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Working with bacteria and putting bacteria to work: The biopolitics of synthetic biology for energy in the United Kingdom

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ABSTRACT

The UK government has made significant investment into so called 'fourth-generation' biofuel technologies. These biofuels are based on engineering the metabolic pathways of bacteria in order to create products compatible with existing infrastructure. Bacteria play an important role in what is promoted as a potentially new biological industrial revolution, which could address some of the negative environmental legacies of the last. This article presents results from ethnographic research with synthetic biologists who are challenged with balancing the curiosity-driven and intrinsically fulfilling scientific task of working with bacteria, alongside the policy-driven task of putting bacteria to work for extrinsic economic gains. In addition, the scientists also have to balance these demands with a new research governance framework, Responsible Research and Innovation, which envisions technoscientific innovation will be responsive to societal concerns and work in collaboration with stakeholders and members of the public. Major themes emerging from the ethnographic research revolve around stewardship, care, responsibility and agency. An overall conflict surfaces between individual agents assuming responsibility for 'stewarding' bacteria, against funding systems and structures imposing responsibility for economic growth. We discuss these findings against the theoretical backdrop of a new concept of 'energopolitics' and an anthropology of ethics and responsibility.

1. Introduction

It has been forecast that the twenty-first century will be fundamentally influenced by a "Biotechnology Revolution", in which synthetic biology will play an integral role [1]. In 2008 a headline in a UK newspaper proclaimed "Synthetic biology aims to solve energy conundrum" [2]. For over a decade, many synthetic biologists have aligned their work with this aim through research that modifies enzymes and bacteria in order to produce new (bio)fuels and new (bio)chemicals. The UK government has also made significant investment in so-called "fourth-generation" biofuel technologies [3].

In this context, synthetic biology has become part of a new "biopolitics" [4], where developing novel sources of bioenergy play a key supporting role in the growing bioeconomy. This biopolitical context has become more complicated since 2011, with the promotion of a new science governance framework, Responsible Research and Innovation (RRI).[1] There is currently no consensus on how RRI should be applied, and it is being operationalised in various ways within different governance and geographical contexts (see [5–7]). UK academics (e.g. [8]) have introduced RRI as a means of reframing responsibility within innovation as a collective activity that acknowledges the uncertain and political nature of controversial science, focussing on the purpose and possibilities of science and innovation, not just the risks.

The Research Councils UK (RCUK) have included RRI in funding calls, especially in the context of setting up six synthetic biology research centres [9]. Some centres focus on energy and the production of biofuels, and it is hoped that re-engineering particular bacteria will produce microorganisms which can feed on 'waste' gases, such as carbon monoxide and carbon dioxide, and also produce biofuels (such as butanol). The UK Government investment in synthetic biology is outlined in the 2012 *Synthetic Biology Roadmap*, which lays out five key recommendations. The third is to "invest to accelerate technology responsibly to market" ([10], p. 31–33). In 2016 the roadmap was reformulated into a strategic plan entitled "Biodesign for the Bioeconomy" [11] with a heavy emphasis on 'acceleration' within synthetic biology research.

Based on the results of ethnographic fieldwork, this article considers two challenges faced by synthetic biologists. One challenge is how to

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[1] The terms RRI and 'responsible innovation' are often used interchangeably. Following the lead of the 2012 *UK Roadmap for Synthetic Biology* [10] and to focus attention on the important role of researchers as 'responsible agents', we use RRI for the purposes of this article.

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balance the curiosity-driven and intrinsically fulfilling scientific process of *working with bacteria* to find out how life works with the task of *putting bacteria to work* in order to achieve extrinsic economic value and generate growth for industry. The other challenge is how to do this within an RRI framework which demands time for reflection and debate. These tensions will be explored by tapping into philosophical reflections on personhood, agency, power and accountability and into anthropological reflections on stewardship [12], which echo some aspects of RRI discourse.

The next section provides a conceptual and theoretical background on the anthropology of energy, "energopolitics" and biofuels, linked to a discussion on the mobilisation of RRI within the context of synthetic biology. Following this, we outline the aims of the article and the methods used in our research. The next substantive results section presents detailed analysis of qualitative interviews and participant observation with a UK synthetic biology research centre, before the final sections which present our discussion and conclusion.

2. Conceptual and theoretical background

2.1. The anthropology of energy, energopolitics and biofuels

A growing body of social science literature has identified the need for greater attention to the complex socio-political dimensions of energy [e.g. 13,14,15,16]. Within this, scholarship on the anthropology of energy is building rich and detailed insights into the varied 'cultures of energy' and multiple technologies and infrastructures that intersect with energy production, distribution, use (or consumption) and waste (see [17]; and this special issue). In this article, we are particularly interested in the intersection of biology, (bio)politics and (bio)energy with RRI. Biopolitics is defined by Michel Foucault as: "the set of mechanisms through which the basic biological features of the human species became the object of political strategy" ([18], p. 1). Since Foucault, the concept has been used widely and varyingly in social theory to study advances in science and technology that pertain to health and medicine, in particular.

Building on Foucault's concept of biopolitics, Dominic Boyer's notion of "energopolitics" provides a useful framework for considering how "the organization and dynamics of political forces across difference scales" manifest themselves in the context of energy ([19], p. 326). Energopolitics highlights the ways in which mechanisms at the macro- and micro- level are entangled. We would extend this entanglement to human-bacteria interactions. In the domain of energy politics, the succession of biofuel 'generations' illustrates how the promise of new energy products may ultimately be undesirable when social, ethical or environmental factors are taken into account. For a case study which explores these complex factors in relation to the original biofuel, wood, see Taylor et al. [20] on the politics of conservation, migration and wood-burning in Guatemala.

We would add that biopolitics also refers to the set of mechanisms through which the basic biological features of *bacteria* became the object of political strategy and with those who work with bacteria. In the context of climate change and trying to find new sources of energy, this type of bacterial biopolitics merges with energy politics or "energopolitics": the set of mechanisms through which the basic choices in energy production and consumption become the object of political strategy.

Each successive generation of biofuels began with promises to 'save the planet' or 'green the planet'. However, each successive generation has eventually come up against major ecological and economic problems [21]. Fourth-generation biofuels are no exception. In 2015, media reported [22] that the synthetic biology biofuels mission had failed. While biofuels produced via the genetic manipulation of algae (supported through over $54 million in loans and backing by the US Government) resulted in the successful development of large amounts of 'green crude', a drop in crude oil prices in 2015 and 2016 meant (syn)biofuels could not compete with the economies of scale of oil and gas. This example illustrates how the threat of economic losses can override potential environmental wins. Biopolitics, energopolitics and economics are intricately intertwined. The concatenation of all three produces new conceptual openings for how we think about research governance and related notions of responsibility and agency in complex innovation systems. This is a complicated 'roadmap' fraught with ethical potholes that scientists have to navigate with care and responsibility.

Deplazes et al. ([23], p. 66) have identified three potential types of ethical issues related to synthetic biology: "method-related" (ethical questions relating to the 'moral status' of the products of synthetic biology); "application-related" (ethical considerations about the potential impacts of future synthetic biology applications); and "distribution-related" (ensuring synthetic biology products are delivered where needed most). This focus on the downstream products and processes of synthetic biology might obscure considerations of the just and responsible treatment of the bacteria that are used to make these products. Bioengineering bacteria for industrial use might raise ethical questions about treating living organisms as machines or tools. In this article we also highlight potential risks to scientists being themselves used as tools in this new biopolitics, risks that are not yet on the horizon of the current RRI agenda.

RRI is a relatively new research governance framework concerned with the nature and trajectory of research and innovation, ensuring that new technologies closely align with societal needs and values. RRI has emerged and evolved in parallel with synthetic biology research and innovation processes. Funders of synthetic biology projects in the UK, such as the EPSRC (Engineering and Physical Sciences Research Council), the BBSRC (Biotechnology and Biological Sciences Research Council) and the European Commission's Horizon 2020 programme, amongst others, have required that RRI is taken into account within the scientific research.

All six UK synthetic biology research centres funded by the Research Councils are expected to integrate RRI into their research programmes. This implementation is facilitated by embedded social researchers who collaborate with the centres' scientists and with external stakeholders, including industry and members of the general public who play both agenda-setting and end-user roles in processes of RRI. Four dimensions of RRI have been identified that provide a framework for raising, discussing and responding to social and ethical questions: anticipating intended and unintended impacts; reflection on research motivations, implications, and uncertainties; broad engagement with public and direct stakeholders; and acting on this information to influence research directions [24,25]. RRI approaches consider broadly how research and innovation could be used in future and the potential impacts that this could have in target markets, but also any indirect effects (e.g., competition for resources; unintended or uneven impacts on different groups or locations) that may arise. In the context of the work undertaken by various synthetic biology research centres around biofuels, these four dimensions are used to inform judgements and practices of 'energy ethics'. In addition to these four dimensions, stewardship is also an aspect of RRI where responsibility in science and innovation has been defined as 'taking care of the future through collective stewardship of science and innovation in the present' ([24], p. 1570) Stewardship, especially environmental stewardship, has a long tradition in ethics and refers to the responsible management of and care for resources – which in our case are not only energy resources, but also bacteria and scientists.

Proponents of RRI are developing new approaches to ethics and responsibility, which are grounded in philosophy, ethics and the social study of science. However, less attention has focussed on theories of stewardship, responsibility and agency, which have long traditions in anthropology [26]. Previous studies with engineers have highlighted how, as agents acting on their own, there is a tendency to shift moral responsibility in techno-scientific innovation to others because of a