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Innovation politics post-Rio+20: hybrid pathways to sustainability?

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Abstract. The ability of innovation—both technical and social—to stretch and redefine 'limits to growth' was recognised at Stockholm in 1972, and has been a key feature in debates through to Rio+20 in 2012. Compared with previous major moments of global reflection about human and planetary futures—Stockholm, Rio in 1992, Johannesburg in 2002—we now have a better understanding of how innovation interacts with social, technological, and ecological systems to contribute to transitions at multiple levels. What can this improved understanding offer in terms of governance approaches that might enhance the interaction between local initiatives and global sustainability objectives post-Rio+20? The global political agenda over the last two decades has largely focused on creating economic and regulatory incentives to drive more sustainable industrial development patterns within and between nation-states—resulting most notably in the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change. At the other end of the spectrum, 'Local Agenda 21', launched at the first Rio summit, envisaged a community-led response to sustainable development challenges locally. This paper discusses the successes and challenges of globally linked local action through a number of illustrative examples, reflecting on how these have contributed to Rio 1992's original objectives. In doing so, we will draw upon innovation studies and development studies to highlight three key issues in a hybrid politics of innovation for sustainability that links global and local: first, the direction in which innovation and development proceed; second, the distribution of the costs, benefits, and risks associated with such changes; third, the diversity of approaches and forms of innovation that contribute to global transitions to sustainability. Drawing on this analysis, we will also reflect on Rio+20, including the extent to which hybrid innovation politics is already emerging, whether this was reflected in the formal Rio+20 outcomes, and what this suggests for the future of international sustainable development summits.

Keywords: Rio Earth Summit, Rio+20, sustainable development, pathways, grassroots innovation

Introduction

Political leaders at the first 'earth summit' in Stockholm in 1972 were encouraged to consider research agendas and technological breakthroughs that would reform industrialism. While this was happening, a group of activists set up an exhibition outside the main conference, where they displayed technologies which they saw as underpinning radical shifts to postindustrial, ecological societies organised at the local level (see, for example, Harper and Boyle, 1976, part B). Some of the technologies on display, such as wind turbines, are now established as multi-billion-dollar global industries in a so-called 'green economy'. But at the time these

were positioned as alternatives to the high-tech incumbent approaches to energy generation that were dominated by state-supported industries and multinational corporations.

As STEPS Centre researchers, we participated in a variety of Rio+20 events and activities before, during, and after the summit, and witnessed the persistence of these dichotomies between incumbent and alternative innovation for sustainability, at least rhetorically. In this paper we reflect on our participation in those debates, and our own research, in order to suggest that the dichotomy actually masks a more complex picture populated by diverse, hybrid forms of innovation for sustainability that can serve to link local and global changes.

Rather than counterposing what have become termed 'industrial' and 'grassroots' innovation approaches, we are increasingly witnessing the emergence of dynamic, hybrid combinations of both—shaped and facilitated by emergent private–public–NGO partnerships and new communications technologies. These offer opportunities not only to enable more sustainable and socially just ways of doing things but also to disrupt the unsustainable pathways that lead us to transgress what earth scientists have called 'planetary boundaries' (Rockström et al, 2009). At Rio+20 these hybrid approaches were highly visible in the side events at RioCentro and at the discussions at the *Cúpola dos Povos* (people's summit) in Flamengo, where diverse political groups focused their attention not only on supporting or opposing specific technological solutions but on a local–global transition to more sustainable development pathways.

Do these hybrid innovations bring with them a new politics? Or do they recast old political cleavages in new forms? To what extent did Rio+20 provide a forum for these politics to play out?

In this paper we make an initial attempt to map out the settings for these innovation politics, and provide heuristics that can help us to navigate them, drawing on a range of illustrative examples. We argue that the emerging politics of innovation—insufficiently addressed in the formal negotiations at Rio+20—should be guided by a local–global agenda around the *directions* of innovation, the more equitable *distribution* of its costs, benefits, and risks, and an appreciation of the *diversity* of innovation both across countries and within them. This '3D' agenda, we argue, sets the foundation for the kind of democratisation of science, technology, and innovation (STI) that can enable creative local responses to flourish, whilst providing a guide for systemic shifts towards sustainable development at the global level.

Innovation at Rio+20

The history of environmental summits (Linnér and Selin, 2013) can be viewed in terms of the contested politics of STI for more sustainable development. At each of the major gatherings—Stockholm 1972, Rio 1992, Johannesburg 2002, and Rio 2012—the role of technological change in stretching and redefining the ecological limits of a finite planet has been subject to vastly divergent views [for an early example see Cole et al (1973)].

Beyond the resource constraints first highlighted in The Limits to Growth (Meadows et al, 1972) and the biodiversity and climate change issues that were the focus at Rio 1992, environmental scientists in the run-up to Rio+20 highlighted no fewer than seven additional planetary boundaries (Rockström et al, 2009), arguing that human activity is moving the earth system beyond these boundaries and outside of the climatically and ecologically stable state that sustained past human development through the Holocene, into zones of unprecedented ecological stress with unpredictable consequences (see Meadowcroft, 2013). The planetary boundaries were influential in focusing attention in advance of Rio, and a group of leading experts at the conference argued that staying within them would "require the full use of humanity's capacity for innovation and creativity *at both global and local level*" (emphasis

added) within "pathways that explicitly recognize the ecological capacity of the planet" (High-level Dialogue on Global Sustainability, 2012, page 1).

Despite these enlightened views recognising global–local interactions and a flourishing of creative solutions, many of the formal debates at Rio took a more constrained and limited view of innovation. The outcome document "The future we want" contains ten instances of the word 'innovation', but is overwhelmingly focused on the role of finance and the provision of advanced technologies from richer countries to the developing world ("technology transfer, as mutually agreed") and the need to "close the technological gap between developing and developed countries" (UNGA, 2012, paragraph 48). The idea that innovation and solutions could emerge from the margins—for example, from communities within developing countries—is almost absent, save only for two brief examples where the text recognises the 'grassroots' component to innovation.[(1)]

Prominent in the run-up to Rio, and informing the view of innovation as a market-driven process in the 'advanced' Global North, was the narrative of the 'green economy', a term discussed twenty years ago (Jacobs, 1992; Pearce et al, 1989) but more recently pushed by the UN Environment Programme (UNEP, 2011), and adopted widely amongst many governments, NGOs, and business organisations. UNEP (2012) describes the green economy as

> "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In other words, we can think of a green economy as an economic environment that achieves low carbon emissions, resource efficiency and at the same time is socially inclusive" (unpaginated).

Part of this vision includes the internalisation of environmental costs into mainstream economic logics, which can act as a driver for innovation for sustainability. In response to this vision, some activists argued prior to Rio+20 that the green economy narrative (especially with respect to its potential for further commoditisation of aspects of the natural world like genetic resources and ecosystem functions, transforming them into 'natural capital') lost sight of the social justice dimensions of sustainable development (ETC Group, 2011). Some of these debates echo the political lines drawn at earlier summits; although, as we explore below, the green economy assumed a discursive dominance at Rio+20 that served to stifle and co-opt many would-be alternative positions.

Science, technology, innovation, and sustainability at previous international conferences

At earlier summits references to innovation in formal outcome documents were often similarly focused at the global level. These and other aspects of periodic international debates are summarised in table 1. The Stockholm Action Plan (UN Conference on the Human Environment, 1972, part B) framed the role of technology at the international level around the UN assisting developing countries to access technologies with respect to monitoring devices

[(1)] With respect to biodiversity, paragraph 197 states

> "We recognize that the traditional knowledge, innovations and practices of indigenous peoples and local communities make an important contribution to the conservation and sustainable use of biodiversity, and their wider application can support social well-being and sustainable livelihoods."

This paragraph is rare in its recognition that innovation is not solely the domain of 'developed countries'—a sentiment reinforced in paragraph 268, which stresses the need to "facilitate entrepreneurship and innovation including among women, the poor and the vulnerable." With respect to food security, nutrition, and sustainable agriculture, paragraph 109 of the text recognises "the importance of traditional sustainable agricultural practices, including traditional seed supply systems, including for many indigenous peoples and local communities." However, in this, as in many other areas in the outcome document, concrete commitments to supporting and connecting such approaches are absent. Aside from these two instances, the recognition of knowledge and innovation in communities around the world is hardly visible at all—in stark contrast to the precedents set in some previous summits.

(like satellites for forestry), and in food technologies, appropriate technologies for water resource management, preventing mining hazards, and new energy technologies. Stockholm, however, saw NGO and civil society groups invited—alongside the 113 countries and 19 intergovernmental agencies represented, over 400 intergovernmental and nongovernmental organisations were also present (Dodds et al, 2012). Their primary engagement took place in a semidetached arena, known as the Environment Forum (or, informally, the Hog Farm), at which the 1972 People's Summit (Björk, 2012) and coordination by activists and academics from across the world (Nilsson, 2003) provided radical alternatives—conceived at the local level—to the industrial, high-tech approaches being discussed at the formal UN Conference on the Human Environment.

An undercurrent of radical alternatives and bottom-up political initiatives has persisted ever since, and were taken forward to Rio 1992, which saw attendance from 108 heads of state with 178 nations represented, 2400 representatives of NGOs, and around 10 000 journalists. Stakeholders at the Global Forum facilitated by the Centre for Our Common Future were estimated in the range 35 000 to 50 000 (Dodds et al, 2012). In Rio the geographical divide between the formal negotiations (in RioCentro, 40 km out of town) and the NGO–civil society discussions at the Global Forum (in Flamengo Park) was more notable than at Stockholm, as was the divided political flavour of discussions—the formal negotiations contrasting to the vibrant debate about radical alternatives at the Global Forum.

This division between the formal negotiations and the subpolitics (Beck, 1997) of sustainable development has continued through successive summits and was evident, albeit in a somewhat more muted form, at Rio+20 (at which the two main components were held at similar sites to 1992). It has contributed to a juxtaposition of different views on, amongst other issues, the role of technology and innovation in achieving sustainable development at local and global levels (discussed in the next section).

The documents emerging from Rio 1992 retained a similar focus on global technological solutions to Stockholm, but also moved towards a greater recognition of the local (see also Lawhon and Patel, 2013). Whilst the Rio principles and the primary components of Agenda 21—the action plan for sustainable development—kept the focus on transfer of modern technology from North to South, the recognition of community-led action through Local Agenda 21 also brought more attention to the potential for grassroots innovation. Principle 9 emerging from the Rio 1992 conference emphasised cooperation for sustainable development "by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies" (UNCED, 1992, page 2). At the same time NGOs were brought in as partners in the sustainable development process, and Agenda 21 was developed for implementation not just at the global level but also "nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment" (United Nations, 1992, chapter 34.11, section 4). Section 4, chapter 34 stresses that tapping the pool of proprietary knowledge "and recombining it with local innovations to generate alternative technologies should be pursued."

The Johannesburg World Summit on Sustainable Development, notable for its focus on industry-led approaches to sustainable development, nevertheless took some of these ideas forward. For example, in the energy sector, section II, part 20(g) called on governments to

> "develop and utilize indigenous energy sources and infrastructures for various local uses and promote rural community participation, including local Agenda 21 groups, with the support of the international community, in developing and utilizing renewable energy

technologies to meet their daily energy needs to find simple and local solutions" (WSSD, 2002a, page 10).

The formal framing of technologically advanced knowledge and expensive hardware being transferred (primarily from North to South) has therefore remained dominant throughout

Table 1. Innovation for sustainability at various UN sustainable development summits.

Sustainable Development Conference	Global: green industrialisation	Local: grassroots innovation
United Nations Conference on the Human Environment, Stockholm 1972	Governments collectively recognise that environmental problems are linked to industrialisation and technology. At the same time "financial and technological assistance" to the developing countries may be required. The conference delivered principle 18: "Science and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind" (UN Conference of the Human Environment, 1972, page 5) ICSU contributes through its new Scientific Committee on the Problems of the Environment (Greenaway, 1996).	Environment Forum/ Hog Farm/ People's Summit: activists and academics coordinate to discuss radical, community-based alternatives to unsustainable industrial development paths (Björk, 2012; Nilsson, 2003).
United Nations Conference on Environment and Development (UNCED), Rio 1992	'Business Charter for Sustainable Development' (International Chamber of Commerce) and 'Business Council for Sustainable Development', formed to give advice to UNCED from a business perspective. This led to the formation of the World Business Council on Sustainable Development.	Global Forum in Flamengo Park: 35 000–50 000 participants discuss responses to challenges including climate change, biodiversity loss, and marginalisation of indigenous peoples.
Johannesburg 2002	Increased emphasis on implementation, privatisation, PPPs, and liberalisation as approaches to enhancing access (eg, to water) and ensuring sustained natural resource management. First International Council of Scientific Unions/Third World Academy of Sciences, Forum on Science, Technology, and Innovation for Sustainable Development.	Amongst other activities, the People's Earth Summit spawned the Johannesburg Declaration on Biopiracy, Biodiversity and Community Right, recognising the key role played by local communities in the conservation and sustainable use of biodiversity (Biowatch, 2002).
Rio+20	RioCentro debates focused on 'green economy' and 'green growth' narratives, including new institutional mechanisms to incentivise ecoinnovation and transfer of cleaner technologies—the central role of (largely incumbent firms in) the private sector. The ICSU Forum on Science, Technology and Innovation for Sustainable Development (PUC University Rio) preceded the conference.	Flamengo Park: alternative debates challenging those at RioCentro, organised by civil society groups (domestic and international), but with involvement and corporate social responsibility support of Banco do Brasil and other private sector actors.

successive conferences (see Perkins, 2013). However, civil society has often advocated radically different innovation processes—those both for the creation of technologies and for the transitions of sociotechnical and ecological systems that they might enable (Smith, 2012). These alternative approaches—often no less knowledge intensive, but linked to more locally derived, 'bottom-up' efforts to transform systems of production and consumption—can be characterised and compared with technology transfer approaches by identifying a number of dichotomies.

Innovation for sustainability: from dichotomies to hybrids

Through these historical debates, then, it is possible to discern two broad approaches to promoting STI in the stretching and redefining of environmental limits, and in dealing with ecological stress. In terms of the 'three pillars' of sustainable development, both of these seek more environmentally sustainable outcomes, but differ in their social and economic priorities and in the forms of transition that they envisage. At the level of socio-techno-ecological systems at local and global levels, the protagonists of these approaches envisage different *pathways* (Leach et al, 2010) to sustainability and enact political strategies to try to ensure that they are realised.

Whilst these are not hard-and-fast distinctions, it is possible to identify two ends of a spectrum of innovation for sustainable development that focus on distinct actors, mechanisms, and knowledges. The first is led by large firms, or by public–private partnerships of multinationals and governments advocating a science-push and top-down form of STI. Whilst the OECD and others argued for this approach at Stockholm (Brooks Report) (OECD, 1971), few governments and businesses really adopted it seriously until after Rio in 1992, when it became known generally as ecological modernisation (Hajer, 1995) and was associated with planning approaches such as industrial ecology (Frosch, 1992). It later attained greater influence through the public–private partnerships for implementing sustainable development at Johannesburg in 2002 (WSSD, 2002b), and later became influential in green economy arguments at the Rio+20 Summit. It was driven by market values and business interests (eg, 'cleantech venture capital'), with government support (eg, through the Clean Development Mechanism and, more recently, green stimulus packages). This approach—which we call *green industrialisation*—has traditionally emerged from innovation in the Global North, with diffusion and transfer to the South the most visible approach in formal intergovernmental negotiations and outcomes.

Green industrialisation approaches emerging in and around Rio+20 include the Global Green Growth Institute (3Gi); the World Bank's initiatives around its report on "inclusive green growth" (World Bank, 2012); the OECD's work on green growth and sustainable development, green growth in developing countries, and consumption, innovation, and the environment; and the Green Growth Knowledge Platform (itself supported by the 3Gi, World Bank, UNEP, and the OECD).

The second approach is rooted more centrally in civil society, and argues for a more participatory, bottom-up form of knowledge production and innovation for sustainability that responds to local situations and the interests and values of the communities involved. After Stockholm it found a focus in appropriate and alternative technology debates, and became associated with Local Agenda 21 after Rio in 1992 (Smith, 2005). This *grassroots innovation* approach for STI, driven by citizen action and emphasising social justice concerns, was more prevalent in and around the People's Summit, beyond the intergovernmental negotiations at Rio+20.

In contrast to the green industrialisation approach, grassroots initiatives seek deeper, alternative forms of sustainable development—forwarding a more transformative agenda around the reorientation and transformation of sociotechnical systems. These forms of

Table 2. Green industrialisation and grassroots approaches to innovation for sustainable development.

Characteristics	Global: green industrialisation approaches	Local: grassroots innovation approaches
Political dimensions		
Predominant actors	corporations; national governments; international agencies	civil society; development—environment; NGOs; international agencies
Priority values	private profit	social justice
Relevant (inter)national political arena	formal intergovernmental negotiations interacting with corporate strategies	social movements and 'subpolitics'
	Clean Development Mechanism as an exemplar from the United Nations Framework Convention on Climate Change	Local Agenda 21 as a rare exemplar in 'formal' negotiations
Mechanisms		
Principal incentives/ drivers	market demand and regulation	cooperation and community empowerment
Sources of investment	state/corporate funded, venture capital	ethical investment funds, community finance, hobbyists (where financial support required), development aid
Forms of appropriability	strong patent-based intellectual property framework	not appropriated—seen as common goods
Knowledge dimensions		
Sites of innovation	laboratories and R&D institutes; board rooms and ministries; market-serving firms based in the Global North	community projects and participatory processes; social movements and solidarity economy in both North and South
Forms of knowledge privileged	scientific and technical knowledge	local, situated knowledge
Emblematic innovations	carbon capture and storage; hydrogen fuel cells	microhydro; solar home systems
	intellectual-property-driven transgenic crops; smart homes	organic food; farmer-led seed production; vernacular housing

innovation emerge both in the global South (eg, in rural development) and from community action in the North (eg, community energy projects), and have in both contexts represented an alternative to the industrialisation approach (Gupta, 2009; Seyfang and Smith, 2007).

The primary characteristics of each approach—albeit highly stylised—are indicated in table 2, which maps the actors, mechanisms, and knowledge-related components of the innovation processes, in each case, as well as some examples of 'emblematic innovations'.

Such dichotomies echo discourse theories in environment-development politics, such as those offered by O'Riordan (1976) (techno-fixes versus ecologists) or Dryzek (1997), as well as in development studies and practice (industrial blueprints versus participatory processes; developmentalism versus postdevelopment; market-led versus social paradigms) (Rist, 2011; see also Bina, 2013). As discussed earlier, these two contrasting approaches to STI have been reflected in all summits, from Stockholm to Rio+20.

However, such stylised representations may in fact hide other forms and styles of innovation. These two approaches are instead best understood as 'ends of the spectrum', within which a range of hybrid possibilities lie. As we discuss below, this traditional dichotomy is increasingly being supplemented by a space of diverse experimentation in hybrid forms

of STI for sustainability between these poles. Nevertheless, conventional tensions between these approaches are creating a splintering and reconfiguring, making way for a new politics of innovation for sustainability.

Hybrid innovation for sustainability

Alongside and sometimes obscured by dichotomies, we argue that we are increasingly witnessing the emergence of a more diverse variety of hybridisations between different approaches to STI for development, that actually bridge previously more distinct sustainability discourses. Hybrids operate across all dimensions (political, actors and mechanisms, knowledge). They include, for instance, grassroots innovation movements adapting high-tech devices and infrastructures (especially to share digitally encoded ideas through open-source peer production networks, such as Hackerspaces) (Anderson, 2012), corporations innovating products for marginal consumers at the 'bottom of the pyramid' (Prahalad, 2004), disparate communities of individuals working voluntarily across international borders towards shared global challenges or for political advocacy (Shirky, 2008), efforts to support the application of technologies in informal sector enterprises (Cozzens and Sutz, 2012), or to bring together networks and movements combining traditional knowledge and laboratory research to generate accessible and effective plant-based (pharmaceutical, cosmetic, food) products (Gupta, 2009).

Thus, transcending the dichotomies outlined in table 2, we see innovation processes that involve actors from across both not-for-profit and private sectors (but primarily from outside government) in dynamic alliances and relationships that form outside traditional political arenas. Many hybrids embody uneasy combinations of values that can be described as 'not *just* for profit' and link to both business values but also cooperative motivations for green or social enterprise. They are financed by specialised venture capital, by microfinance, or increasingly by crowd-sourced capital, and adopt an openness with respect to data and innovation processes that is absent in traditional 'green industrialisation' approaches. The hybrid innovations that we are increasingly witnessing are able to draw on multiple forms of knowledge and bridge across sites of formal R&D and more bottom-up, community-based ingenuity.

The examples below—purposefully chosen to give a historical perspective—illustrate this hybridity further by comparing oppositional approaches with networked, multilevel, transformative approaches in two sectors: agricultural (primarily seed) innovation and wind-based power generation.

Sustainable intensification and crowdsourced agricultural strategies

Institutional infrastructures comprising networked national agricultural research systems and Consultative Group on International Agricultural Research centres have led to the development of 'industrial' agricultural technologies since the 1970s, drawing on breeding techniques and genetics research pioneered and applied in (especially US) seed firms. Alongside these international efforts, farmer-led agricultural development (Chambers et al, 1989) offered an alternative to green revolution discourses and focused on farmers' own local knowledge that was so often overlooked by professionals in the research system. This dichotomy has been visible ever since, especially in conflicts around the use of genetic technologies and resources (Scoones and Thompson, 2011).

Whilst formal debates around agriculture and genetic resources at the Johannesburg summit focused on access and benefit sharing under the Convention on Biological Diversity, conflicting visions over the applicability of various agricultural technologies (especially the use of transgenic crops) raged. The farmer participatory plant breeding movement was counterposed as an alternative to various applications of genetic technologies (largely

controlled by a small group of multinational corporations), and the International Agreement on Plant Genetic Resources for Food and Agriculture (otherwise known as the 'International Seed Treaty', which aimed to secure 'farmers' rights' to such resources) had been agreed the year before.

Johannesburg also took place less than one year before the USA, allied with other large grain-exporting countries (among the third parties, Australia, Argentina, Canada), launched the 'world's biggest food fight'—World Trade Organisation dispute DS291 on European "Measures affecting the approval and marketing of biotech products" (WTO, 2006). The role of agricultural biotechnologies in intensive, industrial agriculture was clearly delineated from the low-external-input sustainable agriculture favoured by a strong international network of civil society groups working on food security (and, later, food sovereignty) (Millstone and Van Zwanenberg, 2003).

More recently, with the larger 'developing' countries (especially Argentina and Brazil) embracing the use of transgenic crops, and technological developments enabling cisgenics and marker-assisted selection to bridge across to conventional or participatory breeding techniques, the potential for hybrids (literally) is increasing. Whilst organisations such as Cambia have attempted to provide open-source (transgenic) models in this area, international legal frameworks are gradually overcoming the barriers for international collaborative work bridging local, situated, and scientific forms of knowledge. The International Seed Treaty's attempts to ease the flow of genetic material internationally through its 'Easy-SMTA' (Standard Material Transfer Agreements) contributes to easier genetic exchange, and its global information system (http://www.planttreaty.org/content/gis) also helps by linking with the Convention on Biological Diversity's Clearing House Mechanism. The Nagoya Protocol on Access and Benefit Sharing now provides a framework (although far from ready for implementation) for globally networked, hybrid innovation approaches.

In this context a number of hybrid innovation initiatives are emerging. For example, 'citizen scientists' have been drawing together modern agricultural biotechnology and local farmer knowledge around seed saving and exchange, conserving diverse traditional varieties, and experimenting with nonindustrial supply channels (Stilgoe, 2009). Participatory plant breeding, involving alliances between farmers and scientists, has been shown to improve the quality and speed of plant breeding, as in India (Walker, 2006; Witcombe et al, 2011) or in France at INRA (The Institute for Agronomic Research), which has focused on maintaining diversity in cauliflower seeds through work with NGOs like Réseau Semences Paysannes (the Peasants' Seeds Network).

More recently, researchers have pointed to the potential of combining open-source approaches to knowledge sharing with modern biotechnologies for agricultural development (Adenle et al, 2012). The considerable potentials of lab-based genomics with field-based farmer assessments have been highlighted as a way of radically changing the way plant breeding is practised, drawing on very different sources of knowledge (Offei et al, 2010; Richards et al, 2009). Others have pointed towards the potential of hybrid innovation approaches that combine bioinformatic and communications technologies with farmer participation, bridging high-tech and participatory approaches through crowdsourcing seed innovation. Such approaches, using mobile devices for information sourcing and open-access software for data management for examples, offer hybrid approaches which could "not only be scalable, but also inclusive through the strengthening of crop diversity as an open informational resource" (Van Etten, 2011, page 102).

Hybrid wind energy formation

Wind energy is frequently referred to within the green industrialisation approach to STI. It is a relative market success in sustainable technology, with huge growth and investment led by utilities and institutional investment funds. It is interesting (for the purposes of this paper at least) that the origins of this successful industry rest in grassroots innovation approaches, specifically in Denmark.

Wind energy began its significant international expansion in the early 1990s.[2] The fact that Danish turbine designs in the late 1980s could generate 70–100% more electricity than competitors, due to a more robust and reliable design (Karnøe, 1996, page 773), meant the former were well placed to lead in the new markets. By the turn of the century, the Danish wind energy industry was world leader, with a turnover of €3 billion, employing over 20 000 people, commanding 50% of the world market.[3] Competition has intensified since then, but largely around the same turbine design as that pioneered by Danish manufacturers. Manufacturers in Germany and, more recently, India and China are taking increasing shares in regional markets (Lema and Lema, 2012). The expansion of wind energy has become an archetype for ecological modernisation discourses and cleantech innovation policy.

Often overlooked are the roots of this development. Danish environmentalists—who, like those elsewhere, wanted alternatives to the nuclear power vision being pushed by states and some electricity utilities in the 1970s—were also unusually practical in reclaiming wind energy technologies overlooked since the 1940s. Turbine development can be traced back through an environmentalist milieu to a deeper culture of collaborative craft production and a tradition of cooperative organisation in Denmark that, in many respects, anticipated the open-source movement. Social networks built up shared knowledge, experience, and ideas about turbine construction and use. The Organisation for Renewable Energy[4] held wind meetings, and disseminated test results and other information about different turbine designs and products through its monthly magazine *Naturilig Energi* (natural energy). A social innovation—a new form of community-based wind cooperative—facilitated investment in turbines for local use, and thereby helped create a market. Some local agricultural machinery manufacturers noticed this niche market and, enterprisingly, began manufacturing wind turbines. In both cases the designs drew on past, practical experience, and tended to be robustly made due to the craft-based engineering skills and tools available.

The grassroots were also lobbying government to support their cause. The (pronuclear) electricity utilities needed to be persuaded into connecting community turbines to the electricity grid. Government support to this effect did eventually occur, as did the creation of a testing and research facility for the use of small turbine manufacturers at the government's Risø laboratory. This further helped develop practical experience with different design options, coordinate standards, and certify the viability of turbines. Support for the grassroots initiatives was by no means easily forthcoming, but what support there was seemed to work. Indeed, learning-by-doing had improved reliability and performance to such a degree that the government announced investment subsidies for turbine installations in the early 1980s. This made it easier for wind cooperatives to purchase and install grid-connected turbines for local electricity supply. Danish turbine manufacturers also performed relatively well in the Californian wind-rush of 1980 to 1986. The Danish wind energy industry began its international emergence.

[2] This section draws upon material in Smith (2006a).

[3] Data supplied by the Danish Wind Industry Association.

[4] It was created in 1975. Preben Maegaard, a 'grassroots engineer', played a part in its creation, as well as establishing the Northern Jutland Centre for Alternative Technology (Jamison, 2002, page 4).

As they emerged, grassroots approaches gained international attention. The People's Summit at Rio 1992 focused a great deal of attention on distributed wind energy, and such approaches were referred to in, for example, the Johannesburg Plan of Implementation, which called on governments to fulfil their common but differentiated responsibilities around energy, including

> "actions at all levels to: (g) Develop and utilize indigenous energy sources and infrastructures for various local uses and promote rural community participation, including local Agenda 21 groups, with the support of the international community, in developing and utilizing renewable energy technologies to meet their daily energy needs to find simple and local solutions" (WSSD, 2002a, page 10).

As mentioned above, wind energy is now a large, high-tech engineering industry. Cooperatively owned wind turbines pioneered in Denmark have been superseded by large utility-owned and investor-owned wind parks using giant turbines greater than 3 MW (100 times more powerful than earlier 30 kW turbines). This cleantech industry has come a long way from the backyard idealists and grassroots innovators. And yet, this move from the grassroots towards one more akin to 'green industrialisation' is accompanied by other hybridisations. Community-owned energy projects are growing in popularity in some locations, such as 'citizens power' movements in the US and Europe. And grassroots innovators continue to experiment with small turbine designs for local, low-power use, typically in remote rural locations—sometimes in response to diminishing smaller-scale turbine supply options arising from the dominance of big wind.

These examples from the agriculture and energy sectors—like other innovation approaches in different sectors—transcend the grassroots–green industrialisation dichotomies above by being the product of both community-level ingenuity and industrial technologies, being driven by both the profit motive (associated with varying levels of appropriation and different sources of investment) and social values, and by drawing on multiple forms of knowledge—both technical and nontechnical—and recombining them to produce new ways of responding to sustainable development challenges.

At the same time, in many cases these approaches begin to bridge earlier global–local (top-down–bottom-up) divisions by being at once sensitive to local contexts but applicable—in altered and adapted forms—across diverse regions. The existence of these hybrid approaches at Rio+20 offered the promise that benefits previously seen in only localities could be translated to greater scales.

Scholars of grassroots innovation elsewhere (Smith et al, 2013), however, describe how these kinds of innovations need simultaneously to fit into existing socio-technical-ecological systems whilst in many cases simultaneously attempting to destabilise and transform them to create more sustainable systems of consumption and production. Translation from the local to global scales thus brings with it the hope (and threat) of wider transformational change as these innovations reconfigure social relations and create greener, more inclusive and socially just economies. It is this potential for transitions and transformational change, and yet the power relations often stacked against such alternative pathways (Smith, 2007), that brings with hybrid innovation approaches a new politics—one that is worthy of further discussion and analysis.

The 3D politics of hybrid innovation

The hybrid innovation approaches described above are more dynamic, complex, and unpredictable than the green industrialisation approaches that national governments and intergovernmental negotiations have been used to dealing with. They also go beyond the grassroots approaches, linking to new sources of innovation and market players. They entail more varied and unstable relations between actors, mechanisms, and knowledges than either

green industrialisation or grassroots approaches imply. As a consequence, hybrid innovation approaches entail a novel politics, structured by new power relations.

These novel politics involve tensions between winners and losers—and relate to power and control over innovation pathways, processes, and outcomes—which the diverse actors involved struggle to negotiate. Across hybrid alliances, not all participating organisations are equally endowed; each brings their resources to the partnership—profiting from interdependencies whilst attempting to secure continued access and control (Smith, 2006b). Tensions can arise as alliances and innovation processes shape current and future access to information, knowledge, technology, authority, and finance, especially where developing infrastructures and formal agreements can harden asymmetrical relationships.

At the same time, beneath this recast innovation politics lurk some enduring fundamentals familiar to the older dichotomies. Specifically, a number of perennially contentious issues form sites of tension and negotiation within, and characterising, the new hybrid politics of innovation, as transformative pathways to sustainability are sought:

- *Appropriation*—many hybrid approaches adopt nontraditional models of intellectual property such as open-source or forms of creative commons licensing. These are in many cases unfamiliar to those organisations from the green industrialisation approach, and some new models of appropriation may meet with resistance from the 'old guard'. For example, several not-for-profit initiatives in the agricultural biotechnology field described above have encountered problems attempting to secure freedom to operate within an area traditionally dominated by strict patent control. Open-source, peer production, and international collaboration via the web can often struggle to link effectively with business models that (despite open innovation rhetorics) see copying as unfair competition and invest resources in preventing it (Benkler and Nissenbaum, 2006).
- *Commodification*—within emerging regulatory regimes attempting to place a monetary value on polluting emissions (eg, carbon dioxide), or potentially on biodiversity or ecosystem services, green enterprise is often seen as commodifying lifeworlds and nature itself (Fairhead et al, 2012). Through focusing on only aspects of development and conservation that are viable within existing economic systems, however, these approaches can contradict postdevelopment values rooted in local cultures and reduce diversity in social, technological, and ecological systems. Many of the hybrid approaches straddle growth–degrowth debates and are therefore open to critique from both sides, and subject to contentious politics amongst actors aligned with multiple positions in debates about green economy (see above).
- *Risk governance*—with the forging of new innovation pathways come risks, uncertainties, ambiguities, and ignorance (Stirling, 1998). Responsibility for the potentially negative impacts of innovation is negotiated alongside control and access to the benefits, raising significant challenges for globally coordinated but locally implemented regulation (Van Zwanenberg et al, 2011). Whilst traditional green industrialisation approaches were driven by relatively observable, manageable, and accountable centres of innovation, distributed crowdsourced solutions defy easy monitoring and accountability. This is especially salient in more open approaches to emerging areas in biotechnology, nanotechnology, and digital manufacturing, where intellectual property enforcement cannot be used to exclude 'unapproved' actors, and where even the reach of health and safety legislation is tenuous.
- *Market and nonmarket mechanisms*—whilst traditional political responses to green industrialisation models relied on economic instruments and market mechanisms favouring incumbents or conventional business models, emerging hybrids often rely more on the role of (cooperative) networks and solidarity economies to disrupt incumbent

economic arrangements and may therefore be incompatible with conventional policy goals. Collective consumption (for example, car clubs) to reduce environmental impact also acts to reduce traditional measures of economic development (GDP) (Albinsson and Perera, 2012). Even potentially potent innovations for sustainability struggle to survive within existing structural constraints.

- *Investment challenges*—again constrained by structural economic barriers, hybrid innovations, when they require external funding, struggle to access venture capital from traditional sources that hold particular expectations around returns, time frames, and size of investment and are wary of opportunity costs (when comparing more complex investments with more traditional green industrialisation approaches). At the same time, when state support is called upon, vulnerability to capture by key incumbents and to economic cycles (as seen in Rio+20) can cause further political tensions (as, can be argued, has been the case with support for wind against a background of fossil fuel incumbency).
- *Diverse settings*—these politics are not played out in the familiar arenas of governmental and intergovernmental conferences but through the processes of alliance building and innovation itself. Actors can find it uncomfortable and difficult to operate beyond familiar sites, suggesting a need for professionals who are able to bridge across to more dynamic domains of corporate–civil society alliances, open-source movements, and development groups working in diverse contexts around the world (Leach and Scoones, 2006).
- *Distributed knowledge*—hybrid approaches must wrestle with both global scientifically determined notions of sustainability, and with other—more situated—understandings based on local cultural perspectives, priorities, and epistemologies. Bridging such disparate epistemologies of sustainability—elsewhere termed 'sustainability brokering' (Leach et al, 2012)—is therefore key, but also a process entangled with sometimes fraught politics of knowledge.

These tensions were evident in debates at Rio+20. Taking them seriously, we see that the new politics of (hybrid) innovation lies in the negotiation and settlement on which *pathways* of change emerge at different levels from local to national to international—where pathways refer to intertwined and mutually supportive social, technological, ecological, economic, institutional, and knowledge processes (Leach et al, 2010). Corporatist–managerialist approaches of business strategy, providing financial support and creating a regulatory framework that provides market signals to drive green industrialisation, are therefore insufficient to enhance or even keep up with hybrid innovation approaches. As researchers from the STEPS Centre, our role in side events at Rio+20, building on our research into innovation for sustainability, was to suggest a '3D' political agenda for innovation—around *direction*, *distribution*, and *diversity*—that can act as a heuristic in understanding some of the tensions above and for guiding innovation and its politics in these emerging hybrid areas.

Firstly, more attention is required to the orientation of the specific *directions* of social, technological, and environmental change that hybrid innovations especially help engender. Beyond being clear on the particular goals and principles driving innovation (for example, meeting specific Millennium Development Goals whilst avoiding environmental stresses), this involves a recognition that multiple possible pathways are indeed available, but that particular courses of action—involving interacting social, technological, and environmental processes—will be self-reinforcing, narrowing our options for future pathways. An attention to directions therefore requires a reflexivity towards these processes of *closing down* and an open, transparent politics to enable their full implications (and associated contestations and trade-offs) to be explored. Thus in the wind case above, for example, alternative directions range from large-scale, grid-networked approaches (involving massive investment in infrastructure and hardware) to distributed, smaller-scale initiatives amenable to community

ownership and control. The kinds of mechanisms driving China's goal of building 1000 GW of installed wind capacity by 2050 (Liu, 2012) are not likely to bring about the kinds of societal transformations advocated in the Hog Farm. The decisions around which of these is favoured in particular contexts reinforce or detract from future directions for low-carbon development.

In recognising the potential for different directions of innovation, a second component of a 3D agenda is the associated *distribution* of costs, benefits, and risks resulting from these potential pathways. Questions of distribution relate to who gains and who loses from particular policies and innovations, who controls them as they move forward (or, conversely, who is empowered by the process of innovation), and who bears responsibility for ensuring that the sustainability benefits of certain courses of action are not outweighed by negative effects on more marginal groups within society. The distribution component of the 3D agenda recognises the social justice implications of innovation processes as well as outcomes. This includes the configuration of innovations themselves, rather than focusing on simply reallocation of resources derived from innovation ex post. In the agricultural biotechnology example above a private-sector-driven approach to transgenic crops modified to withstand particular herbicides has had significant productivity impacts on large-scale, export-led soya cultivation in Latin America, for example, serving wealthier farmers and enabling some subsequent redistribution (Marin and Smith, 2012). Alternative approaches to plant genomics relying less on patent-protected transgenic varieties and chemical-intensive agriculture might offer more equally distributed and sustainable gains across the economy and society.

In trying to reconcile these different perspectives and trade-offs, the 3D agenda for hybrid innovation recognises the crucial importance of fostering *diversity* in any given field. This is so equally in terms of maintaining a diversity of knowledges and ways of doing things that can contribute to sustainable development in the future in terms of harnessing experimentation in diverse new innovation directions; and in terms of 'fitting' innovation to diverse places and contexts, in which attention to combinations of approaches to addressing specific sustainability objectives is required. For example, whilst green or social enterprise initiatives may seek to scale up their own business models within a particular area, the dominance of more profitable or efficient models can close down spaces for experimentation with alternatives (Smith, 2007). Although the detailed ways such diversity is seen will vary across perspectives, diversity in general can be defined as an evenly balanced variety of disparate options (Stirling, 2007). It is in these terms that diversity allows us better to respond to ignorance arising from complex technological, environmental, and sociopolitical dynamics, guards against lock-in to dominant (and sometimes unsustainable) pathways, and provides a stronger foundation for future recombinations of knowledge and resources that fuel innovation. We now turn to asking how and to what extent the Rio+20 conference dealt with the 3D politics of hybrid innovation, and what role might future intergovernmental exercises play in facilitating and supporting hybrid innovation approaches into the future.

Rio+20 and the role of international sustainable development summits

At Rio+20 the UN adopted a convening role, trying to facilitate alliances between actors and—notably—moving far beyond the traditional intergovernmental frame to adopt a new organisational role as a partnership broker:

> "The UN once dealt only with governments. But now we know that peace and prosperity cannot be achieved without partnerships involving governments, international organizations, the business community and civil society. In today's world, we depend on each other" (Kofi Annan addressing the World Economic Forum, 1999; quoted in Dodds et al, 2012, page 231).

At Rio+20 the negotiations retained a similarly structured and formal approach to previous summits, but the side events were left more open, with more approved nongovernmental organisations attending than ever before—allowing space for hybridisation, plurality, and the formation of rapid and dynamic partnerships and networks. This convening and brokering role involved providing a repository for voluntary commitments from across governments, the private sector, and civil society. US $513 billion of voluntary commitments were recorded, such as "empowering 5000 women entrepreneurs in green economy businesses in Africa", and recycling 800 000 tonnes of PVC per year (UN News Centre, 2012). It was also illustrated by the conference's brokering hybrid interactions via a 'partnerships forum', session 4 of which was entitled "speed-brokering for partnerships: scaling up and replicating best practices in sustainable development" and focused on the themes of energy, sustainable cities, and water (United Nations, 2012).

Alongside this reinvigorated focus on partnerships, the UN had made efforts to involve the wider global community in the run-up to the conference; and the Secretary General of Rio+20, Sha Zukang, claimed that 50 million people "took part" in the event via social media (UN News Centre, 2012). The 'Rio+20 dialogues' (http://vote.riodialogues.org/) attempted to bring wider civil society into the process through a networked, virtual approach to formulating recommendations. Rio+20 saw the emergence of a global citizens' movement for sustainable development—working together with the United Nations Department of Economic and Social Affairs but largely in the absence of inputs from individual nation states. The People's Summit, including numerous parallel sessions (but no formal outcome document), drew together civil society and support from the private sector, transcending and blurring some of the differences between types of actor that divided the industrial and grassroots approaches and that had been prevalent in previous summits.

At the same time, however, the speed of these interactions and dynamic nature of the political connections being formed had two critical consequences. First, the UN—and, indeed, member states—struggled to keep up. Whereas one UN agenda and plan of implementation at Rio in 1992 and Johannesburg in 2002 may have seemed reasonable, Rio+20 revealed how impossible such a managerial approach is in the current context, and reinforced the need for an ongoing open politics of innovation for sustainability. The fragile green economy narrative, even if suffixed by 'poverty alleviation and sustainable development', provided little more than a political vacuum in terms of empowering more grassroots-led innovation processes; and at least in terms of the formal outputs of the conference, the postcrisis governmental focus on economic growth enabled powerful industrial approaches to fill the gap.

Second, there was little space to pause and reflect on just how inclusive and progressive the hybrid innovations being discussed actually were. The forms that dialogue took, and the character of the negotiation spaces and texts, often served more to quell and disable resistance to dominant political–economic and market agendas through the illusion of dialogue, rather than to encourage sharp debate about how to rebalance the power between different innovation pathways. There was therefore insufficient opportunity for exploring the 3D aspects in the politics of emerging innovation processes.

It is likely that a disproportionate share of the US $513 billion allegedly pledged in voluntary commitments for sustainable development will support large firms through industrial and export promotion policies in wealthier countries. Hardware and finance within a green economy constituted—as mentioned above—the primary innovation framing of the outcome document "The future we want" (UNGA, 2012). As a result, in place of agreed mappings of alternatives, there were concerns about co-option, control, and capture around particular privileged forms of knowledge and innovation. Questions were closed down

around key topics like research agendas, intellectual property rights, risk governance, and socially inclusive models for business and investment.

Like the activists in Stockholm before them, civil society organisations at Rio+20 believed that responses to conjoined environmental and economic crises have to empower democratic forms of steering of innovation that go wider and deeper than existing institutions of science and technology within an unfettered market (see also Hobson, 2013). The Green Economy Coalition (2012) of NGOs, intergovernmental organisations, and private actors developed a shared alternative discourse to respond to critiques of green capitalism. However, insufficient attention was given to these debates in the intergovernmental process. The green *and fair* economy vision calls for space to enable and empower grassroots innovation, as well as the cleantech approaches favoured by states and corporations. However, a lack of attention, let alone concessions to these processes of empowerment in the outcome document, suggests that grassroots innovation approaches remain marginal; and therefore any hybrid approaches described above are likely to be dominated by incumbent pathways.

Efforts to incorporate these dynamic politics into the formal negotiations were—regrettably—absent. Many of the UN outcomes of Rio+20 (such as the establishment of the Rio+ Centre, the UNEP Sustainable Consumption and Production programme, and the new incarnation of the UN Commission on Sustainable Development) point to means of sharing experiences, but without intervening politically. However, the conflicts described above underline that attention to the politics of innovation processes is required if future negotiations and multilateral efforts are to succeed in enhancing more equitable hybrid innovations for sustainability. Rather than focusing around traditional faultlines and dichotomies, we propose that these politics attend instead to the directions of innovation, the distribution of the associated costs, benefits, and risks, and the diversity of innovation approaches that are enabled and supported in any given area.

This leads us to propose a new role for the UN and for future summits (or more networked, virtual alternatives)—one revealed by the shortcomings at Rio+20 (cf Biermann, 2013; Linnér and Selin, 2013). Alongside a brokering role for hybridisation, an ongoing requirement of international sustainable development summits will be to open up the space for different innovation approaches in ways that ensure the grassroots can participate fully and centrally in shaping the 3D implications of any proposed outcomes and actions. This includes providing support for marginalised groups to craft new forms of grassroots innovation and green industrialisation (and therefore more democratic hybrids thereof). In our view, this policy and political commitment has to be pursued beyond the networks and arenas of global debate. At international, national, and local levels, it needs to be pushed into the institutions of science and technology itself, such that the agendas of research institutes, technology strategies, investment portfolios, and skills programmes that currently shape dominant trajectories are opened up to democratic participation for developing pathways to sustainability.

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