made. Whereas at the time of ploughs we could only scratch the surface of the soil, we can now begin to fold ourselves into the molecular machinery of soil bacteria.

The growing disruptive power of technology to intervene not just in intimate ways with living systems but also at global scales (Beck 1992) magnifies the importance of scrutinizing emerging technologies. Once we get past technological determinism, we can see that there are choices to be made within innovation that do not just relate to its acceptance or rejection, but rather to the multiplicity of mechanisms and arenas through which and within which innovation is constituted and governed. It is this recognition of this multiplicity that, in part, keeps the emphasis on governance from being just another manifestation of neo-liberal framing of research policy (Guston 2014b).

Some in neighbouring disciplines have developed these insights in what could be seen as updates of Winner for the information age – focussing on black-boxed, inscrutable algorithms (Pasquale 2015) and inscribing a maxim that 'code is law' to capture the growing power of software to inscribe new social rules (Lessig 1999). This descriptive approach may be engaged in something of a dialectic with the more normative question of how to democratise the politics of technology: In order to expand (democratize) and diversify (pluralize) participation in the aspects of innovation that legislate for the future, we may need to re-describe what we think the challenges may be, and how we frame those challenges of course help determine the kinds of normative and social responses elicited. The political philosophy behind many such approaches is derived from the realist democratic theorist E.E. Schattschneider (1960), who argued in the context of the American civil rights movement that the first step toward democratization was the creation of a conflict that would then attract more attention and offer the opportunity to reframe the issue at the heart of the conflict in light of the composition of the new set of participants.

The framing of responsible innovation includes in this dialectic how initial conditions are framed as problems such that knowledge-based innovation is presumed to be a solution. At first blush the 21st Century seems to have lost enthusiasm for this presumption, historically captured by the concept of the 'technological fix'. Alvin Weinberg (1966) originally discussed (and endorsed) the term during the Cold War, reflecting an American reaction to what was perceived as Soviet 'social engineering'. Weinberg identified social problems as intrinsically complex (we would perhaps now describe them as 'wicked' (Rayner 2012)) and saw technology as a way to cut through such Gordian knots rather than having to understand and disentangle their social threads. With the end of the Cold War, technological enthusiasm has, according to Morozov (2013), morphed rather than dimmed. 'Solutionism', the idea that technology, especially information and communication technology, can cure our ills, has relocated to Silicon Valley and begun to reframe a huge range of problems such that they become targets for ICT 'solutions'.

STS has not limited itself to revealing alternatives to and contingencies in pre-determined technological trajectories. STS researchers have also sought to constructively engage with governance practices. Sarewitz (2011, p. 95) argues, when it comes to technology assessment (TA), that 'Current approaches are almost entirely reactive, ponderous and bureaucratic'. STS has contributed to the development of new approaches to TA, particularly in the (well-funded) area of nanotechnology. Constructive Technology Assessment (Rip et al 1995), Real Time Technology Assessment (Guston and Sarewitz 2002), Upstream Engagement (Wynne 2002; Wilsdon and Willis 2004) and Midstream Modulation (Fisher et al 2006) all seek to open up (Stirling 2008) technological possibilities while they are still under construction.

Among the ways such work contributes to the agenda of responsible innovation is through reconnecting STS to a perennial debate, but one that had fallen out of fashion, about the direction of science and innovation. The unevenness of technological progress was perhaps most succinctly described by Richard Nelson in his “Moon and the ghetto” lectures in the 1970s when he asked why innovators and policymakers seemed willing and able to solve some problems – such as getting man on the moon and eradicating communicable disease – and not others – such as child illiteracy and drug addiction (for a more recent commentary, see Nelson (2011)). Nelson’s message spoke to a social movement, and associated literature, on appropriate technology and development (Schumacher 1973; Kaplinsky 2011; Leach and Scoones 2006), as well as to a newer literature that has followed up on the promise of emerging technologies and found it wanting (Cozzens and Wetmore 2013; Woodson 2012; Chapter in Handbook on social movements).

A crucial contribution of STS is to delineate instances when problems might or might not be amenable to technological treatment. For example, following on *The Moon and the Ghetto*, Sarewitz and Nelson (2008) offer three criteria to help set priorities among problems to ascertain which might be more susceptible to technological problem-solving. Comparing the relative failure of technologies to alter outcomes in education to the relative success of technologies to do so for infectious disease, they argue that investments in R&D might lead to more rapid social progress when: 1) the technology largely embodies the cause-and-effect relationship of the problem and solution; 2) the effects of the presumed technological fix are able to be assessed by relatively unambiguous and uncontroversial criteria; and 3) the R&D is focused on a pre-existing, standardized technical core.

To say that technological fixes are good only under these conditions, however, may be another way of saying that they are not very good in general. We can add such an analysis to the typologies offered by Winner (1977) and Sclove (1995) for desirable technologies. Winner sees flexibility, intelligibility by non-experts, and the avoidance of dependency as qualities that we should look for and nurture in ‘good’ technology. Sclove’s list of criteria for democratic technologies is longer, including, for example, ecologically sustainable technologies and those that promote global pluralism in technology choice while excluding in particular those that create transboundary ecological impacts. Similarly, deLaet and Mol (2000) describe the attractiveness of the Zimbabwe Bush Pump, an archetypical appropriate technology, in terms of its ‘fluidity’, its adaptability across a variety of contexts. While we might be hard-pressed to disagree with these criteria pertaining to technologies themselves, STS research on responsible innovation also needs to concentrate on questions about what strategies and processes might encode a reliable path toward such technologies (e.g., Mampuys and Brom 2015; Kiran et al. 2015; Ganzevles et al. 2014) and the extent to which the articulation of principles is sufficient or necessary to establish an appropriate approach (e.g., Holbrook and Briggle 2014; Schroeder and Ladikas 2015; Ziegler 2015).

Responsible innovation and public engagement

The imperative to engage in technology assessment at that moment when the technological and the social seem more formative and flexible has led to a growing STS interest in emerging technologies. Worldwide, significant funding for R&D on emerging technologies, as well as some mandates for research integrated with social sciences (Rodriguez et al 2013), has provided the opportunity. As Joly (2015) points out, the previous edition of this *Handbook* contained an entire section on 'emerging technosciences', and STS scholars – ourselves included – have applied many of the types of technology assessment mentioned above in the study of nanotechnology, synthetic biology, geoengineering, robotics and artificial intelligence, personalized medicine and other areas characterised by profound uncertainty, high stakes and a robust politics of novelty (Guston 2014b).

The STS concern with emerging technologies as a site for 'society in the making' (Callon 1987) is elucidated by Jasanoff (2004: 278-9) in terms of the coproduction of natural and social orders:

> Important normative choices get made during the phase of emergence: in the resolution of conflicts; the classification of scientific and social objects; the standardization of technological practices; and the uptake of knowledge in different cultural contexts. Once the resulting settlements are normalized (social order) or naturalized (natural order), it becomes difficult to rediscover the contested assumptions that were freely in play before stability was effected.

The recognition of the lack of determinacy and thus the presence of politics – as well as the structuring effects of innovations such that people live their lives in, with and through new technologies – bring normative consequences to Winner's diagnosis. If Winner's cause is motivated by the identification of technology as legislation, its placards might perhaps read 'No innovation without representation'. If science is to be better aligned with public values, how might those values be articulated? This raises a familiar question for STS: How should publics be engaged and represented in science and innovation (Brown 2006; Chilvers and Kearnes 2015)?

Moves towards responsible research and innovation can be understood as a development of two-way public engagement with science. The last two decades have seen a blossoming of dialogic activities on issues involving science, at least in the US and Northern Europe, but the motivations for this remain confused and contested (Stilgoe et al 2014; Marres Chapter in this handbook). While one can divide rationales for public participation into three categories: *normative*, that participation is a good thing in itself; *instrumental*, that participation can build trust and smooth the implementation of decisions; and *substantive*, that participation produces better decisions (Fiorino 1990), many recent STS perspectives judge the institutional motives behind moves towards greater participation as primarily instrumental. Rayner (2004), for example, makes a compelling case that efforts at public engagement are stubbornly motivated by a deficit model that has mutated as rhetoric has shifted from public *understanding* to *engagement* to *upstream* engagement. Where the aim was once to remedy public deficits in scientific knowledge, engagement now often seems directed at a perceived deficit of public trust (see the chapters in Chilvers and Kearnes 2015 for further discussion).

The public are still routinely seen as a problem in science governance issues (e.g. Rip 2006), and the practice of public engagement can exacerbate this imagined pathology, distracting from pathologies of innovation itself. Inasmuch as STS researchers have been involved in calling for, consulting on and conducting deliberative processes, we are also implicated. As Latour (2007) and De Vries (2007) have discussed, social scientists, by taking their own calls to 'open up' too literally, have been too quick to advocate public dialogue rather than focussing on faulty governance processes that could otherwise have been their target.

Some social scientists and public engagement practitioners have prioritised analysis of the processes of public engagement rather than questioning its purposes (Marris and Rose, 2010). A focus on the public and the means of their engagement may at times force consideration of new perspectives and questions, but it may equally impede the necessary *institutional reflexivity* (Wynne, 1993) required for good governance. If the deficit model critique applies equally to the instrumental and substantive rationales for public engagement, then engagement can only come to be seen as self-evidently worthwhile, rather than as a means to an end. Thus, rather than opening up the possibility of revealing new conflicts, engagement practice is often directed at closure and consensus (Stirling 2008; Horst and Irwin 2010). This has led some STS researchers to describe participatory methods as themselves 'technologies' (Lezaun and Soneryd 2007) or 'experiments' (Laurent 2011; Stilgoe 2012), thereby enabling STS deconstructions and reconstructions.

In a positive development for the co-constructive nature of responsible innovation, public engagement is diversifying beyond conventional deliberative practice (Guston 2014a; Davies et al. 2012; Selin 2014. Rather than focusing on interlocution conditioned by reading and writing, these new engagements involve thinking and conversing around activities including taking photographs, crafting objects, and other forms of making. Not only do such forms of material deliberation provide broader opportunities for people to learn through different modalities, but they also provide concrete opportunities for people to engage in explicit co-creation, hypothetically preparing them for co-creative roles in the course of their everyday governance of innovation as well.

The politics of Anticipation

Like the phrase 'public engagement with science', 'responsible innovation' implies a problem. Where previously the problem was seen as either unengaged science or unengaged publics, depending on one's perspective, tackling 'irresponsible innovation' or what Beck (2000; also Adam and Groves, 2011) calls 'organised irresponsibility', might be seen as a bigger issue. But while moves towards public engagement were actively challenged from some quarters (see, for example, Taverne 2005; Durodie 2003), the term 'responsible innovation' is unlikely to incite direct opposition. Introducing the term to new audiences has prompted more than a few people to ask us: 'responsible innovation: who could be against *that*?' (Guston 2015). There is evidence that one can 'steer with big words' such as responsible innovation (Bos et al. 2014), but there is a risk that responsible innovation could become a new label for business-as-usual, instrumentally deployed to smooth the path of innovation.

The pathologies of innovation to which STS researchers might easily point would include the unpredictability and uncontrollability of large sociotechnical systems (Perrow 1984, 2011; Krohn and Weingart 1987), institutionalised ignorance of early warnings (Harremoës et al 2001), the altered nature of human action (Jonas 1985), the tendency towards hype (Borup et al 2006; Simakova and Coenen 2013) and the various forms of lock-in that make sociotechnical change difficult. Some of the most important STS insights into public engagement come not from studies of explicit engagement but of how 'the public' is constructed in the practice of science and technology (Wynne 1993; Woolgar 1990; Maranta et al 2003; Hill and Michael 1998). In a similar way, in engaging with notions of responsible innovation, we should look not just to the novel activities taking place under this name, but also to the ways in which scientists and innovators imagine their own changing responsibilities.

The emergence of science as an organised activity from the 17th Century onwards has been accompanied by 'metascientific' (Ziman 2001) questions of social responsibility, mostly being posed within the scientific community itself (Glerup and Horst 2014). STS, including its prehistory from Merton onwards, has always maintained an interest in questions of what counts as 'good' science and technology. The links with ethics, in its various forms (see chapter in this Handbook) are now well-established.

Over the last few decades, a view in which good science can be cleanly separated from deviant, bad science, which is often labelled as FFP for "fabrication, falsification and plagiarism", has been questioned by those who observe scientific practice (Gieryn and Figert 1986; Steneck 2006). The more general term 'questionable research practices' has provided a more realistic category of behaviours that ought to be discouraged and the more positive label 'responsible conduct of research' has come to be adopted, which includes not just research *integrity*, evaluated according to professional standards, but also research *ethics*, in which society more broadly might have a say (Steneck 2006; see also Briggle and Mitcham (2012)).

This discussion, however, still tends to maintain a rather tight definition of the responsibilities of scientists and engineers, leading to the distinction between their responsibilities to their professional colleagues, rendered as micro-ethics, and their responsibilities to the broader society, rendered as macro-ethics (Herkert 2005). Philosopher Heather Douglas (2003) has described how the role responsibilities of scientists towards their professional colleagues (or, more grandly, toward the pursuit of truth) are often seen as trumping their general responsibilities towards society. This hierarchy is a dominant 'division of moral labour' (Rip and Shelley Egan 2010), in which scientific cultures have come to see social, ethical and political issues as someone else's business, despite a long history of discussions about social responsibility led by scientists themselves.

During the Cold War, for example, growing concerns about the use of science for military ends led to the creation of initiatives such as the Pugwash conferences on Science and World Affairs (which would go on to win the 1995 Nobel Peace Prize) (Sismondo 2011; see also Rip 2014). In the 1970s, in addition to the Asilomar meeting, others began debating the more general possibility and desirability of setting 'limits of scientific inquiry' (Holton and Morison, 1978).

Since Cold War discussions of scientific responsibility, however, the political economy of science has changed markedly. The emergence of what some have called 'neoliberal science' (Lave et al 2010), with closer interweaving of public and private agendas, has made it even harder for scientists to defend (if it was ever defensible) an independent 'republic of science' (Polanyi 1962) with an unfettered 'right to research' (Brown and Guston 2009). A continued increase in the scale and scope of technoscience, coupled with the potential, captured by Latour in the quote above, to intervene in increasingly profound ways, changes the stakes of the debate on responsibility. In this regard, Latour's (1999) own focus on laboratories as sites of negotiation for such matters (even if we understand laboratories as extending into the outside world) starts to seem limiting. Indeed, if responsible innovation is to have purchase and STS is to contribute to challenging the dominant demarcation of responsibilities, we must remember the insight from literature in the social shaping of technology (Williams and Edge 1996), that innovation happens in use as well as in research and development.

For its defenders, the bulwarks of the autonomy of science protect against overreaching questions of scientific responsibility. But they also protect against scrutiny of and interference in the direction of scientific and technological development, as in Polanyi's (1962) argument that because the progress of science is unpredictable (and its societal consequences even more so), then it is ungovernable. The concept of anticipation as used in anticipatory governance and adopted by responsible innovation is meant to alter this logic by articulating a future-oriented disposition that can provide appropriate guidance for action in the present. Such anticipations would not be needed if scientific and technological development were truly predictable, as governance would then be transparent and certain, but studies in the social shaping of technology have systematically undermined the idea that innovation is inevitable. This process, however, is rendered tractable yet challenging because even if technology is not autonomous it can, especially at scale, offer a convincing impression of autonomy (Winner 1977; Hughes 1993). Sociotechnical systems can build up 'momentum' (Hughes 1993) as their trajectories are constrained by what has been variously described as of 'path dependency' (David 2001), 'escalating commitment' (Staw 1976), 'entrenchment' (Collingridge 1980), 'entrapment' (Walker 2000), 'lock-in' (Arthur 1989), and 'obduracy' (Selin and Sadowski 2015). For Collingridge (1980, 19), the emergent intransigence of technological systems poses a dilemma of control:

> [A]ttempting to control a technology is difficult, and not rarely impossible, because during its early stages, when it can be controlled, not enough can be known about its harmful social consequences to warrant controlling its

development; but by the time these consequences are apparent, control has become costly and slow.

As described above, emerging technologies present insurmountable challenges for risk-based governance models. Some have argued, however, that focusing on the uncertain futures of these emerging technologies and their emergent properties is both impossible and undesirable. Nordmann (2014) holds this to be the case. He argues, first, that the world of the future is not the world of the present, and the latter cannot see into the former; second, we overlook history, and the imagination of alternative words, through paternalistic future projections of the present; and, third, there are trivial and non-trivial version of the future (e.g., easy extrapolations and discontinuities, respectively), and the anticipatory element of responsible innovation seems less able to deal with the latter.

Some, however, counter that anticipations provide appropriate interpretive orientation for future-oriented decision making (van der Burg 2014), recognizing the still-nascent response to non-predictive modes of assessment that are sought by policy makers (Wilsdon 2014). More pointedly, one might recast the problem that Nordmann categorizes as “paternalism” rather as “care”, as many environmental ethicists and some versions of responsible innovation do (Groves 2015). In a rhetorical anticipation, futures scholar Cynthia Selin (2014, 106) argues, “The court of the future seems more likely to condemn us for negligence than for paternalism.” Competing with the hubris of technoscientific visionaries – who claim resources and allegiance based on precisely the kinds of problematic claims that Nordmann attacks – would seem to demand the democratic articulation of alternative futures in ways that have been developed by STS over the last few decades.

Responsible innovation, emergence and technological systems

Technologies that come to pose profound questions of governance may not initially seem problematic. In some cases, as with genetically modified crops or personal genetic tests, one can easily imagine how aspects of technical or contextual novelty might create new ethical dilemmas and political challenges. However, some problematic ramifications many only emerge at larger, systemic scales (Hellstrom 2003). Conventional biofuel crops, which may seem initially mundane or even environmentally benign, may be grown at a scale at which they put land-use pressure on food crops. Similarly, privacy concerns with particular social media may only emerge one a particular platform has reached a saturation point. As science and policy excitement grows around ‘big data’, the rhetoric of which has been radically depoliticised so that value questions are hidden beneath those concerning the practical uses of data (Crawford et al 2014), those interested in responsible innovation will need to pay particular attention to these dynamics of emergence.

In recognition of the impossibility of prediction and control and the limits of authoritative decision-making, some have argued for ‘tentative governance’[3]. Others have described the need for ‘meta-regulation’ (Dorbeck-Jung & Shelley-Egan 2013). These authors argue that the task is one of ‘responsibilisation’, constructing the conditions in which responsible actors are able to respond to surprises in the light of uncertain information. Before we can talk clearly about the allocation of responsibilities we need to outline ‘second-order’ (Illies and Meijers, 2009), ‘meta-task’ (Van den Hoven, 1998) or ‘meta’-responsibilities (Stahl, 2013). These are the responsibilities upon actors to enable the possibility of making responsible choices in the future. So Collingridge’s (1980) proposal for ‘corrigibility’ in technology systems, or Winner’s (1977, 326) principle that ‘technologies be built with a high degree of flexibility and mutability’ could be taken as meta-governance recommendations.

In order for such approaches to have significant effect, however, there needs to be close engagement with the institutional, as well as the cultural and individual, practices of science and innovation. Rip (2006) has discussed the importance of understanding the ‘de facto governance’ of science and innovation, including what Pellizoni (2004) calls the ‘logic of unresponsiveness’ – the often-hidden interests, assumptions and dynamics that steer innovation towards particular ends. A growing body of scholarship is concentrating on the political economy of universities and science (e.g. Lave et al 2010; Berman 2011; Tyfield 2012). ‘Doing’ responsible innovation therefore demands a degree of engagement with dynamics beyond the practices of scientists and innovators.

Responsible innovation in action

So what does responsible innovation look like? How do we know it when we see it? And how might STS play a role in evaluating and, potentially, nurturing its development? Recent years have seen the active, if still modest, involvement of STS researchers in the development of emerging technologies. As described above, nanotechnology has been a focus for the development of multiple models of engagement and technology assessment, all of which can be seen as advancing a broad agenda of responsible innovation, although their specific tools and aims would vary.

The emerging science of synthetic biology has become the second major site for responsible innovation as a form of ‘social innovation’ (Rip 2014). STS researchers have been involved in laboratories as well as policy rooms, seeking to shape trajectories in more responsible ways, and their perspectives have been sought by funding agencies to help construct sponsored research agendas (e.g., Brian 2014). At the same time, they have taken the STS principle of reflexivity to heart, putting their own roles under investigation (see Calvert and Martin 2009;

---

[3] See, for example, the 2010 conference on ‘Tentative Governance in Emerging science and technology’ at the University of Twente, http://www.utwente.nl/igs/conferences/2010-tentative-governance/, accessed March 13 2015

Calvert 2010; Rabinow and Bennett 2012; Stemerding 2015; Sismondo 2007). As synthetic biologists have adopted the language of responsible innovation, STS has been able to trace and critique the uptake of terms and ideas (Marris 2015). And scientometrics research has begun to map the integration of social sciences into various emerging technologies (Shapira et al 2015). The emerging science of geoengineering has also seen STS researchers enter discussions with scientists and funding institutions that point to a more literal and more constructive sense of the word 'collaboration' (Stilgoe 2015).

STS contributions have been, first, to argue that concerns with micro-ethics and with convention legislation apply also to the macro-ethical and to innovation-as-legislation. Second, they have recognized a broader area of application, the innovation system, rather than science or research more narrowly conceived. The challenge is not just a conceptual one; it is also a methodological one. If innovation is a form of collective experimentation (Latour 2011), then responsible innovation has become a form of collective experimentation in which STS researchers have inveigled themselves in various ways.

Some of those most intimately involved have also criticised the ways in which STS has become embedded in emerging science and technology practices and policies. Wynne's (2007) argument is that the involvement of social scientists in emerging innovation risks occluding the politics that their role should be helping to reveal. However, Wynne has suggested some important roles that STS can and does play, including: revealing the normative models of 'publics' that are being enacted in science and policy; understanding and challenging 'expert' presumptions about relevant public issues; describing the diversity of other cultures in which understandings might differ and be able to contribute; and, finally, putting this in the context of historical and philosophical perspectives on science as public knowledge (see also Wynne 2015). While these roles work to undermine the unitary framing of a relatively unreflexive, expert-driven and even technocratic pursuit, they do not necessarily serve the function of diversifying the kinds of people who get to participate in future-making.

One way in which STS has sought to engage with institutionalised conversations about responsibility has been through bioethics. As discussed above, the current machinery of bioethics is in part a response to past failures of responsibility. As it has come to be institutionalised, however, it has attracted critique from STS because of its concentration on particular ethical concerns, such as the protection of human subjects' autonomy through informed consent, to the neglect of what has been called 'public ethics' (Nuffield Council 2012). Macro-ethical concerns about the direction of innovation and the distribution of its benefits and risks have been largely overlooked in ethical governance. And the relationship of ethics to science tends to be oppositional. Rabinow and Bennett (2012, 35), in their reflections on engaging as collaborators in a large synthetic biology project, express their concerns that:

> bioethics, as currently practiced in official settings, tends to undervalue the extent to which ethics and science can play a mutually formative role. More significant, it undervalues the extent to which science and ethics can

collaboratively contribute to and constitute a good life in a democratic society.

Rabinow and Bennett here include the important role of democratic society, but their emphasis on the mutual constitution of the good life between scientists and even new bioethicists can, without grounding with public engagement, remain in the rarefied space of technocracy (see also Thompson 2013).

The experiences of some STS researchers who have been involved in experimental collaborations with scientists (some under the responsible innovation banner but many not) has led them to call for a 'post-ELSI' social science (Rabinow and Bennett 2012; Balmer et al 2012) (eliciting the response that 'we have never been ELSI' (Myskja et al 2014)). The aim is to expand upon critique, in the familiar mode of articulating alternatives and revealing complexities, to develop new styles of engagement. Clearly, this move raises questions about the methodological and analytical challenges of being entangled in emerging science. In this sense, we are seeing a reworking of an older debate about the politics of STS (Radder 1998). Such a debate becomes unavoidable if we are to take seriously responsible innovation as a policy agenda and a set of ideas still in formation. There needs to be an urgent discussion of the opportunities and uncertainties of an approach that is explicitly ameliorative, one in which, rather than just studying coproduction in action (Jasanoff 2004), STS researchers are themselves involved in coproducing knowledge and social order. An STS or a responsible innovation that serves only to expose technocratic framings but not to construct new, more expansive, diverse and participatory ones is, in our view, not going far enough.

References (Chicago style)

Adam, Barbara, and Chris Groves. "Futures tended: Care and future-oriented responsibility." Bulletin of Science, Technology & Society 31, no. 1 (2011): 17-27.

Akrich, Madeleine. "The de-scription of technical objects." In Bijker, Wiebe E., and John Law. Shaping technology/building society: Studies in sociotechnical change. MIT press (1992): 205-224.

Arthur, W. Brian. "Competing technologies, increasing returns, and lock-in by historical events." *The economic journal* (1989): 116-131.

Balmer, Andy, Kate Bulpin, Jane Calvert, Matthew Kearnes, Adrian Mackenzie, Claire Marris, Paul Martin, Susan Molyneux-Hodgson, and Pablo Schyfter. "Towards a manifesto for experimental collaborations between social and natural scientists." (2012). https://experimentalcollaborations.wordpress.com/2012/07/03/towards-a-manifesto-for-experimental-collaborations-between-social-and-natural-scientists/ [Accessed 22.12.13].

Barben, Daniel, Erik Fisher, Cynthia Selin, and David H. Guston. "38 Anticipatory Governance of Nanotechnoiogy: Foresight, Engagement, and Integration." In Hackett, Edward J., Olga Amsterdamska, Michael Lynch, and Judy Wajcman.*The handbook of science and technology studies*. The MIT Press, 2008.

Beck, Ulrich. *Risk society: Towards a new modernity*. Vol. 17. Sage, 1992.
Beck, Ulrich. "Risk society revisited: theory, politics and research programmes."*The risk society and beyond: Critical issues for social theory* (2000): 211-229.
Berman, Elizabeth Popp. *Creating the market university: How academic science became an economic engine*. Princeton University Press, 2011.
Borry, Pascal, Paul Schotsmans, and Kris Dierickx. "The birth of the empirical turn in bioethics." Bioethics 19.1 (2005): 49-71.
Borup, Mads, Nik Brown, Kornelia Konrad, and Harro Van Lente. "The sociology of expectations in science and technology." *Technology analysis & strategic management* 18, no. 3-4 (2006): 285-298.
Bos, Colette, Bart Walhout, Alexander Peine, and Harro van Lente. "Steering with big words: articulating ideographs in research programs." Journal of responsible innovation 1, no. 2 (2014): 151-170.
Briggle, Adam, and Carl Mitcham. *Ethics and science: an introduction*. Cambridge University Press, 2012.
Brian, Jenny Dyck. "Special perspectives section: responsible research and innovation for synthetic biology." *Journal of Responsible Innovation* 2, no. 1 (2015): 78-80.
Brown, Mark B. "Survey Article: Citizen Panels and the Concept of Representation*." *Journal of Political Philosophy* 14, no. 2 (2006): 203-225.
Brown, Mark B., and David H. Guston. "Science, democracy, and the right to research." *Science and Engineering Ethics* 15, no. 3 (2009): 351-366.
Callon, Michel. "Society in the making: the study of technology as a tool for sociological analysis." In Bijker, Wiebe E., Thomas P. Hughes, and J. Trevor. Pinch, eds. The social construction of technological systems: New directions in the sociology and history of technology." (1987). 83-103.
Calvert, Jane. "Synthetic biology: constructing nature?." *The Sociological Review* 58, no. s1 (2010): 95-112.
Calvert, Jane, and Paul Martin. "The role of social scientists in synthetic biology." *EMBO reports* 10, no. 3 (2009): 201-204.
Chilvers, Jason, and Matthew Kearnes, eds. Remaking Participation: Science, Environment and Emergent Publics. Routledge, 2015.
Collingridge, David. *The social control of technology*. London: Open University Press, 1980.
Crawford, Kate, Mary L. Gray, and Kate Miltner. "Big Data| Critiquing Big Data: Politics, Ethics, Epistemology| Special Section Introduction." *International Journal of Communication* 8 (2014): 10.
David, Paul A. "Path dependence, its critics and the quest for 'historical economics'." *Evolution and path dependence in economic ideas: Past and present* (ed. P Garrouste and S Ioannidis) (2001), pp. 15-40. Cheltenham: Edward Elgar.
Davies, Sarah R., Cynthia Selin, Gretchen Gano, and Ângela Guimarães Pereira. "Citizen engagement and urban change: Three case studies of material deliberation." *Cities* 29, no. 6 (2012): 351-357.
de Saille, Stevienna. "Innovating Innovation Policy: The emergence of 'Responsible Research and Innovation'." *Journal of Responsible Innovation*just-accepted (2015): 1-33.
De Vries, Gerard. "What is political in sub-politics? How Aristotle might help STS." *Social Studies of Science* 37, no. 5 (2007): 781-809.
Dorbeck-Jung, Bärbel, and Clare Shelley-Egan. "Meta-regulation and nanotechnologies: the challenge of responsibilisation within the European

Commission’s code of conduct for responsible nanosciences and nanotechnologies research." *Nanoethics* 7, no. 1 (2013): 55-68.
Cook-Deegan. Robert M. *The gene wars: Science, politics, and the human genome*. New York: WW Norton & Company, 1994.
Douglas, Heather E. "The moral responsibilities of scientists (tensions between autonomy and responsibility)." *American Philosophical Quarterly* (2003): 59-68.
Durodié, Bill. "Limitations of public dialogue in science and the rise of new ‘experts’." Critical Review of International Social and Political Philosophy 6, no. 4 (2003): 82-92.
ERA expert group, 2008, Challenging Europe’s Research: Rationales for the European Research Area (ERA), European Commission: Brussels
European Commission (2013) Options for strengthening responsible research and innovation, Luxembourg: European Union DG Research and Innovation
Felt, Ulrike, Brian Wynne. et al (2007). Taking European knowledge society seriously. Luxembourg: European Union DG for Research.
Fiorino, Daniel J. "Citizen participation and environmental risk: A survey of institutional mechanisms." *Science, technology & human values* 15, no. 2 (1990): 226-243.
Fisher, Erik, Roop L. Mahajan, and Carl Mitcham. "Midstream modulation of technology: governance from within." *Bulletin of Science, Technology & Society*26, no. 6 (2006): 485-496.
Funtowicz, Silvio O., and Jerome R. Ravetz. *Science for the post normal age*. Futures, 25(7), 739-755.1995.
Ganzevles, Jurgen, Rinie van Est, and Michael Nentwich. "Embracing variety: introducing the inclusive modelling of (Parliamentary) technology assessment." Journal of Responsible Innovation 1, no. 3 (2014): 292-313.
Gieryn, Thomas F., and Anne E. Figert. "Scientists protect their cognitive authority: the status degradation ceremony of Sir Cyril Burt." In *Böhme, Gernot, and Nico Stehr. The knowledge society: the growing impact of scientific knowledge on social relations. Vol. 10, 1986* pp. 67-86. Springer Netherlands, 1986.
Glerup, Cecilie, and Maja Horst. "Mapping ‘social responsibility’ in science."*Journal of Responsible Innovation* 1, no. 1 (2014): 31-50.
Groves, Christopher. "Logic of Choice or Logic of Care? Uncertainty, Technological Mediation and Responsible Innovation." NanoEthics 9.3 (2015): 321-333.
Grove-White, Robin, Phil Macnaghten, and Brian Wynne. "Wising up: the public and new technologies." Lancaster: IEPPP, Lancaster University (2000).
Guston, David H. "Responsible innovation in the commercialized University." Stein, Donald G. *Buying in or selling out?: The commercialization of the American research university*. Rutgers University Press (2004): 161-174.
Guston, David H. "On consensus and voting in science: From Asilomar to the National Toxicology Program." in Frickel, Scott and Kelly Moore. "The New Political Sociology of Science." (2006): 378-404.
Guston, David H. "The pumpkin or the tiger? Michael Polanyi, Frederick Soddy, and anticipating emerging technologies." *Minerva* 50, no. 3 (2012): 363-379.
Guston, David H. "Building the capacity for public engagement with science in the United States." *Public Understanding of Science* 23, no. 1 (2014a): 53-59.
Guston, David H. "Understanding ‘anticipatory governance’." *Social Studies of Science* 44, no. 2 (2014b): 218-242.
Guston, David H. "Responsible innovation: who could be against that?." *Journal of Responsible Innovation* 2, no. 1 (2015): 1-4.

Guston, David H., and Daniel Sarewitz. "Real-time technology assessment." *Technology in society* 24, no. 1 (2002): 93-109.
Hellström, Tomas. "Systemic innovation and risk: technology assessment and the challenge of responsible innovation." *Technology in Society* 25, no. 3 (2003): 369-384.
Herkert, Joseph R. "Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering." *Science and Engineering Ethics* 11, no. 3 (2005): 373-385.
Hill, Alison, and Mike Michael. "Engineering Acceptance: Representations of the Public in Debates on Biotechnology." *Wheale, Peter, René Von Schomberg, and Peter Glasner, eds. The social management of genetic engineering. Aldershot,, UK: Ashgate.* (1998): 201-217.
Holbrook, J. Britt, and Adam Briggle. "Knowledge kills action–why principles should play a limited role in policy-making." Journal of Responsible Innovation 1, no. 1 (2014): 51-66.
Horst, Maja, and Alan Irwin. "Nations at Ease with Radical Knowledge On Consensus, Consensusing and False Consensusness." Social Studies of Science 40.1 (2010): 105-126.
Hughes, Thomas P. *Networks of power: electrification in Western society, 1880-1930*. JHU Press, 1993.
Hurlbut, J. Benjamin. "Remembering the Future: Science, Law, and the Legacy of Asilomar." In Jasanoff, Sheila, and Sang-Hyun Kim, eds. Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power. University of Chicago Press, 2015. 126-51.
Illies, Christian, and Anthonie Meijers. "Artefacts without agency." *The Monist*92, no. 3 (2009): 420-440.
Jasanoff, Sheila. "Technologies of humility: citizen participation in governing science." *Minerva* 41, no. 3 (2003): 223-244.
Jasanoff, Sheila, Afterword, in Jasanoff, Sheila, ed. *States of knowledge: the co-production of science and the social order*. Routledge, 2004.
Jasanoff, Sheila. "Epistemic Subsidiarity-Coexistence, Cosmopolitanism, Constitutionalism." *European Journal of Risk Regulation* (2013): 133.
Jasanoff, Sheila, Ben Hurlbut, B and Krishanu Saha. (2015) Human genetic engineering demands more than a moratorium, Guardian Political Science blog, 7 April 2015, http://www.theguardian.com/science/political-science/2015/apr/07/human-genetic-engineering-demands-more-than-a-moratorium accessed 1 May 2015
Joly, Pierre-Benoit. Governing emerging technologies – the need to think outside the (black) box, in Hilgartner, Steven, Clark Miller & Rob Hagendijk (Eds.). *Science and Democracy: Making Knowledge and Making Power in the Biosciences and Beyond* (2015). London:Routledge.
Jonas, Hans. *The imperative of responsibility: In search of an ethics for the technological age*. University of Chicago Press, 1985.
Kaiser, David, and Jonathan Moreno. "Dual-use research: Self-censorship is not enough." *Nature* 492, no. 7429 (2012): 345-347.
Kaplinsky, Raphael. "Schumacher meets Schumpeter: Appropriate technology below the radar." *Research Policy* 40, no. 2 (2011): 193-203.
Kearnes, Matthew, Robin Grove-White, Phil Macnaghten, James Wilsdon, and Brian Wynne. "From bio to nano: learning lessons from the UK agricultural biotechnology controversy." *Science as culture* 15, no. 4 (2006): 291-307.

Kiran, Asle H., Nelly Oudshoorn, and Peter-Paul Verbeek. "Beyond checklists: toward an ethical-constructive technology assessment." Journal of Responsible Innovation 2, no. 1 (2015): 5-19.
Krimsky, Sheldon. "From Asilomar to industrial biotechnology: risks, reductionism and regulation." *Science as Culture* 14, no. 4 (2005): 309-323.
Kroes, Peter, and Anthonie Meijers. "The empirical turn in the philosophy of technology." Emerald Group (2001).
Krohn, Wolfgang, and Peter Weingart. "Commentary: Nuclear power as a social experiment-European political" fall out" from the Chernobyl meltdown." *Science, Technology, and Human Values* (1987): 52-58.
Latour, Bruno. "Give me a laboratory and I will raise the world." In Biagioli, Mario. *The science studies reader. Psychology Press, 1999.* (1999): 258-275.
Latour, Bruno. "From “matters of facts” to “states of affairs”: which protocol for the new collective experiments?." Lecture to the Darmstadt Colloquium, available at: www.bruno-latour. fr/node/372 (accessed May 2013). 2001.
Latour, Bruno. "Turning around politics: A note on Gerard de Vries' paper."*Social Studies of Science* (2007): 811-820.
Latour, Bruno. "It’s development, Stupid!” or: How to modernize modernization." *In Postenvironmentalism* (ed J. Proctor) (2008) MIT Press.
Latour, Bruno. "From multiculturalism to multinaturalism: what rules of method for the new socio-scientific experiments?." *Nature and Culture* 6, no. 1 (2011): 1-17.
Laurent, Brice. "Technologies of democracy: Experiments and demonstrations." Science and engineering ethics 17.4 (2011): 649-666.
Lave, Rebecca, Philip Mirowski, and Samuel Randalls. "Introduction: STS and neoliberal science." *Social Studies of Science* 40, no. 5 (2010): 659-675.
Leach, Melissa, and Ian Scoones. "The slow race." *Making Technology Work for the Poor* (2006). London: Demos
Lezaun, Javier, and Linda Soneryd. "Consulting citizens: technologies of elicitation and the mobility of publics." *Public understanding of science* 16, no. 3 (2007): 279-297.
Lessig, Lawrence. Code and other laws of cyberspace. Basic books, 1999.
Macnaghten, Phil, and Jason Chilvers. "The future of science governance: publics, policies, practices." Environment and Planning C: Government and Policy 31 (2013)
Mampuys, Ruth, and Frans WA Brom. "Governance strategies for responding to alarming studies on the safety of GM crops." Journal of Responsible Innovation 2, no. 2 (2015): 201-219.
Maranta, Alessandro, Michael Guggenheim, Priska Gisler, and Christian Pohl. "The reality of experts and the imagined lay person." *Acta Sociologica* 46, no. 2 (2003): 150-165.
Marris, Claire. "The Construction of Imaginaries of the Public as a Threat to Synthetic Biology." *Science as Culture* 24, no. 1 (2015): 83-98.
Marris, Claire, and Nikolas Rose. "Open engagement: exploring public participation in the biosciences." *PLoS Biol* 8, no. 11 (2010): e1000549.
Morozov, Evgeny. *To save everything, click here: Technology, solutionism, and the urge to fix problems that don’t exist*. Penguin UK, 2013.
Myskja, Bjørn Kåre, Rune Nydal, and Anne Ingeborg Myhr. "We have never been ELSI researchers–there is no need for a post-ELSI shift." *Life Sciences, Society and Policy* 10, no. 1 (2014): 1-17.

Nelkin, Dorothy. "Beyond Risk: reporting about genetics in the post-Asilomar press." *Perspectives in biology and medicine* 44, no. 2 (2001): 199-207.
Nelson, Richard R. "The Moon and the Ghetto revisited." *Science and Public Policy* 38, no. 9 (2011): 681-690.
Nordmann, Alfred. "Responsible innovation, the art and craft of anticipation."*Journal of Responsible Innovation* 1, no. 1 (2014): 87-98.
Nuffield Council on Bioethics. Emerging Biotechnologies: Technology, Choice and the Public Good. Nuffield Council on Biotechnologies, London. 2012. (downloaded on 1 February 2013 from http://www.nuffieldbioethics.org/sites/default/files/Emerging_biotechnologies_full_report_web_0.pdf).
Owen, Richard. "The UK Engineering and Physical Sciences Research Council's commitment to a framework for responsible innovation." *Journal of Responsible Innovation* 1, no. 1 (2014): 113-117.
Owen, Richard, Jack Stilgoe, Phil Macnaghten, Mike Gorman, Erik Fisher, and Dave Guston. "A framework for responsible innovation." *Responsible innovation: managing the responsible emergence of science and innovation in society* (2013): 27-50. in Owen, Richard, John Bessant, and Maggy Heintz, eds. *Responsible Innovation: managing the responsible emergence of science and innovation in society*. John Wiley & Sons, 2013.
Pasquale, Frank. "The Black Box Society." Cambridge, MA: Harvard University Press (2015).
Pellizzoni, Luigi. "Responsibility and environmental governance." *Environmental politics* 13, no. 3 (2004): 541-565.
Perrow, Charles. "Normal accidents: Living with high risk systems." (1984). Princeton NJ: Princeton University Press
Perrow, Charles. " Fukushima and the inevitability of accidents." *Bulletin of the Atomic Scientists* 67, no. 6 (2011): 44-52.
Polanyi, Michael. "The republic of science: Its political and economic theory."*Minerva* 1, no. 1 (1962): 54-73.
Rabinow, Paul, and Gaymon Bennett. *Designing human practices: An experiment with synthetic biology*. University of Chicago Press, 2012.
Radder, Hans. "The politics of STS." *Social studies of science* (1998): 325-331.
Rayner, Steve. "The novelty trap: why does institutional learning about new technologies seem so difficult?." *Industry and Higher Education* 18, no. 6 (2004): 349-355.
Rayner, Steve. "Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses." *Economy and Society* 41, no. 1 (2012): 107-125.
Rayner, Steve, Clare Heyward, Tim Kruger, Nick Pidgeon, Catherine Redgwell, and Julian Savulescu. "The Oxford principles." *Climatic Change* 121, no. 3 (2013): 499-512.
Rip, Arie 'Science & Technology Studies and Constructive Technology Assessment', EASST Newsletter 13(3), pp. 11-16. Keynote Speech to EASST Conference, Budapest, 28-31 August 1994
Rip, Arie. "A Co-Evolutionary Approach to Reflexive Governance–and its Ironies." *Voss, Jan-Peter, and Dierk Bauknecht, eds. Reflexive governance for sustainable development. Edward Elgar Publishing, 2006.* 82-100.
Rip, Arie. "Folk theories of nanotechnologists." *Science as culture* 15.4 (2006): 349-365.
Rip, Arie. "The past and future of RRI." *Life sciences, society and policy* 10 (2014).

Rip, Arie, J. W. Schot, and T. J. Misa. "Constructive technology assessment: a new paradigm for managing technology in society." Rip, Arie., Thomas Misa and Johan Schot. *Managing Technology in Society: The Approach of Constructive Technology Assessment;* Pinter, London. (1995): 1-12.
Rip, Arie, and Clare Shelley-Egan. "Positions and responsibilities in the 'real'world of nanotechnology." *Understanding public debate on nanotechnologies: options for framing public policies: a working document by the services of the European Commission. European Commission, Brussels* (2010): 31-38.
Rip, Arie, and Haico Te Kulve. "Constructive technology assessment and socio-technical scenarios." In *Presenting Futures*, pp. 49-70. Springer Netherlands, 2008.
Rodríguez, Hannot, Erik Fisher, and Daan Schuurbiers. "Integrating science and society in European Framework Programmes: Trends in project-level solicitations." *Research Policy* 42, no. 5 (2013): 1126-1137.
Rose, Nikolas. *Powers of freedom: Reframing political thought*. Cambridge university press, 1999.
Sarewitz, Daniel. "Anticipatory governance of emerging technologies" in Marchant, Gary E., Braden R. Allenby, and Joseph R. Herkert, eds. *The growing gap between emerging technologies and legal-ethical oversight: The pacing problem*. Vol. 7. pp. 95-105. Springer Netherlands, 2011.
Sarewitz, Daniel, and Richard Nelson. "Three rules for technological fixes." *Nature* 456, no. 7224 (2008): 871-872.
Schattschneider. 1960. The Semisovereign People: A Realist's View of Democracy in America. New York: Holt, Rinehart, & Winston.
Schroeder, Doris, and Miltos Ladikas. "Towards principled Responsible Research and Innovation: employing the Difference Principle in funding decisions." Journal of Responsible Innovation 2, no. 2 (2015): 169-183.
Schumacher, E. F. *Small is beautiful: Economics as if people mattered*. *Blond & Briggs, London*. 1973.
Sclove, Richard. *Democracy and technology*. Guilford Press, 1995.
Selin, Cynthia. "On not forgetting futures." *Journal of Responsible Innovation* 1, no. 1 (2014): 103-108.
Selin, Cynthia. "Merging art and design in foresight: Making sense of Emerge."*Futures* (2014).
Selin, Cynthia. and Jathan Sadowski. (2015). Against Blank Slate Futuring: Noticing Obduracy in the City through Experiential Methods of Public Engagement Chilvers, Jason, and Matthew Kearnes, eds. *Remaking Participation: Science, Environment and Emergent Publics*. Routledge, 2015.
Shapira, Philip, Jan Youtie, and Yin Li. "Social science contributions compared in synthetic biology and nanotechnology." *Journal of Responsible Innovation* 2, no. 1 (2015): 143-148.
Simakova, Elena, and Christopher Coenen. "Visions, hype, and expectations: a place for responsibility." In Owen, Richard, John Bessant, and Maggy Heintz, eds. *Responsible Innovation: managing the responsible emergence of science and innovation in society*. John Wiley & Sons, 2013. 241-267.
Sismondo, Sergio. Science and Technology Studies and an Engaged Program. In The Handbook of Science and Technology Studies, Ed Hackett, Olga Amsterdamska, Michael Lynch, and Judy Wajcman (eds.) 13-32. Cambridge: MIT Press. 2007.
Sismondo, Sergio. *An introduction to science and technology studies*. John Wiley & Sons, 2011.

Stahl, Bernd Carsten. "Responsible research and innovation: The role of privacy in an emerging framework." *Science and Public Policy* (2013).
Staw, Barry M. "Knee-deep in the big muddy: A study of escalating commitment to a chosen course of action." *Organizational behavior and human performance* 16, no. 1 (1976): 27-44.
Stemerding, Dirk. "iGEM as laboratory in responsible research and innovation."*Journal of Responsible Innovation* 2, no. 1 (2015): 140-142.
Steneck, Nicholas H. "Fostering integrity in research: Definitions, current knowledge, and future directions." *Science and engineering ethics* 12, no. 1 (2006): 53-74.
Stilgoe, Jack. "Experiments in science policy: an autobiographical note." Minerva 50.2 (2012): 197-204.
Stilgoe, Jack, Alan Irwin, and Kevin Jones. "The received wisdom: Opening up expert advice." London: Demos (2006).
Stilgoe, Jack, Richard Owen, and Phil Macnaghten. "Developing a framework for responsible innovation." *Research Policy* 42, no. 9 (2013): 1568-1580.
Stilgoe, Jack, Simon J. Lock, and James Wilsdon. "Why should we promote public engagement with science?." *Public Understanding of Science* 23, no. 1 (2014): 4-15.
Stilgoe, Jack. *Experiment earth: Responsible innovation in geoengineering*. Routledge, 2015.
Stirling, Andy. "“Opening up” and “closing down” power, participation, and pluralism in the social appraisal of technology." *Science, technology & human values* 33, no. 2 (2008): 262-294.
Szerszynski, Bronislaw, Matthew Kearnes, Phil Macnaghten, Richard Owen, and Jack Stilgoe. "Why solar radiation management geoengineering and democracy won’t mix." *Environment and Planning A* 45, no. 12 (2013): 2809-2816.
Taverne, Dick. The march of unreason: science, democracy, and the new fundamentalism. Oxford: Oxford University Press, 2005.
Thompson, Charis. *Good science: the ethical choreography of stem cell research*. MIT Press, 2013.
Tyfield, David. "A cultural political economy of research and innovation in an age of crisis." *Minerva* 50, no. 2 (2012): 149-167.
Van der Burg, Simone. "On the hermeneutic need for future anticipation."*Journal of Responsible Innovation* 1, no. 1 (2014): 99-102.
Van den Hoven, M. J. "Moral responsibility, public office and information technology." In Snellen, I. Th M., and Wim BHJ van de Donk, eds. *Public administration in an information age: a handbook*. Vol. 6. IOS Press, 1998. 97-112.
von Schomberg, René. "The quest for the “right” impacts of science and technology. An outlook towards a framework for responsible research and innovation." In *Les nanotechnologies: vers un changement d’échelle éthique?* (2011): 269.
von Schomberg, René. "Prospects for technology assessment in a framework of responsible research and innovation." In *Technikfolgen abschätzen lehren*, pp. 39-61. VS Verlag für Sozialwissenschaften, 2012.
von Schomberg, René. "A vision of responsible innovation" in Owen, Richard, John Bessant, and Maggy Heintz, eds. *Responsible Innovation: managing the responsible emergence of science and innovation in society*. John Wiley & Sons, 2013.
Walker, William. "Entrapment in large technology systems: institutional commitment and power relations." *Research policy* 29, no. 7 (2000): 833-846.

Weart, Spencer R. "Scientists with a secret." *Physics Today* 29, no. 2 (1976): 23-30.
Weinberg, Alvin M. "Can technology replace social engineering?." *Bulletin of the Atomic Scientists* 22, no. 10 (1966): 4-8.
Williams, Robin, and David Edge. "The social shaping of technology." *Research policy* 25, no. 6 (1996): 865-899.
Wilsdon, James. "From foresight to hindsight: the promise of history in responsible innovation." *Journal of Responsible Innovation* 1, no. 1 (2014): 109-112.
Wilsdon, James, and Rebecca Willis. *See-through science: why public engagement needs to move upstream*. London: Demos, 2004.
Winner, Langdon. *Autonomous technology: Technics-out-of-control as a theme in political thought*. MIT Press, 1978.
Woodson, Thomas. "Research Inequality in Nanomedicine." *Journal of Business Chemistry* 9, no. 3 (2012): 133-146.
Woolgar, Steve. "Configuring the user: the case of usability trials." *The Sociological Review* 38, no. S1 (1990): 58-99.
Wright, Susan. "Legitimating genetic engineering." *Perspectives in biology and medicine* 44, no. 2 (2001): 235-247.
Wynne, Brian. "Public uptake of science: a case for institutional reflexivity."*Public Understanding of Science* 2, no. 4 (1993): 321-337.
Wynne, Brian. "Creating public alienation: expert cultures of risk and ethics on GMOs." Science as culture 10.4 (2001): 445-481.
Wynne, Brian. "Risk and environment as legitimatory discourses of technology: reflexivity inside out?." *Current sociology* 50, no. 3 (2002): 459-477.
Wynne, Brian. "Public participation in science and technology: performing and obscuring a political–conceptual category mistake." *East Asian science, technology and society* 1, no. 1 (2007): 99-110.
Wynne, Brian. "Ghosts of the machine: publics meanings and social science in a time of expert dogma and denial" Chilvers, Jason, and Matthew Kearnes, eds. *Remaking Participation: Science, Environment and Emergent Publics*. Routledge, 2015.
Ziegler, Rafael. "Justice and innovation–towards principles for creating a fair space for innovation." Journal of Responsible Innovation 2, no. 2 (2015): 184-200.
Ziman, John. "Getting scientists to think about what they are doing." *Science and engineering ethics* 7, no. 2 (2001): 165-176.