Good intentions:

Expectations of benefit from technoscience innovation: genetic modification and wind energy in New Zealand

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Ronnie Cooper

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Abstract

New developments in science and technology are promoted through projections of anticipated benefit that justify research, help secure funding and institutional, political and public support, and encourage technology diffusion. This thesis explores the strategic influence of constructs of expected benefit through analysis of the claims advanced for two technology fields in New Zealand: genetic modification and wind energy. The ways benefits are framed, and the kinds of returns and outcomes that are promoted, have major implications for technoscience. Some technology pathways and applications are supported and fostered, while others are rejected or marginalised.

The "downstream" impacts and potential risks of scientific innovation have received extensive academic and policy analysis, while the benefits claimed for R&D and new technologies have largely been taken for granted. However, science and technology futures have recently been addressed in an emerging field of international scholarship – the sociology of expectations. This thesis follows technoscience trajectories back "upstream", to better understand the work of benefit framings in legitimating and valorising innovation in two sectors in New Zealand. Understanding the dynamics of such optimistic projections is crucial for publics, interested groups, practitioners and policy-makers engaging with the challenges of contemporary technoscience.

Keywords: Science; technology; innovation; expectations; benefits; genetic modification; wind energy; New Zealand.

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Contents

Glossary

AAT	Alpha-1-antitrypsin protein
AHB	Animal Health Board
ANT	Actor Network Theory
CDA	Critical Discourse Analysis
CEO	Chief Executive Officer
CF	Cystic fibrosis
CRI	Crown Research Institute
DNA	Deoxyribonucleic acid
EC	Electricity Commission
EECA	Energy Efficiency and Conservation Authority
EPA	Environmental Protection Authority
ERMA	Environmental Risk Management Authority
FRST	Foundation for Research, Science and Technology
FSANZ	Food Standards Australia New Zealand
GM	Genetic modification
HSNO	Hazardous Substances and New Organisms Act
Marae	Meeting-places and buildings of a local Maori community
MED	Ministry of Economic Development
MFE	Ministry for the Environment
MOBIE	Ministry of Business, Innovation and Employment
MORST	Ministry of Research, Science and Technology
MS	Multiple sclerosis
MSI	Ministry of Science and Innovation
OIE	Office International des Epizooties (animal health agency)
PCE	Parliamentary Commissioner for the Environment
R&D	Research and development
RCGM	Royal Commission of Inquiry on Genetic Modification
RSNZ	Royal Society of New Zealand
SEA	Sustainable Electricity Association
SOE	State-owned enterprise
Tangata whenua	People of the land; Maori tribal communities
Tb	(Bovine) tuberculosis
WEA	Wind Energy Association

Prologue

Possums, science, and unanswered questions

The origins of this thesis – and my focus on the claims of expected benefit that build support and legitimacy for science research and technological innovation – go back to questions that caught my attention more than a decade ago, in a very different context. From 1997 to 2004 I worked as Principal Investigator for the New Zealand Parliamentary Commissioner for the Environment (PCE).[1] One of the projects I led for the PCE was an inquiry into issues involved with the potential introduction of a radical new kind of technology – a controversial application of genetic modification (GM). This project explored the intended use of GM for biological control of the Australian brushtail possum (*Trichosurus vulpecula*), a major environmental pest in New Zealand; the biocontrols aimed to disrupt fertility and thus contribute to reducing possum numbers in the landscape (Parliamentary Commissioner for the Environment 2000).[2] Escalating public concerns and protest about GM, and about the wide dispersal of poisons for possum control, prompted the PCE's interest.

The debates at that time about the possible use of GM were fiercely intense. Public and policy-world engagement with GM in New Zealand and internationally was dominated by polarised politics that pitted advocates against opponents of the new technology. There were, however, a number of questions which received little attention in those early days of New Zealand's engagement with GM; many issues were effectively eclipsed by more urgent concerns around risk and its management, regulation, consultation processes, and public involvement in policy and decision-making. As the PCE's project team grappled with New Zealanders' responses to the prospect of an invisible, self-disseminating biological technology that would shut down normal breeding and render its targets infertile, I kept coming back to some of the underlying questions that were not being explored in the immediate debate. My curiosity centred around the significance of the purposes and ideals driving development of a controversial new technology such as a GM biocontrol. The

[1] The Office of the Parliamentary Commissioner for the Environment (www.pce.parliament.nz) is independent of the government of the day, reporting directly to Parliament through the Speaker of the House. Established under the Environment Act 1986, the PCE's role is to monitor and assess the effectiveness of New Zealand's systems for environmental management and sustainability, and to investigate and report on matters of environmental importance.

[2] The biocontrols research is discussed in detail in Chapter Six of this thesis.

reasons advanced for this particular use of GM were fundamentally different from other proposed applications, such as herbicide-tolerant crops that were focused primarily around commercial and agronomic objectives. The biocontrols research targeted inarguably noble, public-good goals – to help get rid of the millions of possums that infest New Zealand and wreak havoc on indigenous biodiversity and ecosystems. Did such altruistic intentions make a difference for publics, policy-makers and science funding? Was the purpose of saving threatened native birds and forests appreciated as a more worthy kind of justification than commercial profit-making for developing a potentially risky new technology?

The aims of the PCE's study were to advise government on improved environmental policy and consultation processes, and to identify key criteria of acceptability for the various biocontrol methods being considered (Parliamentary Commissioner for the Environment 2000, pp 83-90). Our project team enjoyed an often challenging process gathering a wide range of information and views.[3] But that investigation was not the place to address deeper issues around the implications of different kinds of purpose underpinning R&D and innovation.

A year after the biocontrols project, New Zealand engaged in an extensive process of consultation and public discussion for the inquiry of the Royal Commission on Genetic Modification (RCGM).[4] Again, although there was intense debate around issues of risk from GM organisms, there was little critical engagement with questions around the framings of anticipated benefit used to argue for this technology's development and possible use in New Zealand. Broad claims of the profits, improvements and efficiencies expected from various applications of GM were advanced in submissions and evidence, and reiterated in the

[3] As was the practice with all such "big-issue" investigations at the PCE, the biocontrols project canvassed a diversity of interests and perspectives. These included: farming, science, national and regional government, bioethics and animal welfare groups, activist groups opposed to GM, conservation organisations, the biotechnology industry, the pest control industry, urban and rural communities, and tangata whenua (the indigenous people of Aotearoa – New Zealand) (Parliamentary Commissioner for the Environment 2000, pp 6-9).

[4] The Royal Commission was established as part of the arrangements between Labour and the New Zealand Green Party in the formation of a government in 1999 (McGuinness et al. 2008b, p 9). Its task was to investigate and report on strategic options available to New Zealand with GM, and appropriate statutory, regulatory and policy provisions. A series of formal hearings and consultation meetings and a public submission process resulted in the Commission's finding that the 'exciting promise' offered by GM was such that the country should 'proceed with caution' to 'preserve opportunities' (Royal Commission on Genetic Modification 2001a, pp 2, 6). The PCE was granted 'Interested Person' status in the Commission's hearings process and provided extensive evidence based significantly on our work on the possum biocontrols study. I attended many of the hearings and other Commission consultation sessions as an observer and contributor.

RCGM's report. But there was disappointingly limited analysis of such projections, particularly in comparison with the exhaustive deliberations around risk and the potentials for adverse outcomes.[5]

As a participant in these official processes, I became interested in the ways that many actors in policy and research arenas – usually but not exclusively the proponents of particular interests in technoscientific fields – based their approach on a relatively uncritical acceptance of the claimed benefits of applications of GM. Challenges to such assumptions were primarily manifested in assertions of the possible risks involved – environmental, public health, economic, and to New Zealand's exports and international reputation – and arguments about the assessment and appropriate management of such risks. But there was little scrutiny of the projections of future benefits that were put forward as validation for the policy or commercial decisions to pursue this new technology.

I grew more interested in these dimensions of science and technology processes through further PCE work, notably a project on the role of science in environmental policy and decision-making (Parliamentary Commissioner for the Environment 2003a). In this study too, fundamental assumptions of the benefits and beneficence of scientific R&D were largely taken as beyond critique or questioning.[6] Another thought-provoking experience was when I represented the PCE office at a Sustainable Energy Forum hosted by the Shell corporation in Wellington in the early 2000s, where a group discussion led to the question: "Why isn't every roof in New Zealand covered in solar energy panels and mini wind turbines?" Neither the men in smart suits from Shell nor the forum attendees from various government agencies had answers to that.

My fascination with science and technologies, and the values and purposes behind them, evolved over several years into the questions driving this thesis. I have no formal training in science or engineering, but considerable experience in the work of words, images, ideas and narratives through my previous work in literary, marketing, journalism and policy worlds.[7] I

[5] The Commission's report and subsequent GM policy in New Zealand are discussed in Chapter Six.
[6] A personal turning point of my years in the PCE office was the profoundly significant moment when I was required to remove (under protest) the word "epistemological" from the draft science-issues report, such dimensions being deemed unnecessary and inappropriate for policy-oriented analysis of science processes.
[7] The ways the research for this thesis has been framed and influenced by my personal history are acknowledged in Chapter Four.

can quickly glaze over with too much technical detail, and have little patience for a lab bench – but I get really interested when scientists and engineers start expanding on the reasons why they do what they do, and the goals and ideals that give them confidence that what they do is worthwhile.

Blokes in boiler suits and Bruno Latour

For the last three years of writing this thesis, I have enjoyed a sunny office space in a small engineering workshop in a semi-rural community just north of Christchurch. "Real technologies" go on all around me here – showers of welding sparks, forklifts trundling huge steel structures dangerously close to my window, and oily machinery being dismantled outside my door. It has been a privilege to have this kind of environment for my exploration of the arcane complexities of the discourses and social construction of technoscience. These men (and the one female mechanic at the garage next door), engaged in the pragmatic, dirty business of technologies "in action", have helped keep my study thoroughly grounded. The abstract questions I have been engaged with on my laptop are in many ways very remote from what they do with bits of clanking metal, intricate pipework and chugging motors. But it has been important to keep in view (literally) the point that technologies exist in the actual world, and that their efficient functioning and genuine purposefulness are crucial for people to get things done.

Both dimensions – the theoretical and the practical – are central to the effectiveness of science and technology. I very much value the insights I have gained in my academic research into R&D and innovation processes. Once you have been exposed to the critical analysis of technoscience paradigms and practice, no apparently innocent artifact can ever be the same, however familiar and taken-for-granted. Each time I drive over the vicious speed bumps on the roadway through the Canterbury University campus I think of Bruno Latour and his explanation (also provoked by campus traffic control systems!) of how society's norms are enforced and made tangible in such seemingly innocuous objects (Latour 1999, pp 186-190). But my own awareness of the socially constructed nature of technological systems, and the rich diversity of scholarship addressing this, is tempered by continual reminders of the superficiality of most contemporary engagement with technoscience. It worries me that there is so little interest in these dimensions of science and technology, and so little questioning of the implications for our everyday lives and for the future, even amongst people who are thoughtful and sceptical on other important social issues. It irritates me that the "Technology" sections in the news media are all about electronic gadgets and games, the most trivial kinds of consumer toys. It astonishes me that New Zealand universities encourage enrolments in science and engineering with no requirement that students undertake even a basic orientation in the sociology of science and technology. And it seems dangerously reckless to me that policies and business commitments for R&D and innovation are often made with only the most cursory analysis (typically for trade-off purposes) of the meanings of development, the qualitative dimensions and longer-term societal implications.

The blokes in grimy overalls outside my window probably don't really need a deep philosophical engagement with Latour – or Bourdieu, Winner, Sarewitz, van Lente, Bijker, and the many other scholars whose thinking has contributed to my own. And in contrast to the unproven, speculative nature of the innovations studied in this thesis, the technologies in which my neighbours exercise their knowledge, skills and creativity are long-established, mature fields. Nevertheless there is an authenticity to their work that is perfectly attuned to the real benefits of what they do. In comparison to the rhetorics, politics and positioning strategies I deconstruct in my little office – the grand claims made for technoscience, innovation and the "knowledge economy" – the relationships between activity and purpose, practice and outcome, are very direct. Rodney fashions iron and aluminium into useful, strong and beautiful structures; Gavin, Paul, Nick and Donna fix cars, trucks and our ageing utes to run sweetly and safely; Slim and Jeremy organise wells, pumps and intricate filtration systems to deliver reliable potable water for rural households, farm irrigation and livestock. The benefits are clearly, immediately evident.

But as my research has found, the correlations between the intentions claimed for technoscience and the actual trajectories of R&D and innovation processes are often rather more complicated, qualified, contingent and opaque. The work of this thesis has only reinforced the concerns that began for me with the unanswered questions around research into possum biocontrols. It has made me even more certain of the importance of careful scrutiny, thoughtful analysis and independent critique of all the claims and framings, the hype and hope, the confident forecasts and official pronouncements – indeed, of everything that is taken for granted in the promotion and legitimation of technoscience.

Chapter One

The benefits of science and technology

Introduction

In every historical and prehistorical era, life has been unavoidably technological. From stone tools and digging sticks through to the printing press, steam engine and 20th-century assembly-line, humans and prehumans have applied intelligence, skill and ingenuity to the challenges of survival (Norman 1976; Adams 1991; Brown 2002; Dugan 2003; Fagan 2004; Misa 2004; Edgerton 2008). The entire fabric of contemporary existence depends upon the accumulated knowledge, products and promises of science and technology in their myriad forms – in energy and transport, food production, medicine and health, environmental management, education, communications, and societal infrastructure at every level.

In recent decades, academic attention has turned to analysis of science and technology as dynamic processes for the production of knowledge and diverse products, artefacts and complex sociotechnical systems. Work in science and technology studies and related fields has developed awareness of the multi-faceted and socially constructed nature of science and technology.[8] These domains are shown to involve much more than the scientific and technical and to be closely inter-related with social, political, sectoral, commercial, economic, ethical and epistemological dimensions.

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[8] The distinctions and relationships between science and technology, as professional fields with their respective approaches, objectives, modes of practice, criteria for success, and public perceptions, are the focus of 'long-running definitional disputes' (Greenberg 2001, p 4). This thesis follows Greenberg's recognition that science and technology are best understood as zones along a spectrum, most clearly differentiated at their extremes: science aims to create knowledge, whereas technology development applies knowledge in the production of artifacts, technical systems and processes. However scientific and technological dimensions are more often inextricably intertwined in iterative research and development (R&D) pathways, working back and forth between the pursuit of information and the requirements of technological purpose. Rip (1992, pp 231-233, 258) describes the continuum between science and technology, or knowledge and artifact, using a metaphor of the two partners in a dance. In this thesis, the terms 'science' and 'technology' will be used when appropriate for activities and entities at the respective ends of the spectrum; the term 'technoscience' refers to hybrid modes and processes where it would be counter-productive to try to disentangle the scientific and technological aspects. Latour (1987, pp 174-175) dismisses artificial definitional boundaries, describing technoscience as 'all the elements tied to the scientific contents no matter how dirty, unexpected or foreign they seem'.

This thesis focuses on the promotion of scientific and technological development through the claims and scenarios of anticipated future benefit that are used to justify research and development (R&D) and to encourage the diffusion of innovations. These are explored via analysis of the projections of expected benefit advanced for two fields of technological development in New Zealand: genetic modification (GM) of animals and plants for a range of agricultural, commercial and environmental purposes; and generation of electricity using turbines to harness wind power.

Like any societal enterprise, science and technology are supported and validated by positive narratives that highlight the appeal of particular projects, the profits and worthy outcomes that are expected, and the relief anticipated from resolving needs, inadequacies or problems. Such enthusiastic projections of future benefit are important strategic resources, instrumental in securing funding and institutional, political and public support for ongoing R&D. The plausibility and attractiveness of expected benefits are all the more important when there is uncertainty or controversy around a particular project or technological field. Furthermore, the overall enterprise of technoscience is generically validated by broader patterns of assumption of the utility, profitability and desirability of dealing with diverse societal and environmental issues through scientific and technological means.

The ways future benefits are framed, and the kinds of returns and outcomes that are valorised in technoscience, have major implications for the kinds of priorities followed in R&D and the kinds of technologies, systems and practices that result. The orientation of research and technological innovation around particular kinds of goals can be strongly influential – some technological pathways and applications are supported and fostered, others are rejected, delegitimated, or marginalised to "fringe" status. Assertion of the kinds of projected benefits that answer the expectations and interests of dominant actors and groups in technoscientific and policy fields is crucial for the relative success or failure of potential innovations.

There has been extensive academic, sectoral and policy analysis of the dynamics of technoscience processes, the complexities of sociotechnical systems, practices and communities, and the interactions of societal groups with technoscience.[9] However the frameworks of optimistic expectation – the particular benefit claims and assumptions of broader technoscientific beneficence that drive processes of technoscientific development – have as yet received only limited critical, political, sectoral or public attention. Much analysis and policy has focused on the consequential impacts of research products and technologies after release, either encouraging diffusion and market uptake, or addressing potential adverse effects and unintended consequences through risk management. While risk debates are important and enlightening, nevertheless they engage with the "downstream" implications of technoscience innovation, well after research has begun, funds have been invested, and commitments established. Considerable effort is expended on *post hoc* analysis and negotiation of possible negative impacts, while the projections of benefit justifying particular R&D directions are largely taken for granted and rarely questioned by practitioners, policy actors and publics.

However, the significance of projections of future outcomes from science and technology has become the focus of analytical scrutiny in an emerging field of international scholarship, the sociology of expectations (for example, van Lente 1993; Brown et al. 2000a; Brown & Michael 2003; Borup et al 2006). As yet there is little awareness, amongst policy and institutional actors or wider communities, of this academic work or its insights into the ways expectations validate, influence and foster technoscientific development. Nor is there much recognition of the importance of understanding how projections of future benefit shape present-day research priorities and technology trajectories. A key starting point for this thesis is that such understanding is crucial for publics, interested groups, and official and sectoral actors to engage effectively with the many challenging issues around the development and deployment of technoscience.

This thesis takes engagement with technoscience back "upstream" to investigate the significance of benefit framings in the processes of scientific and technological innovation. The origins of technology trajectories lie in the concepts of progress, improvement, advantage, problem-solving and profit that drive R&D. The thesis

[9] These literatures are surveyed briefly below, and discussed in more detail in Chapters Two and Three.

focuses on the constructions of expected benefit deployed in two technological fields in New Zealand, GM and wind energy, and explores how benefit projections have influenced the evolution of those technologies and their applications in this country.

The research problem

The problem this thesis addresses is the lack of comprehensive critical engagement with the projections of benefit that justify and valorise technoscientific innovation in the early 21st century. This lack of engagement is clearly evident in the analytical and policy frameworks and in broader public engagement with science and technology in New Zealand and internationally. This is additionally problematic in highly contested technology arenas – such as proposed applications of GM, or transitions to renewable energy technologies such as windfarms.

This is a significant problem because particular concepts or narratives of technological benefit are central to the evolution, application and outcomes of the technologies they are used to promote. Benefit framings have a powerful influence on the kinds of research pursued, the kinds of technology options considered useful or practical, the amounts of taxpayer dollars invested in R&D and institutional and regulatory systems, and the actual products and processes eventually manifested in our landscapes, agriculture, foodstuffs, medicines and essential infrastructure.

This problem has salience in several arenas – including government policy, the strategic development of scientific research institutions, environmental and interest group advocacy, and local community action – where technological innovation is often the site of sustained contestation. Without more thorough scrutiny of the goals or benefits asserted as justification for particular research orientations, or of the ways such expectations legitimate and strengthen favoured fields, technoscientific trajectories are, by default, driven by the values and objectives of the proponents of those R&D programmes. Principal among such frameworks are ubiquitous narratives of science and technology as prerequisites for unlimited progress and economic growth (Sarewitz 1996; Cohen et al. 2001; Greenberg 2001).

In his analysis of the power relations inevitable in technoscientific fields, Bourdieu (2004, pp 35, 62-63) highlights the hegemony enjoyed by dominant actors with the strategic resources and status to assert their particular interests and frameworks of value as norms within the field. Publics are relegated to the status of awed and grateful recipients of the technology and its outcomes, an enrolment that Winner (1986, pp 5-10) describes as 'technological somnambulism'. With little scrutiny of the framing and functioning of promissory benefit claims in the promotion of particular innovations or developments, dominant groups' interests and projections of benefit are perpetuated, and alternative discourses and technological benefits are marginalised. As Foucault (1972, 1980, 1994) argues, the assertion of certain versions of reality and value – or 'regimes of truth' – is an ongoing ideological process through which existing social, political and economic arrangements are maintained and the appeal and legitimacy of other options are diminished.

A lack of critical understanding of the ideas and assumptions shaping technology trajectories might be judged as irresponsible given the myriad implications of contemporary innovations and changes: 'Vast transformations in the structure of our common world have been undertaken with little attention to what those alterations mean' (Winner 1986, p 9). But policy and public discourse around technoscientific innovations and their application remain 'stubbornly innocent' of scholarly analysis of the socially constructed, embedded nature of knowledge, artefacts and technological systems (Sarewitz 2004, p 386). Some studies highlight this lacuna as a major risk. Williams (2005, p 17), acknowledging the increasingly political nature of technoscientific change, argues for careful scrutiny and 'more balanced attention' to the full spectrum of issues, actors, interests, interpretations and values frameworks involved in 'high technology futures'. Bourdieu (2004) insists on the necessity of comprehensive reflexive awareness of the power relations and social and ideological frameworks that drive technoscientific development. The European Commission (2007, pp 15-16, 41, 54, Chapter 7) recommends improved engagement and awareness of the taken-for-granted 'imaginaries' that rationalise societal investment in R&D and innovation. The Commission identifies 'an essential neglected role for clarifying and deliberating the crucial assumptions and commitments which frame ostensibly "neutral", "objective" scientific activities' (2007, p 83). And Wynne (2003, pp 9, 25) calls for more constructive involvement and debate around:

> …the trajectories, driving purposes, proper conditions, and other implications of such major scientific-technological commitments, before their impacts have already been created… to identify questions which have been inadvertently pre-empted and concealed in the forms of knowledge and technology which emerge… [and] social issues which may be lying unseen and unresolved beneath the superficial appearance of scientific determinism.

Addressing the research problem – sites of inquiry

This thesis addresses the problem of limited critical understanding of the significance of benefit claims for new technologies by analysing the constructions of expected benefit advanced for two fields where technological innovation has been enthusiastically promoted in New Zealand – GM and wind energy.

These two fields offer productive opportunities to address the work of benefit claims, although GM and generating electricity from wind are very different kinds of technology. GM aims to delve into and manipulate the most fundamental levels of biophysical reality in ways previously impossible, to produce living organisms with qualities and characteristics that would not otherwise occur. GM deliberately sets out to make radical interventions in the natural order, targeting lucrative outputs in the form of specialised plants, animals and biological substances (Gottweis 1998; Rifkin 1998; Hindmarsh & Lawrence 2004b; Hindmarsh 2008). Generating electricity from the wind is in comparison a rather conservative technology, merely harnessing existing elemental forces. The only alterations are to the landscapes and communities in which turbines and associated infrastructure are sited (Parliamentary Commissioner for the Environment 2006a, 2006c). The basic commodity product delivered by this technology, electricity, is no different from that produced by other generation systems such as hydro dams or gas or coal fired plants (Sustainable Energy Forum 2005; Ministry of Economic Development 2006a; New Zealand Government 2007; Pernick & Wilder 2008). But despite these basic ontological differences between the two technoscience fields, it is useful to compare them in terms of the claims of expected future benefit advanced by their proponents – the promissory discourse, projections and strategic framings of meaning constructed around the technologies, as distinct from the technologies themselves.

Although not new in the global context, both technologies are innovations in the New Zealand context. Their adoption and diffusion in this country require major shifts in the usual taken-for-granted modes of doing things. The distinction between technoscience process and product is a useful clarification (Jasanoff 2005a); while the end commodity or outcome is not necessarily radically new (vegetables, pest management, pharmaceutical compounds, electricity), the means of delivery involves significant change from the status quo. The relevance for this thesis of these technoscience fields in New Zealand is not only in the products and services they offer, but also in the changes required for them to be developed and deployed – changes that must be justified with sufficiently convincing benefit projections. Both innovations have significant uncertainties and unknowns as to their acceptability and diffusion, their actual performance, and the longer-term effects (environmental, social and economic) involved in their adoption in New Zealand. They both attract fierce controversy and arouse intense concern amongst the public and interested groups. Each requires the development of new knowledge and capacities, systems and practices, infrastructure, policy, governance and regulatory frameworks, funding, and public involvement processes. Thus the trajectories of GM and wind energy in New Zealand offer valuable insights into the persuasive work of benefit claims in creating and contributing to a momentum for change.

Another key factor in the choice of these technoscience fields is that GM and wind energy advocacies employ promiscuous modes of appeal. Each is promoted in relation to both economic and commercial objectives, and idealistically disinterested public-good goals such as health, environmental sustainability and general societal wellbeing. These technologies' representations in policy, sectoral and public discourses are based in a mix of fundamentally different, even incommensurate constructs of intended benefit. However there has been little critical attention to these divergent, indiscriminate framings of purpose and expectation, or to the prioritising of particular kinds of interests and value frameworks. This thesis' analysis of the patterns of justification of R&D and innovation in the two fields in New Zealand allows interrogation of this heterogeneity and its implications for technoscience development.

The comparison of disparate research fields or communities is a practical way to identify and assess the frameworks of meaning underpinning science and technology. As shown by Knorr Cetina (1999) and by Borup and Konrad (2004) in analyses of differing scientific 'cultures', contrasting the goals, orientations, practices and assumed values typical of each field can be highly revealing. Other studies develop an understanding of broader issues by teasing out differences and shared patterns across a range of diverse technoscience areas; for example, Collins and Pinch (1998a, 1998b) address a rich spectrum of cases, from cold fusion to Pasteurisation, the space shuttle, AIDS, and military technologies in the Gulf War.

Exploration of the benefit claims deployed in support of GM and wind energy technologies in New Zealand cannot consider these fields in isolation from the wider societal discourses and values frameworks that govern their orientation and application. The thesis addresses projections of benefit from these technologies in relation to the norms, myths, assumptions and beliefs that shape science and technology trajectories (Winner 1986; Midgley 1992; Sarewitz 1996; Feenberg 1999; Greenberg 2001). The development pathways of GM and wind energy technologies show clearly the influence – both enabling and constraining – of such broader societal narratives and general concepts of the purposes, potentials and qualities of science and technology. Two such narratives are prominent in the framing of anticipated benefits for these fields both in New Zealand and internationally: firstly, the utilitarian economic mode of commercial profitability; and secondly, the imperatives of environmental sustainability.

A broad diversity of analytical and theoretical literatures informs the approach of this thesis in addressing the problem of limited attention to expectations in science and technology; these are discussed in the following three chapters. But the focus of this investigation has been strongly shaped by the thinking of two Frenchmen – Pierre Bourdieu (Bourdieu 1990; Robbins 1991; Calhoun et al. 1993; Bourdieu 1999; Brown & Szeman 2000; Webb et al. 2002; Bourdieu 2004; Grenfell 2004), and Michel Foucault (Foucault 1972, 1980, 1994; Mills 2003; Prior 2004; Motion 2005; Weaver et al. 2006; Motion & Leitch 2007; Powers 2007). Their work has provided practical tools and guiding principles for this exploration of the work of benefit projections for technoscientific innovation. Bourdieu's analysis of the dynamics of social and sectoral fields, in terms of the characteristic habitus of actors and the strategic utilisation of symbolic and other forms of capital, offers a robust framework for locating specific benefit constructs within their larger contexts. And Foucault's focus on discourse as the ongoing expression and perpetuation of power relations endorses the centrality of rhetorical and strategic positioning in the development, promotion and diffusion of new technologies.

Aims

The primary aim of the thesis is to conduct a critical analysis of the constructions of expected benefit that legitimate and shape technological innovation in GM and wind energy in New Zealand. The purpose of this analysis is to understand the influence of such benefit framings on research and development trajectories and the diffusion of new technologies. This aim addresses the problem of limited critical attention to the ways in which claims of benefit shape policies and decisions, and influence the viability and uptake of various technology options.

Supporting this objective and sharpening the focus of inquiry are the secondary aims of the thesis:

1. To explore the ways benefit projections are used as strategic resources in the promotion and justification of innovation in contested technology domains, specifically with respect to the development and diffusion of particular GM and wind energy applications in New Zealand.
2. To identify and analyse the different registers or qualitative modes of benefit in the framing of technoscientific developments (for example, remote future benefits of minimising climate change via renewable energy technology as distinct from short-term local benefits of commercial profitability of a large windfarm).
3. To identify the fields, sectors and discursive contexts in which different frameworks of scientific and technological benefit are deployed and given recognition and acceptance (for example, policy, institutional and professional fields, commercial business environments, publics and communities).

Research questions

My exploration of the work of benefit claims in the development of GM and wind energy technologies in New Zealand is informed by a suite of open-ended inter-related questions. These establish a research framework that both focuses on the specific claims advanced for particular applications within the two technology fields in New Zealand, and orientates and interprets these claims within the larger contexts of academic and policy engagement with technoscience.

- How are innovative technologies – such as GM and wind energy in New Zealand – framed, positioned and promoted? Which framings and values are advanced by particular groups and actors?
- What ideals and principles are featured in this promotion to enhance the appeal of technoscientific innovation to publics, interested sectors and decision-makers? How do these ideals and values shape the development and use of new technologies? What broader societal discourses and narratives are used to validate and valorise the expected benefits of the technologies?
- What kinds of benefits and profits are projected from the technologies' development and application, and which groups and interests are targeted or assumed as beneficiaries?
- What institutional and policy framings, and what practices and assumptions of research, policy and regulatory agencies, inform the construction of expected benefits and the development of the technologies?
- What kinds of problems, needs and imperatives are referenced in advocacy for innovation as requiring the new technologies for their solution or amelioration?
- How are the framings of expected benefit of one technological option used strategically to marginalise other technology alternatives and potential benefits, and to diminish their appeal or perceived viability?

The research approach encapsulated in this series of questions gives both flexibility and precision, allowing the identification of key aspects of the ways projections of future benefit shape technoscience trajectories, and the significance of the values frameworks and assumptions of particular groups and interests. The thesis methodology and process are discussed in detail in Chapter Four.

The next section briefly surveys the official and sectoral environments for science and technology in New Zealand, and the orientations of the major areas of academic analysis of technoscience fields. To date, benefit claims for R&D and innovation have been largely taken for granted in these domains, and accepted, deployed and perpetuated in technoscientific development processes with little critical scrutiny. The remaining sections of this chapter address the significance of the thesis, its scope and focus, and its structure.

The neglect of benefit projections

The New Zealand context

Science and technology, and the opportunities believed to derive from investment and development in prioritised fields, are highly valued in New Zealand as in most nations. Governments, public institutions, universities and the private sector assert the centrality of science and technology to the nation's economic prosperity and quality of life. This reflects the modernist narrative of progress and profitable improvement that has underpinned Western capitalism since the Industrial Revolution and earlier (Winner 1986; Mokyr 1990; Lowenthal 1995; Sarewitz 1996; Greenberg 2001; Wilsdon & Willis 2004).

In New Zealand this confidence in progress is enshrined in official policy, and manifested in an array of institutional, statutory, regulatory and funding provisions to support and foster scientific and technological activity. A predominant focus on expectations of economic profitability and growth from technoscientific innovation runs strongly through policy and sectoral discourse (Cartner & Bollinger 1997; Leitch

& Davenport 2005; Macdonald et al. 2011).[10] The value of investing in research and technology development is a driving principle or legitimating narrative in policy for science and technology generally (New Zealand Government 1996, 2002), and for particular fields or sectors (New Zealand Government 2001, 2003; New Zealand Trade and Enterprise 2005; New Zealand Government 2007, 2010). Research institutions, science sector advocacy bodies, and organisations representing specific disciplinary and professional interests in New Zealand all share the same core belief in the essential importance of science and technology to the nation's future. For example, the Royal Society of New Zealand articulated its commitment to technoscientific advance in a determinedly visionary *Manifesto* document:

> Our science system – embracing innovation, research, science and technology – supports all that we seek to achieve in our national life: prosperity, health, sustainability and credibility. Without a healthy science system we will always fall short of those goals (Royal Society of New Zealand 2007, p 8).[11]

Various government agencies have had responsibility for policy to guide New Zealand research and innovation through the first decade of the 21st century (the period covered in this thesis).[12] Actual R&D activity, and strategic direction-setting and decision-making for research in particular technoscience fields, is devolved to the Crown Research Institutes (CRIs). These autonomous state-owned entities each focus on a specific research domain, and are tasked with developing knowledge and innovations for the benefit of the nation.[13] With all these agencies, technoscience

[10] These dimensions of New Zealand's R&D policies and sector orientations are particularly strong in biotechnology, and are discussed in detail in Chapter Six.

[11] Established in 1867, the Royal Society works under its own enabling legislation to advance and promote science and technology in New Zealand. It undertakes a broad range of advocacy, educational, publishing, advisory and science-sector support roles (www.royalsociety.org.nz).

[12] These agencies include: the Ministry of Research, Science and Technology (MORST) setting overall policy directions; the Foundation of Research, Science and Technology (FRST) managing science and technology funding streams; other ministries such as the Ministry of Economic Development (MED) with responsibility for the nation's energy policy, and the Ministry for the Environment (MFE) dealing with climate change and sustainability; and regulatory bodies such as the Electricity Commission (EC), overseeing New Zealand's electricity industry, and the Environmental Risk Management Authority (ERMA) managing assessment and approval of new organisms and hazardous substances. Some of these agencies have more recently been restructured. In 2010 the Electricity Commission was replaced by the Electricity Authority (www.ea.govt.nz). In 2011 ERMA was restructured into the Environmental Protection Authority (EPA) (www.epa.govt.nz). Also in 2011, MORST and FRST were amalgamated into the Ministry of Science and Innovation (www.msi.govt.nz), and in 2012 further restructuring was announced to combine this agency with the MED and other government departments responsible for trade, industry, commerce and labour, to form a new "super-Ministry", the Ministry of Business, Innovation and Employment (www.mbie.govt.nz).

[13] The CRIs were created in 1992 from the former Department of Scientific and Industrial Research. Their role and purposes are defined in the Crown Research Institutes Act 1992, which requires both commercial viability as business entities, and that research is undertaken for the benefit of the nation

policy is predicated upon the fundamental worthiness and positive value of scientific and technological development, as a necessary requirement firstly for economic growth and competitiveness, and also for broader societal wellbeing.

Analysis and theory

Most policy-world and academic analysis of scientific innovation and technology development, both in New Zealand and internationally, has focused on four principal areas: issues of risk and risk management; the character and dynamics of sociotechnical systems; public understanding of science and citizens' engagement with approval and risk management processes; and the diffusion of innovation.[14]

While the discussion and conceptualisation of risk from science and technology are sometimes posed in relation to the intended benefits, the predominant emphasis of analysis and critique has been on describing, ameliorating and communicating risk subsequent to approval or release (for example, Beck 1992; Krimsky & Golding 1992; Tenner 1997; New Zealand Association of Scientists 1998; Beck 1999; Perrow 1999; Slovic 2000a; Ericson & Doyle 2003). Public opinion surveys have canvassed the relative acceptability of various technoscientific developments, and explored the values and concerns behind citizens' agreement or unease about certain technological applications (Coyle et al. 2003; Cook et al. 2004; Cook & Fairweather 2005, 2006; Hunt & Fairweather 2006). However, such surveys present prospective products or technologies for acceptability ranking with minimal or no consideration of their implicit purposes or societal contexts.

(CRI Act s5). In addition, CRI activities are framed within a Statement of Core Purpose required by government in 2010 to provide 'a clear, explicit and enduring strategic role' for each institute (http://www.morst.govt.nz/current-work/CRI-Taskforce/Statements-of-core-purpose). The work of each CRI is based around a productive sector of the economy or a grouping of natural resources; for example, AgResearch focuses on biological science for agriculture, Scion on forestry and wood products, and the National Institute of Water and Atmospheric Research (NIWA) on marine and freshwater systems and resources (http://www.morst.govt.nz/rst-links/crown-research-institutes/). The three CRIs with most significance for this thesis are AgResearch, Plant and Food Research (formerly Crop and Food Research) which focuses on science for crops and vegetables, and Landcare Research (Manaaki Whenua) oriented around science for sustainable land management; their projects in GM livestock, vegetables and pest control are discussed in Chapter Six.

[14] Chapters Two and Three provide more detailed discussion of these literatures in terms of their relevance for the construction and deployment of projections of benefit from technoscience.

The emphasis on risk management in academic, policy and professional domains has deflected attention from other dimensions of science and technology development.[15] Risk assessment and mitigation methodologies – the reasons for caution and strict regulation – have dominated many technoscientific fields. But there has not been an equivalent critical focus on the originating impetus for R&D enterprises – the reasons for enthusiasm and investment, for taking a risk in the first place. Attending to the concepts of projected benefit driving technoscientific trajectories has effectively been foreclosed by the more pressing demands of anticipating and managing possible adverse outcomes:

> [W]e possess far better developed tools and criteria for thinking about the potential… risks of a new technology and how they may be reduced than [for] considering social benefit… The issue of promised social benefits has been systematically excluded from established regulatory processes (Williams 2005, p 17).

A growing field within risk studies centres on processes for better communication between technical elites and publics, and on ways to recognise or to manage the concerns of citizens, environmental and health groups, and some scientists and policy actors about potentially risky developments (Funtowicz & Ravetz 1992; Wynne 1992; Sclove 1995; Cronin 2003a; Gough 2003a). Recently there have been calls for improved 'upstream' consultation and public engagement about new science and its applications, particularly nanotechnology (Wilsdon & Willis 2004; Macnaghten et al. 2005; Wilsdon et al. 2005; Kearnes et al. 2006; European Commission 2007; Pidgeon et al. 2009).[16] However, this literature, focused on advocacy for citizen participation, offers only limited critical analysis of the frameworks of anticipated benefit used to justify technoscientific development.

An extensive field of science and technology studies explores the intricacies of science and technology development as sociotechnical systems. These analyses explain the complex interactions and dynamics of societal, sectoral and technical realms. Key theoretical frameworks include Actor Network Theory (Latour &

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[15] There has been little reflexive consideration of the effects of the dominance of risk framings in official and public discourses around technologies and their application (Winner 1986, pp 148-154).
[16] Williams (2005, pp 15-16) notes that the widespread assumptions about such 'upstream' focus – that it will enhance public acceptance of technoscientific innovations and help to forestall controversy and opposition – are as yet unproven.

Woolgar 1979; Latour 1987, 1992; Law 1992), and the social construction of technological systems (Bijker et al. 1987; Hughes 1989; Bijker & Law 1992a; Bijker 1995; Kline & Pinch 1999; Hughes 2004; Dattée & Weil 2007). Other work has developed valuable analytical concepts such as technological regimes or paradigms (Dosi 1982; Green et al. 1999; Perez 2002; Barben 2007; Vanloqueren & Baret 2009), and technology pathways and life cycles (Garud & Karnøe 2001b; Kaplan & Tripsas 2008). Other science and technology scholars have focused on institutional, structural and governance dimensions of science and technology (Gibbons et al. 1994; de la Mothe 2001; Nowotny et al. 2001; de la Mothe 2004), or on epistemological cultures and ideals (Midgley 1992; Lenoir 1997; Knorr Cetina 1999; Lightman et al. 2003). This work illuminates the richness of science and technology as inextricably embedded in human social constructs and value frameworks, but the influence of benefit projections on the directions and practice of technological research and development has thus far received little attention.

A vast range of theoretical work has also developed around the public understanding of science.[17] This has been accompanied by an expanding literature on public involvement in science and technology decision making. Matters highlighted in these areas of science and technology studies include processes for citizens and user groups to be recognised and heard, and to participate in the management of science and technology (Frankenfeld 1992; Funtowicz & Ravetz 1992; Irwin 1995; Sclove 1995; Rappert 1999a; Macnaghten et al. 2005; von Hippel 2005; Kearnes et al. 2006; European Commission 2007). Other concerns include balancing and bridging the differences between elite or expert science and lay knowledges (Ravetz 1986; Otway 1992; von Winterfeldt 1992; Wynne 1992, 1996; Slovic 2000c; Schot & De la Bruhèze 2003), and improving communication about science and technology and risk (Nelkin 1995; Gregory & Miller 1998; Allan et al. 2000; Priest 2001; Cronin 2003a; Gough 2003a; France & Gilbert 2005). The insights emerging through this literature build understanding of the ways science and technology are discursively and socially constructed and contested. However, there has been little analysis of the dynamics of

[17] Advocacy for improved public understanding of science and technology is often predicated on the assumption that this is a prerequisite for public support and acceptance of new developments and products. This framework of belief, the (in)famous Deficit Model, has been comprehensively challenged, but still persists in much science and policy discourse (Wynne 1992; Irwin 1995; Irwin & Wynne 1996; Sarewitz 1996; Wilsdon et al. 2005; Kearnes et al. 2006).

benefit projections in public interactions with science and technology, or of the diverse and divergent framings of value underpinning different groups' and sectors' concepts of benefit.

Articulating the intended positive outcomes of research and technology development is logically the business of business, and researchers associated with different sectors and with economic policy. There is a considerable and insightful literature on the diffusion of technological innovation to maximise adoption and commercial opportunities. This work is useful in its exploration of the processes of development and spread of innovations through particular sectors and wider societies (Utterback 1994; Dosi & Lovallo 1997; Bassanini & Dosi 2001; Garud & Karnøe 2001b; Allen 2003; Franklin 2003; Hargadon 2003; Rogers 2003; Chakravorti 2004; Petrick & Echols 2004; Coburn 2006; Montalvo 2006; Berkun 2007; Van de Ven et al. 2008), and its analysis of the dynamics of the economic dimensions of science and technology trajectories (Rosenberg et al. 1992; Rosenberg 1994; Mowery & Rosenberg 1998). The distinction between radical, disruptive science and technology and more conventional developments is a key finding (Gooley & Towers 1996; Christensen 1997). However, the majority of these studies focus on the diffusion process and on fostering markets, acceptance and profitability for promising new products. Their commercial and promotional orientation gives little scope for questioning the assumptions of benefit and desirability underpinning technoscientific innovation: 'Such "why" questions about adoption have seldom been probed effectively by diffusion researchers' (Rogers 2003, p 115).

Of more direct relevance to the research concerns of this thesis is the emergent literature focusing on expectations in science and technology fields (for example, van Lente 1993; Brown et al. 2000a; Brown & Michael 2003; Sturken et al. 2004; Brown 2006). This work analyses the strategic and performative functions of expectation and promise in the promotion and introduction of new science and technology. The importance of projections of future outcomes from science and technology is emphasised by van Lente (1993, 2000) and colleagues in the Netherlands and the UK (Brown et al. 2000b; Brown et al. 2003; Borup & Konrad 2004; Brown et al. 2005). These scholars trace the influence of projected futures in technology trajectories, helping to secure funding and other political and sectoral support. Other studies analyse the rhetorical construction of futures, and their role in building persuasive visions and narratives to foster acceptance and uptake of innovation (Brown 2000; Deuten & Rip 2000; Wyatt 2000; Nye 2004; Turkle 2004; Hedgecoe & Martin 2008). The wider societal, sectoral and ideological dimensions of science and technology expectations have been outlined by Winner (2004), Sarewitz (1996), and others (Michael 2000b; Hedgecoe & Martin 2003; Lightman et al. 2003; Sturken & Thomas 2004). And the Consortium for Science, Policy and Outcomes at Arizona State University has a specific focus on analysing the impacts and effects of science and technology, and linkages with desired societal outcomes.[18]

There is, however, little awareness in New Zealand policy and science and technology environments, or in wider public discourse, of this work on expectations and the justificatory frameworks underpinning technological innovation. Two modes or stances towards technoscience prevail: the enthusiastic embracing of R&D and new technologies and products as the pathway to economic prosperity and growth, or sceptical opposition based around issues of potential risks and inadequate public engagement with technoscientific decision-making processes. This typical polarisation offers little opportunity to develop understanding of the dynamics of research and technology trajectories, and the ways benefit projections influence technoscientific developments, policies, orientations and outcomes.

Significance

This thesis aims to redress the lack of critical attention to constructions of benefit from scientific research and technology development, via discussion of the benefit claims advanced for two technological fields in New Zealand. The thesis contributes to the emergent literature on technological expectations, bringing a unique New Zealand perspective to the recent international work addressing these important dimensions of science and technology. My analysis of the role of benefit claims in the trajectories of GM and wind energy in New Zealand is a specifically local application of – and an addition to – emerging international theory on expectations in science and technology. The thesis makes a novel contribution by linking the

[18] See http://www.cspo.org/ .

concepts developed in this new research field to specific New Zealand technology innovations. This study is also intended as a contribution to the broader academic fields of the sociological study of science and technology, with relevance and interest both for New Zealand scholarship and for those studying similar issues of technological development elsewhere in the world.

The thesis also develops a preliminary conceptual toolkit for the critical analysis and deconstruction of new scientific and technological developments, that may be useful for citizens, interested groups and research, policy and regulatory communities in their interactions with these processes. By focusing on framings and discourses of expected benefit, the thesis offers a different analytical approach for engagement with issues of technological innovation and social and environmental futures, an approach that has not yet been undertaken in the New Zealand context. Understanding how benefit projections are strategically deployed will add to the critical repertoires of all actors in contested technology innovation fields, and help the development of more critically informed and socially useful debate.

Scope and focus

Given that this thesis addresses the role of expectations of benefit in advancing technological innovation, it is also important to have clear expectations about the thesis itself.

The focus of this inquiry is strictly around the discursive and strategic constructions of expected benefit from technology developments in two fields, GM and wind energy in New Zealand. Other important aspects of technological innovation are considered only briefly and only from the perspective of how they might better inform analysis and understanding of the work of benefit claims.[19] These include such strongly developed and interesting academic fields as the analysis and assessment of risk, the democratic participation of publics in processes of technology approval, or the interactions and relationships forming technoscientific networks.

[19] Issues of methodology and focus are discussed in Chapter Four.

There are also important constraints of time and space on the methodological aspects of the research. This study concentrates on only two selected technological fields – GM and wind energy – and furthermore, on particular projects or exemplary cases within those fields in New Zealand.[20] The focus on these examples facilitates appropriate depth and detail in the analysis, but there are inevitably limitations in the New Zealand location and the choice of these technologies. Many other interesting and potentially fruitful examples of scientific and technological benefit framings, both in New Zealand and internationally, might equally have been useful for analysis – for example such innovation-rich technoscience fields as nanotechnology, biofuels, sustainable architecture and building construction, or mobile communications.

A number of studies have used ethnomethodological approaches – where a social scientist is 'embedded' within science and technology institutions or laboratories to study practice and paradigms at close range (for example, Latour & Woolgar 1979; Knorr Cetina 1999). However, this technique was neither possible nor appropriate for this project's focus on the larger societal and sectoral frameworks of expected benefit underpinning science and technology development. Nor were the methods of quantitative surveys and questionnaires suitable for this study's inherently qualitative, exploratory approach.[21]

The third area where the scope and approach of this research should be clarified is its stance towards the phenomena and issues under consideration. This study might be assumed to be based in an anti-science or anti-technology stance. But exploration and critique of the discourses of benefit driving new technoscientific developments is not the same as opposition or hostility to innovation. The thesis is not intended as fuel for activists campaigning against GM or windfarms. However, neither does this research aim to advocate for scientific and technological innovation, whether generically or for particular fields or cases. While focusing on the benefits anticipated from new

[20] The original scoping for the thesis also considered a third technology field – intensive irrigation for the conversion of dry agricultural landscapes to dairy farming. It was soon obvious that this would be a thesis topic in itself and the decision was made to focus on GM and wind energy.

[21] The principles underpinning the choice of a qualitative methodology are discussed in detail in Chapter Four. While many practitioners in the two technology fields in New Zealand were interviewed for this thesis, discussions were necessarily open-ended and wide-ranging, given the lack of previous academic attention to issues of benefit projections and the freshness of these questions to interviewees.

science and technology might suggest a purpose of promotion or endorsement, such assertions and assumptions are the subject of this thesis, not its objective.

Furthermore, the thesis does not assess the actual validity of any of the claims of expected benefit offered by advocates for technological innovation in the two fields in New Zealand or generally. This would require extended timeframes and specialist expertise in arcane technological, economic and policy areas. Moreover, debunking science and technology ‘hype’ is, while an interesting and entertaining process, not the focus of this thesis (Konrad, 2006). Evaluating actual outcomes against earlier plans or projections is a long-term task for investors and managers of science and technology programmes. The focus of this thesis is on the immediate, present-day performative work of assertions of future benefit. The future is inherently contingent and uncertain, and hopeful claims or projections of future states cannot be reliably substantiated until some later point in time. The thesis can only consider the influence of such rhetorical and strategic constructions on current science and technology development processes.

The thesis structure

This chapter has introduced the questions and problems that will be explored in the thesis. These aspects of technoscience processes have received little attention to date, although the influence of projections of intended benefit on R&D and innovation is often profound. The focus of this research on the workings of benefit claims in the fields of GM and wind energy development in New Zealand is intended to contribute towards knowledge of these dimensions of science and technology.

Chapters Two and Three survey the academic literatures. Chapter Two focuses on the frameworks of belief and expectation that shape societal enterprises such as technoscience development. Embedded and naturalised in the paradigms and values of fields, these patterns of orientation are manifested in common narratives or myths that guide and govern activity. Chapter Two describes three such stories of science and technology – framings of R&D as the source of prosperity and societal wellbeing, as a desperate competitive race, and as a teleological linear progression. Chapter Three explores the strategic side of benefit projections in technoscience processes, and the performative work of expectations in legitimating research and innovation, and securing support for development activity.

Chapter Four outlines the methodology of this thesis, and the theoretical approaches from which I have drawn useful tools and principles for my analysis of benefit claims in the two New Zealand fields. This chapter describes my engagement with the academic literatures and primary documents, and discusses the process of interviews with sector actors.

Chapter Five tells the story of the introduction of wind energy technologies in New Zealand. The promotion of this innovation in the New Zealand electricity sector, and in the international evolution of the wind industry, is strongly associated with environmental benefits. However the chapter shows that the pragmatic requirements of business interests have been powerfully influential on the diffusion of wind energy, which has largely been established in the form of large commercial windfarms that align with the priorities of dominant groups. Alternative modes of this technology offering other kinds of benefits have had limited uptake, and are relegated to "fringe" applications.

Chapter Six follows the justification of GM research in New Zealand through multiple projections of anticipated benefit and multiple strands of research. The various areas of scientific endeavour in this field demonstrate the heterogeneity of benefit claims; however, New Zealand's regulatory systems for research on new organisms establish a relatively narrow range of criteria for approval. Work on GM vegetables and on biopharmaceutical potentials from GM livestock is associated strongly with economic objectives, although health and environmental benefits are also claimed. The uniquely New Zealand application of GM techniques to develop radically new biocontrol tools for environmental pest management, was focused around the primary aim of biodiversity protection. But this research was also mixed with economic frameworks of value, in the intended contribution of the proposed biocontrols to the New Zealand dairy industry.

Chapter Seven cuts across the two technoscience fields to consider some of the underlying issues. This chapter explores the strategic association of benefit claims with various drivers, needs and problems as incentives for innovation. The differences and tensions between economic and altruistic, public-good frameworks of intended benefit are discussed. This chapter concludes by considering the vulnerabilities of benefit claims, when despite the confidence typical of sector rhetorics and positioning, the momentum of R&D programmes can not be sustained.

Chapter Eight offers a brief assessment of the key findings of the research, and suggests ways forward where the thesis might contribute to further scholarship and to the challenges of community engagement with technoscience innovation processes.

Chapter Two

Frames and narratives

Introduction

This thesis investigates expectations of future benefits from new technoscience developments, and explores the implications of these constructs of benefit for R&D trajectories and the kinds of technologies that result. The focus is on benefit claims advanced for two fields of innovation in New Zealand, GM and wind energy, and the ways these projections are framed within the broader contexts of societal attitudes and institutional support for science and technology.

This chapter and the next develop the theoretical basis for this assessment of benefit claims for technological innovation. Chapter One briefly surveyed a range of studies of science and technology, and argued that the significance of benefit projections in technology advancement has not yet received much detailed academic scrutiny. The thesis now returns to the scholarly literatures, to identify key theoretical insights for understanding the significance of benefit expectations for science and technology generally, and for particular developments in GM and wind energy in New Zealand.

The construction and deployment of projections of expected benefit from technoscience are inherently matters of ideology and rhetoric, of 'how people are made to believe and behave and… how to persuade others' (Latour 1987, p 30). Benefit claims are reifications – scenarios of desirable future states, and strategic expressions of purpose and intent. Analysis of such abstract, contingent, relational constructs requires attention to frameworks of meaning and value – the norms, ideals, interests and power relations governing the activity and orientation of technoscience. This chapter and the next bring together a synthesis of theoretical approaches to provide a foundation for the thesis's exploration and analysis of these phenomena in the two New Zealand fields. Interpretational tools are drawn from the sociologies of expectation and of science and technology, from studies of the diffusion of innovations, and from studies of discourse and power.

This chapter focuses on the patterns of assumption and expectation that shape technoscience innovation. Widely shared amongst actors in science sectors, policy environments and the wider public, these guiding narratives or frameworks of meaning are deeply embedded in the practice and orientation of fields. They are thoroughly naturalised, and taken for granted as part of science and technology processes and outcomes. Reflecting the priorities, perspectives and interests of different social and sectoral groups, such patterns can be powerfully influential – although they are not uncontested, with considerable heterogeneity in the framings of purpose and value shaping technoscience. Some narratives, however, have long been established as “master stories” of science and technology, dominating sectoral and societal expectations, and determining the direction of R&D trajectories. The chapter discusses three dominant narratives with particular salience for benefit projections: technoscience as the essential driver of economic growth and societal wellbeing; technoscience as an urgent, ruthlessly compulsive competition; and technoscience as a rational process of linear, teleological development.

The next chapter then addresses the theoretical dimensions of the performative work of constructs of benefit for technoscience. The focus in Chapter Three is on benefit projections as strategic resources for the advancement of R&D and innovation – valuable assets in contested, competitive science and technology domains. That chapter surveys scholarly analysis that illuminates the role of benefit claims in securing societal, sectoral and political support for research and new technologies. As the stories of GM and wind energy in New Zealand will show in Chapters Five and Six, the assertion of anticipated benefits is central to the processes through which some technological options achieve acceptance and uptake rather than others.

Making meaning

Every society, community or specialist group is both constituted within and shaped by a suite of foundational beliefs and assumptions about itself, its purposes and activities. The contexts for any human enterprise begin with structures of meaning that sustain direction and commitment, signal ideals and aspirations, and foster identity and group cohesion. Ubiquitous and enduring, these core beliefs exert enormous influence; Bourdieu (2004, p 15) describes them as ‘the equivalent of a language or a culture:

[determining] the questions that can be asked and those that are excluded, the thinkable and the unthinkable'. Such structures are central to the concepts of value, utility and desirability that underpin projections of future benefit from particular activities or societal choices. They are thus the logical starting point for analysis of the benefits anticipated from science and technology.

Many sociological and political studies have explored the significance of such deeply embedded ideological frameworks, examining the ways they shape and affirm activity, purpose and expectations. Such structures of belief are often termed "myths", indicating their symbolic, cultural, emotional and psychological power (Sarewitz 1996, p 10-13; Holton 2000, pp 88-89). For Midgley (2003, p 4) such frameworks of meaning are both teleological, asserting the goals and ideals towards which activity is oriented, and epistemological, 'shaping the world-pictures that determine… the standards by which we judge what is possible and plausible' (Midgley 1992, p 15). Myths are useful as essential hermeneutic frameworks that assist sense-making, establish priorities and enable decisions and action: 'The way that we view the world determines the way that we draw our maps; the way we draw our maps will determine the paths we can follow' (Sarewitz 1996, p 191). Analyses of these kinds of societal frameworks highlight their close inter-connections with power and the interests of dominant groups (for example, Fiske 1998, p 306; Hall 1998, pp 1050-1052). A key theme is the way such constructs and patterns are rendered invisible, normalised and naturalised as "common sense" or "the way things are". Hall (1998, pp 1055-1057) describes this as 'the reality effect':

> [T]he inventory of traditional ideas, the forms of episodic thinking which provide us with the taken-for-granted elements of our practical knowledge… this "deep structure" of presuppositions [is] rarely made explicit and [is] largely unconscious.

The construction of value and meaning is a central concern in the work of Michel Foucault (1972, 1980, 1994; Mills 2003; Motion & Leitch 2007). A Foucauldian critical approach questions 'what kinds of assumptions, what kinds of familiar, unchallenged, unconsidered modes of thought' are the basis for practice and societal orientations (Leitch & Motion 2007, p 72). Foucault's analysis of the dynamics of power in discourse and institutional structures illuminates the processes by which norms, knowledge and legitimacy are socially produced (Foucault 1980, pp 89-90, 98-

99, 114, 131-133; Mills 2003, pp 5, 23-28, 55-65; Motion 2005, pp 505-506; Leitch & Motion 2007, p 75). For Foucault, discourse is an active, purposeful exercise:

> [D]iscourse is not a slender surface of contact… between a reality and a language… Of course, discourses are composed of signs; but what they do is more than use these signs to designate things… [Discourses are] practices that systematically form the objects of which they speak (Foucault 1972, p 54).

Discourse, in a Foucauldian sense, is understood as much more than texts, statements and other communications that articulate and convey meaning. Mills (2003, p 55) describes discourse as 'a system which structures the way we perceive reality… [and] constrains our perceptions'; Motion and Weaver (2005, p 52) explain it as 'the vehicle through which power and truth circulate'. Foucault argued that every society or group functions according to its own 'regime of truth' (1980, p 131), the kinds of discourse and expectation that are accepted and valorised, establishing 'a symbolic and constitutive system that structures knowledge and social practice' (Weaver et al. 2006, p 18). He stressed the ways that particular discourses of science, at various periods through history, determine the boundaries of possibility:

> [S]hared presuppositions and theoretical frameworks which organise thought, representation and categorisation… discursive frameworks and pressures which operate across a social body and… condition how people think, know and write (Mills 2003, p 63).

Such frameworks are thoroughly entrenched in the activities, ideals and assumptions of the group or community holding them, having 'a solidity and a normality which it is often difficult to question' (Mills 2003, p 56). But for Foucault, it was crucially important to expose and challenge such taken-for-granted patterns, and the power relations they perpetuate: 'There is a battle "for truth", or at least… a battle about the status of truth and the economic and political role it plays' (Foucault 1980, p 132).

The inevitability of these kinds of frameworks is also central to the sociological theory of Pierre Bourdieu, who considered that 'all perceptions, visions, beliefs, expectations, hopes, etc, are socially structured and socially conditioned' (2004, p 95). Bourdieu's notion of habitus encapsulates the internalised systems of meaning shaping beliefs, expectations, identity, institutions and practice – in a word, all that is habitual:

> [A] system of acquired dispositions functioning on the practical level as categories of perception and assessment or as classificatory principles as well as being the organizing principles of action (Bourdieu 1990, p 13).

Habitus is embedded in the assumptions and values of individual actors and groups, and functions largely subconsciously as a taken-for-granted suite of norms and ideals (Webb et al. 2002, pp 33-34, 38-40). The patterns that comprise habitus are often beneath reflective awareness; according to Grenfell (2004, pp 166-167), they 'hide their provenance, the values they represent, and the interests they ultimately serve'. Comprehensively internalised, habitus influences outcomes in the absence of any specific intention or overt imposition (Bourdieu 1990, pp 11-12, 107-109; Calhoun 1993, pp 71-74; Bourdieu 1999, pp 109-111; Holton 2000, pp 88-89).[22] It is expressed in guiding narratives that establish (or presume) direction and purpose, and determine the ideas and activities that are acceptable, praiseworthy or even plausible within a group, professional field, or community (Bourdieu 1990, pp 108-111; 1999, pp 108-109, 113; Grenfell 2004, pp 25-29, 129, 166-167).[23]

The particular habitus of science is the focus of Bourdieu's analysis of the practices and norms of research communities (2004, pp 38, 41-42). He shows strongly influential frameworks of thinking orienting the direction and practice of research, and constraining options and possibilities. These patterns of expectation are, however, 'largely invisible and never questioned' (2004, p 65). Moreover, the scientific habitus demands not merely competence in the field or specific discipline,

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[22] The way such dispositions or value frameworks are socially acquired is central to their effectiveness in guiding action and legitimating orientations. Habitus is absorbed through an ongoing process of lived experience in the culture or field, and exposure to that group's characteristic modes of action and ideas of appropriateness (Bourdieu 1990, pp 9-14, 90-91; Robbins 1991, p 107).

[23] Habitus encapsulates the "fit" between people and the social and professional communities within which they live and function. Robbins (1991, p 54)explains these symbiotic linkages as 'a reciprocal relationship between the structures of thought within a society and the institutional structures which both reflect and generate the thought'. For Bourdieu, habitus becomes evident in the dynamics of fields – the social groups whose actions, identities and institutions express and perpetuate these norms (Bourdieu 1990, p 14; Calhoun 1993, p 72; Postone et al. 1993, pp 2-3, 6; Bourdieu 2002, pp 299-300). A basic principle is the co-construction of fields and habitus in the ongoing interactions between paradigms and practice, orientations and structure (LiPuma 1993, pp 15-17; Postone et al. 1993, p 4; Grenfell 2004, pp 27-28). This mutual interaction is a feature of other models, notably Giddens' theory of structuration (Giddens 2002). His work explains the structure of fields as 'both the medium and the outcome of the practices that constitute [social] systems' (2002, p 238), and highlights the ways structure both constrains and enables action (Craib 1992, p 34; Kaspersen 2000, p 43). Other studies also draw attention to the two-way mutual influence of interconnections between structure and action, frameworks and orientations, in relation to the evolution of technological systems (for example, Winner 1986, pp 47-50; van Lente 1993, pp 30-32; Barben 2007, p 56).

but also a fundamental faith in the worthiness and utility of science generically (2004, p 50). Such ingrained assumptions of the inherent value of technoscience – as a way of relating to the world, developing knowledge and addressing societal needs – run deep in the discourse of research and policy communities, and help to sustain projections of future benefit from R&D and innovation.

Bourdieu's critique of science as a 'a field like others' (2004, p 3) takes concepts developed in analyses of other social worlds as equally pertinent in research sectors (Postone et al. 1993, p 3). The New Zealand science and technology sectors studied in this thesis – and their associated political, policy, corporate, professional and stakeholder communities – comprise an inter-related cluster of fields characterised by the kinds of ideological and normative patterns discussed in the work of Foucault and Bourdieu.[24] Studies of technoscience processes and trajectories highlight the ways that orientation and purpose are shaped by such frameworks, deeply internalised by actors and in institutional structures in these fields. For example, Seidman (2004, p 60) explains the powerful influence of such patterns of expectation on R&D processes:

> Reality is always filtered through… a series of assumptions about the nature of the world… These overarching, cohering frameworks are… pivotal in scientific research. They guide our problem selection; they frame what we see.

Critical analysis of the dynamics of science and technology has produced a range of models to explain practice and developments in these fields. Kuhn's concept of scientific paradigms, originally argued in the early 1960s, has been enormously influential (Kuhn 1996).[25] Analysing the emergence and evolution of major frameworks of meaning, purpose and utility in scientific work, Kuhn defines a paradigm as 'the entire constellation of beliefs, values, techniques and so on shared by

[24] For Bourdieu, fields extend beyond the immediate professional groups or sites to encompass wider social networks and frameworks (Bourdieu 2004, pp 32-33). Fields are broadly defined as the diverse contexts that sustain identity and practice: 'a series of institutions, rules, rituals, conventions… which… produce and authorise certain discourses and activities' (Webb et al. 2002, pp 21-22).
[25] The general applicability of this concept to other fields is acknowledged in Kuhn's 1969 "Postscript" to his original work (Kuhn 1996, pp 208-209). The usefulness of Kuhn's paradigm model to describe technological developments is well-recognised (for example, Michael 2000a, p 6; Kaplan & Tripsas 2008, p 793; Vanloqueren & Baret 2009, p 972).

members of a given community' (1996, p 175).[26] Kuhnian paradigms comprise more than just knowledge and systems of knowing; they incorporate professional and institutional structures and cultures, practices, goals and objectives, expectations, and assumptions of the value and benefit of particular science programmes. Paradigms guide the directions and trajectories of research activity, establishing which kinds of problems, methods and solutions are considered significant, useful, and epistemologically legitimate at that time in that field (1996, pp 37-38, 109, 184).[27]

The normative aspects of scientific and technological frameworks are highlighted in numerous studies. Shared mindsets and assumptions of actors within development and innovation fields determine the kinds of questions and goals given priority, and the kinds of benefits sought: 'A technological paradigm defines an idea of "progress" by embodying prescriptions on the directions of technological change to pursue and those to neglect' (Vanloqueren & Baret 2009, p 972). These underlying patterns of expectation are manifested through narratives, 'imaginaries', 'stories' or 'maps' for technoscientific development, guiding decisions and policies and constraining actors' concepts of what might be possible (Marcus 1995, pp 3-4; Sarewitz 1996, pp 190-191; Van Dijck 1998, pp 10-23; Deuten & Rip 2000, p 77; Kearnes et al. 2006, pp 13, 16-17, 28-33; Sunder Rajan 2006, Chapters 3 & 5). The European Commission (2007, Chapter 7) focuses on the influence of such 'master narratives' and 'imaginaries' of science and technology:

> These are not 'merely' stories or fictions. They are an important part of the cultural and institutional fabric, of taken-for-granted aspects of social order… [T]hey intersect dynamically with the material, institutional, economic, technical and cultural forms of society… and reinforce collective aspirations… [Narratives] tacitly define the horizons of possible and acceptable action… [and] serve simultaneously as prior framing, starting point, justification, and mode of sense-making for the policy domain (European Commission 2007, pp 12, 73, 76).

Particular 'visions' or framings of potential can have profound effects on the kinds of goals envisaged and the technoscientific pathways followed by entire sectors

[26] Kuhn also acknowledges a second meaning of the term 'paradigm' as the past achievements of research which, as exemplars, serve as a basis for the solution of problems in normal, as distinct from revolutionary, science (1996, pp 179, 187).
[27] The processes of a 'paradigm shift', where an established framework comes under pressure and eventually changes to a new mode and orientation, are discussed in Chapter Three.

including research teams, industry, and policy and regulatory systems (Hedgecoe & Martin 2003, pp 331, 349, 355-357). Incorporating crucial assumptions about the future and about potential alternatives, such interpretive frames govern the evaluation of options, and determine the plausibility of possible projected solutions and benefits (Kaplan & Tripsas 2008, pp 791-792). For Davies Burns (2000, pp 302-303), the distinctive discourse of a particular technoscientific field:

> …stabilizes a technology by internalizing uncritical acceptance of its practices and compliance with its values and beliefs… [A]n established technological Discourse delineates a circumscribed region of the "search space" for conceivable innovations (capitalisation in original).

Such frameworks have enduring influence from their basis in the social and psychological realms described by Bourdieu as habitus. Tenaciously embedded within R&D fields and in policy and public discourses, these paradigmatic constructs serve deep societal needs, offering reassurance, confidence and optimism in the capacities and effectiveness of technoscience. Van Lente (1993, pp 150-152; 2000, pp 44-46) borrows a term from linguistics, ideographs, for such conceptual structures; self-sufficient encapsulations of more complex drivers, they are sufficiently flexible to achieve wide acceptance and legitimacy. Such frameworks' durability can be seen as a circular self-perpetuating process driven by a collective investment in their credibility: 'Myths are often more satisfying to us than the truth, which explains their longevity and resistance to facts: we want to believe that they're true' (Berkun 2007, p 6). Addington (2003, p 104) suggests that the deeply entrenched 'ideological underpinnings' of some technologies mean that these systems, and expectations associated with them, are 'not allowed to fail'. The seductive power of such structures of belief about research and technological innovation helps to explain their persistence in the face of such challenges as inadequately managed risks, inequitable distribution of benefits and problems, or simple failure of a technology to deliver (Tenner 1997; Franklin 2003; Berkun 2007, pp 136-144).[28] These frameworks of assumed value and benefit have a resilience quite independent of the actual outcomes of R&D and the performance of innovations (Wynne 2003, p 6; Grossman 2004, pp

[28] Some analyses focus sceptically on such patterns of faith in terms of their function in helping secure finance and support for technoscience. Greenberg (2001, p 6) critiques them as 'self-serving political myths and fables of science'. Mirowski (2012) describes the dynamics of R&D promotion as a 'Ponzi scheme'. Similar patterns are identified behind the self-generating momentum of the (in)famous Moore's Law for the incremental expansion of capacities in computer technology: '[the law] may be true because we insist that it be so' (Barlow 2004, pp 181-182).

191-193; Seidman 2004, p 60). For Sarewitz (1996, p 10), the confidence of policy-makers and publics in technoscience is sustained by:

> powerful and oft-heard arguments that… are widely subscribed to and commonly repeated, even though they are not derived from well-developed empirical or theoretical foundations. They are, at root, expressions of ideology and tools of political advocacy, accepted and expressed as truth.

To sum up, the strongly normative influence of frameworks of expectation in technoscientific fields is a key factor in the processes by which concepts of benefit are affirmed in the advancement of R&D and technological innovation. The kinds of benefits asserted as justification for developments in GM and wind energy in New Zealand emerge from the broader frameworks of purpose prevailing in these fields and for science and technology generically. In turn, benefit projections for particular technology options contribute to the consolidation and hegemonic acceptance of those wider narratives.

Such frameworks of expectation and value are tenaciously pervasive forces in technoscience in New Zealand and internationally. However, such patterns are rarely recognised or acknowledged. Their influence – on framings of intended benefit, research trajectories and technology applications – is largely subliminal, taken for granted as part of the process of technoscientific development. Nevertheless, they are unavoidable – in the overall orientations of R&D, in the stated purposes and intended outcomes of science programmes and particular technology applications, and in broader claims of the generic societal beneficence of technoscience. Assumptions of the worthiness of some research pathways and technology applications, and the diminished credibility or appeal of less favoured alternatives, are already pre-established within these paradigmatic contexts.

Chapters Five and Six follow the influence of such priorities as economic competitiveness, and the utilitarian application of innovation to solve environmental problems. Developments in New Zealand are patterned within wider societal and sectoral frameworks of assumption that determine perceptions of utility and benefit, and strengthen the appeal of some options and applications over others. With wind energy, sector expectations of commercial profitability and political imperatives related to global environmental sustainability have resulted in this technology finding acceptance in the form of large centrally-feeding windfarms. Belief in the necessity of sustaining an active biotechnology capacity in New Zealand has supported GM research activity. These technologies' trajectories, the forms they have taken in New Zealand, and the kinds of benefits claimed for their development, reflect the presuppositions of the fields in which they have evolved. But there is seldom any acknowledgement of the ways these larger social and sectoral frameworks of meaning and value have shaped the directions and outcomes of R&D in these fields. As Wynne (2003, p 7) points out, New Zealand has given little attention to 'the implicit social and cultural assumptions embedded in scientific and technical knowledge-production processes'.

Heterogeneity

Technoscience is motivated and legitimated by powerful conceptual and values frameworks embedded in particular R&D fields, and more widely in perceptions across public and policy domains. However, such frameworks are far from monolithic, encompassing diverse interests and perspectives and a spectrum of actors, institutions and practices. Studies of the social construction of technologies draw attention to heterogeneity. Recognition of multiple sources and channels of influence on science and technology trajectories is important for analysis of the work of the benefit projections that justify and valorise innovation. The promotion and positioning of new technologies are driven by multiple criteria and affected by different, divergent, or even incompatible frameworks of value and expectation. The stories of wind energy and GM in New Zealand, discussed in Chapters Five and Six, trace the influence of various contesting interests and concepts of future benefit bearing upon these fields and technologies.

Some models of technoscientific processes focus on specific research and technology domains as communities of practice. The historical evolution of scientific research and engineering as distinctive communities – professional cultures with their own standards, orientations and identity – has been extensively analysed (for example, Mokyr 1990; Pickering 1992; Shapin 1994; Lenoir 1997; Misa 2004; Woodhouse 2006). Specialist fields are shaped by their own suite of assumptions:

> [E]ach discipline having its own traditions and national particularities, its obligatory problematics, its habits of thought, its shared beliefs and self-evidences, its rituals and consecrations, its constraints [and] specific forms of censorship… the whole set of presuppositions inscribed in the collective history of the speciality (Bourdieu 2004, p 94).[29]

In a comparative study of two scientific disciplines, experimental high energy physics and molecular biology, Knorr Cetina (1999, pp 9, 246-249) analyses their unique 'epistemic cultures' – the conventions, modes of practice, research assumptions, ontologies and institutional systems characteristic of each field. Controversial fields such as climate change research or genetic science are further subdivided, riven by contesting perspectives and disciplinary approaches (Sarewitz 2004, pp 389-392). In technology development domains, similar patterns are found constraining and legitimating evolving trajectories (Fairtlough 2000, pp 267-268, 275-276). The concept of technological regimes, an evolutionary economics model developed by Nelson and Winter and by Dosi (Dosi 1982; van den Belt & Rip 1987, pp 136-137; Mokyr 1990, p 274; Nelson 2000, p 67), explains structures of strategic orientation across industrial sectors. A technical community's typical activities, knowledge, priorities and strategies emerge from processes of competition and in turn shape future trajectories of development and economic growth.

The concepts of anticipated benefit that are utilised to justify and valorise innovative technological developments are firmly embedded within these kinds of professional and disciplinary frameworks. Chapters Five and Six discuss benefit projections for GM and wind energy in New Zealand, showing the strong influence of the cultures and expectations of the respective practitioner communities. The interests of biotechnology research institutions are closely intertwined with projections of generic benefit from their work. In the electricity sector, the commercial expectations of established generation companies have shaped the prevalent form of wind energy technology in the New Zealand environment.

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[29] Bourdieu's exploration of social and political science alongside other scientific fields is central to his concept of the practitioner's reflexivity (Robbins 1991, p 158; Bourdieu 2004, Part III). However distinguished between different research disciplines, from the kinds of knowledge and ontologies accepted in such fields as physics or chemistry, to the 'idées-forces' or symbolic representations characteristic of fields working with political and ideological phenomena (Robbins 1991, pp 138-141).

However, R&D development processes and technoscientific benefit claims must also engage with the wider community. Many studies extend the scope of analysis beyond narrowly scientific or technical domains to consider technoscience as interconnecting with broader social, sectoral, economic and political contexts. These domains are the spaces within which benefit claims circulate. They can be described as arenas (Renn 1992b), in which expectations and intentions are resources strategically deployed to further the interests and strengthen the positions of those advancing them.

Studies have highlighted the formation of extended socio-technical networks, where actors, institutions and resources cohere in alignment of interests and goals around the benefits intended from a technology or a research field (for example, Hughes 1989, pp 51-55; Cozzens 1990, pp 168, 170; Bijker 1995, pp 49-50; Green et al. 1999, pp 778, 783; Garud & Karnøe 2001a, pp 10-11, 20, 31; Hedgecoe & Martin 2003, pp 330, 341-342, 355).[30] Many analyses of technoscience fields develop similar themes and models, outlining the involvement of heterogeneous groups and actors in 'hybrid socio-technical formation[s]' (Green et al. 1999, p 783).[31] Models of networks of influence, where strategic alliances and resources are deployed to support (or hinder) the advance of technological innovation, are developed in several studies (for example, Collyer 1997, pp 198-199; Rappert 1999a, pp 3-4; Chakravorti 2004, pp 470-477; Van de Ven et al. 2008, pp 150-154). Focusing on the political values inherent in artefacts and systems, Winner (1986, pp 22-29, 47-55) traces the far-reaching interactions between technologies and different societal groups.[32] And

[30] The conceptual frameworks of Actor Network Theory (ANT) incorporate multiple dimensions within the socio-technological matrix (Latour & Woolgar 1979; Latour 1987, 1992; Law 1992; Latour 1996). Societal interests, natural and epistemological phenomena, and the artefacts themselves – humble items such as door keys, speed bumps and seat belts – are equally salient: 'technical, scientific, social, economic, or political considerations have been inextricably bound up into an organic whole… The set of postulated associations is the context that gives each entity its significance' (Callon 1987, pp 84, 95). While ANT is an exciting analytical approach, this thesis uses other theoretical frameworks more suited to my focus on the paradigmatic and ideological dimensions of R&D and innovation, as explained in Chapter Four.

[31] Some studies categorise groups with interests in technoscience; for example, Vanloqueren and Baret (2009, p, 972-979) distinguish the following groups engaging in their respective ways with agricultural technologies: policy actors, markets, regulators, lobby groups, consumers, farmers, private and public sector researchers, and science journals. Borup and Konrad (2004, p 4) indicate the potential for differing assumptions and engagement of institutional policy makers, and engineers and researchers. Kaplan and Tripsas (2008, p 792) analyse the different frames and roles of producers of technology, users, government agencies, the media, standards bodies and industry associations.

[32] Winner's interpretation of the political influences in his famous example of the Long Island highway bridges (Winner 1986, pp 22-23) has, however, been challenged as 'counterfactual' (Joerges 1999).

Kaplan and Tripsas (2008, pp 791-798) work from a basic technology life-cycle model to explore the influence, at each phase of the cycle, of the assumptions, needs and benefit-seeking of interested groups.[33]

Social constructivist analytical theory for technoscience systems insists upon a wide-ranging approach to recognise the range of interests that make up technological 'ensembles' or 'webs' (Bijker 1987, pp 171-172; Pinch & Bijker 1987, p 40; Bijker 1995, pp 15, 273-276). The stories of such diverse artefacts as bicycles, Bakelite and fluorescent lighting show how a technology acquires multiple meanings, forms and applications – and multiple constituencies – through the stages of its development. Bijker (1995, p 6) insists that 'technologies are shaped and acquire their meanings in the heterogeneity of social interactions'. Each interested group brings its own perspectives, assumptions and requirements to its engagement with technology (Funtowicz & Ravetz 1992, pp 262-263; van Lente 1993, pp 46-51; Michael 2000a, pp 6-9; Garud & Karnøe 2001a, p 10; Borup & Konrad 2004, pp 2-4; Williams 2005, p 12). Decision criteria for assessment of a technology's effectiveness and usefulness vary depending on the worldviews and priorities of different groups (Nelson 2000, p 71; Dattée & Weil 2007, pp 579-591). Bijker (1995, p 77; emphasis in original) argues that '[t]he meanings given by a relevant social group actually *constitute* the artifact'. Such value frameworks can also change over time. Judgements of the desirability or success of a technology are inherently provisional, subject to shifts and changing circumstances in society at large and in the expectations of interested groups (Bijker 1995, pp 270, 280-281; Williams 2005, p 14; Berkun 2007, p 28).

Analysis of wind energy and GM in New Zealand shows that innovation is supported by a range of concepts or projections of benefit, each appealing to and consistent with the needs, assumptions and desires of particular groups (Brown et al. 2000b, p 6). Diverse values and interests, changing over time, have influenced the trajectories of

[33] The life-cycle metaphor or model of evolutionary technological change distinguishes four iterative stages in the development of a technology: variation or diverse options in a phase of ferment and uncertainty; the emergence of a dominant design by processes of selection and stabilisation; a phase of retention marked by incremental improvements within the dominant paradigm; and a discontinuity phase where the status quo is disrupted, assumptions change and new possibilities emerge, leading into a new phase of ferment (Kaplan & Tripsas 2008, pp 790, 794). This has similarities with concepts from complexity theory, such as Gunderson and Holling's "figure-8" panarchy model for the dynamics of systemic change (Gunderson & Holling 2002).

research and technological applications (or intended applications) in these fields in New Zealand. Chapters Five and Six follow a sometimes uneasy mix of economic, sectoral, social and environmental ideals driving these technologies' evolution in New Zealand. Integration of these disparate frameworks of value and benefit is achieved by positioning technoscientific innovation in relation to particular political and institutional interests. Sectoral priorities are particularly evident in the promotion of some of New Zealand's GM research programmes, where the maintenance of biotechnology capacities is argued to be a benefit in itself.

No single paradigm, interest group or framework of expectations shapes these technologies and their assumed benefits – they are protean, hybrid, many-faced in the complex process of securing support, validation and acceptance: 'A technology isn't one single character; it's a city, it's a collective, it's countless' (Latour 1996, p 227). Nevertheless some frameworks of belief about technoscientific R&D and innovation are consistently prominent, thoroughly entrenched in the discourse of practitioner communities, in policy and in wider public perceptions. Deuten and Rip (2000, p 68) describe the emergence of 'master stories' that establish status and purpose for technological developments, providing connections between the roles and concerns of diverse actors, enabling activity if also constraining it in certain directions. The remaining sections of this chapter discuss three dominant ideological constructs or narratives for technoscience. The importance of these master stories for GM and wind energy, in the projections of benefit used to advance these technologies in New Zealand, will be explored in Chapters Five and Six below.

Technoscience tales

The goose that lays golden eggs

The concept that science, technology and innovation are essential for a society's wellbeing and advancement is one of the most ubiquitous and firmly established frameworks of assumption in technoscientific domains and in wider public discourses (Winner 1986, p 5; Sarewitz 1996, pp 122, 131; Meikle 2003, p 152; Rogers 2003, p 110; Woodhouse & Sarewitz 2007, p 139). The technologies transforming society are celebrated as 'a series of advances that have allowed humanity progressively to escape the constraints of its environment' (Sarewitz 1996, p 129). Such triumphal achievements become their own justification:

> We have so much history with innovation as the driving force for our culture, economy, and psychology – from the cotton gin and Industrial Revolution to the personal computer and the Internet Age – that our confidence in innovation approximates a faith: when in doubt, innovate (Berkun 2007, p 139).[34]

The concept of positive forward progress is thoroughly embedded within science and technology domains as a 'grand narrative' that dominates perceptions, policy and discourse (Sarewitz 1996, pp 117-120; Bingham 2008, pp 112-113). The belief that research and technological innovation are required to deliver prosperity and wellbeing is the first of Sarewitz's 'myths' of contemporary science and technology, the 'myth of infinite benefit' (1996, pp 10, 17-29). Widespread in the promotion of R&D, this framework of belief 'uniformly assumes a causal linkage between progress in science and technology and progress in society' (Sarewitz 1996, p 4). Rip (1992, pp 233-234) notes the persistence of the mythical constructions of science as 'the source of all good things… the horn of plenty', and of technology as 'the magic wand… the means to achieve, supposedly in an unproblematic way, whatever we want'. He describes the common perception of technoscience as 'the goose that will produce golden eggs, as long as it is fed properly' – highlighting the implicit qualification of support and funding for R&D activity.

Faith in scientific and technological advance as a necessary requirement to generate material abundance, economic security and societal improvement has long been 'conventional wisdom' or 'the normative mode of Western understanding' (Lowenthal 1995, pp 386, 390). The history of this belief evolves from the ebullient technological optimism of the 18th and 19th centuries (Winner 1986, pp 44-47; Feenberg 1999, pp 1-2; van Lente 2000, pp 43-44; Misa 2004, Chapters 3, 4 & 5; Barben 2007, p 58). These patterns of expectation intensified through the second half of the 20th century. Some analyses (eg Greenberg 2001, Chapter 3; de la Mothe 2004, pp 531-532; Hård & Jamison 2005, p 255; Barben 2007, p 58) refer to the legacy of Vannevar Bush's *Science: The Endless Frontier*. This influential manifesto

[34] Some studies acknowledge the 'Whiggishness' inherent in such teleological framings of technological history (Latour 1987, p 100; Mokyr 1990, p 15; Feenberg 1999, p 81).

insisted that prosperity and quality of life are dependent on well-resourced science and technology sectors:

> Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure… higher standards of living… the prevention or cure of diseases... But to achieve these objectives… the flow of new scientific knowledge must be both continuous and substantial (Bush 1945, Chapter 1: Scientific Progress is Essential).[35]

Studies follow a shift in expectations of scientific purpose and practice, from a focus on knowledge generation valued as a worthy end in itself, to a utilitarian justification of technoscience as delivering a practical service to society (Funtowicz & Ravetz 1992, pp 255-258; Sarewitz 1996, Chapter 7; Gieryn 1999, p 357; Brown 2000, pp 93, 103-104; de la Mothe 2004, pp 531-533; Barben 2007, pp 58-63).[36] The meaning of scientific activity is renegotiated from curiosity-driven research to the enabling of profitable new applications (Kearnes et al. 2006, pp 27-28). Funtowicz and Ravetz (1992, p 255) summarise the new orientation: 'Problems were chosen… with a view to applicability [and] solutions [were] evaluated similarly'.

The progress paradigm is now well-established in policy frameworks, both in New Zealand and internationally, as 'government[s] pursue science and technology policy as a primarily economic strategy' (Thorpe 2008, p 78).[37] The expectation that technoscience guarantees economic growth and security runs strongly through policy debates, advocacy for funding, and strategic foresight programmes for R&D (Sarewitz 1996, pp 119-120; Rappert 1999a, pp 1-4; Greenberg 2001, pp 399-401; de la Mothe 2004, pp 528, 530; Williams 2005, p 5). Wynne (2003, p 6) describes the assertion of 'implacable normative commitments to commercial exploitation even of frontier scientific promises'. There is an extensive range of studies on the economic and commercial benefits anticipated from scientific research and new technologies,

[35] Bush's report, delivered to the US President at the close of WWII, argued for ongoing government support for science and particular governance structures. Although its specific recommendations were not implemented, it has been enormously powerful in shaping the culture, roles and expectations of scientific research and technology development in the US and internationally for the last six decades (Greenberg 2001, pp 42-58).
[36] This framing is not uncontested, with many, often passionate, arguments in defence of the need for independent, disinterested, "basic" science research. To give just one example, Callon (1994, p 397) argues that science is a public good in itself, and 'should be protected from market forces'.
[37] These patterns of belief are consistent with wider societal values frameworks, notably the expectations of ongoing growth and wealth creation that underpin contemporary economic paradigms (Winner 1986, p 108; Sarewitz 1996, pp 122-3, 191; Barben 2007, pp 59-60).

predicated on ‘the key role of technological advance in driving economic growth’ (Nelson 2000, p 67). This dominant narrative is the basis for analyses of the dynamics of profitable innovation trajectories aimed to foster successful business ventures (for example, Mokyr 1990; Kamann & Nijkamp 1991; Utterback 1994; Christensen 1997; Garud et al. 1997; Mowery & Rosenberg 1998; Martinelli 2001; Hargadon 2003; Hindle & Yencken 2004; Talke 2007; Van de Ven et al. 2008). The instrumental relationships between technoscience and economics have been theorised as an evolution from “Mode 1” to “Mode 2” research (Gibbons et al. 1994; Gibbons 2001; Nowotny et al. 2001), and, borrowing an image from biotechnology, as a “Triple Helix” intertwining the activities and interests of business, academe and government (Leydesdorff & Etzkowitz 1998; Benner & Sandström 2000; Leydesdorff 2000; Shinn 2002; Etzkowitz 2003).

In New Zealand, confidence in the projected economic benefits of R&D and innovation is reflected in official technoscience policy and in specific strategies for GM and energy (New Zealand Government 1996; Royal Commission on Genetic Modification 2001a; New Zealand Government 2002, 2003; Ministry of Research Science and Technology 2005b, 2006a, 2007; 2007, 2010, 2011a). Studies of the discourses of these fields, and of developments in New Zealand’s governance and institutional structures for science and technology, highlight an increasing dominance of economic and commercial priorities over the last two decades (Cartner & Bollinger 1997; Leitch & Davenport 2005; Motion 2005; Motion & Weaver 2005; Goven 2006; McGuinness et al. 2010; Macdonald et al. 2011). The framing of R&D around perceived economic imperatives has been particularly strong in the legitimation of GM research in New Zealand, and the influence of these narratives is discussed in detail in Chapter Six.

The assumed inextricable links between technoscientific progress and other societal or commercial outcomes are often idealised generically (Winner 1986, pp 44-46; 2004, pp 34-37; Williams 2005, p 8). Jasanoff (2005b, p 197) observes that utilitarian science is ‘automatically coded as a “public good”… [in a] friction-free vision of service to humanity’. But Sarewitz (1996, p 119) identifies two ways that benefits are assumed to flow from technoscience – either directly from the focused application of research and technology to specific problems, or indirectly via ‘catalysis of economic growth and rising standards of living'. The equation, or elision, of commercial profits and business competitiveness with generic societal benefits is a common assumption of economic framings of justification for technoscience. As Weaver and Motion (2002, pp 329, 340) explain: 'In a market-driven political economy the public interest and the market are constructed as one and the same… the "public interest" has been subsumed by corporate and market interests'. Analysing industry perspectives on technological innovation, Henderson et al (2007, p 25) identify a powerful 'market rationality' which juxtaposes the '*altruistic* collective benefits of improved global health from [new technoscience]… with the self-interest of the *financial* benefits expected to accrue… for the industry shareholders' (italics in original).[38] The strategic interweaving of economic benefit claims with broader social interests – and the tensions between these divergent framings of technoscientific purpose – are clear in the trajectories of wind energy and GM in New Zealand, discussed in Chapters Five, Six and Seven below.

The concept of technoscientific inevitability is a strong contributing strand in the narrative of ongoing progress. Technological developments and their projected benefits are rhetorically constructed as unstoppable certainties, inexorably on the way, regardless of doubts, opposition or uncertainties in the present: 'the key question is not *whether* a certain option will be pursued, but rather *when* it will come… there is really no choice but to push ahead' (Brown et al. 2000b, pp 4, 9; emphasis in original).[39] Acceptance of a new technology and its claimed benefits is similarly projected as only a matter of time (Brown et al. 2000b, p 9; Nye 2004, p 160; Sturken & Thomas 2004, p 3). In the performative discourses promoting technoscience, such oncoming futures are strongly optimistic; these narratives assume the most idealised, utopian outcomes (Sarewitz 1996, pp 7, 10, 18; Nye 2004, p 171; Winner 2004, pp 34-37; Berkun 2007, p 137).

The grand progress narrative is a key dimension of the persuasive power of projections of benefit from particular research programmes or technological

[38] The typical elision of economic with societal interests has been strongly contested (for example, Mirowski & Sent 2005; Mirowski & Van Horn 2005; Goven 2006). McGuinness et al (2012, pp 2-5, 9) argue the need for 'greater compatibility' of New Zealand's science system with the public interest.
[39] The use of imperative verbs – "will" and "must" – is typical of this rhetorical mode (Brown et al. 2000b, p 9; Winner 2004, p 37; McNally & Glasner 2007, p 262).

applications. Faith in the delivery of prosperity, profits and better lives through technoscience provides a supportive context for benefit claims for GM and wind energy in New Zealand. For GM research in particular, this powerful myth sustains ongoing institutional and political support with the promise of commercial returns and other sectoral benefits. The introduction of wind energy into New Zealand is justified in official policy and corporate promotions as satisfying increasing demand for electricity as the fundamental requirement of a thriving economy and societal wellbeing. These technologies' advance via the narrative of prosperity and progress will be illustrated in Chapters Five and Six.

Running with the Red Queen

Closely intertwined with concepts of technoscientific advance as essential for societal progress is the principle of competition as a driving force in science and technology domains. The Red Queen myth frames scientific research and technology development as a race run at relentless speed, where the first challenge is simply to be able to stay in the contest.[40] This encompasses not merely rivalries between research and engineering teams and companies, but competitive striving on a grand generic scale. Technoscience is conceptualised as a frantic contest to be first to deliver knowledge, innovation and commercial returns in an environment of desperate Darwinian struggle: 'The world is a hostile place where nation-states and corporations battle each other for supremacy' (Rappert 1999a, p 5).

The Red Queen imperative has a powerful effect on official policies, with governments and research and technology institutions concerned to demonstrate

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[40] This metaphor is taken from Lewis Carroll's children's classic *Alice's Adventures in Wonderland and Through the Looking-Glass*:

> Just at this moment, somehow or other, they began to run… and the Queen went so fast that it was all she could do to keep up with her: and still the Queen kept crying, 'Faster! Faster!"… And they went so fast that at last they seemed to skim through the air, hardly touching the ground with their feet, till suddenly, just as Alice was getting quite exhausted, they stopped, and she found herself sitting on the ground breathless and giddy… Alice looked around her in great surprise. 'Why, I do believe we've been under this tree the whole time! Everything's just as it was!' 'Of course it is,' said the Queen: 'what would you have it?' 'Well, in *our* country,' said Alice, still panting a little, 'you'd generally get to somewhere else – if you ran very fast for a long time, as we've been doing.' 'A slow sort of country!' said the Queen. 'Now *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!' (Carroll 1939 (1871), pp 141-143, emphasis in original).

competitiveness and credibility in innovation and “cutting-edge” knowledge: ‘the perceived need to ‘keep up’ in the global race to develop [new technologies]’ (Kearnes et al. 2006, p 35). The European Commission (2007, pp 14, 52) notes that the European Union’s 2000 Lisbon Agenda, aiming to develop ‘the world’s leading knowledge-based economy’ in ten years, intensified pressures to develop marketable commodities from research. Godin (2004, p 1226) describes a ‘political obsession’ with competitiveness in R&D, and Hacking (1986, p 11) outlines the belief of governments that:

> … early participation in new technologies is axiomatic for maintaining a leadership and thereby creating future wealth and employment… no-one wants to be left on the starting line.

The taken-for-granted assumptions comprising the Red Queen imperative serve as a ‘rhetorical device’ in policy and strategic planning (Rappert 1999a, pp 5-6). What is seen to be at stake is nations’ economic performance – even their economic viability – as well as the prestige of the country and its R&D (Wilsdon & Willis 2004, p 20; Brooks 2005, p 364; Barben 2007, pp 61,63; Henderson et al. 2007, pp 23-24). Framing R&D and innovation as a fierce global contest justifies the assertion of politically-determined priorities in promising areas of research, and engagement in profitable science and technology fields: ‘those areas that might be most up-and-coming and likely to have a broad economic impact’ (Barben 2007, p 61).[41] This has been a strongly influential pattern in policy for GM development in New Zealand, with government support and regulatory systems being based in the claimed necessity of the country’s science institutions and production sectors maintaining capacities and international reputation in this technoscience field; the influence of these framings of justification is discussed in detail in Chapter Six.

The imperatives established by the Red Queen are framed as unavoidable, equivalent to the ruthlessness of biological evolution: ‘Species that fail… become extinct’ (Mokyr 1990, pp 282-283). Competition is seen as an inevitability: ‘Complacency is not an option… those unable to step up to the challenge of competition today will face decline’ (Rappert 1999a, pp 5-6). Howells (1994, p 2) explains these patterns of

[41] Analyses of nations’ respective competitiveness, and of the economic, social and political criteria and systems considered necessary as drivers of improved performance, are often oriented towards fostering investment in competitiveness (for example, Zanakis & Becerra-Fernandez 2005)

compulsion in terms of the dynamics of radical competition theorised by Schumpeter: 'strik[ing] not at the margins of the profits and the outputs of existing firms but at their foundations and their very lives'.[42] The threat posed by faster, more well-resourced R&D competitors is the "stick" behind the "carrot" of economic success from technoscientific innovation; this chronic threat is expressed as a fear of being 'left behind' or of 'losing competitiveness' (Abramovitz 1986, p 396; Froggatt & Rankine 1999, p 466; Forbes 2006, pp 76-77; Kearnes et al. 2006, p 35; Birch 2007a, pp 95, 107).[43] The psychology of competitiveness creates a compulsion, a 'crisis to be part of the phenomenon' where the prospect of missing out demands investment in potentially lucrative R&D fields (Coburn 2006, p 60; Hindmarsh 2008, p 36).

At national levels, the incentives are political as well as economic and scientific; Winner (1986, p 46) outlines the dominant rationale of economically-driven technoscience: 'unless a society keeps pace… it will lag behind its competitors, a precondition of cultural decline'. Technoscience is conceptualised as an 'unstoppable train' (van Lente 2000, p 57).[44] Given such momentum, failure to keep up with the latest technoscientific advances is feared as resulting in an ignominious slide into poverty and societal misery: 'the only alternative to progress is "decadence"' (Bingham 2008, p 114). The European Commission (2007, pp 23, 25) describes a 'winner takes all' mentality:

[42] Voelpel et al (2005, pp 37-40) develop a slightly different version of the Red Queen analogy, arguing that the pressures of competitiveness keep R&D locked into existing modes, running faster but getting nowhere, when businesses should embrace new ideas and practices.

[43] The corresponding positive incentive is the prestige and influence – and the continual insecurity – of being at the front of the pack. Vannevar Bush's passionate argument for post-war investment in science and technology insisted that one key benefit from and purpose for supporting R&D was 'to maintain a position of world leadership' (Bush 1945, Chapter One: Scientific Progress is Essential). Studies of the dynamics of innovation in business also stress the considerable advantages of first-mover status; more competitive enterprises which capitalise most rapidly on new opportunities and practices are presented as enjoying not only significant commercial success but also the ability to influence the evolution of R&D communities and the future trajectories of technoscientific development (Utterback 1994; Rogers 2003; Van de Ven et al. 2008, pp 176-177).

[44] An invidious dimension of the Red Queen myth is the concept that technoscientific change is itself accelerating exponentially (Michael 2000b, pp 31-32; Sunder Rajan 2003, pp 88, 92-93; Misa 2004, pp xvi-xvii, 273; Hindmarsh & Lawrence 2004b, p 36; Forbes 2006, pp 69, 75-76; Bingham 2008, p 115). The need for competitive striving is further intensified as actors, institutions and nations perceive the rate of scientific discovery and technological innovation to be speeding up relentlessly: '[T]he assumption that change is taking place at an increasing pace… at such a rate that no university, government or business is unaffected… change is itself a virtue, necessary because of intense pressures' (Rappert 1999a, pp 5-6). However, Tudge (2000, pp 288-289) observes that: 'Science and technology seem to progress at a bewildering pace. But… in reality complex technologies take decades or centuries to unfold… Scientists exaggerate the speed of progress because they need to attract government grants and venture capital'.

> [A] diagnosis that we are in a world competition and that Europe will not be able to afford its social model if it is not in the race… those who are late won't have any place… "we must move forward if we are not to fall behind".

The Red Queen myth has significant effects on the framing of expected benefits from technoscientific innovations in New Zealand, and on the structuring, regulation and resourcing of research, notably in biotechnology. Active, credible competitiveness in prioritised fields such as GM is assumed as an unquestionable imperative in government policy and institutional strategy. New Zealand's capacity to participate in the "race" of cutting-edge technoscience is asserted as a benefit in itself, an obligatory commitment essential for the country's future development, economic viability and international reputation.[45] Chapter Six discusses the influence of this framing of sectoral benefit – the compulsion to maintain competitive R&D capabilities as a first-order outcome regardless of the other products, knowledge and profits that might be delivered – in the trajectories of GM research in New Zealand.[46]

Walking the line[47]

An enduring narrative in scientific and technological fields is the framing of practice and standards within a paradigm of rational, neutral, impersonal objectivity. One of the major ways in which technoscience distinguishes itself, its practitioners and its products from other societal endeavours is by positioning research knowledge and technologies as based in "cold hard facts" – rigorously tested and empirically verified, free from any partisan values and biases. This defining narrative of technoscience persists despite scholarly analysis of the ambivalence, contingency, uncertainties and socially constructed nature of these fields and knowledges (Wynne 1992, pp 278-283; Feenberg 1999, Chapter 4; Rappert 1999a, p 10; Rampton & Stauber 2001, pp 2-3; Bourdieu 2004, pp 19-28).[48]

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[45] A typical example of such patterns is the rhetoric of a biotech industry lobby group, quoted by Motion and Weaver (2005, p 58): 'If we do not allow… research to continue in New Zealand, we all pay the price. To cease the hard work would have an unprecedented negative impact on our economy and on our critical position in the knowledge economy'.

[46] However, these patterns are not evident in the evolution of wind energy, where New Zealand has taken a position as a "fast adopter" of the latest international developments in turbine technologies; this difference is discussed in Chapter Seven.

[47] With apologies to Johnny Cash.

[48] This principle of objectivity is itself a product of the conventions, methods and norms, or the habitus, of science fields (Gieryn 1999, p 25; Bourdieu 2004, pp 71-83). Reliance on such frameworks of

The narrative of clinical rationality characterises technoscience as precise and strictly controlled, and thus a predictable, effective management tool (Kearnes et al. 2006, p 32).[49] The principle of control via stringent empiricism is closely linked with the generic claim of technoscience to control and manipulate nature (Davies Burns 2000, p 305; Sarewitz & Woodhouse 2003, pp 74-75; Levidow & Carr 2007, pp 409-410). The salience of this myth for analysis of the benefit projections advanced for technological innovation is in the implicit, and often explicit insistence that technoscience delivers outcomes and understanding that are more robust and more reliable than other ways of knowing and engaging with reality (Gieryn 1999, pp 354-358). The authoritativeness inherent in this framing of technoscience establishes a context of dependability and confidence for the findings and benefit claims of R&D and innovation (Grenfell 2004, p 133). Chapters Five and Six follow the assertion of this narrative in the promotion of GM and wind energy technologies in New Zealand, as practitioners in these research and policy domains deploy reassuring rhetorics of objectivity and certainty around their work and its intended benefits and outcomes.

Narratives presenting R&D and technology diffusion as a purposeful linear progression are a common manifestation of this paradigm. There is widespread recognition, by both actors in these fields and analysts of technoscience, that the actual realities of these processes are iterative, chaotic, complicated, contingent and serendipitous (Deuten & Rip 2000, p 66; Nelson 2000, p 74; Barry 2002, p 152; Williams 2005, pp 5-6; Dattée & Weil 2007, pp 579-586, 595-599; Van de Ven et al. 2008, pp 23-37). Nevertheless the model persists of a tidy sequence of distinct phases – from basic or "pure" scientific research, through development targeting a particular application, to the eventual release of a technology and its marketing and dissemination (Pinch & Bijker 1987, pp 22-23; Sarewitz 1996, pp 97, 124; Wilsdon et al. 2005, p 35; Kearnes et al. 2006, pp 17, 27; Pielke 2007, pp 77-78, 80-87; Van de Ven et al. 2008, pp 3-4, 8). Linear narrative structures simplify complex processes by focusing attention on one successful strand or trajectory (Deuten & Rip 2000, pp 68,

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instrumental efficiency and neutrality is an effective way to protect technoscience from larger and messier questions of social value (Winner 1986, pp 46-57; Sarewitz 2004, pp 388, 397-398).

[49] Bourdieu (2004, p 24) gives a version of a table of wryly humorous "translations" of common phrasings in formal science discourse, and what actually happened in the lab.

79; Turkle 2004, pp 19, 22).[50] These framings link the earlier stages of a project through to an eventual goal or future benefit, attributing direction and asserting teleological intent, even if retrospectively (Kuhn 1996, pp 138-139).[51] The beneficial virtue or desirability of the proposed outcome is inherent in its being posited as the end point of the process. In the policy, regulatory and institutional framings of GM technology in New Zealand, discussed in Chapter Six, the processes from research through to eventual application of new products or techniques are often framed as such a linear sequence. This has facilitated approval of GM research projects as a separate stage from the projected outcome; official support has been legitimated in the recognition of benefits in the form of knowledge and skills as necessary earlier steps along a linear pathway.

Use of quantification as a way of presenting the issues and intended beneficial outcomes of technological innovation is another common means by which the narrative of rationality is sustained. Analysing the political and strategic work of quantification in relation to scientific and technological developments, Porter (1995) describes the ways advocates for particular research and innovation options attempt to defuse uncertainty and controversy via the use of ostensibly objective non-partisan quantitative frameworks. These discursive tools are useful in tactical efforts to counter disunity, distrust or outright opposition to a technology or its diffusion:

> A decision made by the numbers… has at least the appearance of being fair and impersonal. Scientific objectivity thus provides an answer to a moral demand… Quantification is a social technology… having more to do with moral economy than theoretical rigor (Porter 1995, pp 8, 49-50)

However, such framing of technological issues in the language of numbers is often an indication of vulnerability in political and sector domains arising from controversy and contested values (Porter 1995, pp 199, 215).[52] The stories of wind energy and GM in New Zealand, discussed in Chapters Five and Six, show the promoters of these

[50] Other options, implications and uncertainties are dismissed as irrelevant or extraneous, or simply retrospectively ignored (Deuten & Rip 2000, pp 66-68, 70; Kearnes et al. 2006, pp 72-73).
[51] Linearity often appears in metaphorical form in the presentation of research and technology development as a journey or a quest (Deuten & Rip 2000, pp 66, 82; Van de Ven et al. 2008, pp 21-22). This metaphor emphasises the idea of purposeful forward movement towards a destination or goal, and recognises that R&D processes can be lengthy and arduous.
[52] The historical evolution of this mode of technoscientific engagement with the world has been traced back to the Middle Ages (Crosby 1997; Cohen 2005).

technologies frequently resorting to quantitative modes of presentation. But, as discussed in Chapter Seven, both rational, quantitative framings and more creative, qualitative discursive forms are important in the construction of sufficiently persuasive projections of expected benefit to justify investment and acceptance of new technologies.

Conclusion

This chapter has drawn from a broad range of studies of science and technology processes and sociological theory, to develop a basis for this thesis's analysis of the ideological and values frameworks that underpin technoscientific development in two fields in New Zealand.

Constructs of anticipated benefit from technoscientific innovation are inevitably framed within, and perpetuate, the worldviews and interests of heterogeneous actors and groups. These dispositions and orientations are deeply embedded and normalised within ongoing practice in particular fields, in policy, sectoral, institutional discourses, and in wider public perceptions of science and technology.

Chapters Five and Six examine projections of benefit advanced for GM and wind energy in New Zealand, showing how the claimed outcomes and purposes of R&D and innovation in these fields are shaped within the prevailing frameworks of expectation. Assumptions about the benefits of science and technology are grounded in such resilient myths as ongoing progress, economic profitability, urgent competition, national prestige, clinical rationality, and linear purposefulness. These powerful narratives contribute to supportive societal, political and sectoral contexts for innovations such as GM and wind energy in New Zealand. The importance of such generic ideological frameworks is evident in the formal policies and processes sanctioning R&D and technology diffusion in GM and electricity generation, and in the perspectives of practitioners and decision makers in these fields.

The next chapter surveys theoretical insights into the strategic power relations governing science and technology fields. Chapter Three builds from the ideas about technoscientific paradigms and narratives discussed above, to consider the dynamics of change in contested fields, and the manoeuvres deployed to assert and strengthen the position of dominant technological options. The performative work of benefit claims for technoscientific innovations such as GM and wind energy is central to these processes.

Chapter Three

Strategies and positioning

Introduction

Technoscientific development is validated by influential constructs of belief and expectation that determine the orientations, objectives, norms and practice of fields. These frameworks are hegemonically entrenched in communities of interest – such as the biotechnology sector, the wind energy industry, and associated policy and governance bodies in New Zealand – and in wider public perceptions of science and technology. Such patterns of assumption are central to the framing of benefits anticipated from R&D and innovation, and in turn, are reinforced by the benefit claims advanced for particular research programmes.

Understanding the ideological frameworks, myths and narratives that shape and sustain technoscience is key to understanding culture and practice in these domains. But further exploration and analysis are necessary to account for the priority given to favoured technologies, research areas and applications, and the persuasive force of influential concepts of benefit. Green et al (1999, p 782) distinguish the paradigmatic from the strategic aspects of R&D and technology diffusion:

> Paradigms and trajectories offer some understanding of how technological growth proceeds, but they do not explain how some technologies come to be selected in preference to others, or how some succeed where others fail.

Why do some kinds of technology have irresistible appeal for policy, research and business communities, regardless of their value or acceptability to other groups and wider publics? Why are some kinds of benefits upheld as so desirable and important that development of these trajectories is virtually inevitable? Why are other technoscientific options, and the benefits projected from them, given little credibility? For Brown et al (2000b, p 4), the challenge is 'to understand how it is that some [technological] futures come to prevail… [and] how other futures are marginalised'.

This chapter explores scholarly analysis of the strategies and power relations governing science and technology fields; it focuses on the dynamics of change in contested fields, on the drivers behind innovation, and on the performative work of benefit claims in these processes. A central question is the assertion of dominant technoscientific options and applications – associated with particular kinds of expected benefit – over possible alternatives. Persuasive benefit projections are crucial resources for the advancement of technoscientific research and innovation. In Bourdieu's terms (Bourdieu 2004, pp 55-61; Grenfell 2004, pp 28-29, 173), benefit claims are valuable symbolic capital – essential to confer legitimacy on technoscience fields and projects, to maintain funding and official support for R&D and diffusion, and to market new technologies to interested sectors and wider society.

Projected future benefits that align with the priorities and expectations of established interests have significantly greater traction, in policy and decision-making domains, than options requiring radical new configurations and value frameworks. This chapter considers analyses of conservatism and inertia in technoscientific systems, in terms of the central role of benefit projections in overcoming entrenched modes and generating momentum for change – or at least for research towards potential change. Research programmes and policies are justified via the projection of suitably attractive expected benefits, but it is also useful for sector actors and agencies to link R&D and new technology potentials with a sufficiently demanding problem for which innovation is positioned as the solution. As will be seen in Chapters Five, Six and Seven, these strategic dimensions are strongly evident in the trajectories of wind energy and GM in New Zealand. The complex inter-relationships between claims of benefit from research and innovation in these fields, and the imperatives of existing systems and practices, show new technoscience developments as inextricably embedded in their wider social, sectoral and political contexts – from the immediate requirements of commercial competitiveness to the inter-generational challenges of environmental sustainability.

The work done by benefit projections

The perceived value, desirability and beneficial outcomes of research and new technologies, and the claimed pertinence of technoscientific innovations to societal needs, priorities and wellbeing, are powerful assets in the framing of R&D policies and programmes. Studies of expectations in science and technology highlight the ways such constructs or scenarios of future outcomes serve pragmatically instrumental purposes in the present.

A key study focusing on the performative work of future claims in technoscientific development processes is Harro van Lente's detailed analysis (1993) of the role of expectations in three innovation domains. Optimistic projections of anticipated or intended results are shown contributing to strategies of 'agenda-building' in technology fields – indeed, in the case of membrane technology, helping to create the field itself (1993, Chapter Three). Van Lente models a progressive ratcheting-up of expectations – opportunities are built into promises, which then become compelling requirements, establishing momentum and demanding commitment (1993, pp 147-150, 182-184, 195-201). Discourses about intended technoscientific futures actively work to create those futures:

> [T]he statement itself alters social reality… [E]xpectation statements are not only representations of something that does not (yet) exist, they *do* something: advising, showing direction, creating obligations (1993, p 191; emphasis in original).

The stories of GM and wind energy in New Zealand, discussed in Chapters Five and Six, show the purposeful construction of compelling futures as a key dimension of these technologies' advancement. GM is framed as bringing New Zealand science and agriculture into "the Biotech century" and creating major economic growth; wind farms are promoted as a solution to increasing demand for electricity and to the challenges, both environmental and political, of global climate change.

Studies of research and innovation processes and policy highlight the importance of strategic constructions of anticipated future outcomes in the immediate positioning of new technology developments:

> *[E]xpectations mobilize the future into the present*… they perform a real-time purpose in shaping present day arrangements… they incite, block, justify… [and] shape the plot… expectations are crucially constitutive, especially in the early stages of innovation (Brown et al. 2003, p 3; emphasis in original).

Sufficiently persuasive projections can have profound effect: ‘*performatives*… prove themselves by transforming the world in conformity with their perspective on the world’ (Latour 1996, p 194; emphasis in original). The influence of expectations on technology trajectories has been described as a process of ‘colonisation’ (Brown et al. 2000b, pp 3-4). The concepts, associated values and symbolic meanings that underpin projected technoscientific visions or scenarios can lead to very different kinds of outcome (Wyatt 2000, pp 111, 116, 122; Winner 2004, pp 38-41). Particular framings of expectation can influence R&D orientations and the entire complex of a technology – its form, applications, scale, targets, intended users or audiences, funding, pace of development, institutional support, and marketing (Geels & Smit 2000b, p 147; Hedgecoe & Martin 2003, pp 331, 334, 340, 349, 354-355; Lave et al. 2010, pp 664, 669).

Concepts of anticipated benefit and of the generic worthiness of technoscience are constructed in discourse, through a repertoire of narratives, imaginaries, scenarios and metaphors. These rhetorical dimensions are fundamental to the persuasive influence of benefit claims: ‘inventors and corporate research departments create not only products but compelling narratives about where these things will fit into our lives’ (Nye 2004, p 160). Language, stories and imagery are the means by which abstract future outcomes are reified to achieve performative power in contested fields (Mulkay 1993, pp 723-7; Brown et al. 2000b, pp 5-6, 10; Mol & Law 2002, p 19). Such framings are more than merely description or imaginative representation – they are significantly constitutive of societal and technoscientific domains and trajectories (Lakoff & Johnson 1980, pp 3, 236, 243-246; Coffey & Atkinson 1996, pp 62-63, 85-86; Deuten & Rip 2000, pp 6-7; Callon 2002, pp 199-200). Metaphors and narratives establish enduring frameworks of meaning, value and purpose for technoscience. The stories help shape the forms and applications perceived as useful and desirable, and influence the power relations associated with R&D and technology diffusion (Nye 1997, pp 3, 6, 179-180; Brown 2000, pp 92-93; Michael 2000b, pp 22, 28; Sturken & Thomas 2004, pp 3, 7-14; Williams 2005, pp 3, 6-7, 17).

The repertoires of innovation and technology promotion rely on well-established conventions and rhetorical modes that are widely accepted within research and policy communities, used in diverse contexts from formal policy to the popular media, and rarely challenged (Nelkin 1995; Gregory & Miller 1998; Meikle 2003, p 152; Nelkin & Lindee 2004; Nye 2004, p 171; Williams 2005, pp 3, 17). Reductiveness and generalisation are standard in the idealising of 'radically simplified' technoscientific futures and expected benefits (Mulkay 1993, p 728). Nye (1997, pp 179-189; 2004, pp 171-172) distinguishes a suite of archetypal 'American Technological Narratives' within which people make sense, optimistically or fearfully, of the systems and innovations shaping their world and their lives.[53] Drama is often constructed through framings that attribute polarised values to technoscientific processes, actors and artefacts. For example, the metaphorical construction of R&D developments as battles, where a technology and its proponents must fight through adversity and resistance before achieving "victory", is a common mode which bolsters actors' sense of worth and commitment (Deuten & Rip 2000, pp 67, 81, 82).[54] Framing technoscience objectives and practice in such terms helps to maintain a kind of "high ground" for practitioners and advocates, especially when R&D and innovation are being pursued in domains marked by controversy and opposition.

Chapters Five, Six and Seven explore the rhetorics associated with promotion of expected benefits from GM and wind energy, and technoscience generally, in New Zealand. Discourses around GM in this country have followed patterns typical of the rhetorics of biotechnology internationally, from the framing of broad utopian futures and economic profits through to "gee-whiz" excitement. Such tactics feature more

[53] The six narratives are categorized according to predominantly positive or negative orientations. Utopian narratives include: the Natural, where technologies are considered natural outgrowths of society; the Ameliorative, where technologies improve the quality of life; and the Transformative, where innovations radically reshape social reality. Dystopian narratives are: the Hegemonic, where some social groups use technologies to control others; the Apocalyptic, where new technologies bring doom and disaster; and the Satiric, where innovation entails unexpected negative consequences (Nye 2004, pp 171-172).

[54] Casting researchers, engineers or technologies as heroes – devoted to the noble cause of the projected benefits of the project – is a powerful rhetorical and psychological tactic (Latour 1996, pp 118-119). When research programmes fail or are discontinued, the metaphor shifts to cast the technology or project as a tragic hero, unloved and misunderstood (Latour 1996, pp 200-202, 248-249, 293-296; Deuten & Rip 2000, pp 69, 82). Such patterns are evident in the promotion of GM in New Zealand, where strong public opposition has resulted in considerable defensiveness amongst researchers and policy and institutional actors.

strongly in the promotion of GM in New Zealand than in the advancement of renewable energy. Nevertheless, wind energy is marketed using dramatic visual imagery and the moral imperatives of environmental sustainability, to position this technology in relation to national and global discourses of public good.

Scenarios of the future are necessities for success – even for survival – in the present (Bijker & Law 1992b, p 107; Michael 2000b, pp 21-22; Nye 2004, pp 160-161; Wajcman 2008, p 814). The performative work of benefit claims is conceptualised in terms of commercial leverage, with technoscientific 'promises' described as the 'currency' necessary to secure a mandate or social contract for research and innovation (van Lente 2000, p 53). Brown et al (2003, p 6) explain technology futures projections via an extended metaphor:

> [A] political economy of expectations [and] transactions… quasi-markets, where anticipations have a substantive value [and] can even be understood as tradable assets whose value lies only in the future, and whose investment burdens are borne in the present.

The instrumental relationships between constructs of intended eventual benefit and the current requirements of technoscience processes are indicative of the conjectural, contingent, uncertain nature of much R&D. The trajectory of an emerging technology or research area depends upon participants' and publics' evaluations of its likely prospects. Claimed future outcomes are central to securing institutional, sectoral and political protection for development work on as yet unproven new technologies.[55] Anticipated benefits are assiduously promoted – and indeed often inflated or exaggerated – to foster positive perceptions of emerging fields or untried innovations (Geels & Smit 2000a, pp 881-882; European Commission 2007, pp 24-25; Van de

[55] Studies of research and innovation processes highlight the strategic value of niches – protected spaces within which new technoscientific ideas can be developed. These logistical and institutional spaces, created through the choices and policies of research organisations, firms or governments, can be crucial in establishing a secure starting point for R&D trajectories, and building acceptance and knowledge of the innovation amongst relevant groups in the field (van Lente 1993, pp 20, 59-60, 197-199; Latour 1996, pp 44-46; Kemp et al. 2001, pp 270-275, 288-289). Expectations of future benefit help to create a privileged space within which a new idea or research pathway – with as yet low performance characteristics, and unable to compete in normal markets – can be fostered and become profitable (van den Belt & Rip 1987, p 141; Utterback 1994, pp 92-93; Geels & Smit 2000a, pp 879-881; Vanloqueren & Baret 2009, p 981). Such development work can be slow and unpredictable (Christensen 1997, pp 150-151, 178-179), but an initially modest niche application can be the basis for a 'march upmarket' to achieve a significant sector share (1997, pp 101-108).

Ven et al. 2008, pp 30-34).[56] But support must be sustained by ongoing faith in the projected benefits amongst key groups and wider publics.

Benefit claims are chimerical abstractions, articulations or reifications of optimism and intention (Mulkay 1993, pp 724-725). They are rhetorical and political suppositions, 'constituted through an unstable field of language, practice and materiality', and thus subject to contestation (Brown et al. 2000b, p 5). Despite the confidence with which expected technoscience benefits are usually asserted (Grossman 2004, pp 188-193; Winner 2004, p 37), such conjectural phenomena are inherently vulnerable in the ongoing dynamics of fields. The most enthusiastic claims can be eroded or discredited by disappointing performance or simple failure, or by shifts in the power relations and politics of the field; they can be relegated to obsolescence or ignominious marginalisation as other, more appealing futures gather stronger social, political, financial and symbolic force (van Lente 1993, Chapter 2; Latour 1996, Chapters 3 & 7, and Epilogue; Geels & Smit 2000a, pp 877-880; 2000b, pp 129, 142-146; Franklin 2003; Rogers 2003). Some of the hopeful claims advanced for GM and for wind energy technology in New Zealand, discussed in Chapters Five, Six and Seven, show this kind of susceptibility to contestation or dissipation. Despite confident earlier promotion, many of New Zealand's GM research programmes, and a number of windfarm proposals, have later been quietly discontinued or not pursued beyond regulatory approval, suggesting the fragility of insufficiently persuasive projections in ruthless political and economic environments.

To understand the workings of benefit claims for technoscience, it is useful to consider these domains – including research and innovation practitioners and their associated policy and governance communities – in terms of sociological analyses of the dynamics of fields. Theorists such as Bourdieu outline the ways that such domains are inherently competitive, sites of ongoing struggle and insecurity, defined by the unequal distribution of power and other resources (Bourdieu 1990, pp 55, 111; Calhoun 1993, p 64; LiPuma 1993, pp 16-17, 23; Beasley-Murray 2000, p 102;

[56] These patterns are strongly evident in the institutional and policy discourse around GM research in New Zealand, discussed in Chapters Six and Seven. In this country, GM has not yet advanced beyond lab research and field trials, and the real-world effectiveness and marketability of applications of this technoscience have not been tested. Wind energy technologies, however, now have a well-established track record in the New Zealand electricity generation industry, as detailed in Chapter Five.

Bourdieu 2002, pp 289-291; 2004, pp 33-35, 58-61; Seidman 2004, p 149). Options and effectiveness depend upon the diverse assets Bourdieu describes as symbolic capital – tangible and intangible resources that help to advance the interests and strengthen the position of those enjoying them: 'capital… entails the capacity to exercise control over one's own future and that of others. As such, it is a form of power' (Postone et al. 1993, p 4).[57] In fields of technoscientific innovation such as GM and wind energy in New Zealand, benefit claims are valuable capital for R&D actors, assets that help to ensure the strongest position and best prospects in the field.

Bourdieu distinguishes three basic kinds of capital: economic, social, and cultural (Calhoun 1993, p 70; Guillory 2000, p 28; Webb et al. 2002, p 22). Scientific capital is also identified as a particular form of symbolic capital governed by the structures and assumptions of research fields (Webb et al. 2002, pp 80-81; Bourdieu 2004, pp 33-34, 55, 59).[58] The different forms of capital are convertible from one dimension of influence to another; intangible, qualitative kinds of symbolic capital inevitably correlate with financial advantage (Calhoun 1993, p 69; LiPuma 1993, p 29; Beasley-Murray 2000, p 102; Guillory 2000, pp 28-29; Webb et al. 2002, p 22; Bourdieu 2004, p 55). The economic mode has particular dominance, underpinning the strategic value of other kinds of capital (Lash 1993, pp 200-201; Grenfell 2004, p 113).[59]

Bourdieu's recognition of the economic dimensions inherent in other kinds of strategically useful capital – such as the perceived beneficence of R&D oriented around objectives valorised by society or a particular field as worthy or important – is salient for analysis of the performative work of technoscience benefit claims.[60] Such

[57] Such resources are generally described as symbolic capital, because their meaning, and the advantages they confer, depend on the norms and expectations of the field (Grenfell 2004, p 28). Bourdieu's idea of capital differs from more conventional political or economic understandings of capitalism. While there are similarities in his analysis of actors strategically manoeuvring assets for maximum advantage, Bourdieu distinguishes his concept from economics, which is relegated to merely an example of the broader patterns pertaining in all fields (Guillory 2000, pp 22-25).

[58] Scientific capital can be further defined as of two kinds: capital of 'strictly scientific authority', and capital of influence and professional and institutional status which strengthens financial and political advantage in the field's interactions with society (Bourdieu 2004, p 57; Grenfell 2004, p 173).

[59] Foucault (1980, pp 88-89, 101) also recognises the 'economic functionality of power' and the unavoidable links 'between power and commodities, power and wealth'.

[60] Numerous other analyses also highlight the dominance of economic frameworks of value and expectation in technoscientific processes, promotion and discourse (for example, Cohen et al. 2001, pp 145-146; Le Heron 2003, pp 122-123; Motion 2005, pp 506-509; Forbes 2006, pp 75, 83; Kleinman & Kinchy 2007, pp 196, 198, 203; Lave et al. 2010, pp 660-662; Bruni 2012).

inter-connections between symbolic or qualitative values and economic value are evident in the framings of anticipated benefit advanced for GM and wind energy in New Zealand. Chapters Five and Six show how the immaterial values associated with these technologies – GM's glamour as an ambitious "high" technology, and wind's appeal as an environmentally sustainable form of energy – are translated into pragmatically commercial benefits. Projected profits from products derived from GM feature strongly in biotechnology policy and institutional discourse. And the economic competitiveness of large windfarms has been strongly influential in establishing corporate and political commitment to this form of the technology in New Zealand.

To sum up this section, the future benefits projected from technoscientific R&D and innovation perform important work in the present. These claims' value as symbolic capital is fulfilled in the immediacy of the strategic advantage, legitimation and leverage they provide to research pathways and new technologies, regardless of whether or not their promises are eventually achieved over the longer term. Although they project out into the future, their principal role is in the "now" – in contested fields characterised by uncertainty, chronically limited funding, and continual jockeying for political and institutional support and public acceptance. Constructs of expected benefit can be powerfully influential on the evolution of research fields and innovations, but they are also vulnerable to challenge or erosion. Frameworks of economic value predominate in policy and institutional discourse, and are closely intertwined with other more qualitative framings of anticipated benefit and utility.

If a key function of benefit claims is to assert the worthiness of a particular technology, application or scientific research area, this inevitably involves positioning it favourably in comparison to existing systems and alternative options. How do benefit claims contribute to processes of change and uptake of innovation, and help to shift practice and expectation from the status quo into new modes? The next section considers the work of benefit projections in the dynamics of change in technoscience.

From flexibility to alignment and closure

A multiplicity of groups and interests form technoscientific fields, and bring diverse priorities and perspectives to their engagements with science and innovation. According to Latour (1996, p 173), 'technological projects are deployed in a variable-ontology world'. As discussed in Chapter Two, the significance attributed to research and technology developments is dependent upon the values, criteria and expectations of heterogeneous parties. R&D pathways, and changes to new technoscientific modes, may be constructed and contested within divergent, even incommensurate frameworks of meaning (Bijker 1995, p 279). The anticipated benefits that justify research and innovation are qualified by the interests, agendas and ambitions of particular groups, and a technological field may be the site of multiple competing ideals and objectives (Latour 1996, pp 79, 137; Brown et al. 2003, pp 5-6; Borup & Konrad 2004, pp 3-4; Dattée & Weil 2007, p 579). The trajectories of GM and wind energy in New Zealand are influenced by the expectations of different groups ranging from research institutions and corporations to environmentalists, farmers, sufferers of chronic disease, and, inevitably, politicians.

Shifts in meaning and value occur as protagonists endeavour to assert and stabilise their particular rationale for a given technology, and to direct that technology's trajectory into pathways conducive to their interests (Law 1987, pp 111-114, 129-130; Bijker & Law 1992a, pp 3-11, 291-293; Bijker 1995, pp 48-50, 279-280; Kline & Pinch 1999, p 113-114). This fluidity, where differing meanings and qualities are associated with an evolving technology, is described as 'interpretative flexibility' (Pinch & Bijker 1987, p 27; Bijker 1995, pp 75-77, 119, 236, 270).

Such multiplicity of concepts and potentials is more evident in the earlier stages of development of a technology or a scientific research programme, when, as Latour (1996, p 48) explains, 'reality remains polymorphous'. There are still, theoretically, a range of possible options as to how research might unfold, how the technology might be deployed, the forms it might take, and the ends it might target (Latour 1987, p 104; Pinch & Bijker 1987, p 28; Bijker & Law 1992a, pp 7-8; van Lente 1993, pp 47-49; Hughes 1994, p 101; Utterback 1994, pp xviii, 23; Bijker 1995, p 280; Van Merkerk & Van Lente 2005, p 1095). Kaplan and Tripsas (2008, pp 791, 794-5) note the richness of this phase of 'ferment' generating variation and potential. These times in technology development are described as full of opportunity: 'complex bundles of innovation ideas [where] the process diverges into multiple, parallel, and interdependent paths of activities' (Van de Ven et al. 2008, p 10).

Inherent in such uncertainty, however, is a need for resolution. Brown, Rappert and Webster (2000b, p 8) suggest that the 'indeterminate character' of technological futures, and the struggles between 'competing innovation agendas', drive an impetus to construct shared frameworks and priorities through official policy and Foresight programmes for R&D.[61] Hughes (1989, p 52) argues that:

> …one of the primary characteristics of a [technological] system builder is the ability to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos.

Alignment of the interests and paradigms of relevant actors in the field is a key factor in the success of R&D trajectories and innovation diffusion. Kaplan and Tripsas (2008, pp 791-4, 799) insist that achievement of a collective frame of meaning, resolving divergent and competing perspectives, is an essential prerequisite for a new technology to become established. Van Lente (1993, pp 34, 50-51, 70, 111) also highlights the crucial importance of 'interlocking' of expectations and R&D activity. Latour's analyses of technoscientific networks (1987, 1992, 1996, 1999) show the importance of alignment of diverse interests – as well as the cooperation of physical and natural phenomena and epistemological data – to secure maximum credibility, momentum and durability for an R&D programme and 'make dissent impossible' (Latour 1987, p 103). In the trajectories of GM and wind energy in New Zealand detailed in Chapters Five and Six, such alignment has often been (ostensibly) achieved via official government policies, sanctioning technoscientific directions through formal strategies for development in particular sectors.[62]

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[61] Some studies highlight contests between divergent alternative framings of possible technoscience trajectories (for example, Kleinman & Kinchy 2007; Davenport & Leitch 2009; Vanloqueren & Baret 2009).

[62] Such politically-driven agenda-setting is, however, often strongly contested and critically deconstructed (for example, Cartner & Bollinger 1997; Davenport et al. 2003; Le Heron 2003; Genus & Rogers-Hayden 2005; Motion 2005; Goven 2006; Davenport & Bibby 2007; Leitch & Davenport 2007; Rogers-Hayden & Jones 2007; Davenport & Leitch 2009; Bloomfield & Doolin 2011).

Alignment leads to the consolidation of a shared meaning for a research field or new technology – a collective understanding of its value and benefits, and its most appropriate and advantageous applications – which satisfies the needs, priorities and expectations of key participants. Development pathways are analysed as processes of iterative negotiation through interactions in the field (Utterback 1994, p 26; Bijker 1995, pp 270-271; Bourdieu 2004, pp 14-17, 65-73, 80; Chakravorti 2004, p 481; Grenfell 2004, pp 172-173). Eventually a version of the technology emerges that can be described as "dominant", gaining stronger support and wider acceptance than alternative modes (Pinch & Bijker 1987, p 44; Utterback 1994, pp xviii, 23-29; Bijker 1995, pp 51-52, 85-88, 270-271; Green et al. 1999, p 783; Van Merkerk & Van Lente 2005, pp 1095-1096; Berkun 2007, p 29; Kaplan & Tripsas 2008, p 794). Closure is reached with the consolidation of development processes around a particular form, application and function of the technology or field – associated with particular kinds of benefits, values and expectations (Pinch & Bijker 1987, p 27; Rappert 1999a, pp 3-4; Garud & Karnøe 2001a, pp 10-11, 31; Brown et al. 2003, p 5). Future developments are then oriented around the "successful" model, and a trajectory established (Utterback 1994, pp 50-51; Green et al. 1999, p 782; MacKenzie & Wajcman 1999, p 19; Garud & Karnøe 2001a, pp 4-5; Kaplan & Tripsas 2008, pp 790, 794).

The dominant framing becomes the norm, retrospectively accepted as the ideal or goal of the development process, and absorbed into the expectations and practice of the field. Bijker (1995, p 85) draws a parallel with scientific controversies, where underdetermined meanings are resolved via negotiation to a consensus: 'from then on only one interpretation is accepted by all. Such a closure is not gratuitous, but has far-reaching consequences: it restructures the participants' world. History is rewritten'. Bourdieu (2004, p 75) also highlights the universalisation or neutralisation that results as the contingent specific origins of a new idea or technology are obliterated in its acceptance into the established orthodoxies of the field; the innovation 'become[s] anonymous, subjectless… independent of the historical agent who produces it and the social conditions of which it is the product'.

These patterns are evident in the evolution of GM and wind energy in New Zealand, discussed in Chapters Five and Six, and in the kinds of projected benefits that underpin the orientation of dominant technology modes in these fields. GM research in this country has largely followed paths set by the international biotech industry, focusing on agronomic goals through development of herbicide-resistant vegetable crops, and on production of potentially lucrative pharmaceutical compounds in the milk of GM livestock.[63] And wind energy has been accepted and deployed in New Zealand in forms established in the US and Europe as the norm for this technology – large industrial-scale windfarms feeding a centralised grid.

Despite some studies' analyses of collective shared meaning-making, the process of reaching closure and securing acceptance of change is often intensely manipulative, and such struggles are invariably political (Funtowicz & Ravetz 1992, pp 262-263; Kaplan & Tripsas 2008, pp 791, 798). Beder (1991, pp 226-229, 251-253) argues that the apparent closure of technoscientific differences depends on power relations and inequalities; she shows that power 'enables some groups to control negotiation and… arbitrarily limit interpretative flexibility' (1991, p 227).[64] Bijker (1995, pp 262-264, 279, 283) also highlights the ways that dominant groups, or powerful amalgamations of vested interests within a field, 'insist upon [their] definition of both problems and appropriate solutions' (1995, p 276). Green and colleagues (1999, p 786) observe that: 'the rate and direction of technological change result[s] from the ability of some actors to shape technologies to their own preferred ends.' For Bourdieu, fields' evolution is dominated by those with the greatest symbolic capital.[65] More powerful groups are able to assert their particular interests and consolidate their position as leaders in the field (Bourdieu 2004, p 35; Grenfell 2004, p 28).[66] Symbolic capital is the foundation for influence over norms and practice:

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[63] The exception was the research into the potential application of GM to develop a biocontrol for possums (a major environmental pest in New Zealand), discussed in Chapter Five. This use of GM technology would have been unique in the world in that its primary focus was on public-good benefits from improved ecosystem management and biodiversity protection.

[64] Beder identifies five ways in which disputes of interpretation, legitimacy and value may be resolved: closure through loss of interest or abandonment; closure through force, where an external authority imposes a decision; closure through consensus even though the option adopted may not necessarily be the most effective choice; closure through negotiation, again not necessarily around the best solution but where compromise is accepted in order to end the debate; and the ideal process of closure through sound argument, where participants agree on the most appropriate solution (Beder 1991, pp 227-228).

[65] Such advantages are cumulative: 'The scientific field gives credit to those who already have it' (Bourdieu 2004, p 56).

[66] Symbolic capital also offers dominant players and institutions power over the relative positions of others, allowing stronger groups to establish and enforce boundaries around the field, to set criteria for settling controversies, and to delegitimate or marginalise alternatives (Bourdieu 1990, pp 37, 135; Robbins 1991, pp 97, 100; Lash 1993, pp 197-199; Bourdieu 2002, pp 294-295; Webb et al. 2002, pp

> The dominant players are those who manage to impose the definition of science that says that the most accomplished realization of science consists in having, being and doing what they have, are and do (Bourdieu 2004, pp 62-63).

The workings of power in the assertion of particular meanings and values as "truth" and "knowledge" are also a central concern for Foucault (1972, 1980, 1994). His focus was on the interconnections and mutual reinforcing of power and discourse, showing how the interests of the powerful are privileged and perpetuated in the circulation of discourse (for example, 1980, pp 93-94, 101-102, 118-119, 131-133). Foucault notes the effects of power in processes of scientific change, highlighting 'the problem of the regime, the politics of the scientific statement' (1980, p 112). Discursive constructs – such as framings of expected benefit from technoscientific R&D and innovation – orient knowledge, perceptions and beliefs around the interests of dominant groups (Hook 2001, p 2; Mills 2003, pp 72, 79; Motion 2005, p 505; Motion & Weaver 2005, pp 50-52). Foucauldian analysis also highlights the ways that such agenda-driven discourse works to exclude or delegitimate alternative values and voices (Gaventa & Cornwall 2001, p 71; Mills 2003, pp 54, 72, 76; Davenport & Leitch 2009, pp 946-947).

Studies of technoscientific development recognise that there are losers, as well as winners, in such processes of strategic positioning and change. The success of one particular framing of an innovation or research area has the corollary that other, different possibilities are foreclosed. Alternative modes of a new technology – and the benefits and positive outcomes that might be derived from those other options – are often marginalised by the ascendancy of the dominant form (Hughes 1989, p 52; Brown et al. 2000b, p 13; Edwards 2008, p 184).[67]

23, 152; Bourdieu 2004, pp 35-36, 58, 62; Grenfell 2004, p 134). These patterns are reflected in the policy and regulatory processes for GM and wind farms in New Zealand, discussed in Chapters Five and Six (for example, Leitch & Davenport 2005; Goven 2006; Hindmarsh & Du Plessis 2008; Kurian & Wright 2010).

[67] Early forms of an innovation, such as the penny-farthing bicycle, effectively disappear as new versions of the technology emerge that are more in alignment with the interests of key social groups (Pinch & Bijker 1987, pp 28-46; Bijker 1995, Chapter 2). But historical studies of technology "contests" – such as the displacement of steam-powered vehicles by the gasoline engine (eg Arthur 1999) – note that the ascendancy of a particular technological mode may not occur because of any inherent superiority in performance or meeting societal needs (van Lente 2000, p 56; Brown et al. 2000b, p 10; Nye 2004, pp 167-168). Such "victories" can be due to complex and arbitrary conjunctions of random events and influences that create patterns of increasing returns for the retrospectively "better" option: '[I]n 1914 there was an outbreak of hoof-and-mouth disease [which]

The dominance of favoured modes or fields is enabled via the assertion of narrowly-focused frameworks of reference for policy and discourse. Studies of science and innovation processes trace the influence of hegemonically normalised constraints that limit the range of perspectives, options, criteria, information, and expected benefits deemed relevant to the evolution of a research pathway or a technology and its application. Such "fencing off" defuses potential challenges, minimises obstacles and uncertainties, and censors out alternatives, thus privileging presumed or intended technoscience trajectories.

Gieryn's analysis of boundary work in science domains (1999, pp x-xii, 4, 6-10) develops an extended cartographic metaphor. The borders around technoscience need constant defending, and are continually challenged and renegotiated (Fisher 1990, p 101; Gieryn 1999, pp 14-15). Determining what is recognised and valorised within technoscience frameworks is also a process of exclusion, an assertion of power and a claim on support and resources (Cozzens 1990, pp 164-168; Fisher 1990, pp 98-99, 112-113; Gieryn 1999, pp 12-13, 23, 29). Boundaries serve an important protective function for technoscientific enterprise, but can also limit opportunity (Hargadon 2003, p 72). Validity and prestige may be accorded to some technological modes and objectives, but other promising options and potential benefits are eclipsed, relegated to the margins of discourse and policy processes, or trivialised in non-threatening minor applications. This has been the fate of alternative applications of wind energy technologies in New Zealand, discussed in Chapter Five.

The issues and perspectives most likely to be delegitimated in such boundary processes are the complex, fuzzy subtleties of social, political, ethical and spiritual dimensions, qualitative considerations, and questions around the perception, meaning and significance of research and innovation (Funtowicz & Ravetz 1992, p 253; Sarewitz 1996, pp 158-160; 2004, pp 397-399).[68] Reliance on such blinkered

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led to the withdrawal of horse troughs – which is where steam cars could fill with water. It took the Stanley brothers about three years to develop a condenser and boiler system that did not need to be filled every thirty or forty miles. But by then it was too late. The steam engine never recovered' (Arthur 1999, p 112).

[68] Boundaries are maintained around technoscientific agendas not only through assertion of the dominant mode of scientific rationality (Habermas 1971; Beck 1999; Feenberg 1999), but also through

functional thinking – where broader societal implications and values frameworks are neglected or excluded – is identified as a common pattern in technoscience processes (Geels & Smit 2000a, pp 878-879; Wilsdon et al. 2005, pp 25-26, 53, 56; Kearnes et al. 2006, pp 19, 23; Berkun 2007, pp 62, 98; Woodhouse & Sarewitz 2007, pp 139, 141).[69] Winner (1986, pp 4-5, 46-55, 172; 2004, pp 38-41) analyses technological and engineering domains as shaped within severely limited frames of reference which establish de facto 'regimes of instrumentality' and preclude consideration of social, ethical and public-good dimensions. These patterns are strongly evident in the framing of GM and wind energy in New Zealand, discussed in Chapters Five and Six. Public debate and formal regulatory processes for GM research and releases have been dominated by ostensibly scientific modes of risk assessment. Windfarm proposals have also been promoted and decided according to a limited spectrum of criteria, and other dimensions (such as the concerns of local communities) have been minimised, neutralised or over-ruled.

To summarise, the effective assertion of sufficiently persuasive benefit projections is essential for alignment and closure in technoscience change processes. Benefit framings must not only be convincing as the justification for technoscientific R&D; they must establish a narrative of value and meaning powerful enough to advance one interpretation of the technology as the dominant mode, and to discredit or diminish the appeal of alternatives. Chapters Five and Six trace the ascendancy of certain framings of anticipated benefit in the trajectories of GM and wind energy in New Zealand. Options associated with attractive economic potentials have achieved dominance – lucrative pharmaceutical and agronomic applications of GM, claims of the revitalisation of production sectors, and profits from competitively large-scale windfarms. Other possible R&D and innovation trajectories – and the different kinds of benefits, goals and criteria driving alternative technoscientific modes – have little traction in the political, institutional and sectoral arenas where policies and decisions are made.

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the seductive persuasiveness of framings of benefit anticipated from technological innovation (Spigel 2004, pp 139-140; Sturken & Thomas 2004, pp 3, 8, 10, 12; Turkle 2004, pp 22-28).

[69] Such narrowing of the scope of matters that are given validity and included in the consideration of technological and scientific issues is the focus of critique in studies of processes of public engagement around risk (Beck 1992; Wynne 1992, 1996; Beck 1999; Kearnes et al. 2006; Levidow & Carr 2007).

Lock-in and inertia

Alignment of technoscientific developments around a dominant mode, with the effective closure of uncertainty around potential alternatives, can be the point at which technologies or research fields begin to ossify. Successful technoscientific applications or modes become entrenched, and block evolution of fresh ideas and new possible benefits. Analysing structures of power in 20th century technology, Winner (1986, p 29) explains:

> Because choices tend to become strongly fixed in material commitment, economic investment, and social habit, the original flexibility vanishes for all practical purposes once the initial commitments are made.

The paths of GM and wind energy in New Zealand demonstrate such tensions. As Chapters Five and Six show, the inertial weight of established technological paradigms, systems and infrastructure exerts significant influence, restricting the range of potential uses and benefits envisaged from these innovations. Particularly in electricity generation, existing technological frameworks (both physical infrastructure and institutional and policy expectations) have imposed significant constraints on opportunities to maximise the benefits of wind energy.

Such inertia is an inherent aspect of Bourdieu's concept of habitus (Bourdieu 1999, pp 109-111); the familiar modes and paradigms shared within a group or field can limit awareness and openness to future options. Economic interests and status are also strong factors; Bourdieu identifies an inherent conservatism, where resistance to innovation results from the protection of 'the distribution of the chances of profit' (Bourdieu 2004, p 62). In his classic study of scientific paradigms, Kuhn (1996, pp 24, 64) describes the conservatism of established frameworks of expectation and practice, circumscribing the boundaries of inquiry and possibility:

> No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all… novelty emerges only with difficulty, manifested by resistance.

Technology development and diffusion are often strongly patterned within existing frameworks of meaning and application (Mokyr 1990, pp 261-262, 266-267; Arthur 1999, p 107; Chakravorti 2004, pp 475, 477; Van Merkerk & Van Lente 2005, pp 1095, 1097; Dattée & Weil 2007, pp 584-585; Vanloqueren & Baret 2009, pp 977, 980). Priorities, expectations and solutions are framed within current modes of thinking and value (Utterback 1994, pp xv, xxviii, 50-51; Christensen 1997, pp xxiii, xxvi-xxvii, 35, 64, 100, 259). Collective commitment to prevailing paradigms and networks is powerfully influential (Deuten & Rip 2000, p 77; Brown & Michael 2003, pp 14, 16). The established norms, beliefs and goals of the field, and compliance to the dominant technological mode, are reinforced by incentives and institutional processes (Green et al. 1999, pp 781-782; Hargadon 2003, pp 116, 184; Petrick & Echols 2004, pp 83, 86, 96; Kaplan & Tripsas 2008, pp 799-801; Van de Ven et al. 2008, p 209). There can be significant commercial pressures to recoup sunk investments (van Lente 2000, p 60; Van de Ven et al. 2008, p 92). The priority is protection of previous achievements: 'security, risk aversion, and optimization of the status quo eventually become dominant positions' (Berkun 2007, p 62).[70]

These patterns are strongly evident in the evolution of GM and wind energy in New Zealand. Policy and institutional frameworks for the development of these technologies have focused around existing concepts of benefit and necessity – the assumption that electricity generation will be undertaken by large corporations for commercial profit, and the belief that GM will foster the competitiveness and reputation of New Zealand agriculture, the basis of the country's economy, via new high-value products and improved efficiencies.

The inertia of paradigms and expectations is closely intertwined with the inertia of physical artefacts and infrastructure: '[Technological systems] are like ocean liners, once they are on course and at full speed, they have considerable momentum and therefore take a long time to change direction (Gooley & Towers 1996, p 5). Analyses of path dependence in technology trajectories emphasise the narrowing of options created by pre-existing systems and structures (David 1985, p 332; Gooley & Towers 1996, pp 3, 8; Williams 2005, p 13). Bassanini and Dosi (2001, pp 41-47)

[70] Such behaviours are not confined to contemporary systems and processes. The Renaissance political theorist Niccolo Machiavelli observed: 'There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. For the reformer has enemies in all those who profit by the old order' (Machiavelli, *The Prince* (1532), cited in Berkun 2007, p 56).

offer a diverse range of illustrations for the theme that 'history matters'.[71] Garud and Karnøe (2001a, pp 25, 30) argue for a more active, future-oriented approach in 'path creation', but nevertheless recognise the constraints of 'initial conditions' and 'structurational processes' on technological development.

The stories of GM and wind energy technologies in New Zealand have been powerfully shaped by such historical patterns. In the trajectory of wind energy in particular, the demands of New Zealand's extensive electricity infrastructure, as well as assumptions of the industry, policy actors and publics, have significantly influenced the opportunities and diffusion of this technology.[72] With GM, the systemic effects of inertia have been more a consequence of the relative scale of New Zealand's research community; R&D has primarily followed directions already well-established by multinational technoscience corporations.

Radical change

A key factor in the dynamics of technoscience is the degree of change, relative to current systems and paradigms, involved in development and uptake of an innovation. Normal practice, via incremental expansion or refinement of accepted knowledge and applications, is very different from 'revolutions', where previous assumptions must be significantly changed or even abandoned (Kuhn 1996, Chapters III and IV; Bourdieu 2004, pp 14-17, 80). Such differences are evident in the trajectories of GM and wind energy in New Zealand. More revolutionary modes of technoscientific change have found very limited acceptance and support: 'the more radical and disruptive an innovation and the less its compatibility with existing practice, the slower its rate of adoption' (Rogers 2003, p 247). The forms of these technologies that have become the dominant mode in New Zealand – and the benefits that have been prioritised and valorised in justification of these developments – are more conservative options, most compatible with conventional frameworks of value in those sectors.

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[71] The configuration of the QWERTY typewriter keyboard is commonly used to demonstrate the intransigence of physical technological structures and associated practices (David 1985; Utterback 1994, pp 5-7, 24-5, 49; Garud & Karnøe 2001a, pp 3-4; Rogers 2003, pp 10-11).

[72] This kind of 'lock-in' or entrenchment in large electricity networks – including major technological infrastructure for production and transmission, as well as complex networks of public and private organisations, stakeholders and consumers – is featured in several international studies (Winner 1986, p, 53, 57; Hughes 1989, pp 76-79; Wilsdon & Willis 2004, p 31; Woodhouse & Sarewitz 2007, p 143).

The crucial distinction is between ‘routine’ and ‘radical’ innovations (Gooley & Towers 1996, pp 5-7), or between ‘sustaining’ and ‘disruptive’ or ‘discontinuous’ technologies (Christensen 1997, pp xviii, 16, 80, 112, 150-151, 252). Hedgecoe and Martin (2008, p 820) describe two broad registers of expectation in genomics and biotechnology discourses: the contextual, claiming continuity between innovation and earlier technoscience, and the transformational, asserting a radical break with the past and revolutionary new potentials. And Michael (2000b, pp 27-30) discriminates between accounts of the future that extend present-day conditions and values, and more substantive utopian visions of techno-social possibility.

Radical or disruptive alternatives are deeply challenging to mainstream paradigms, requiring major changes to beliefs and value systems as well as to practices, routines, knowledge requirements, regulatory processes, physical structures and relations within the field.[73] As Hargadon (2003, p 10) points out, such change involves considerable risk and disruption:

> Breakthrough innovations cause [technological] networks to shift dramatically… New technologies [can render] obsolete not just old objects, but also the people and ideas linked to them and, in a chain reaction, the complex organisations and markets that grew up around these combinations.

A central factor in change processes is that the perceived benefits of new technologies must outweigh the challenges of adoption (Coburn 2006, pp 10, 23-25); there are particular difficulties for new technologies that require change through an entire support system or infrastructure (2006, pp 84, 102). Protection of profitable interests results in understandable opposition to developments seen as revolutionary or extreme (Hughes 1989, p 59). Not surprisingly, technology development and diffusion processes are often more successful when they conform with established paradigms, infrastructure and systems (Utterback 1994, chapters 7 & 9; Gooley & Towers 1996, p 8; Hargadon 2003, pp 60-61, 191-192; Rogers 2003, pp 1-5, 7-11; Berkun 2007, p 55). As Coburn (2006, p 43) argues, innovations ‘are much more likely to be adopted

[73] Schumpeter’s theories of the economic dimensions of technological development highlight the principle of ‘creative destruction’ (Mokyr 1990, pp 6, 147, 261, 282-283; Garud & Karnøe 2001a, p 6; Van de Ven et al. 2008, p 211). Such dramatic change is described as ‘innovational transilience’, when established industries, markets and professional sectors are made obsolete by new technologies (Fairtlough 2000, p 270).

if they offer incremental adjustments… and not complete deviations from life as we know it'. The status quo offers more favourable prospects for new technologies that: 'simply build on what is already there, requiring… change in only subtle, nearly invisible ways' (Van de Ven et al. 2008, p 171). The form of wind energy that has become dominant in New Zealand – large windfarms feeding the central grid – illustrates these themes. Radically different applications of wind technology, such as distributed generation via small community-based installations or independent domestic turbines, are perceived by the industry and policy-makers as requiring too great a reconfiguration of existing systems and infrastructure. As discussed in Chapters Five and Seven, decentralised wind energy systems are promoted as offering societal benefits that are insufficiently compelling to sector decision-makers and political interests to warrant major disruptions and expense.

Achieving compatibility with existing technological systems and organisational structures can require significant changes in the concepts of benefit, value and purpose shaping an innovation and its application. Becoming mainstream usually involves (re)framing a new technology or research field within economic criteria of instrumentality, efficiency and profitability, and can result in the loss or compromise of other modes of potential benefit (Winner 1986, pp 47-57; Hawken 1993; Hård & Jamison 2005, pp 270-271, 279, 285-291; Hess et al. 2008, 482-487; Vanloqueren & Baret 2009, p 980). Such strategic framing – positioning the projected benefits from new technologies within established sector paradigms, particularly the economic – is itself a valuable dimension of symbolic capital in technology development fields (Bourdieu 2004, pp 33-34; Grenfell 2004, pp 113, 167). The increasing adoption of wind technologies for electricity generation in New Zealand is in part due to the ability of advocates in both industry and policy domains to position the dominant form of this innovation as compatible with existing infrastructure and with the priorities of powerful groups.

Gaining acceptance for new technologies and their projected benefits requires not only consistency with the field's conventions and frameworks of expectation, but also the involvement of actors or advocates with appropriate conformity to the norms and culture of the dominant groups. Rogers (2003, pp 305-6, 382) emphasises the importance of 'homophily' – similarity of style, background, and experience – for credibility and effectiveness in promoting the benefits of a new technology. Confidence and trust between people with similar histories, styles and thinking in R&D and technoscience fields is a key aspect of gaining consensus (Knorr Cetina 1999, pp 202, 258-259; Rappert 1999a, pp 3-4, 9-10). Bourdieu emphasises the importance of habitus – or the "fit" between actors and fields – in such strategic positioning. Insiders, thoroughly habituated to their field and its norms and frames of meaning, enjoy greater influence than 'the marginal, the heretics, the innovators, who are often situated on the boundaries of their disciplines' (Bourdieu 2004, p 43). Dattée and Weil (2007, p 583) observe that innovative technologiess are more likely to be seen positively when introduced by firms with high status and 'institutional weight'. Outsiders with few connections in the field or sector are 'often disdained and… the information they generate is just not considered as relevant'; technological communities focus as much on advocates' credibility and conformity to the norms of the field as on product performance (Dattée & Weil 2007, p 596). The trajectories of GM and wind energy in New Zealand have been strongly influenced by the attribution of authority and reliability to mainstream actors and institutions – and to the framings of expected benefit they advance – and by the corresponding difficulties for advocates of alternative applications offering different kinds of potential benefit.

The imperative of imperatives

Given the challenges of overcoming the inertia of established technological systems, particularly when R&D and innovations are perceived as radically disruptive, a major dimension of the performative work of benefit claims for technoscience is to identify suitably compelling problems, needs or inadequacies for which the new technology offers a solution. It may seem perverse for this thesis – an exploration of the benefit claims advanced to justify technoscientific innovation – to focus on dysfunction and difficulty. But problems, real or perceived, current or projected, urgent or chronic, are inextricably intertwined with the construction and value of projected technological benefits. Problems provide impetus for change, benchmarks for assessments of value, and motivation for investment, through 'the two-fold practical orchestration of present problems and future solutions' (Brown 2000, p 89). Sturken and Thomas (2004, pp 8-9) suggest that projections of future benefits and improvements from technoscience perpetuate a 'childlike relationship to technology', where '[t]echnology is consistently posed as that which will alleviate our sense of lack and fulfil our needs'.

In his analysis of the dynamics of scientific paradigms, Kuhn (1996, p 77) highlights the importance of crises as a 'necessary precondition' for the emergence of new ideas and frameworks of value.[74] In the ongoing activity of fields, anomalies and new information challenge existing paradigms; such disjunctions may be given weight by associated broader social and epistemological developments (1996, pp 52ff, 69, 82). Kuhn (1996, p 92) reiterates the importance of a 'sense of malfunction' indicating that 'existing institutions have ceased adequately to meet the problems posed by an environment that they have in part created.'

The strategic work of problem definition, and its inherently political, negotiated nature, are crucial in securing and maintaining support for technology development (Funtowicz & Ravetz 1992, pp 262-263; Deuten & Rip 2000, p 69; van Lente 2000, p 55; Michael 2000b, p 22; Berkun 2007, p 10; Levidow & Carr 2007, p 409). The importance of a compelling problem to instigate momentum for research and change is highlighted in a number of studies; for example, Van de Ven et al (2008, pp 10, 30) describe the genesis of innovation:

> Concentrated actions to allocate resources and initiate innovation development are triggered by "shocks", not mere persuasion… When people reach a threshold of sufficient dissatisfaction with existing conditions, they initiate action… [N]ecessity, opportunity and dissatisfaction are the major preconditions that stimulate people to act.

Rogers' model of the generation of new technologies (2003, pp 137-140, 171-172, 189) begins with the identification (or creation or encouragement) of a problem or need as the incentive for R&D. Coburn (2006, pp 17-20, 53, 86, 160) poses a spectrum of various levels of need and urgency, distinguishing between deep 'core' crises and those manufactured or 'inspired' by marketing and other sectoral and societal pressures. Even abstract, broadly generic framings of need can create a sense of compulsion that helps to justify support for research and innovation. A notable example of such wide-ranging constructs is the Red Queen imperative, discussed in

[74] Although his model of paradigm shifts was developed to explain processes in scientific research fields, Kuhn specifically acknowledges its usefulness and "wide applicability" in other domains (Kuhn 1996, p 208).

Chapters Two, Six and Seven – the conceptualisation of technoscientific innovation, and particularly GM, as a desperate high-stakes competition. This narrative asserts a general presumption of the necessity of involvement and striving in this R&D field, both for scientific prestige and for vaguely-defined economic and social outcomes. The demand established by such patterns of belief and expectation is far from an immediate crisis, yet can be no less powerful a driver for policy and research sectors; the Red Queen imperative has legitimated the active participation of New Zealand research institutions in GM work, irrespective of specific environmental, agronomic and medical problems targeted by these projects.

Technoscientific benefit claims are phenomena existing in the future, and the needs and difficulties they aim to address may also be projections forward in time. The concept of a 'presumptive anomaly' – an anticipated problem predicted to arise at some eventual future time – was initially suggested to explain innovation in the field of aeronautics, and the impetus for aircraft engineers to develop a completely new technology, the turbojet (Hughes 1989, p 75; van Lente 1993, pp 51, 86-87; Bijker 1995, pp 278-279). The expectation of different, more challenging conditions and criteria for technological performance in the future establishes an 'imagined context… generated by extrapolation' (van Lente 2000, p 58).[75] Predicted needs or inadequacies, even in the remote future, can have as much influence as any present situations in justifying R&D activity and innovation; as Constant (1987, p 225) observes:

> The old system still works, indeed still may offer substantial development potential, but science suggests that the leading edge of future practice will have a radically different foundation.[76]

[75] Michael (2000b, pp 24-25) discusses the relative influence on present day decision-making of near and distant futures: 'what are the respective impacts of measuring a future's distance from the present in terms of weeks, in terms of parliamentary sessions, in terms of a technological age? … Long distance would diffuse urgency: there is no dire need to do anything immediately, and in the meanwhile "we" can wait for technology to develop fixes. Contrariwise, if this future is situated close by, then action is needed immediately'.

[76] Van Lente (1993, pp 164-169) extends these ideas to outline the phenomenon of 'self-justifying technologies', innovations that are legitimated via circular 'tautological' constructs of anticipation and inadequacy. His example of high-definition television technology illustrates the principle where R&D processes are driven by invidious comparison with projected future intentions: '[T]he main shortcoming of the present system is that it is not HDTV. The present system is deficient exactly to the degree that it does not live up to the projected characteristics of HDTV. The present is measured by the yardstick of the technological promise, and found wanting' (1993, p 167).

The development of wind energy technology in New Zealand demonstrates the strong motivation that can be asserted by a future crisis – the enormous environmental, social and intergenerational challenges of global climate change. As discussed in Chapters Five and Seven, problems that may not have their full impact for decades to come are used to justify significant technological change in the present.

The trajectories of GM and wind energy as innovative technologies in New Zealand demonstrate the usefulness of problems and needs in overcoming inertia and forcing fields into different modes. The identification of urgent present problems – or anticipated future ones – as drivers for development of new technologies is the "flip side" of the strategic work of benefit claims. For without a crisis of sufficient severity as an imperative for decision-makers and communities to consider other kinds of options, a new technology will have a much harder pathway to acceptance and diffusion. Would the claimed benefit exert a powerful enough "pull" to justify R&D and bring about change without a corresponding problem "push"?

As Chapters Five and Seven show, political recognition of the necessity of responding to global climate change created a new framework of value for wind energy as an environmentally sustainable form of electricity generation. Chapters Six and Seven explain how research into possible GM technologies for possum biocontrol and horticultural production was justified by the limitations and adverse effects of current environmental management methods. Other GM research claimed goals of alleviating suffering from chronic diseases via production of pharmaceutical compounds, boosting economic performance in struggling production sectors, and securing New Zealand's position in relation to the perceived international competitiveness of the Red Queen imperative, introduced in Chapter Two. Projection of a satisfactory benefit is only one dimension of the validation and advancement of new technoscience. Equally important is recognition of a big enough crisis – or looming future problem – demanding resolution.

Conclusion

The successful promotion of technoscientific innovation and change requires the resources – symbolic as well as institutional and economic – to assert and sustain a sufficiently convincing framework of meaning and value for the technology or research, and to persuade policy and sectoral decision-makers and publics of its desirability and utility. Central to this process is the creation and circulation of projections of expected benefit from innovations such as GM and wind energy technologies – strengthened and made more appealing through imagery, narrative and metaphor. Benefit claims are assets in the contested fields of R&D and technology diffusion, but they are also constraints, influencing and limiting the possible forms and applications of new technologies and the kinds of outcomes that are envisaged and supported.

The ascendancy of some applications of new technologies – and the priority accorded to some kinds of benefits and beneficiaries – result from the power relations and negotiations that are inherent in such fields, and from the histories of previous technological developments and socio-political frameworks. Innovations that are consistent with the interests and paradigms of dominant groups, and can be smoothly integrated with existing technological systems, are more likely to find acceptance and uptake, despite the potential for important and attractive societal benefits from other more radical technological options. However, the identification of a significant problem or difficulty, either in the status quo or in the future, can help foster commitment to R&D and innovation, with the projected solution posited as the incentive for change.

These processes are evident in the evolutions of GM and wind energy in New Zealand, detailed in Chapters Five, Six and Seven. However, while such patterns are fundamentally strategic and political, it is important to acknowledge that they are not necessarily the result of deliberate Machiavellian tactics on the part of actors and institutions in the respective fields. There may indeed be purposeful efforts to position these new technologies as positively as possible, to emphasise benefits and applications conducive to the interests of dominant groups, and to highlight urgent problems intended to be addressed via these innovations' development and diffusion.

But this thesis considers such manoeuvres as primarily outcomes of the patterns of disposition described by Bourdieu as habitus – the internalised beliefs and assumptions of participants in technoscientific fields, taken for granted via their involvement in ongoing practice and acceptance of shared norms and orientations. As discussed in Chapter Two, such frameworks of value and expectation are largely tacit, beneath conscious awareness, and deeply embedded as "the way things are" in the field (Bourdieu 1999, pp 108-111).

The next chapter turns to the framing assumptions underpinning this thesis itself, and outlines the methodologies adopted for this analysis of the work of benefit claims in technoscientific innovation.

Chapter Four

The means to the end

Introduction

Any construction – such as this thesis – depends for stability and coherence on its design and the methods of its assembly. This chapter outlines the methodology developed for my research and analysis of the materials, information and ideas gathered. With most aspects of the process there were several possible methodological options or theoretical frameworks, and this chapter explains why I chose certain approaches and why I considered others less useful. It also describes some of the practical challenges that arose, particularly in relation to the interviews.

The focus for this thesis – technological benefit claims and their performative role in research and innovation – is central to the rationale for the research methodology employed. Firstly, the sociology of technoscientific expectations is a relatively recent scholarly field and there were few precedents or models to follow. Therefore an open, exploratory approach was taken, giving flexibility as the investigation evolved. And secondly, the phenomena under investigation are abstractions, provisional, mutable, multi-faceted social constructions articulated within the value frameworks and power relations of heterogeneous groups. This required a constructivist stance to recognise and accommodate multiple meanings, interests and perspectives.

The choice of GM and wind energy as sites of inquiry into projections of benefit is discussed in Chapter One. These technoscience fields are diverse, complex assemblages of artefacts and actors, ideas and values, politics and practices. Benefit claims are associated with particular cases and applications, but also have wider implications for the field and for science, technology and innovation generically. This chapter outlines the conceptual framework used to distinguish different levels of significance of the benefit claims advanced in the two fields.

The discussion then shifts to the rationale behind my engagement (in the previous three chapters) with the academic literatures, and the principles underpinning my selection of primary documents from the GM and wind energy sectors and wider technoscience discourse in New Zealand. I describe the methods used to review and analyse these texts and the transcripts of my interviews with key sector actors. The chapter concludes with a discussion of the actual process of my direct interactions with these science and technology actors, as I met with them to explore their thinking about research and innovation and the benefits anticipated from their work.

Framing the investigation

This thesis ventures into territory where there is as yet little in the way of established research traditions. While there has been considerable academic analysis of science and technology fields and the dynamics of innovation (as discussed in the preceding three chapters), the particular questions explored in this thesis have not previously received extensive scrutiny. A few studies have discussed expectations in specific technoscience fields – for example, insulation and membrane technologies and high-definition TV (van Lente 1993), pharmacogenetics (Hedgecoe & Martin 2003), computers (Turkle 2004), transportation systems (Latour 1996; Geels & Smit 2000a), or nanotechnology (Kearnes et al. 2006; Pidgeon et al. 2009). However much work in the sociology of expectations deals with projected futures at more generic levels. Most studies outline the broad principles of the performative work of technoscience expectations, with only brief references to particular cases or the salience of different kinds of outcome framings (for example, Michael 2000b; Brown et al. 2003; Borup & Konrad 2004; Winner 2004).

As this thesis addresses aspects of technoscience where analytical conventions and theoretical canons have yet to become established, an exploratory methodology is appropriate. Such a topic area necessitates a process of discovery, described by Patton (1990, p 40) as ‘openness to whatever emerges [without] predetermined constraints on outcomes’. An initial scoping of the research problem was necessary to clarify the focus of inquiry without specifying any particular standpoint in relation to the issues, ‘beginning not with a hypothesis but with a research situation’ (McGhee et al. 2007, p 3). The principle of pragmatic flexibility continued through the research, in response to the ideas, information and contexts encountered as the project developed (Denzin & Lincoln 2003, pp 5-9).

The approach taken in this thesis owes a major debt to the methodologies of grounded theory, a commonly-used framework for inquiry in social science (Suddaby 2006, p 633; Bryant & Charmaz 2007, p 1). Originally developed by sociologists Glaser, Strauss and Corbin in the 1960s, grounded theory challenged prevailing disciplinary assumptions at that time, particularly the empiricist methods, aims and conventions of the natural sciences that many considered were also necessary for good social research (Charmaz 2006, pp 4-7; Bryant & Charmaz 2007, pp 7-8; Charmaz 2009, p 128). The core principle of grounded theory is that knowledge and theory evolve in a "bottom-up" process, derived from and grounded in the data as it is gathered; this is the reverse of a "top-down" process where existing knowledge or theory is elaborated through data generated for the specific purpose of testing a predetermined hypothesis (Suddaby 2006, p 635; McGhee et al. 2007, p 5; Charmaz & Bryant 2011, p 295). Charmaz (2006, p 169) explains the distinction:

> The theoretical framework [in grounded theory methods]… emerges from your analysis and argument about it. In contrast, researchers who use a traditional [methodology] invoke an established theory and deduce hypotheses from it before conducting their studies… their theoretical framework is already there.[77]

The inductive, evolutionary approach of grounded theory is an obvious choice for research in an exploratory topic area (Pidgeon 1996, p 80). Grounded theory methods work iteratively as the research materials are collected and analysed simultaneously. Key tools include the techniques of coding or categorising, and interpretational memo-writing (Pidgeon & Henwood 1996, pp 87-88, 91-94; Charmaz 2002, p 677, 683-690; Bryant & Charmaz 2007, pp 16-19; Charmaz & Bryant 2011, p 292). The continual 'immersion' of the researcher as material accumulates – through ongoing comparison and review of the developing interpretations – encourages reflexivity about the evolving analysis and allows new directions to develop (Charmaz 2002, pp 678-681; 2006, p 178; Henwood & Pidgeon 2006, pp 347, 349; Suddaby 2006, pp 634, 639). These techniques were useful (and the principles underpinning them were reassuring) through the thesis process, as information accumulated and possible

[77] In an early interview for this thesis (Interview 49), my *modus operandi* was challenged by a prestigious science policy advisor, trained in the physical sciences, who assumed that the inquiry had to be focused around testing a specific hypothesis about technology benefits; the idea of an open exploratory process was completely alien to his expectations.

theoretical frameworks were explored. Some ideas initially seemed promising but later proved unhelpful; one such disappointment was an early attempt to model technoscience benefit projections as a "180-degrees mirror-image flip" of constructs of risk, adapting the established theoretical frameworks of risk assessment (for example, Krimsky & Golding 1992; Slovic 2000a). Other emerging ideas were, however, only strengthened through the ongoing process of discussion and data-gathering. For example, the strategic importance of a sufficiently compelling societal demand as a driver of technoscientific innovation – the problem "push" corresponding to the "pull" of projected benefits – was continually affirmed and consolidated as the research proceeded.[78]

The second principal reason for the qualitative research methodologies used for this thesis is that the phenomena being studied are intrinsically "fuzzy" or non-empirical, comprising a heterogeneous assortment of intangible constructs, meanings and values frameworks, inextricably situated in diverse social and sectoral contexts.

Four 'paradigms' for qualitative inquiry are identified by Guba and Lincoln (1994, pp 105-109), research frameworks determined by different ontological, epistemological and methodological assumptions: positivism, post-positivism, critical theory, and constructivism. For the multiple, qualified, underdetermined entities that are the focus of this thesis, constructivism seemed to me to be the only useful approach (Guba & Lincoln 1994, pp 109-110; Pidgeon 1996, p 85; Charmaz 2002, p 678). Considerable academic debate has been generated around the fundamental tensions between empiricist modes, and ways of working and knowing that recognise and integrate the socially constructed nature of whatever we call "reality" (for example, Latour & Woolgar 1979; Latour 1987; Burawoy 1998; Feenberg 1999; Hacking 1999; Yearley 2005). This thesis, however, deals not with questions of scientific knowledge but with the hypothetical futures conjectured about the development and application of such knowledge – inherently unprovable, speculative 'conjurations' (Sunder Rajan 2006, p 34). Furthermore, as outlined in Chapter Two, the meanings and value of anticipated benefits from technoscience are inevitably situated and conditioned by the ideological frameworks and power relations of the actors advancing them (Latour

[78] The interconnectedness of benefits and problems is discussed in Chapters Three and Seven.

1996, pp 169-170; Gieryn 1999, p 27). In my view, a relativist ontology is the most practical way to deal with such shifting, partisan, Protean terrain (Guba & Lincoln 1994, p 113; Rappert 1999b, p 708).

The methodological field of constructivist grounded theory offers an approach that accommodates these complexities (Charmaz 2003, 2006, 2009). Developed in response to the implicit positivism of "classic" grounded theory methods – presuming an external reality awaiting discovery, and a neutral, detached, objective observation process where solid "facts" are separated from values – this approach recognises that the phenomena being studied and the researcher and other actors involved in the process are situated within and shaped by their contexts and belief systems (Charmaz 2002, p 677; Timmermans & Tavory 2007, p 500; Charmaz 2009, pp 137-141; Charmaz & Bryant 2011, pp 292-293). Meaning and methodological strategies are also acknowledged as constructions, outcomes of ongoing interactions between the researcher and the research material (Pidgeon 1996, p 75; Bryant & Charmaz 2007, p 10; Mruck & Mey 2007, pp 525-526).

A constructivist framework requires attention to the ways the project is affected by the researcher's background and experience, knowledge of the topic area and the field, professional and scholarly practices, values, beliefs and perspectives (Suddaby 2006, p 640; McGhee et al. 2007, pp 8-9; Mruck & Mey 2007, pp 518-519). These dimensions of the researcher's life influence both the approach to the topic and issues under consideration, and expectations of the research process itself (Clarke 1990, p 15; Pidgeon 1996, p 83; Warren 2002, p 97). Bourdieu (2004, p 89) insists on reflexivity in social science as 'epistemological vigilance', a central part of the researcher's habitus and modus operandi. Dismissing 'the illusion of the absence of illusion, of the pure, absolute, "disinterested" point of view', Bourdieu advocates a comprehensive process of 'objectivation' of researcher and research activity as embedded in their social, scholastic and disciplinary contexts (2004, p 94). Such reflexivity can be valuable in the research process:

> [E]xperience linked to one's social past can and must be mobilized in research, on condition that it has previously been submitted to a rigorous critical examination… It allows one to understand the game instead of undergoing it or suffering from it… [A]ny social experience… can be converted from a handicap into capital, so long as it is mastered through analysis (Bourdieu 2004, pp 113-114).

With this thesis, the ongoing obligations of reflexivity highlight many ways in which the research has been influenced by me as the researcher. As explained in the Prologue, my professional background includes seven years with a parliamentary agency investigating and advising on environmental management issues, where every day demanded delicate negotiation through diverse, often conflicting perspectives, agendas and versions of reality. My approach to this thesis was also informed by my earlier academic work in English literature, where my Masters' thesis on Chaucer's *Canterbury Tales* dealt with the rich, often intensely ironic interactions between the different pilgrims' stories and personalities.[79] Also relevant were my years involved in the media and marketing and public relations industries, where I became acutely aware of the ways meaning and perception can be manipulated to satisfy particular interests and perpetuate particular worldviews. These experiences have given me a strong personal affinity for the principles encapsulated in constructivism, as a practical way to engage with the world's multiplicity and complexity. And they have left me with a deeply sceptical distrust of the simplistic and the taken-for-granted (Foucault 1980, 1994; Powers 2007).

Another significant factor in the evolution of this thesis was that my previous academic experience was in literature, history and classics, rather than social or political science, or the natural or physical sciences. Prior to this thesis, my knowledge and familiarity with such science fields was acquired *in situ*, working in various roles in policy, advocacy and environmental management. This lack of formal training in either mode of science has, however, given me some distance from the disciplinary habitus and assumptions of the fields which I am studying and in which this thesis is located. At times this "outsider" position has seemed a handicap; more often though it has been an advantage, giving me a relatively pragmatic

[79] Cooper, R 1985, *Lowsy Jogelours: Art and Craft in Chaucer's Canterbury Tales*, MA thesis in English, Victoria University, Wellington.

perspective in my encounters with technoscience actors and my analysis of their framings and representations of their work.[80]

The concept of 'empathic neutrality' allows for recognition of the researcher's personal history, objectives, beliefs and framing assumptions while still retaining a non-judgemental, non-partisan stance (Patton 1990, p 41). The intensively contested nature of the two fields explored for this thesis – wind energy and GM – highlighted the importance of ongoing attention to my own values and assumptions. In some of the interviews and other discussions as the research developed, people took for granted that I would have either positive or hostile views about windfarms or GM. Not surprisingly my personal views about the various potential applications of these technologies are contingent, ambivalent, endlessly qualified and continually shifting. My inability to adopt a solidly "pro" or "anti" position – or my acceptance of indeterminacy as a practical working position on such questions – has been challenging at times in my interactions with some research participants. However, such partisanship is the subject of this thesis, not its raison d'etre.

A key aspect of reflexivity is a focus on the intended purposes of the research. Some approaches, such as 'critical theory' or 'action research', have the explicit aim of transforming existing situations, policy and practices through trenchant critique and strategic interventions (Guba & Lincoln 1994, pp 109, 112; Cassell 2005, pp 169, 171). Such objectives must be predicated upon judgements of the inadequacies or iniquities of the status quo, and confidence that the alternatives promoted through the research are achievable and desirable. In the shifting terrain of technoscience benefit projections, dealing with reifications of abstract, conditional future states, I felt increasingly that any such certainty would be pure hubris.

With a constructivist approach, the aims of inquiry are more modest – not to advance any particular agenda, but to develop understanding of the multi-faceted, situated nature of the phenomena under scrutiny, and to formulate 'more informed and sophisticated constructions and [more awareness] of the content and meaning of

[80] The implications of interviewees' perceptions of my status as an "insider" due to my experience in the Wellington bureaucracy, or an "outsider" with no formal science background, are discussed below.

competing constructions' (Guba & Lincoln 1994, pp 112-113). Winner (1993, pp 367-376) advances a fierce critique of constructivism, arguing that focusing attention on the diversity of meanings and interests in technoscience results in an evasion or abdication of responsibility in relation to crucial moral and political questions. However, other scholars have endorsed the usefulness of improving understanding of such dimensions. Rappert (1999b, p 708) highlights the importance of social science research providing actors with 'concepts and analytical frameworks [and] aiding in the identification of problems hitherto marginalised'. Wynne (2007, pp 493-496, 500) dismisses supposed boundaries between instrumental STS work, intended to influence policy in particular directions, and more 'reflective cultural critique'. Sceptical investigation of the taken-for-granted frameworks of meaning, expectation and enculturation in technoscience domains is valuable and valid academic activity – both in itself, and in terms of the complementarity of such analyses with more targeted policy-oriented projects. An ongoing long-term agenda for STS is to encourage awareness of and reflection on such deeply entrenched patterns in science and technology, as the basis from which change might evolve (2007, pp 492, 496, 500-501). Wynne highlights the open-endedness necessary in such a mission:

> [T]his alternative witness does not point to alternative completed forms of policy or social order; but as a matter of principle only to questions, and cues – openings, not final forms (2007, p 500).

In this thesis, the aim of my exploration of the normative and performative work of benefit claims for innovation in GM and electricity generation in New Zealand is not to promote specific benefits, value frameworks or paradigms for technoscience. The analysis of benefit projections in these fields are intended to be useful as 'witness to those larger historical-cultural issues and challenges that need to be recognized and addressed' (Wynne 2007, p 496).

Sites of inquiry

Innovation in the fields of GM and wind energy in New Zealand is promoted through a range of different kinds of anticipated benefit – public good goals in health and environmental quality, commercial returns for companies and organisations, and improvements for the national economy. The heterogeneity of benefit projections associated with these technologies is paralleled by the fields' complexity and richness as promiscuous assemblages.

In exploring claims of future benefits for GM and wind energy, this thesis follows the principles established in studies of the social construction of technology, to consider the diverse physical artefacts, actors and institutions, practices and mindsets, discourses and policies that constitute the sociotechnical networks of each field (Bijker & Law 1992a; Bijker 1995). But my focus is on the paradigmatic dimensions – the meanings and values associated with innovation in these two fields in New Zealand – rather than on networks *per se*. Actor Network Theory is a valuable tool for analysis of technoscience processes and the relational aspects of knowledge production and technology use (for example, Callon 1987; Latour 1987, 1992; Law 1992).[81] As the thesis evolved, however, I concluded that this theoretical framework was less suitable than constructivism to address the dimensions of benefit projections that I found most compelling.[82] Nevertheless some key concepts of Actor Network Theory were valuable in developing my approach – for example, the importance for technoscience projects of aligning with powerful interests, and artefacts' vulnerability when network support fluctuates (Latour 1996).

As domains or sites for investigating benefit projections, GM and wind energy technologies in New Zealand have multiple dimensions of significance. They are physical objects and practices in the world, as well as conceptual categories that encompass a range of interests, communities, meanings and values (Ragin 1992a, pp 8-10). These fields are empirically particular, firmly grounded in the specificity of their New Zealand contexts, but also serve as examples of broader technoscience processes with relevance for other situations, technologies and sectors (Walton 1992,

[81] Application of Actor Network Theory to questions of projected benefits of technoscience innovation would doubtless lead in interesting directions. There would be rich potentials for analysis of the interplays between the diverse actors and non-human actants in GM and wind energy – which might feature cows, proteins, laboratory equipment, field trial fences, the DNA configurations responsible for multiple sclerosis, possums, fungal diseases of vegetables, the bovine tuberculosis bacillus, chemical residues in soils, supermarkets, rural streams, turbines, lightweight metal alloys, meteorological forecasting technologies, transmission lines, household electrical appliances, and 4WD vehicles.
[82] Rip (1992, pp 261-262) considers that Actor Network Theory has limited usefulness for engaging with the influence and performative work of expectations in technoscience, arguing that ANT 'focuses on processes as if legitimations were irrelevant [and] neglects the search and expectation part of technology dynamics'.

pp 121-124). Studies of particular cases, stories and situations can be indicative of larger patterns (Ragin 1992b, p 225; Burawoy 1998, pp 5, 14-16). The conceptual model below (Figure 1) maps the degrees of specificity and generality in the analysis. GM and wind energy in New Zealand are the fields within which particular cases and examples are located – specific applications or forms of these technologies. Each case and example is supported by benefit projections, strategic constructions aligned with wider frameworks of societal and sectoral value. The nested, interlinking levels of meaning associated with the cases are in turn indicative of key aspects of the dynamics of technoscience processes.

Figure 1:

Technoscience field	*Genetic modification*	*Wind energy*
Case	GM crops	Wind farms
Example	Plant&Food Research's herbicide-resistant onions	Meridian's West Wind project at Makara
Benefit claims	Agronomic production efficiencies, profits for growers and agrichemical companies	Locally produced "green" electricity for the Wellington region, profits for the generator
Value frameworks	Appealing to economic interests of established sector groups and multinational corporations	Appealing to regional identity, NZ's international commitments, public environmental awareness and commercial profitability
Implications	Power of economic elites to exploit commercial potentials of R&D and override public concerns about GM foods	Power of increasing social and political recognition of climate change issues to improve acceptability of renewable energy technologies

Discussion of the interactions between these different levels is also informed by the principles of middle range theory, the focus of recent attention in science and technology studies (Wyatt & Balmer 2007). Theories of the middle range were originally advocated by Merton (1949 (2007), 1957) as a practical solution to what he considered to be extreme positions in sociological theory-making at the time, the orientation towards either 'production of descriptions or production of theories of everything' (Wyatt & Balmer 2007, p 621).[83] Middle range theory avoids ambitious

[83] Merton criticised the social sciences of the time for aiming for grand unified theories that would explain and accommodate 'all the observed uniformities of social behaviour, social organization, and

grand abstractions or untheorised empiricism (Rappert 2007, pp 693-694, 698).[84] It focuses on delimited sites and problems (Merton 1957, p 108; Weick 1989, p 521; Geels 2007, pp 628, 635), yet allows for conceptual flexibility and accommodation of diverse perspectives (Wyatt & Balmer 2007, p 623). Middle range research emphasises engagement with particular fields or societal situations (Merton 1949 (2007), p 452; Hine 2007, p 653; Wyatt & Balmer 2007, p 621), and encourages the development of theoretical insights with some relevance for practice (Geels 2007, pp 630, 646). As Rappert (2007, p 708) explains, the aim is to focus on:

> …the social and political commitments made in situations of uncertainty and disagreement… to initiate a line of sceptical questioning attentive to the contingencies of analysis that can provide a basis for further questioning of conventional claims.

The principles underlying the middle range approach resonate with this thesis's focus on claims about GM and wind energy in New Zealand, and with the research goals outlined in Chapter One – to develop understanding of the work of benefit projections, as a resource for further critical engagement with the worlds of R&D and technology innovation (Denzin 2001, pp 24, 43).

Within these frameworks of purpose for the thesis, the research activities entailed engagement with relevant literatures and primary documents, a series of interviews, and an analysis of these materials and information. These processes are the focus of the rest of this chapter.

Lost in a good book – the literatures and texts[85]

One of the most important dimensions of the thesis process, for me as the researcher, has been the opportunity to immerse myself in a wide range of literatures and texts. This contextualising of issues and information was not encouraged in my previous work in Wellington policy environments, where concepts and strategies were

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social change' (1949 (2007), p 448), a quest he described as 'extravagant… premature and apocalyptic' (1949 (2007), p 453). The alternative, where research focused down narrowly on the data itself, he found equally unsatisfactory and unproductive of meaningful theory: 'the opposing strategy of constructing inventories of low-level empirical propositions' (Geels 2007, p 628).

[84] The principles of this research framework are not dissimilar to Austrin and Farnsworth's (2005, p 161) interpretation of Latour's methods and aims as a 'relativist sociology' deliberately avoiding the 'pretensions' and presumptions of theory-making.

[85] With apologies to Jasper Fforde.

advanced and deployed in technoscience domains without any reference to what scholars like Bourdieu, Bijker, Kuhn, Latour, Sarewitz or Winner might have said about them. The requirements of thesis reading have been a wonderful luxury.

A key issue in the development of Grounded Theory methodologies is the relationship between the empirical data and relevant literature. Debate about inductive methods has focused on the deferral of reference to theoretical and analytical literatures to avoid 'forcing' the analysis and to allow unprejudiced 'emergence' of interpretation from the empirical data (Suddaby 2006, pp 634-635; Bryant & Charmaz 2007, pp 16, 25; McGhee et al. 2007, pp 3, 8; Mruck & Mey 2007, p 518). However it is argued that such purist methodological ideals are unrealistic; reflexivity acknowledges the researcher's situatedness and experience informing inquiry from the outset (Charmaz 2004, p 501; Timmermans & Tavory 2007, p 499). Early familiarity with relevant literatures is important to clarify and guide developing research pathways without committing to any particular theoretical position (Henwood & Pidgeon 2006, pp 349-350; McGhee et al. 2007, pp 4-8). As Bryant and Charmaz (2007, p 20) advise, 'an open mind does not imply an empty head'.

The grounded theory method is an iterative process, moving between the established literatures and the accumulating research materials, between the theoretical and empirical dimensions (Henwood & Pidgeon 2006, p 347; Suddaby 2006, p 639; Timmermans & Tavory 2007, pp 499-500). This kind of symbiotic mix was an efficient tactic given the exploratory nature of my investigation. In practice, I followed parallel trajectories – weaving together the work of interviews and transcript analysis, immersion in science and technology studies and associated literatures, and surveys of the vast range of primary materials from relevant agencies and science institutions.

The practicalities of analysis involved an ongoing sequence of distillations of the ever-expanding materials. The initial reviews of the interview transcripts and primary texts identified basic patterns in the framing of expectations of technoscience, highlighting issues or constructs that reappeared in numerous locations. Moving back and forth between the interview transcripts and the primary documents focused attention on frequently-occurring phrases and concepts, and on the links between these patterns and the institutional and policy-agency sites in which they are manifested. Categories and themes identified in this process included: the powerful influence of economic growth and competitiveness (the Red Queen imperative) as drivers for R&D and innovation; the importance of environmental sustainability; the value placed on advancing scientific knowledge as a benefit in itself; the symbiotic mixing of commercial and public benefits, whether in aspirations for pharmaceutical innovations, pest control technologies, or green energy generation; and the persistence of the deficit model in various forms in interactions between sector actors and others around the presumed benefits of technoscience and innovation.

Simultaneous reading in the STS literatures offered theoretical frameworks to help explain the situations unfolding in the New Zealand technology stories. For example, immersion in Bourdieu (Bourdieu 1990, 1999; Webb et al. 2002; Bourdieu 2004; Grenfell 2004) at the same time as interviews with senior ministry officials was useful in understanding the dynamics of those interactions. Some of the sector actors I interviewed made valuable recommendations; a biotech research scientist loaned me Franklin's *Why Innovation Fails* (2003) and expanded on its themes in relation to New Zealand R&D. And a venture capital manager investing in local technoscience startups insisted I read Christensen's (1997) work on radical innovations; this cast light on patterns of wind technology uptake in the New Zealand electricity sector.

The key concepts from the primary material and the literatures were developed and refined through an extensive process of annotating the margins of interview transcripts, writing notes, memos and outlines, and building lists of references.[86] Large sheets of paper were filled with increasingly complicated mind-maps to diagrammatically explore the distribution and inter-connections of themes, and to organise the primary research material within theoretical frameworks derived from the academic literatures.[87] These notes and mind-maps were transformed into the tentative structuring of lines of argument, and eventually the outlines of chapters. The

[86] I chose not to use computer programmes (such as NVivo) for this process. By the time such tools were available to me, I had already advanced significantly through the analysis, and repetition of this work for the sake of a transition to electronic methods did not seem efficient.
[87] When working on investigations of complex issues at the Office of the Parliamentary Commissioner for the Environment, such analytical exercises regularly covered whiteboards with intricate detail, and were known as "horrendograms".

discipline of selection has been a major challenge throughout; there are a wealth of interesting and important questions to be explored in the domains of GM, wind energy, technoscience and innovation in New Zealand, some of which are indicated in Chapter Eight. The focus on constructs of expected benefit, and their performative work in these domains, anchored the research process.[88]

The academic literatures canvassed for this thesis have been outlined in the preceding three chapters. I found it valuable to spread the net widely, to gather insights, ideas, arguments, cases, models and theoretical frameworks relating to science and technology and innovation generally, GM and wind energy in particular, and governance, policy, politics, social construction, history and philosophy in these domains. The specific literature on technoscientific expectations was a major focus (notably, van Lente 1993; Brown et al. 2000a; Sturken et al. 2004), but I also found crucially salient material in more general studies. The literatures on the two fields of inquiry were interesting for their differences: there is an exponentially greater amount of commentary, analysis and debate on GM than on wind energy. Furthermore much of the work on GM is marked by the partisanship characteristic of this field and its intensely contested politics, focusing around matters of risk, safety and public engagement. Selectivity was necessary, particularly in the GM area.

The range of texts accumulated as primary data for the thesis (along with the interview data) is almost as diverse as the academic and theoretical materials. I concentrated on New Zealand texts produced by agencies and organisations involved in science and technology generally, and GM and wind energy specifically; some international examples were also included in the analysis. The texts include policy documents and official strategies, legislation, politicians' speeches, conference presentations, website materials, media releases, annual reports, statements of intent,

[88] Ideas and issues that are interesting but not directly relevant to my topic are indicated in footnotes. Many themes or strands of academic analysis were interesting in their own right even though I found them to be only peripheral to the issues addressed in this thesis: for example, explorations of the complexities of technoscience networks, whether framed within Actor Network Theory or other conceptual frameworks (for example, Hughes 1983, 1989; Ziman 2000; Law & Mol 2002; Hughes 2004); studies of communication and media treatment of science and technology (Nelkin 1995; Anderson 1997; Gregory & Miller 1998; Priest 2001; Cronin 2003a, 2003b; Gough 2003c; France & Gilbert 2005); discussions of apparent patterns of technological determinism (Winner 1977; Smith & Marx 1994); or histories of science and technology (Norman 1976; Mokyr 1990; Petroski 1999; Brown 2002; Gribbin 2002; Dugan 2003; Fagan 2004; Misa 2004; Hård & Jamison 2005).

regulatory agencies' evaluations and reports, court cases, promotional brochures and advertisements, and interpretational signage at windfarm sites.

When studying primary texts, a constructivist approach draws attention to multiple levels of significance and contextual relations (Guba & Lincoln 1994, pp 110, 113; Pidgeon 1996, p 80; Charmaz 2009, pp 138-139). The most obvious level of meaning is in the immediate content, but methodological theory also highlights the importance of texts' development, uses and functions, and strategic role in the fields in which they are deployed.[89] The primary texts from New Zealand technoscience sectors surveyed for this thesis are more than mere statements or accounts. Like the interviewees, texts are situated constructions, shaped by their environments and discursive frameworks, and oriented towards particular purposes and interests (Prior 2004, p 320; Motion & Weaver 2005, pp 50, 52-53; Atkinson & Coffey 2011, pp 78-80).[90] Texts can be understood as resources in social and sectoral processes and power relations (Leitch & Davenport 2005, pp 891-893; 2007, pp 44, 59; Prior 2011, pp 94, 96, 106). In terms of Bourdieu's theoretical concepts discussed in Chapter Three, textual representations in strategic fields are a kind of symbolic capital. In the often contentious domains of GM and wind energy in New Zealand, these aspects of the documents – their origins and intended roles in technoscience trajectories – are often highly salient. An obvious contrast might be an official national strategy, setting directions and goals for an entire sector (for example, New Zealand Government 2003, 2007), compared with advocacy statements from an industry lobby group or company (for example, New Zealand Wind Energy Association 2005; Meridian Energy 2005d; Orion Energy 2006; NZBio 2008b, n.d.).

Texts also function normatively, asserting and maintaining certain versions of reality in terms of the strategic ends for which they are produced and deployed (Atkinson &

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[89] Theorists in critical discourse analysis (CDA) give useful insights for engaging with such constructions and the frameworks underpinning them (Lakoff & Johnson 1980; Swales 1990; Fowler 1996; Gee 1996; van Dijk 1996, 1997; Jaworski & Coupland 1999; Fairclough 2001; Gee 2005; Woods 2006). In developing the research methodology for this thesis, I did not consider that the strong text-focus and specific methods of CDA would be practical; however the broad principles of CDA (such as scepticism, recognising contexts and situatedness, and following power) are consistent with my approach and were influential in my more thematic interpretation of the work of benefit projections.
[90] The originators of Grounded Theory, Glaser and Strauss, describe documents as equivalent to human research participants (Prior 2011, p 94).

Coffey 2011, pp 78-79). Foucault (1972, p 54) describes the creation of meaning via 'practices that systematically form the objects of which they speak'. As Prior (2004, pp 321, 325) observes:

> …a text instructs us how to see the world, how to differentiate the parts within it, and thereby provides the means by which we can engage with the world… [discourse] restricts, limits and arranges what can and cannot be said about the phenomena within its domain.

The textual materials surveyed for this thesis demonstrate the particular frameworks of value and meaning supported by their representations of GM, wind energy, technoscience and innovation. Whether aiming to perpetuate dominant, established social and sectoral interests, or to challenge and oppose such hegemonies and promote alternatives, the primary texts circulating in technoscience fields in New Zealand are never neutral. The following chapters of this thesis, looking into the stories of GM and wind energy and the benefit claims advanced for them, show the performative nature of documentary representations and discourse in these sectors (Weaver & Motion 2002, pp 326-328, 339; Henderson et al. 2007, pp 10, 13-14, 28; Davenport & Leitch 2009, pp 943-947). Texts work to position these innovations as favourably as possible, to legitimate them and align them with the priorities and interests of influential groups – or conversely, to diminish their credibility and desirability in arenas of public and sectoral perception.

In the survey and analysis of diverse texts for this thesis, there was often a numbing repetitiveness in the framings and statements – even the specific wordings – about GM, wind energy and technoscience and their projected future benefits. The same concepts appeared over and over again, particularly in official policy documents.[91] While this created some difficulties, in terms of a tension between efficiency in multiple citations and faithfulness to the empirical materials, I found these patterns in the documents to be useful in themselves. They confirm the prevailing habitus or paradigmatic frameworks governing activity and orientation in these sectors, discussed in Chapter Two (Green et al. 1999; Bourdieu 2004; Dattée & Weil 2007; Vanloqueren & Baret 2009). The repetitions demonstrate these texts' embeddedness in social and political domains.

[91] Leitch and Davenport (2007, p 46) describe these texts as 'highly formulaic'.

The next section turns to my engagement with the human actors who produce these documents, and the ways in which the interviews conducted for this thesis sought to develop a deeper appreciation of the ideas “between the lines” of the texts – the concepts of expected benefit that justify and motivate technoscience in New Zealand.

Let’s give ‘em something to talk about – the interviews[92]

At the centre of this thesis are the people engaged in R&D and innovation, the institutions and firms in which they work, and the beliefs and values they hold about their activities and the purposes of that work. These frameworks are expressed, explicitly and tacitly, in documents and formal discourse, as discussed above. But to grapple with the complex subjectivities of actors in the fields under scrutiny, the most effective method is the interview.

The individuals targeted for interviews for this thesis were identified because of their leading positions in the fields of wind energy and GM and in New Zealand science and technology policy. They represent a range of institutional and professional situations, and are all to some degree expert “insiders” in the GM and wind sectors and the wider technoscience community in New Zealand. Given the exploratory approach of this thesis, I decided the most practical method was to canvass the thinking and experience of active, established participants in these domains.[93] Research via “expert interviews” or “elite interviews” is an efficient means of probing the workings of specialist communities or sectors, and the power relations and hegemonic systems of value and meaning through which they function (Odendahl &

[92] With apologies to Bonnie Raitt.

[93] Broad surveys of public attitudes towards science in general and particular technological developments such as GM and nanotechnology have been conducted from time to time by official agencies and academic researchers in New Zealand (for example, Gamble et al. 2000; Coyle et al. 2003; Hunt et al. 2003; Cook et al. 2004; Cook & Fairweather 2005; Ministry of Research Science and Technology 2005c; Cook & Fairweather 2006; Hunt & Fairweather 2006). These studies offer useful insights, but take a different approach from this thesis in their presentation of technoscientific innovation and the presumed benefits, and of publics and their positions, as relative “givens”, evaluated via detached, neutrally objective methods (Burawoy 1998, p 12). Some studies delve into some dimensions of respondents’ demographics and general beliefs and values, and relate these contexts to positive or negative attitudes towards new science and technology applications. However in this thesis I have taken a more interpretative approach to explore the construction and performative work of expectations of technoscientific benefit within the specialist sectors and New Zealand policy fields.

Shaw 2002, p 314; Conti & O'Neil 2007, pp 65, 67; Bogner et al. 2009, pp 2, 6; Bogner & Menz 2009, pp 47-48, 52).

New Zealand's technoscience communities are fairly small, and the choice of technology fields for study in the thesis determined the logical targets. I sought interviews with individuals at the most senior levels of their organisation – chief executives, chairs or board members, science programme leaders, policy managers – and with senior researchers, project managers and practitioners actively working on new developments in their fields. Nobody approached for an interview rejected my request to meet with them; indeed, the process was remarkable for my interviewees' generosity in making time to talk about the ideas of benefit driving their work.[94] This availability is somewhat at odds with some of the methodological literature on researching elites, where difficulties in gaining access, and tight time constraints, are highlighted (Odendahl & Shaw 2002, pp 299-300, 305-309; Conti & O'Neil 2007, pp 67-71). Sector actors' willingness to be involved may be partly attributable to perceptions of my background, as discussed below; with many there was simply a genuine enthusiasm for their field, and for an opportunity for in-depth discussion of the ideals motivating their work.

The range of interviewees covers the two technoscience sectors and the background environment of policy and regulatory institutions in New Zealand. Sixty individuals were interviewed.[95] Twenty-one were involved in GM research, policy, regulatory oversight or biotech industry development. Twenty-three were engaged in wind generation and alternative energy, in policy and regulatory roles, sector advocacy, researching new energy options, or managing windfarm projects. Sixteen interviewees' interests and experience in technoscience were more generic, including policy analysis and advice, managing R&D funding (both from government agencies and private investment firms), communications and business development.[96] There

[94] Some interviews were restricted according to busy executives' diaries, but even the briefest of these was an hour long. Other sessions were extended, wide-ranging discussions taking several hours.
[95] Only thirteen of these were women, perhaps reflecting the gender imbalances typical of science and technology (Cronin & Roger 1999; Etzkowitz et al. 2003; Ellemers et al. 2004; Blickenstaff 2005; Etzkowitz et al. 2008). However these individuals had achieved high status in their fields, and included the Chief Executive of a government ministry, the former Chairperson of the Board of a large energy company, and senior managers in regulatory agencies and research institutions.
[96] Since the interviews were conducted, some interviewees have moved on from the roles they occupied when I met with them, and many of the official agencies have been restructured.

was considerable overlap, with many interviewees targeted primarily for their expertise or position in a particular sector commenting freely on wider issues of science and technology and future potential benefits from innovation.

The range of organisational and institutional locations of the interviewees reflects the diversity of the two sectors and New Zealand's science and technology communities. The agencies and businesses from which interviewees were drawn include: policy ministries (MORST, MFE, MED), and other government agencies (FRST, EECA, AHB, FSANZ); parliament (PCE); regulatory agencies for the two technology fields (ERMA, the Electricity Commission); organisations working to advance a particular sector or perspective (Royal Society of NZ, NZBio, Horticulture NZ, Canterbury Manufacturers' Association, Canterbury Employers' Chamber of Commerce, NZ Green Party); Crown Research Institutes (AgResearch, Crop & Food, Landcare Research, Industrial Research); universities (Auckland, Canterbury, Victoria, Massey); large electricity companies (Meridian Energy, Orion Energy, Mainpower); smaller alternative energy systems companies and consultancies (including Windflow Technology and Energy3); and representatives of venture capital investors in technoscience innovation.[97]

Selecting and contacting potential interviewees was a sequential process. The first set of conversations, scoping out the research topic, was conducted with a few key individuals in science and technology policy agencies. Subsequent interviewees were approached because they occupied key positions in New Zealand R&D and technoscience domains; some were specifically recommended to me in a "snowball" process. Several interesting connections occurred spontaneously in the best tradition of scientific serendipity, through encountering people at conferences, or as fellow participants in strategic processes such as the Navigator Network, a futurewatch project organised by the (then) Ministry of Research, Science and Technology (MORST).[98] All interviewees were approached on the basis of their capacities as

[97] The interview schedule is given as Appendix 1.

[98] At the time of my research interviews, the Navigator Network was actively pursuing a wide-ranging scanning process of emerging technoscience developments with relevance for New Zealand (Cameron et al. 2008). Close involvement of scientists with key policy agencies and representatives of sectors such as health, agriculture and environmental management was intended to focus attention on science and technology issues "coming over the horizon". Subsequently, in the merger between MORST and FRST and the more recent restructuring of the Ministry of Science and Innovation, the Navigator

spokespersons for their organisations and their professional experience and knowledge of their fields.

My former status and experience at the PCE office (discussed in the Prologue and above) was a significant asset in organizing interviews – in Bourdieu's terms, my background in policy worlds was crucial symbolic capital (Bourdieu 2002, pp 289-291; 2004, pp 34-35, 58-59). This was advantageous in terms of my existing networks; twelve interviewees were already well known to me.[99] With interviewees I had not met before, being able to introduce myself and my research in the context of my earlier role as a Wellington "insider" was often important in establishing credibility and smoothing the approach to senior executives and policy managers. My Wellington work had also given me considerable experience in "cold-calling" – the process of contacting complete strangers, negotiating with personal assistants and other gatekeepers, and efficiently introducing myself and the topic under investigation. Sensitivity and skill in such aspects of research processes are highlighted in the methodological literature (Odendahl & Shaw 2002, p 305-308; Conti & O'Neil 2007, pp 69-70; Stephens 2007, p 206).

Each interviewee was emailed a brief introduction to the thesis research, well in advance of our scheduled meeting.[100] This explained the focus on anticipated benefit from technoscience innovation, and outlined the range of questions informing my investigation. Few interviewees followed the list of questions very closely. Each discussion was unique; I chose to allow the conversations to follow their own natural course rather than attempt to impose an arbitrary structure or formal sequence of questions (Charmaz 2002, p 679; Odendahl & Shaw 2002, pp 310-311; Conti & O'Neil 2007, p 70).[101] Nevertheless, most interviews ended up covering the full range of themes posed in the introductory email.

Network is no longer operational and futurewatch activities have been 'put on hold' (advice from MSI Communications section, 28 March 2012).

[99] I had already had extensive involvement with most of the researchers working on possum biocontrols through the PCE's *Caught in the Headlights* study, discussed in the Prologue and Chapter Five (Parliamentary Commissioner for the Environment 2000).

[100] This is attached as Appendix 2.

[101] Another personal advantage I enjoyed in undertaking this research was the extensive experience I had gained interviewing people in a range of contexts for investigations undertaken by the PCE Office. Each PCE study involved an exhaustive information- and opinion-gathering process, taking project teams into various settings from executive boardrooms and Ministerial offices through to marae

All the interviews were conducted face-to-face, giving maximum opportunity for interaction and spontaneity, and for sensitivity to the tacit, non-verbal dimensions of the interactions (Burawoy 1998, pp 7, 15; Stephens 2007). While many interviewees were based locally in Christchurch, Lincoln and the Canterbury region, the research took me throughout New Zealand for meetings in policy and corporate environments in Wellington, and offices, labs and wind energy sites in Auckland, the Waikato, Palmerston North, Otago and rural Southland.

I found that a relatively loose semi-structured interview process was effective given that the research topic – concepts of benefit expected from technoscientific innovation – is territory that had not yet been specifically traversed amongst New Zealand science and technology communities. The exploratory nature of my inquiry meant that I adopted an interpretative interview approach, with the goals both of obtaining information and of traversing the views and experiences of each individual (Warren 2002, p 83; Bogner & Menz 2009, pp 46-48). An organic, open-ended format in each discussion meant that the flow of ideas was more spontaneous and natural, reflecting the concerns and priorities of each interviewee (Pidgeon & Henwood 1996, pp 89-90; Charmaz 2002, pp 676, 678-681; Warren 2002, pp 86-87; Stephens 2007, p 206). Some interviewees made considerable digressions, some of which were extremely revealing and entertaining. Some of these apparent digressions were in fact useful for the thesis inquiry, although they could never have been anticipated in advance in the form of a structured question.

Most interviews began with an initial explanation of the focus of my research, and an opening query about the interviewee's work. After these preliminaries, the talk was invariably sustained by interviewees' enthusiasm for their particular branch of science or technology, and for the potentials and opportunities it offered. Conversations with active practitioners – scientists researching GM and engineers working on alternative energy technologies – were full of rich technical detail. A biocontrol research

kitchens, farm paddocks, industrial plants, schoolrooms and protest sites. The role required engaging with an incredible mix of people, encouraging them to tell their stories and share their ideas, often in situations of intense conflict and controversy, where suspicions ran high and resolution was uncertain. That experience was invaluable in the thesis process.

manager at AgResearch in Invermay showed me through the enclosures where captive possums roosted in fragrant pinetree cuttings, and opened a freezer to display the grisly remains of sparrows and joeys as proof that possums are carnivorous. The site manager at a Meridian windfarm, under construction at the time, spent a whole afternoon driving me up and over steep ridgelines in his 4WD ute, and walking me around the massive concrete foundation structures to show me the giant turbines in various stages of installation.

In all the interviews, when time was running out or the discussion drawing to a natural close, I finished with the same open-ended question: 'In the best of all possible worlds, what would be your vision for your technoscience field, and for science and technology generally, for the future?' The responses were often fruitful in allowing interviewees to stretch their imaginations and build personal scenarios; ideals of societal, qualitative public-good benefit came strongly to the forefront, and the economic criteria often dominant in many interviewees' professional and sectoral value-frameworks faded into the background.

Many interviewees expressed appreciation of the opportunity to talk about the goals and purposes of their work, and to explore the issues posed by my research focus; they welcomed a chance to consider aspects of their work that are seldom directly addressed, and to come at things from a different perspective (Conti & O'Neil 2007, pp 73-74). There was a strong sense that, while the frameworks of value and benefit underpinning particular fields are powerful motivations both individually and for professional communities, there are few places where these dimensions of technoscience can be acknowledged, explored and discussed. Furthermore, given the contested, controversial nature of both GM and windfarm developments and the vehement opposition encountered by most R&D teams, there was for some interviewees almost a sense of relief that a social science researcher was focusing not on the conflicts and risks but on the intended benefits.

The intensely polarised, adversarial nature of GM science influenced my interaction with some individuals in this field, who assumed that my research must be based in either a pro- or anti-GM stance. Some spoke with considerable bitterness about what they perceived as public and media misinterpretation of the ideals and beneficent purposes driving their work, shifting into implicit lobbying mode in the hope that, because it was addressing technoscience benefits, my thesis would "take their side" in ongoing debates.[102] I dealt with such enlistment efforts by maintaining neutrality in the flow of the discussion, on the principle that downplaying my own position (or lack of it), and giving priority to the interviewee, would allow maximum openness for them to express their particular perspectives (Conti & O'Neil 2007, pp 74-77).

As well as assumptions of partisanship, some interviews were marked by the power dynamics inherent in those actors' elite status in their sector. This occurred in meetings with individuals working in GM, a field marked by major contestation and defensiveness, but also in some general technoscience and policy interviews.[103] These patterns seemed habitual in those experts' interactions with "outsiders" or laypeople, and were manifested in displays of authoritativeness, patronisingly simplistic explanations of science or regulatory systems, and judgements based in the Deficit Model of science communication. A few interviewees tended to lecture me, delivering generic "scripts" about their work and their field, obviously familiar discursive tactics intended to override controversy and assert authority and "expert" status (Stephens 2007, p 208). Issues of power in the interview situation have been analysed in terms of the relationships between researcher and subject and the implications for the evolving discussion (Burawoy 1998, pp 7, 22-23; Odendahl & Shaw 2002, pp 310-311; Cassell 2005, p 170; Conti & O'Neil 2007, pp 67, 71-73; Bogner & Menz 2009, pp 68-69). However, basing my research in a constructivist approach enabled me to observe such demonstrations as research material in themselves, interesting rather than offensive, revealing the characteristic habitus of some technoscience elites. As Denzin (2001, p 25) explains: 'the interview functions as a narrative device which allows persons who are so inclined to tell stories about themselves'.

[102] Despite equally intense controversy around windfarm proposals, discussed in Chapter Five, these patterns and assumptions that the thesis would take an advocacy position were not evident in any of the wind energy sector interviews.

[103] Some interviewees assumed that because I am not formally trained as a scientist, I would have little knowledge or understanding of technical matters, R&D processes, or issues such as risk or environmental effects.

Many other interviews, however, were meetings of equals where dialogue flowed with natural spontaneity, and mutual recognition of key issues was marked with considerable irony and humour. Such rewarding discussions were not only with interviewees whom I already knew; many "cold-call" meetings produced lively and highly productive interactions. While these sessions were more creative, all the interviews were shaped by interaction effects (Charmaz 2002, pp 677-678; Warren 2002, pp 83-84; Cassell 2005, pp 168, 176; Bogner & Menz 2009, pp 45, 55-57). The flow of semi-structured discussions, and the immediacy of face-to-face meetings, allowed maximum attentiveness "in the moment" to the thinking and personality of each interviewee in their engagement with me as the researcher and with my topic.

The interviews were conducted primarily in 2006 and 2007. However due to unforeseen interruptions that necessitated time out from the thesis work – including illnesses, surgery and long months on crutches, family crises and funerals, and the disruptions of the Canterbury earthquakes – the analysis and drafting were completed between 2010 and mid 2012.

The focus of my thesis on questions of professional and sectoral interest, and the choice of interviewees who were spokespersons for their organisations, meant that the research was exempt from the formal requirements of the University of Canterbury's Human Ethics Committee.[104] Nevertheless it was agreed in advance with each interviewee that a complete transcript would be emailed to them so they could review, amend or remove any comments they might reconsider, and make any additions they wished. This reflected the interactive principles of co-constructive knowledge generation underpinning my research approach, and demonstrated respect for the professional situations of the interviewees in their institutions and fields (Odendahl & Shaw 2002, pp 313-314; Warren 2002, pp 88-89; Charmaz 2004, p 504). All interviewees were comfortable with this arrangement. Some did edit their transcripts, usually to tone down comments made in strong or colourful terms. Subsequent to the

[104] Under the University's Human Ethics Committee's 2004 policy and guidelines (part 4) the principles for research include informed and voluntary consent, and respect for rights of privacy and confidentiality. Part 3 of the regulations provides for exemptions from the more formal consent requirements for interviews, when (3(b)) the interviews are conducted with public figures or professional persons in the areas of their duties or competence, and (3(f)) when the research involves case studies of business organisations and institutions and does not involve gathering personal information of a sensitive nature about or from individuals.

interview process, it was agreed in discussions with my supervisors that, further to these agreements with the interviewees, it would be appropriate to maintain the anonymity of individual participants, to protect these actors' confidentiality and their positions in their sectors and professional communities (Odendahl & Shaw 2002, p 313). Accordingly the interview citations in Chapters Five, Six and Seven refer to individuals only in terms of their roles and fields.

All the interviews were included in the analysis process, but not all have been cited in the thesis. Some discussions merely confirmed ideas and experiences already powerfully articulated by others. Henwood and Pidgeon (2006, p 358) explain theoretical saturation as the point where additional material makes no further contribution to the analysis. Stern (2007, p 117) describes saturation as 'when the learner hears nothing new'. Some discussions are not specifically cited because they provided no information or ideas that were not already available in the published documents or policy of the institution or sector. Such patterns indicate the embedded nature of those interviewees in the habitus of their field, perpetuating the frameworks of value and assumption shaping thinking and orientation in the domain.[105] Some interviews have not been cited because, as the thesis evolved, those discussions proved less relevant than originally anticipated. As Stern (2007, p 118) explains, analysis of interview transcripts should develop interpretation rather than description; he recommends 'a search and seizure operation looking for cream in the data'. I trust that my interviewees will appreciate their position in the larger process, and my gratitude for their generosity in sharing their ideas and experience with me for this thesis.

Conclusion

This chapter has addressed the "how" and "why" of my investigation process. Given the rich heterogeneity of the two technology fields that are the sites of this study – complex networks of social, physical, technical, epistemological and teleological phenomena – a constructivist approach proved to be a practical way to accommodate the diversities I encountered "in the field". An open, exploratory methodology was

[105] Bourdieu's concept of habitus is discussed in Chapter Two.

adopted, following the principles of constructivist grounded theory. The research and analysis took their own shape as the material accumulated and the interpretation evolved. Insights and principles from other theoretical frameworks, including Actor Network Theory and middle range theory, were valuable in developing my approach to the issues around technoscience benefit claims, the tactics and business of undertaking the research, and my aims for the thesis and its usefulness to others engaging with science and technology.

Metaphors can be an efficient way to clarify experience (Lakoff & Johnson 1980). Denzin and Lincoln (2003, pp 4-11) describe the development of qualitative research methodologies as a strategic ‘bricolage’, combining different methods, techniques and traditions in a pragmatic response to ‘the specifics of a complex situation’. I have benefited from a wide range of academic studies – mainly analyses of technoscience and methods for social science research – as I constructed my own pathways through the thesis process. Gieryn (1999, pp 6-12) develops an extended metaphor of cartography to explain the ways fields are described and understood, and at times my research has felt like a map-making expedition through untamed jungles. However the creative dynamics of thesis work suggest also another metaphor offered by Denzin and Lincoln (2003, p 9): ‘researchers all tell stories about the worlds they have studied… the product [is] a performance’.

The next three chapters show this methodology in action, following projections of expected benefit as they justify and influence R&D and innovation in the domains of GM and wind energy in New Zealand.

Chapter Five

Gone with the wind[106]

Introduction

The introduction of wind energy in New Zealand since the mid-1990s illustrates the strategic framing of expected future benefits to promote technological innovation within an established sector. The benefits projected in support of wind energy include environmental, commercial, political, societal and technical outcomes associated with the interests and value frameworks of different groups, and with different forms or applications of the technology. Wind energy has been utilised in New Zealand in different ways by individual property owners, by small private companies developing modest stand-alone turbine systems, and by major State-owned enterprises building extensive industrial-scale generation facilities.[107]

Analysis of the social construction of technologies highlights the inevitable influence of the paradigms, expectations and power relations of actors and groups. Claims of benefit, positioning an innovation such as wind energy to appeal to powerful interests, are important strategic resources for proponents and developers, as discussed in Chapter Three. Projecting positive outcomes from a new technology justifies policy, commitment and expenditure, and helps break through the inertia of existing systems and assumptions (van Lente 1993; Latour 1996; Sarewitz 1996; Green et al. 1999; Brown et al. 2000b). Predictions of benefit also help counter controversy and opposition to innovation; wind energy projects in New Zealand and internationally have often met with fierce resistance from local communities and environmental groups (Ansley 2006; Parliamentary Commissioner for the Environment 2006a; Barry 2007; Smith & Klick 2007; Graham et al. 2009; Coddington 2010).[108]

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[106] With apologies to Margaret Mitchell, Clark Gable and Vivien Leigh.

[107] To date, the other technoscientific innovation addressed in this thesis, genetic modification, has only been used in New Zealand as a research tool in the lab or in contained field trials.

[108] Opposition is driven by a range of concerns, including: effects on landscapes, views, ecosystems and local communities (including property values); noise and low frequency effects; "flicker" effects from the shadows of spinning turbine blades, or "disco" reflection effects; impacts on bird life; and opposition to large commercially-driven developers and corporate control of electricity infrastructure (Asmus 2001, pp 137-142, 164-173; Parliamentary Commissioner for the Environment 2006a, pp 34-35, 40-61; Kaltschmitt et al. 2007, pp 344-347; Dawson & Spannagle 2009, pp 404-405; European

This chapter analyses the strategic and performative functions of benefit claims in the discourses around windfarms and wind technology in New Zealand. Two frameworks of projected benefit have predominated in the advancement of wind generation in New Zealand over the last decade and a half: environmental sustainability and commercial profitability.

The chapter traces the ways that expectations of wind energy are closely interwoven with environmental ideals. This may find expression in the independence of a small stand-alone turbine powering a remote lifestyle farm, in the branding and marketing of major corporations, or in the carefully negotiated provisions of a statutory amendment or government policy document. As a renewable form of generation, wind energy provides important additional "green" benefits as well as the basic product, electricity. Political and public recognition of the challenges of global climate change have strengthened the advantages of wind energy relative to fossil-fuel-based generation, and enabled wind technology's advancement by building support in political domains where its appeal to sustainability and inter-generational ethics translates into strategic advantage.

But wind systems also deliver a commodity product, electricity, and this chapter follows the dominance of frameworks of commercial benefit associated with one application of wind technology – large corporate-owned windfarms feeding electricity into the national grid. The evolution of technological innovation is inevitably shaped within the context of existing systems, processes and institutions, and wind energy in New Zealand has accommodated itself to established structures and expectations in the electricity sector. Other more radically innovative ways of using wind turbines, such as stand-alone systems or community-based distributed generation networks, are associated with other kinds of projected societal and environmental outcomes. These

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Wind Energy Association 2009, pp 329-335, 403-408; Fanchi 2010, p 169; Toke 2010, pp 20-21; Burton et al. 2011, pp 532-562). While protests against proposed wind energy developments raise interesting and important questions around citizen engagement with technology, and public participation in planning and decision-making for technological innovation (Bell et al. 2005; Devine-Wright 2005; Apt & Fischhoff 2006; Devine-Wright 2007; Hindmarsh 2010), such issues are not the main focus of this thesis.

modes of the technology have been relegated to secondary or marginal applications, or dismissed altogether in the New Zealand electricity sector.

Before turning to the detail of wind energy's introduction in New Zealand, the next section provides a brief outline of the evolution of this technology and its rapid global advance over the last three decades.

You'll be blown away[109]

Humans have harnessed the power of the winds to facilitate various tasks for centuries.[110] But wind energy is seen as an innovation in the late 20th and early 21st centuries because of this technology's significance in its social, economic, technical and political contexts. As well as the obvious differences – between wind turbines and other means of making electricity, or between a sleek contemporary turbine and a traditional windmill – the characterisation of wind energy as a "new technology" results from its representation, and the discourses, values and assumptions associated with it. Bijker (1995, p 6) recognises the importance of these contextual interconnections:

> [O]ne should never take the meaning of a technical artefact or technological system as residing in the technology itself. Instead, one must study how technologies are shaped and acquire their meanings in the heterogeneity of social interactions.

Analyses of electricity generation and transmission systems, such as Hughes' studies of large electricity networks (1983, 1989, 1994, 2004), show how their evolution is closely inter-related with wider frameworks of meaning and expectation, as the

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[109] This phrase closes Meridian Energy's 2012 television advertisements featuring dramatic imagery of the windfarm at Makara, Wellington; viewers are encouraged to visit the Meridian website and learn more about the advantages of wind energy and the company's focus on renewable generation.

[110] Windmills are a medieval technology, imported from the Moslem world, which became widespread across Europe in the twelfth century (Mokyr 1990, pp 45, 59-60; Asmus 2001, pp 25-26; Nelson 2009, pp 1-4; Ngô & Natowitz 2009, p 211). Wind was first utilised for electricity generation in the late 1880s when Ohio inventor-entrepreneur Charles Brush built a turbine with 144 rotor blades made of cedar wood driving a 12 kW generator (Asmus 2001, p 38; Danish Wind Industry Association 2003). Turbines were common in the US mid-West and California until the middle of the 20th century for pumping water and providing energy to farms remote from transmission networks (Asmus 2001, pp 28-32, 39-40; Nelson 2009, pp 2-5; Tubbs 2011, Chapter 4; Dodge n. d.). In Europe, turbine technology was developed from the turn of the 20th century to produce electricity for local authorities (Nelson 2009, pp 5-9; Ngô & Natowitz 2009, p 213). In 1904 the Society of Wind Electricians was founded and the *Journal of Wind Electricity* initiated by Danish engineer Poul La Cour (Danish Wind Industry Association 2003).

technology comes to: 'embody… economic, political, and social characteristics that it needs for survival' (1989, p 62). Vasi (2010, pp 11-14, 22, 30-32, 50, 192-193) identifies social norms and values and political support as critical for acceptance and uptake of an innovation such as wind energy. Other studies also highlight the diversity of perspectives and interests involved in energy technologies, and the complexities of change processes (Jacobsson & Johnson 2000, pp 630-633; Foxon et al. 2005, pp 2123-2125; Jørgensen 2005, pp 720-722; Bergek et al. 2008, pp 576-577; Sarewitz & Cohen 2009, pp 8, 22).

Such dimensions are recognised in discourse around the strategic development of New Zealand's electricity sector. The Energy Panel of the Royal Society of New Zealand (2006a, p 7) acknowledged the significance of factors such as economics, governance systems, and public and industry perceptions for the deployment of new technologies.[111] The need for integration of a range of considerations and community interests was highlighted by the Parliamentary Commissioner for the Environment (PCE) (2003b, pp 35-43; 2006a, pp 34-61, 109-117). The PCE's energy-sector advisor, interviewed for this thesis, summed it up:

> It's not so much the technology but also how it's applied, the context or the philosophy or the gestalt around it… it's the social construct that's around it as well (Interview 10, 16/8/2006).

The benefits projected from a new technology such as wind energy, the ways it is promoted, and the forms it takes, derive from and affirm these broader frameworks of meaning and value. Contemporary applications of wind energy technology have evolved since the 1980s in association with increasing awareness of environmental sustainability and constraints on the world's dependence on fossil fuels. The international wind energy industry has gone from strong growth through the 1980s and 90s to enjoy "hypergrowth" at the turn of the 21st century (Wüstenhagen 2006, pp 480-483).[112] With increases in global installed generating capacity averaging over 30% per annum since the mid-90s, the wind energy sector is celebrated as an exciting

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111 See www.royalsociety.org.nz . The Energy Panel of sector experts was established 'to provide scientific and technological leadership for a secure and sustainable energy future for New Zealanders and our economy' (Royal Society of New Zealand 2005, p 1).

112 Global generating capacity from wind technologies increased from 2.5 GW in 1992 to 94 GW in 2007 and 121 GW at the start of 2009 (Nelson 2009, p 10; Quaschning 2009, p 165; European Renewable Energy Council 2010, pp 98-99; Vasi 2010, p 4).

success story with enormous further potential (Parliamentary Commissioner for the Environment 2006a, pp 28-33; Ngô & Natowitz 2009, pp 216-219; Belhomme et al. 2010, pp 103-104; Maczulak 2010, pp 97-98; Vasi 2010, pp 4-5, 24-25; Lever-Tracy 2011, pp 68-70; New Zealand Wind Energy Association 2012, pp 10-11).

The rapid global spread of wind energy has been associated with incremental design improvements for both turbines and windfarms, which give increased commercial competitiveness (Asmus 2001, p 4; European Renewable Energy Council 2010, p 99; Junginger et al. 2010, p 73; Vasi 2010, pp 17-18; New Zealand Wind Energy Association 2012, pp 6, 15, 21). But support for and expansion of wind energy are more significantly due to this technology's strong positioning as a "green" way to produce electricity (Jacobsson & Johnson 2000, pp 625-627; Dawson & Spannagle 2009, p 400; Belhomme et al. 2010, p 104; European Renewable Energy Council 2010, p 95). The European Wind Energy Association (2009, p 309) outlines the merits:

> Wind energy is a clean and environmentally friendly technology… Its renewable character and the fact it does not pollute during the operational phase makes it one of the most promising energy systems for reducing environmental problems at both global and local levels… Wind energy… not only reduces emissions (of other pollutants as well as CO_2, SO_2, and NO_2), it also avoids significant amounts of external costs of conventional fossil fuel-based electricity generation.

The significance of these environmental advantages at this particular point in history is explored by Vasi (2010). He explains the "greening" of the global electricity industry in relation to recent decades' rising environmental awareness and activism. Highlighting the importance of alignment with government policy and with the interests and expectations of key groups (2010, pp 29-32, 50-51, 192-194), Vasi follows the evolution of wind energy as closely linked with societal and political recognition of climate change and pollution (2010, pp 13-15, 33-36, 187-188). Bergek and colleagues (2008, pp 581-582) describe the legitimation of renewable energy technologies as a process of 'changing problem agendas at the societal level [that] alter the weight of different performance criteria and the power of different arguments'.[113]

[113] The importance of climate change as a compelling imperative for change in energy systems both in New Zealand and internationally will be discussed in more depth in Chapter Seven. Acceptance and

The story of wind energy in New Zealand also reflects the influence of increasing public and political awareness of environmental issues over the last twenty years. Wind technologies advanced strongly in New Zealand through this time, when environmental sustainability and the challenges of global warming were becoming increasingly prominent concerns.[114] The situation in this country, where most electricity was already produced from renewable sources via hydro and geothermal systems, differs from the pattern elsewhere in the world where electricity is often heavily dependent upon fossil-fuel and nuclear technologies.[115] Nevertheless, wind energy's "clean green" credentials have been significant in the promotion and legitimation of this innovation in the New Zealand energy sector (Sims 1996; New Zealand Wind Energy Association 2012).

Beyond the particular interests of various sectors and groups, wind energy technology also has a powerful symbolic function. Standing out boldly in the landscape, tall modern turbines are dramatically iconic structures to rival the historical hydro dams as evidence of New Zealand's technological sophistication and green consciousness. Local communities have identified proudly with the wind structures on their hilltops.[116] Photos of sleek white turbines, often starkly silhouetted against a clear blue sky, are regularly featured in industry materials (Meridian Energy 2004, pp 8, 30, 46; 2005a, back page; Mainpower 2006) and policy documents (Ministry of

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uptake of new technologies such as wind energy have been strongly influenced by the strategic positioning of their projected benefits alongside sufficiently urgent societal needs or problems for which the technology is promoted as a solution – a dialectical co-construction of crisis and response (Kuhn 1996; Brown 2000).

[114] A trial turbine was installed at Brooklyn high above Wellington in 1993, and New Zealand's first windfarms, in the Wairarapa and Manawatu, followed in 1997 and 1999 (Parliamentary Commissioner for the Environment 2006a, pp 23-25). In the first decade of the 21st century, eleven new windfarms and major extensions to existing installations were established, and twenty proposals were developed to the point of seeking resource consent (http://www.windenergy.org.nz/nz-wind-farms/).

[115] New Zealand has historically enjoyed a high proportion of its electricity from renewable sources with the government's extensive investment in hydro technology through the middle decades of the 20th century. However, as discussed below, there are severely limited potentials now for further hydro developments and in recent decades New Zealand has provided additional generation by developing technologies utilising oil, coal and gas resources.

[116] The main shopping street of Brooklyn, the Wellington hill suburb where a trial turbine was installed in the early 1990s, features coloured pavement tiles with a bold stylised turbine as a symbol of community identity (Meridian Energy 2005d). And Te Apiti, the windfarm on the ridgeline above Palmerston North, has achieved such iconic status within the region that in 2006 the Manawatu rugby team was re-branded as "the Turbos", with a team logo of three spiralling turbine blades (www.manawaturugby.co.nz).

Economic Development 2006b, front cover; New Zealand Government 2007, front and inside covers). Though perceived by some as visual pollution of ridgelines and other natural sites, the elegant turbine structures are evocative symbols of progress in a new 21st–century modernity, icons of a marriage of contemporary technology and environmental principles.

Green energy in New Zealand

The benefits associated with wind energy as an environmentally friendly technology are major drivers of its acceptance, both in small-scale local modes and in the form of large industrial-scale commercial windfarms. These benefits are often intangible qualities, derived from deeply-held personal values and ethics, and impossible to assess quantitatively. Nevertheless they are powerfully compelling in different ways for different groups and actors – individuals, energy companies and developers, and government.

For environmentally conscious individuals, the choice of wind power for their household, farm or business is an expression of personal ideals and a contribution to improving the future of the planet. Awareness of global and local environmental issues, and a commitment to a sustainable lifestyle, are the incentives for installing small turbines and associated technologies (Black 2009, p 20). A consultant who designs such systems described this kind of client as intensely conscious of the constraints of the world's limited resources and 'passionate' about doing their bit (Interview 6, 18/7/2006). Such value frameworks also drive many industry actors and advocates for wind and other sustainable energy technologies. The knowledge that the technologies they work with are making a positive contribution to New Zealand's efforts towards sustainability can be a powerful motivation. Many of the sector actors interviewed for this thesis expressed a strong personal commitment underpinning their work. A Christchurch turbine designer and promoter of wind energy described his acute sense of the challenges of planetary sustainability as central to his efforts to change the electricity industry (Interview 31, 28/4/2006). Policy actors in sector agencies were unabashed about sharing their personal beliefs in the importance of environmental sustainability (Interviews 10, 43 and 56). And a Meridian Energy windfarm manager acknowledged:

> Working for a company that you believe in what you're actually doing, you know, these issues out there, global warming, climate change, all these things get thrown in to the mix and you know, I'm pretty proud of the company and the way they've taken a stand and are going for sustainable energy, yeah, it's a big driver (Interview 26, 21/11/2006).[117]

The green benefits of wind energy technology have also been significant in company positioning. Meridian has developed a strategic brand of environmental commitment, promoting a strong identity as a green electricity provider using only renewable generation technologies.[118] A Meridian executive explained the company's approach: 'You don't just pay lip service to [sustainability], you get in boots and all, and… actually demonstrate that' (Interview 40, 8/12/2006). The choice of wind technologies, and promotion of the environmental advantages of wind energy, are central to Meridian's corporate brand (Meridian Energy 2004, 2005a). Other electricity companies have also developed environmentally responsible profiles, highlighting investments in renewable generation, undertaking audits of environmental performance, and encouraging customer awareness of energy sustainability (for example, Mainpower 2006; Orion Energy 2006; Contact Energy 2008).[119] Such corporate strategies provoked skepticism from some in the sector as calculated primarily for market advantage in attracting environmentally conscious consumers. An industry consultant explained the marketing focus: 'If you're looking at two products that are maybe the same price, you go with the green one' (Interview 55, 7/12/2006). And a policy manager at the Electricity Commission identified:

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[117] Meridian Energy (www.meridian.co.nz), a State-owned enterprise, is one of the biggest electricity generation companies in New Zealand. It has developed three major windfarms – Te Apiti in the Manawatu, White Hill in Southland, and West Wind at Makara, as well as 'the world's coolest wind farm' at Ross Island in Antarctica, powering Scott Base and McMurdo Station.

[118] www.meridianenergy.co.nz/AboutUs/. The company's office building on the Wellington waterfront is a model of environmentally efficient design (Meridian Energy 2005c, p 4). The state-of-the-art building serves as: 'a practical demonstration that good environmental principles and commercial imperatives are not mutually exclusive' (www.meridianenergy.co.nz/AboutUs/NewWellingtonoffice/). The offices were recognised with a Five Star rating from the New Zealand Green Building Council (www.nzgbc.org.nz/images/stories/downloads/public/knowledge/casestudies/Meridian_Building.pdf).

[119] Mainpower New Zealand (www.mainpower.co.nz) owns and operates the electricity distribution network through the North Canterbury and Kaikoura regions. The company's generation strategy for the region (Mainpower 2006), focuses on renewables and demonstration projects for community-level distributed generation. Its Rangiora office building features a frontage of solar panels. Orion New Zealand (www.oriongroup.co.nz) owns and operates the electricity distribution network in central Canterbury. Servicing an 8,000 sq km area that includes many remote farming districts, Orion offers advice on stand-alone generation for remote locations as an alternative to expensive grid connection. Contact Energy (www.contactenergy.co.nz) is a private company established with assets from the former government-owned generating infrastructure in 1996. As well as generating around 25% of New Zealand's electricity, it also provides much of the country's natural gas and LPG. Contact has proposals for two large windfarms in the Waikato.

> …a demand pull… by New Zealanders who value renewables as part of their non-commercial judgements. From a commercial point of view organisations will recognise that need, just like any commercial market, and make products to satisfy that… because there's economic value in doing so (Interview 41, 7/12/2006).

There is also direct economic value in the environmental benefits from wind energy in the form of financial mechanisms such as carbon credits. Green values and the long-term public benefits of responsible technological options are translated into monetary value through the complex transactions of emissions trading (New Zealand Government 2007, p 10; 2010, p 18).[120] Carbon credits secured on the international carbon market can be significant for the economic viability of new developments, and are acknowledged as an incentive for deploying renewable technologies. The sale of emissions credits to the Netherlands government provides an additional revenue stream for the Te Apiti windfarm (Meridian Energy 2004, p 44). Such additional returns can be decisive, as the manager of a Meridian windfarm admitted:

> We've got $5 million worth of carbon credits associated with this project… now if we didn't have those this project would be underneath the line, so carbon credits played a big part (Interview 26, 21/11/2006).

As discussed in Chapter Three, Bourdieu's analysis of the different modes of symbolic capital – strategic assets such as the projected benefits and positive qualities of a technological innovation – recognises the ways that qualitative capital translates into and overlaps with economic values (Calhoun 1993, p 69; Bourdieu 2004, p 55). The New Zealand electricity industry's conversion of wind energy's environmental benefits into profitable market share, crucial top-up funding, and attractive corporate branding illustrates this advantageous mutability.

The appeal of wind energy as a "clean green" technology has helped build societal support for this innovation. However sector actors interviewed for this thesis considered that such benefits were meaningful for only a small minority of the public. Information about global environmental problems – notably Al Gore's movie *An Inconvenient Truth* – was acknowledged as fostering some interest in energy

[120] However a recent review criticises New Zealand's emissions trading scheme as weak and ineffective (WWF New Zealand 2012, p 9).

alternatives (Interviews 43, 56 and 60).[121] But the sector view was that most ordinary consumers are neither sufficiently well informed nor concerned about environmental issues to prioritise renewable energy. In the experience of the industry, for the majority of the public the source of their power is largely irrelevant. So long as they can turn on lights, heat and appliances, how the electricity is generated is a remote abstraction, mostly taken for granted. As a Mainpower development manager observed: 'most people actually don't give a toss one way or the other; they just want to flick the switch and have it work' (Interview 38, 20/4/2006). Questions of price were seen as more compelling drivers of energy choices.[122]

Beyond the ideals of strongly committed individuals, the marketing of electricity companies and the economic incentives of emissions trading, the environmental benefits of wind energy also translate into significant political advantage. The principal benefit of this technology in political and policy domains is its contribution to improving the percentage of New Zealand's energy derived from renewable energy sources, thus helping to fulfil the country's international commitments to reduce greenhouse gas emissions in response to climate change.[123] The goal of minimising New Zealand's need for environmentally unfriendly forms of electricity generation is consistently emphasised in government reports and policies (Ministry of Economic Development 2006b, 2006c; Parliamentary Commissioner for the Environment 2006c, pp 37-38; New Zealand Government 2007, pp 6, 59; Ministry for the Environment

[121] The salience of global climate change as a major problem creating an impetus for technology change is discussed further in Chapter Seven.

[122] The limits of consumers' ideals-based values frameworks, where choice of green technologies is predicated upon altruism or a sense of duty in response to appeals to save the planet, are recognised in some marketing fields: '[T]he gap between green concern and green consumerism is pretty vast' (Pernick & Wilder 2008, pp 273-275).

[123] In 2002 New Zealand ratified the Kyoto Protocol, committing to reduce the country's greenhouse gas emissions to 1990 levels by 2012 (Ministry of Economic Development 2006a, pp 2.8-2.9, 4.1-4.7; Ministry of Research Science and Technology 2006a, p 21). New Zealand's policies are outlined at www.mfe.govt.nz/issues/climate/international/ . More recently the National government has projected targets of a 50% reduction in emissions from 1990 levels by 2050, and, under the agreements made at Copenhagen in 2009, emissions reductions between 10% and 20% below 1990 levels by 2020 (New Zealand Government 2010, p 17). However a recent sobering evaluation of New Zealand's environmental performance against its international sustainability commitments from the 1992 Rio Earth Summit (WWF New Zealand 2012, pp 8-11) strongly criticizes the levels of actual achievement, noting overall increases in greenhouse gas emissions, and, as at 2010, in emissions from the electricity sector relative to 1992 levels: 'The hard data show that greenhouse gas emissions have been steadily rising since 1992 with no policy measures in place, or on the horizon, that will set emissions on a downward trajectory' (WWF New Zealand 2012, p 32). In 2012, ten percent of New Zealand's greenhouse gas emissions was produced by electricity generation via thermal power plants (Parliamentary Commissioner for the Environment 2012, p 51).

2008), and by the research sector developing energy policy (Royal Society of New Zealand 2005, pp 1, 7; Ministry of Research Science and Technology 2006a, pp 9, 13-17, 35; Royal Society of New Zealand 2006b, p 17).[124]

The next section outlines the policies and institutional structures governing the New Zealand energy sector. How have the claims of benefit advanced for wind energy technologies been received in these domains?

Power structures

The structure and governance of New Zealand's electricity sector have, inevitably, affected the trajectories of different applications of wind energy technology in this country. As outlined in Chapter Two, technoscience developments are framed within prevailing institutional and policy arrangements, and the values, orientations and expectations these formal systems reflect (Green et al. 1999; de la Mothe 2001; Jasanoff 2005a; European Commission 2007; Vanloqueren & Baret 2009). Inherent in each sector's governance systems are strongly normative patterns of perception of constraint, possibility, utility and opportunity. These frameworks of assumption have particular salience for the introduction of a new technology such as wind energy.

Future projections and planning for New Zealand's energy sector are predicated on ongoing increases in demand for electricity (Ministry of Economic Development 2006a, pp 3.4-3.7; 2006c, pp 7, 49; Parliamentary Commissioner for the Environment 2006c, p 12; New Zealand Government 2007, p 72; New Zealand Wind Energy

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[124] Coal and gas fuelled generation technologies comprised one-third (34.2%) of New Zealand's total electricity generating capacity in 2008, but due to increased renewables-derived generation coming onstream, the proportion of coal and gas fuelled electricity fell to 27.3% or just over a quarter of New Zealand's capacity in 2009 (Ministry of Economic Development 2009, 2010). However over the three decades from 1975 to 2005 the proportion of New Zealand's electricity derived from renewable sources declined by approximately 10%; increases in renewable capacity did not keep pace with the increase in total electricity generation, with the majority of increased demand over this period being met by thermal generation (Parliamentary Commissioner for the Environment 2006b, pp 30-32; Graham et al. 2009, p 3348). Furthermore, there are major constraints on future hydro development in New Zealand, with the best dam sites already long-established, and formal recognition and protection of significant conservation values of other river ecosystems (Royal Society of New Zealand 2005, p 14; Ministry of Economic Development 2006a, pp 8.1-8.2; Parliamentary Commissioner for the Environment 2006c, p 13; 2012). As a Commissioner at the Electricity Commission observed: 'the easy hydro has been used up, so now it involves building dams in more difficult places or more sensitive places as far as the environment's concerned' (Interview 9, 31/10/2006).

Association 2012, pp 4-5).[125] Assumptions of continuing growth and expansion in the sector are consistent with the dominant metanarrative of societal improvement and economic progress (discussed in Chapter Two), and the centrality of electricity to this expected advance (New Zealand Government 2010, pp 1-2).[126]

The governance provisions specify objectives and guiding principles for New Zealand's electricity system, and are profoundly influential on sector strategies. Commercial profitability, efficiency and competitiveness are requirements established in policy and legislation, and in the institutional and industry structures set up in sweeping sectoral reforms of the 1980s and 90s.[127] Before the reforms, New Zealand's electricity system was almost totally controlled by central government acting in the national interest, owning large generation plants, notably the South Island and Waikato hydro stations, and the national transmission grid. The broader public benefits of electricity, and the state's duty to develop and finance infrastructure to meet rising demand, were fundamental principles (Parliamentary Commissioner for the Environment 2003b, p 16; 2005a, pp 15-16; Ministry of Economic Development 2006a, p 2.3). Providing electricity as an essential public service was a strong social and political priority, acknowledged by an energy systems consultant looking back rather nostalgically from the perspective of 2006:

> Those hydro plants [built in the 1950s and 60s] were highly uneconomic, you know; they would never have been built in today's environment… That's the wonders of central planning… People believed in the common good back then (Interview 55, 7/12/2006).

[125] This is consistent with projections of global energy requirements. The last two decades of the 20th century saw global energy demand increase by 20%; fossil-fuel-based production dominated this rise (Jacobsson & Johnson 2000, p 626). Global demand for electricity is projected to continue to grow from 17.3 trillion KWh globally in 2005 to 33.3 trillion KWh in 2030 (Vasi 2010, p 185).

[126] Counter to expectations of growing demand are initiatives undertaken by government agencies and energy companies to encourage energy conservation and efficiency, and thus reduce pressure on infrastructure and generating capacity; programmes include subsidised eco-lightbulbs, home insulation and efficient heating systems (www.energywise.govt.nz).

[127] The reform process was itself a product of the particular ideologies of that era, part of larger public sector changes driven by neoliberal free-market economic theory. Most of New Zealand's large electricity generators are State-owned enterprises; the SOE Act 1986 s4(1)(a) establishes as the principal objective of SOEs that they 'operate as successful businesses' and are 'as profitable and efficient as comparable businesses that are not owned by the Crown'. This focus is only somewhat moderated by s4(1)(c) which requires SOEs to 'exhibit a sense of social responsibility by having regard to the interests of the community… and by endeavouring to accommodate or encourage these when able to do so'.

The transition from a public service ethic to a semi-privatised market-oriented system occurred over more than a decade from the mid-1980s.[128] Core principles behind the restructuring were to maximise profits, minimise costs, and encourage competition (Ministry of Economic Development 2006a, p 2.3). Another guiding principle was the separation of government's role from the managerial and strategic decision-making of State-owned enterprises and private firms. Direct government intervention to achieve particular benefits or outcomes, whether via hands-on management or targeted incentives, was rejected in favour of a deregulated market system:

> [I]nvestment decisions are made by individual firms in response to commercial drivers… [The government's role is to provide] the right economic framework through an efficient market, effective infrastructure and supportive regulation (New Zealand Government 2007, pp 62, 71).[129]

Nevertheless the government imposes broad-level requirements over the ostensibly independent sector agencies. Legislation and policy, principally the New Zealand Energy Strategy (New Zealand Government 2007, 2010, 2011a), establish clear directions as to the outcomes expected.[130] Other formal mechanisms set goals for demand-side efficiency and establish policy frameworks for new developments.[131] Through the period covered by this thesis, regulation of the sector was the responsibility of the Electricity Commission.[132]

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[128] The reform process included: replacement of the Ministry of Energy with the Electricity Corporation, a State-owned enterprise (SOE), in 1986; the deregulation of the sector in the early 1990s and the separation of Transpower as another SOE to own and manage the national distribution grid; later in the 1990s, splitting up the country's generation resources amongst three SOEs and the fully privatised Contact Energy, and introducing a competitive wholesale trading market for electricity; and the establishment of the Electricity Commission in 2003 to provide regulatory oversight of the sector and electricity pricing (Parliamentary Commissioner for the Environment 2003b, pp 15-17; 2005a, p 16; Ministry of Economic Development 2006a, p 2.3). The Electricity Commission was in its turn disestablished in October 2010 to be replaced by the Electricity Authority, which is to focus more on market-related issues under the 2010 Electricity Industry Act (www.ea.govt.nz).

[129] This distancing of government from sector activities is reiterated in the 2011 version of the Energy Strategy. The government's function is defined as ensuring 'effective and efficient' energy markets, although there is a shift toward allowing more active interventions: 'The Government's role in both industry development and in energy efficiency is to provide incentives and information, and to help remove barriers to markets operating effectively' (New Zealand Government 2011a, p 4).

[130] Consultation for the 2007 version of the NZ Energy Strategy was under way at the time of the interviews undertaken for this thesis. Many of the interviewees were involved in this process.

[131] These policies include the New Zealand Energy Efficiency and Conservation Strategy (New Zealand Government 2001), and the 2011 National Policy Statement on Renewable Electricity Generation, which requires the national benefits of renewable electricity to be considered in consenting processes for windfarm and infrastructure developments under the Resource Management Act 1991 (New Zealand Government 2011b).

[132] The principal objectives of the Commission were (a) to ensure that electricity was produced and delivered to consumers in an efficient, fair, reliable, and environmentally sustainable manner; and (b) to promote and facilitate the efficient use of electricity. To achieve this the Commission had to (inter

The governance arrangements reflect the priorities and political ideologies of the government of the day; as these wider contexts change, there is a corresponding shift in the concepts of benefit and purpose associated with particular technologies. The 2007 Energy Strategy (New Zealand Government) shows a strong environmental orientation. It establishes a target for 90% of New Zealand's electricity to be from renewable resources by 2025, asserting this goal as a response to the challenges of global climate change and New Zealand's obligations under the Kyoto Protocol (New Zealand Government 2007, pp 6, 17, 22, 59, 71, 78). Market mechanisms and ensuring security of supply of electricity are also highlighted, but the emphasis on renewables was a clear indication of the commitment to sustainability policies of the Labour government of that time. The intended technological trajectory was unambiguous:

> For the foreseeable future, it is preferable that all new electricity generation be renewable, except to the extent necessary to maintain security of supply… the government's view is that there should not be a need for any new baseload fossil fuel generation investment for the next ten years. The government expects all generators, including state-owned enterprises, to take its views into account when considering new generation investments (New Zealand Government 2007, p 17).

The National government elected in 2008 has taken a rather different approach to the energy sector and desired technological pathways. Its 2010 review of the Energy Strategy signalled a shift in focus, giving priority to more intensive development of New Zealand's petroleum and mineral resources to maximise the mining sector's contribution to economic growth (New Zealand Government 2010, p 1; 2011a, pp 1-3).[133] The revised Strategy retains the target of 90% renewable electricity by 2025, and expected social and environmental benefits are acknowledged. But the major focus is now on economic dimensions – renewable energy is justified under criteria of

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alia) manage risks relating to security of supply, maintain incentives for investment in generation, and contribute to climate change objectives via renewables and distributed generation (Government Policy Statement, May 2009, www.med.govt.nz/templates/MultipageDocumentTOC_40723.aspx, www.electricitycommission.govt.nz/rulesandregs). In an interview with a senior policy manager at the Commission for this thesis, the priorities emphasised most consistently were ensuring security of supply and efficiency in the operation of the electricity market (Interview 41, 7/12/2006).

[133] Events subsequent to the Strategy review have somewhat tarnished the reputation of the minerals industry in New Zealand. The Pike River disaster later in 2010, when 29 men were killed in an coal mine explosion, was investigated through a Royal Commission of Inquiry which revealed inadequate safety provisions and poor commercial performance in the coal industry.

efficiency and competitiveness, maintaining the country's international reputation and securing advantage for New Zealand exports (2010, pp 9, 20-21, 27).[134] Green energy options and innovation are firmly positioned as serving economic development goals:

> Capturing the upside of existing and emerging renewable technologies is a source of competitive advantage to New Zealand… [renewables will] help make New Zealand more resilient to fluctuating commodity prices, leading to improved energy security… Deploying new energy technologies offers significant potential to create wealth… to contribute to an increased rate of economic growth for New Zealand… The Government will prioritise research funding to areas… where there is commercial potential (2011a, pp 2, 6, 7).

The respective strategy documents show the same technologies – renewable generation from wind and other sources – promoted for different kinds of reasons. The anticipated benefits emphasised as the primary rationale for a particular technological trajectory reflect the ideological frameworks and priorities of the time. Analyses of technological development follow the shifts that occur as protagonists seek to assert and stabilise a particular meaning for a given technology consistent with their interests (Law 1987; Bijker & Law 1992a; Bijker 1995; Kline & Pinch 1999). The shift from an environmental sustainability framework to a predominantly economic growth framework – deployed by successive New Zealand administrations to justify encouragement of wind generation and other renewable energy technologies – demonstrates the contingent, partisan, agenda-oriented nature of benefit projections (Latour 1996; Sarewitz 1996; Brown et al. 2003; Winner 2004).

How have the governance and institutional structures for New Zealand's energy sector, shaped within particular political and economic ideologies, influenced the achievement of broader societal and environmental benefits from technological innovations such as wind energy? The decentred structuring of New Zealand's electricity industry, with separate competitive commercial entities pursuing their own profits, is predicated upon the assumption that such market systems will provide optimal outcomes and maximise benefits not only for the respective organisations but also for society as a whole: 'to grow the New Zealand economy to deliver greater prosperity, security and opportunities for all New Zealanders' (New Zealand Government 2010, p 1). But some in the industry consider that the management of

[134] The value of New Zealand's clean green image for our exports and tourism is well recognised (Ministry for the Environment 2001a, 2001b; Coyle et al. 2003, pp 73-77, 89-90).

energy services within cost-conscious commercial frameworks, and the lack of direct government intervention in support of particular outcomes, has hindered the promotion of broader societal benefits. The former Chair of Orion Energy observed:

> The government has chosen to make it other people's fault… to hold it at arm's length… It's part of the whole deregulation thing. When all of electricity was owned by the government, they could have [supported renewable energy technologies] more easily… It's somehow harder to justify now because they say, well, it's market forces (Interview 12, 17/10/2006).

For some sector actors interviewed for this thesis, the decentralised governance structure has diminished opportunities for recognition and pursuit of the benefits of new technologies such as wind generation. The sector is described as fragmented and Balkanised, with no shared commitment to societal and environmental benefits that are not sufficiently prioritised under the prevailing competitive business paradigm. Powerful industry players were criticised as 'too interested in looking after their own patch [and] their own agendas' (Interview 23, 19/10/2006). And a turbine systems developer argued that the sector lacked clear responsibility for initiating constructive change:

> The New Zealand model of government is not one where they embrace the notion of incentives [or] subsidies… There is an awful lot of authority pushed downwards, so it's like both sides looking at each other saying, well, is [innovation for public-good benefits] your job or is that my job? and it's actually quite difficult for people to take leadership (Interview 33, 11/5/2006).

Similar patterns are identified in Europe, where neoliberal market-oriented energy policies assert a focus on short-term optimisation of profits. However analysis of innovation processes and transitions to new technologies stress the need for long-term iterative processes of learning, heterogeneous evolution and complex societal changes (Geels & Smit 2000a, pp 877-880; Rogers 2003; Foxon et al. 2005, pp 2132-2135; Jørgensen 2005, pp 722-730; Van de Ven et al. 2008).

There are strong signals in the New Zealand Energy Strategy and other policies that environmentally friendly renewable generation via technologies such as wind turbines is to be fostered. But there are also, inherent in the governance and culture of the electricity sector, fundamentally divergent expectations around the kinds of purposes for which technological systems are developed, the kinds of benefits to be prioritised, and the kinds of guidance and direction considered appropriate in the national interest.

The disjunction between commercial and non-monetary societal objectives is neither absolute nor impenetrable, and, as discussed above, the conversion of environmental values into strategic economic and political advantage has been useful in advancing wind energy in New Zealand. Nevertheless, the prioritisation of commercial profit focused modes of benefit has affected the evolution of wind energy technologies in New Zealand.

The next sections explore the success of one particular application of this technology, the mode most compatible with the interests of dominant commercial and political groups, and the eclipsing of other potential applications aimed towards other kinds of benefit goals.

The dominance of "Big Wind"

Studies of the development of technological innovation trace the emergence and ascendance of a particular form or application of a new technology, understood and valued in particular ways, satisfying the needs and expectations of key groups (Bijker & Law 1992b; Bijker 1995; Garud & Karnøe 2001a; Brown et al. 2003; Kaplan & Tripsas 2008). Central to this process is the alignment or accommodation of the technology, and the benefits and services it offers, with the interests and requirements of power in the field. Other possible development trajectories, and other benefits that might be derived from developing innovation in different directions, are marginalised in a process of closure and retrospective legitimation around what has become the "dominant" mode of the technology (Winner 1986; Pinch & Bijker 1987; Beder 1991; Utterback 1994; Woodhouse & Sarewitz 2007; Vanloqueren & Baret 2009).[135]

From the late 1990s onwards, one configuration of wind energy technology in New Zealand has achieved an advantageous alignment with powerful political and institutional interests and, despite resistance to some specific projects, general public support. The momentum generated by such alignment around renewable energy was acknowledged by the CEO of the Ministry of Research, Science and Technology (Interview 1, 6/12/2006) and by a Commissioner of the Electricity Commission:

[135] The rich literature developing theoretical analysis of these evolutionary processes is discussed in Chapter Three.

> So it's been possible to change the way things are done, so there you get the coming together, the coalescence of the environmental ideal and the economics and the engineering (Interview 9, 31/10/2006).

Achieving such alignment can require significant changes in the frameworks of value and purpose shaping a new technology and its application. Historical analyses of environmentally-friendly technologies trace their evolution from an original activist ideals base – committed to wide ecological, social, humanitarian and inter-generational goals – to profitable commercial enterprises firmly oriented within contemporary capitalism (Hawken 1993; Hård & Jamison 2005, pp 270-271, 279, 285-291; Hess et al. 2008, 482-484). The accommodations necessary for such a transition include the repositioning or repackaging of environmental values to fit the expectations and modus operandi of business. Discussing the politicisation of environmental concerns in European energy debates through the last third of the 20th century, Hård and Jamison (2005, pp 279, 286) conclude:

> [E]nvironmental ideals came to be appropriated by business interests… incorporat[ing] environmental concern into the dominant institutional and discursive frameworks… Wind energy was a particularly good example of how alternative visions came to be realized by more commercially minded actor-networks.

Such adaptive metamorphoses affect not only the physical forms and applications of the technology, but also the meanings and benefits associated with it. The process of becoming mainstream can require advocates to conform to different modes of discourse and to uphold different values and purposes for the innovation. This can result in compromise, as more radical applications of the technology give way to pragmatic tactical expectations. Hess and colleagues (2008, p 487) observe that:

> At a technical level, the success of alternative technologies and products comes at the cost of a… process in which the more politically charged design elements and social organizational innovations drop out. At the discursive level, social movements must often pitch critical alternatives in a language that reflects the dominant "governing mentalities" that prevail in a particular policy arena in order to be heard as credible.

In the New Zealand electricity sector, this kind of reorientation of wind energy has resulted in one form of the technology – large commercial windfarms – moving from the "greenie" margins to general acceptance in the industry.

In the early stages of its introduction in New Zealand, wind technology was generally perceived as a "fringe" option, of interest only to committed environmentalists, activists and groups with very different value frameworks and personal style from conventional industry and policy actors. Early proponents of wind energy and sustainability had little credibility or leverage in the dominant sector paradigm. As the PCE's energy-sector advisor observed: 'a lot of people in the alternatives [were seen as] pretty flakey' (Interview 10, 16/8/2006).[136] The CEO of a turbine design company described his difficulties in getting traction for arguments for sustainable energy technologies in the early 1990s; despite being 'very active and vociferous in various forums,' he encountered considerable resistance in the electricity sector and policy environment at that time (Interview 31, 28/4/2006). However one form of wind technology, positioned as a solution to the newly recognised issues of global climate change, was about to have a major "make-over".

Changes in the early 2000s in the organisations advocating for renewable energy reflected a shift in focus in the sector.[137] The PCE's energy-sector advisor described the New Zealand wind energy community's transition to a slick corporate culture:

> I used to go to the Wind Energy Association meetings back in the early 90s, and it was cardigans and sandals, you know, we had square dancing and everything, it was great fun… [Since then] the energy debate in this country has been captured by the sharp guys in business suits … [At the wind industry conference in 2003] they were talking billions. They weren't talking, "oh, can we get this one up and if we build it ourselves can we use Number 8 wire and corrugated iron." These guys were, "oh we're bringing in 30 Vestas V90s and it's going to cost us $400 million"… and there were no cardigans any more (Interview 10, 16/8/2006).[138]

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[136] Asmus (2001) highlights the personalities of many early developer-entrepreneurs in the US wind energy industry as eccentric, idealistic, defiantly non-conformist mavericks.

[137] The proponents of locally-based distributed wind energy models split off from the Wind Energy Association to amalgamate with the former NZ Photovoltaics Association, rebranded as the Sustainable Electricity Association to promote small wind, small hydro and photovoltaic solar energy technologies; the SEA became a voice for alternative distributed technology applications, while the WEA was oriented more towards large windfarm development (Interview 56). Vasi (2010, pp 34-35, 194) notes a similar 'transformation' in the advocacy communities working for green energy technologies in Europe and the US, moving from activist modes to become more institutionalised, from challenging governments and business to adopting non-confrontational, cooperative tactics, and from promoting small-scale technological alternatives to large industrial-scale windfarms.

[138] A Meridian wind project manager explained the importance of the perceived credibility, within the established culture of industry and policy communities, of the messengers promoting innovation; advocates perceived as "outsiders" are less effective in advancing the benefits of new technologies such as wind energy: 'You need champions that people [in the industry] can respect… When you start off with scientists and environmentalists, people sort of go "aah, whatever." But it's when you actually have people who [sector decision-makers] think "hmm, they actually know what they're talking about" that it starts to build the pace and the momentum' (Interview 40, 8/12/2006). The importance of

By the mid-2000s, Meridian was positioning wind technology as unexceptional, asserting that: 'Wind power is no longer an "alternative" source of energy – it is now a mainstream and economic form of utility-scale generation' (2004, p 10). The CEO of Orion Energy also stressed the importance of promoting renewable energy technologies as ordinary and unremarkable: 'the more we can make it seem as mainstream and normal the better' (Interview 48, 18/7/2006).

The model of an economically efficient, competitive-scale windfarm, feeding electricity into the national transmission grid, effectively eclipsed other modes of wind technology in New Zealand. This trend was recognised in an assessment of New Zealand's electricity systems: 'the focus of investment in the electricity sector is still with "Think Big" large-scale supply-side solutions' (Parliamentary Commissioner for the Environment 2006b, p 9). This is consistent with the standard pattern of electricity infrastructure in New Zealand and throughout the world. Hughes' studies of the historical development of large technological systems (1989, pp 70-73; 2004, pp 204-205) follow the expansion of electricity networks into centralised profit-oriented mass-production networks. A recent analysis of New Zealand's energy sector acknowledges the typical model for electricity systems:

> For most of the history of wide-scale electricity use the paradigm has been large scale central generation with transmission and distribution to the point of consumption… institutional and market arrangements have evolved around a central large-scale generation model relying on one-way transmission and distribution flows (Stevenson 2010, pp 4, 5).

The outcome of this kind of framework for wind technology and its introduction in New Zealand has been the dominance of big corporate-controlled generation plants:

> Investment in new energy generation continues to be mostly large scale and remote from demand… To be competitive with other forms of generation, investment in wind power… is largely driven by economies of scale. Projects are therefore mostly large scale, in both size of turbines and number of turbines in each wind farm (Parliamentary Commissioner for the Environment 2006a, pp 14, 18).

'homophily' or compatibility between advocates and audiences is strongly emphasised in Rogers' analysis of the diffusion of innovations (2003, pp 19, 36-37, 305-307).

The importance of scale in framing economically attractive applications of wind technology was acknowledged by a project manager at Meridian, the company responsible for New Zealand's most extensive windfarms:

> Where Meridian sees its particular niche in the wind industry is at the very large scale end, so we're really focused on delivering the largest possible wind developments in New Zealand… where you get the economies of scale and you get significant chunks of power out that are really going to make a difference (Interview 13, 18/4/2006).[139]

Scale matters in the dominant model of the commercial windfarm not only in the land area covered and number of turbines, but also in the size of the turbines themselves (Meridian Energy 2005a, p 2; Parliamentary Commissioner for the Environment 2006a, pp 46-47).[140] The importance of factors of scale in wind energy technology's shift to economic viability was highlighted by a policy manager at the Electricity Commission: 'you need to have some kind of economies of scale to get enough generation to warrant all the setup costs' (Interview 41, 7/12/2006). According to a Meridian executive, the ability to build windfarms on a sufficiently major scale was a key factor:

> The reason why the costs were coming down was because turbines were getting larger and so the economies of scale were becoming more appropriate… We pushed the envelope on the size of the turbines, so we went to much larger turbines than had previously been built in New Zealand… if you tried to put smaller ones on the output would be much less but you'd still have the same infrastructure costs… so there's an optimum size (Interview 40, 8/12/2006).

The pattern of corporations such as Meridian framing the benefits of wind technology as dependent on sufficiently large installations, is wryly noted by others in the sector: 'New Zealand's power generators have always had a think-big mentality' (Macdonald

[139] The scale of many New Zealand windfarms is considerable: Meridian's Te Apiti in the Manawatu covers 1,150 hectares with 55 turbines generating 90 MW; the White Hill site in Southland extends over an area 8 km by 3 km for 29 turbines generating 58 MW; and West Wind at Makara has 62 turbines on a 53 sq km site producing 142.6 MW (www.meridian.co.nz). The original proposal for Project Hayes in Central Otago was for 176 turbines over a 92 sq km site (Meridian Energy, "How to make a submission in support of Project Hayes" pamphlet, 2006).

[140] For example, the Vestas turbines used at Meridian's White Hill windfarm in Southland are 107 metres tall, with a steel tower 68 metres tall and rotor blades with a 78 metre diameter sweep. The combined weight of tower and nacelle is 193 tonnes. Each tower stands in a base structure using 380 cubic metres of reinforced concrete, or 65 truckloads, with 36 tonnes of reinforcing steel (*Discover White Hill Wind Farm*, 2009, www.meridianenergy.co.nz). The 2.3 MW Siemens turbines at Makara have towers 67 metres tall weighing 211 tonnes. The blades have an 80 metre diameter sweep, and each foundation structure used 48 tonnes of reinforcing steel (*Discover Project West Wind*, 2009, www.meridianenergy.co.nz).

2008, p 2). The Sustainable Energy Forum (2005, pp 15, 22) identified the dominant large-scale industry paradigm as a constraint on development of alternatives. The CEO of a small turbine company, interviewed for this thesis, compared his approach with the mainstream model:

> Big business and government like big fixes, big gigantic fixes… if you use smaller turbines like ours, you don't shift as much dirt as Meridian does (laughs)… Meridian are good at shifting dirt, they like getting their Tonka toys out and building something (Interview 31, 28/4/2006).

And the PCE's energy advisor observed:

> Meridian, they've made it big wind because then it fits the big mentality, we're used to multi-megawatt power stations… it's big windfarms compared to big hydro or big thermal, because that's what they're comfortable with… I think it's in the nature of [business] to look for that big solution, the capital-letter Answer (Interview 10, 16/8/2006).

This trend is not unique to New Zealand, with the development of wind energy infrastructure globally on increasingly grand scales.[141] This pattern reflects Winner's (1986, pp 47-48) principle of the 'gigantism' of modern technological systems. As an assessment of green technologies acknowledges:

> Most of the world's energy today comes from large, centralized, generation facilities, including massive power plants… of a size once unimaginable. Utilities [work] on a large scale to take advantage of centralized production and to leverage existing networks (Pernick & Wilder 2008, p 173).

Analyses of the evolution of wind technology and windfarm systems acknowledge exponential increases in scale making this technology more competitive within mainstream commercially-oriented value frameworks (Dawson & Spannagle 2009, p 401; European Wind Energy Association 2009, pp 6, 72-73; European Renewable Energy Council 2010, p 99; Junginger et al. 2010, p 73; Vasi 2010, p 18; Burton et al. 2011, p 525).[142] Tracing the trajectory of wind energy in Denmark, Hess and colleagues (2008, p 483) observe:

[141] Wind farms in the US have expanded to awesome dimensions. The largest include: Roscoe Wind Farm in Texas with 627 turbines (781.5 MW) covering nearly 100,000 acres (http://www.eoncrna.com/contentProjectsRoscoe.html); Horse Hollow, also in Texas (735.5 MW) (http://www.nexteraenergyresources.com/content/where/portfolio/pdf/horsehollow.pdf); and the Tehachapi Pass Wind Farm in California, with 5,000 turbines (http://www.ludb.clui.org/ex/i/CA4977/).
[142] Asmus (2001, p 227) notes that the Vestas V-66 turbine, with a tower over 270 feet tall and blades reaching 370 feet above the ground, is taller than the Statue of Liberty.

> The scale of the technology increased. The transformations of technology design involve a process of "complementarization" or redesign that adapted alternative… technologies to fit into existing portfolios of industrial production.

The framing of the expected benefits of wind technology configurations that satisfy the expectations of economic returns and efficiencies of dominant business decision-makers has been crucial for the acceptance and uptake of this technology in New Zealand, and for the form of its application that has become the dominant mode.

The technical and systemic benefits of wind energy are another significant dimension of this technology's commercial appeal. Wind technologies provide diversity in the generating network and are promoted as offering benefits to system managers in improving security of supply (Őlz et al. 2007; New Zealand Wind Energy Association 2012, p 5).[143] Ensuring security of New Zealand's electricity supply is a fundamental requirement for the sector, enshrined in formal policy and in strategic planning for future developments (Royal Society of New Zealand 2005, p 10; New Zealand Government 2007, pp 13, 18, 59-60; 2010, p 13). Maintaining reliable supply is a strong imperative; a Meridian policy manager explained: 'the system is designed so the lights never turn off' (Interview 40, 8/12/2006). The CEO of Orion Energy highlighted the need for dependability in the system:

> All the crises we tend to have in energy are about the lights going out… When reliability is threatened, everything else goes out the window… Reliability is number one (Interview 48, 18/7/2006).

In its proposal for the Makara wind farm, Meridian argued for the contribution of wind technology:

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[143] The intermittency of wind, and the risks of sudden increases or drop-off in wind speeds upsetting system equilibrium, are the subject of considerable debate in the sector; studies of the dynamics of the national grid and ways to protect from catastrophic "cascade failure" from abrupt variations in wind generation were a priority for the Electricity Commission at the time of interviews for this thesis (Interviews 9 and 41). A key issue is the overall proportion of generation derived from wind relative to other technologies (Electricity Commission 2007; Ministry of Economic Development 2007). Nevertheless some policy and sector discourse (New Zealand Wind Energy Association 2005; Meridian Energy 2005a, 2005d; Ministry of Economic Development 2006c; Electricity Commission 2007; Clark 2010), and some industry interviewees (Interviews 9, 33 and 40) consider that the national system can be managed or enhanced to withstand such fluctuations. The Parliamentary Commissioner for the Environment (2006b, p 45) reports that 'New Zealand's electricity system could cope with about 35 percent wind generation at peak demand, based on the installed capacity'. Research shows that New Zealand's wind resource is more reliable than seasonal rainfall; improved forecasting methods give accurate predictions on an hourly basis (New Zealand Wind Energy Association 2012, pp 7, 15-16, 18).

> Electricity is seldom appreciated until it is gone… New Zealand cannot afford to take electricity for granted… Diversifying the way we generate electricity through the development of wind farms and other renewable energy projects helps to ensure the security and reliability of New Zealand's energy supply (Meridian Energy 2005b, p 12).

Wind generation is also promoted as a technology that is compatible with New Zealand's existing hydro generation plants, contributing to energy security by allowing conservation of water and thus serving as a buffer for the vulnerabilities of dry years when hydro lake levels fall (New Zealand Wind Energy Association 2005, p 2; Meridian Energy 2005a, p 3; Bone 2006, p 26; Ministry of Economic Development 2006a, p 8.5). A Meridian project manager highlighted the strategic advantages of integrated management of wind and water resources: 'the two can work together, you can store the wind energy in the hydro lakes' (Interview 13, 18/4/2006). This was endorsed by a Meridian windfarm manager:

> One of the big things about wind is it's almost like banking water… If we got sufficient wind capacity into the system then you've got more options with your hydro system and maintaining that, riding out some of the highs and lows and the dry years (Interview 26, 21/11/2006).

The success of the large-scale commercial windfarm as the dominant mode of wind energy in New Zealand reflects the compatibility of the concepts of benefit associated with this form of the technology with the interests of key commercial and policy actors, focused on large-scale production, reliability and revenue, and on satisfying shifting political requirements. This alignment around framings of benefit that appeal to powerful groups is itself a beneficial dimension of this mode of the technology, a valuable asset in securing acceptance and uptake. In terms of the theoretical constructs developed by Bourdieu (2002, 2004), discussed in Chapter Three, the benefit claims advanced for "Big Wind" can be understood as symbolic capital providing legitimacy and leverage:

> Those in possession of a high degree of capital have the capacity to project strategies which can involve changing the rules of the game whereas those without capital have only limited control over their future (Robbins 1991, p 100).

The next section turns to alternative applications of wind energy technology which have enjoyed limited political and industry support and thus remain on the margins. These uses of the technology are tolerated in minor niche applications or dismissed altogether, despite advocates' assertions of significant potential benefits. These configurations of wind technology are valued and defined in relation to different concepts of projected benefit from those underpinning the dominant mode of "Big Wind".

Blowing in different directions

Technologies are far from deterministic, despite perceptions of the autonomous momentum of technological development and innovation (Winner 1977; Smith & Marx 1994; Guice 1999; Garud & Karnøe 2001b; Woodhouse 2006; Van de Ven et al. 2008). Particular applications or forms of a new technology may be retrospectively legitimated as the obvious or intended option, but there are always, at various points in the trajectory of R&D and through the diffusion process, other possible ways to use and benefit from innovations.

Two alternative applications of wind energy technology in New Zealand are important to consider in terms of this thesis' focus on expectations – small stand-alone turbines servicing individual homes or businesses, and local community-level distributed generation systems where a cluster of turbines provides power for the immediate area. These alternatives are useful in understanding the significance of benefit claims in the justification and promotion of new technologies, because the projected benefits associated with these uses of wind energy have been insufficient to achieve wide societal and sectoral acceptance and uptake of either option. As scholars of science and technology systems have shown, innovation failures can be just as revealing as the success stories (Braun 1992; Latour 1996; Geels & Smit 2000a, 2000b; Franklin 2003).

In New Zealand, small-scale independent wind turbines have been installed to provide electricity for remote sites where connection to the transmission grid is extremely costly.[144] The justification for this kind of technology decision is primarily economic.

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[144] Transmission costs to remote locations can be prohibitive. Energy technology engineers interviewed for this thesis cited costs of between $50,000 to $100,000 to connect buildings on isolated rural sites to the grid (Interviews 6 and 48). The costs of installing a small turbine are not insignificant, but less daunting relative to such connection charges. A small domestic turbine installation on a lifestyle block north of Wellington cost its owners around $18,000 in 2008: 'it is expected to take

One consultant engineer explained that clients in such isolated locations were not necessarily driven by environmental ideals, but simply weighed up the costs of setting up their own generating system relative to network connection (Interview 6, 18/7/2006). Orion Energy's CEO described the options for clients building at a remote bay on Banks peninsula: 'don't spend your 50 grand on this new powerline, go direct to [independent generation technologies]' (Interview 48, 18/7/2006). Mainpower's generation systems manager outlined the choices for such locations:

> You want to be connected to our network, you would have to pay for us to go in and put in poles and wires, so we'd be happy to do that, but maybe the alternative would then be to rather than string up a long line is to create some distributed generation yourself (Interview 38, 20/4/2006).

The benefits of alternative generation technologies such as wind energy are accepted as non-controversial in these kinds of circumstances, where linking to the network is a major disincentive, both in New Zealand (Orion Energy 2006; Black 2009, pp 20-21) and internationally (Wood 2008, pp 42, 136; European Wind Energy Association 2009, pp 7, 125-127).

Where grid connection is straightforward and affordable, however, the potentials for small independent turbine systems for properties or businesses have as yet had little appeal in New Zealand.[145] In these situations the cost incentives are heavily weighted towards the conventional service.[146] Only rare, determined individuals driven by

about seven years of reduced power bills to pay for itself' (Black 2009, p 20). The government's energy advice website explains that the costs of an independent generation system will depend on the combination of technologies used; interested householders are advised to expect prices for a middle-range wind turbine system of between $15,000 and $25,000, plus an additional $3,000 to $10,000 for an inverter to convert the electricity from DC to AC (http://www.energywise.govt.nz/how-to-be-energy-efficient/generating-renewable-energy-at-home/stand-alone-power-systems (as at November 2010)).

[145] The ideals of autonomy and independence from the corporate-controlled system are also highlighted in promotion of stand-alone wind technologies (Barnett 2010, p 21; Stevenson 2010, p 17). Having your own turbine is promoted as giving: 'control that's never before been achieved over how we source and manage our energy requirements' (Parliamentary Commissioner for the Environment 2006c, p 5). A Canterbury engineer offered a visionary ideal behind his company's focus on small-scale energy systems: 'We will increasingly see people take back the ownership and responsibility for providing themselves with energy' (Interview 33, 11/5/2006).

[146] A further disincentive is the complexity and poor economic returns of New Zealand electricity companies' systems for independent small generators to feed back any excess generation (Barnett 2010, p 20).

strong environmental ideals and personal commitment have been prepared to make that scale of investment (Black 2009, pp 20-23; Barnett 2010, pp 20-21).[147]

A more radical alternative configuration of wind energy technology is local distributed generation systems, where smaller installations of perhaps only a few modest-sized turbines are located within or close to the communities they power. This option for utilising wind technology is relatively well-established in Europe.[148] There has been some enthusiasm for dispersed, small-scale wind generation in New Zealand (Parliamentary Commissioner for the Environment 2006c; Macdonald 2008). Principles of sustainability and community involvement drive a model of dispersed local-level generation, a radically different technology configuration from the established centralised electricity network. Advocacy for community systems was described by an energy analyst at the Ministry of Economic Development as idealistically building a 'new paradigm' where: 'the days of large-scale generation are gone [and] we're going to have small plant dotted all around in communities' (Interview 60, 7/12/2006).[149]

A range of benefits are advanced for distributed wind technology. The projected advantages of local generation systems include environmental benefits from greater utilisation of renewable generation technologies, and improved efficiency by avoiding significant losses in extended transmission systems (Parliamentary Commissioner for the Environment 2006c, pp 35-38; Wood 2008, pp 123, 136).[150] Deferring or

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[147] There was considerable scepticism amongst some of the industry actors interviewed for this thesis, based in pragmatic assessments of the average person's technical skills and willingness to grapple with turbine technology. A designer of stand-alone systems had found it important to 'understand the client's personality, how practical they are… It needs a practical hands-on person to be an owner of a wind turbine [and] have the ability to manage anything that might need attention' (Interview 6, 18/7/2006).

[148] Community-owned and managed wind energy systems are relatively common in Denmark, the Netherlands and Germany (Bolinger 2001; Toke 2005; Toke 2010). Co-operative structures and financial incentive systems have been established to support this kind of application of wind technology: '[M]any commercial-scale wind turbines are installed as single units or in small clusters distributed across the countryside, or scattered around and sometimes within urban agglomerations. And many of these turbines are either owned by the farmers on whose land the turbine stands, or by local residents' (Gipe n.d.). Wood (2008, pp 121-122) notes the value of supportive government policies to help establish local small-scale generation systems.

[149] The MED analyst did not himself consider such an option was realistic.

[150] The amount of electricity lost over lengthy transmission networks in the centralised grid is considerable: 'Losses are still usually quoted as around 6% for transmission and 6% for distribution networks. These are certainly underestimates… In New Zealand, almost half the retail cost of

avoiding the costs of major infrastructure development is also promoted as an advantage of smaller decentralised systems (Hoff et al. 1996). A Canterbury designer of small turbines described this as 'the lumpy investment problem', arguing that:

> Lots of little things can add up… wind power is just perfect from an economic and financing point of view because you can do it in 25 MW increments which is tens of millions of dollars, as opposed to 500 MW increments which are hundreds of millions if not billions… if you do lots of little things you don't need to do the big things, or you can defer them, and that has economic value (Interview 31, 28/4/2006).

Such benefits for the overall national generation capacity are promoted by advocates for alternative energy technologies:

> If you have 1000 small wind turbines or solar panels… that's another power station that doesn't need to be built (Prof Ralph Sims, Massey School of Engineering and Advanced Technology, quoted in Barnett 2010, p 20).

> [I]f every farm had 30kW of generation, which is two of the 15m turbines we do, that would give you 2.3 gigawatts of capacity. New Zealand's peak load is only 6.6GW so that would be a third of New Zealand's capacity (Tony Pearson, Proven Energy wind turbines, quoted in Black 2009, p 22).

Advocacy for distributed generation also emphasises the social outcomes claimed for community electricity systems, with optimistic expectations of increased public awareness of energy issues, improved demand-side savings, and enhanced democratic engagement of ordinary citizens with the technologies that power their lives (Asmus 2001, p 226; Hoffman & High-Pippert 2005; Parliamentary Commissioner for the Environment 2006c, p 41).

The benefits of local wind generation have been also promoted as securing regional independence in electricity supply from the generalised national infrastructure. This was highlighted by Canterbury energy company Mainpower (2006, back cover):

> At the moment, our region generates no electricity. We rely on importing electricity from around the country. There is real potential [for wind generation] in North Canterbury and Kaikoura… Using local resources to generate electricity will… help protect [our region] against power shortages.

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electricity supply to most consumers is attributable to capital and maintenance costs and losses on the transmission and distribution network' (Sustainable Energy Forum 2005, pp 15-17).

Meridian's advocacy campaign for the Makara wind farm also emphasised the advantages to local communities, arguing that Makara would provide enough energy to power all the households in Wellington, Lower Hutt and Porirua cities (Meridian Energy 2005b, p 5). This focus was acknowledged by Meridian's project manager:

> The whole concept of the wind farm being able to supply most of Wellington's energy needs is really powerful… it's energy being generated locally, used locally (Interview 13, 18/4/2006).

Some advocates have advanced the possibility of New Zealand developing a mixed technological mode combining both conventional large-scale wind energy and innovative, community-focused applications.[151] The Parliamentary Commissioner for the Environment (2006c, p 13) argued that local energy could 'complement' the existing centralised system. A researcher into distributed generation (Barry 2007) argued: 'Small-scale wind should not be developed instead of large-scale windfarms, but rather alongside them.' An engineer researching alternative energy technologies suggested that:

> Local energy services will be provided increasingly by these local technologies… The major power stations and so on will still be there and will provide backup and support (Interview 23, 19/10/2006).

And a policy analyst at the Energy Efficiency and Conservation Authority outlined the potentials in using a mix of technological applications:

> [New Zealand] could meet all of our new load growth in electricity for twenty or thirty years just from renewables… some of that would be on rooftops and alot of that would be larger windfarms (Interview 43, 6/12/2006).

However the benefits and possibilities of dispersed or decentralised community-level uses of wind technologies have as yet gained little recognition in New Zealand. The difficulties in achieving recognition for new ideas and new technology applications – appealing to different paradigms and offering different kinds of benefits from the expectations of dominant groups, particularly those of large commercially-focused companies – were acknowledged by the Royal Society of New Zealand (2006a, p 5) in its analysis of microgeneration potentials for New Zealand:

[151] Such "both-and" wind energy systems are also promoted in the US and Europe (for example, Asmus 2001, p 227).

> [Alternative energy technologies] face a structural problem. They are not beneficial to existing industries because there is no ongoing revenue stream… Existing industries have no incentive to provide them.

The challenges inherent in introducing such models into existing generation and delivery systems are daunting (Sarewitz & Cohen 2009, p 6). Resistance is framed primarily as based in economic and technical or managerial issues. There is a wide perception across the electricity industry that distributed generation may be a nice ideal, but is simply not commercially competitive.[152] A Commissioner of the Electricity Commission was pragmatic about the economics of devolved community-level generation, describing it as an expensive ‘pipe dream’ (Interview 9, 31/10/2006). Commenting on the sector’s orientation around profitability, the Energy Panel of the Royal Society of New Zealand (2006a, p 4) was sceptical about distributed energy’s acceptance:

> The benefits of renewable microgeneration are more social and environmental rather than economic. The exclusive focus on a competitive market limits changes in generation and supports incumbents.

Mindsets and expectations within the industry are also significant: ‘Many electrical engineers trained in the realm of large scale power generation systems are less willing to accept a vision for DG becoming mainstream’ (Royal Society of New Zealand 2006a, p 3). A researcher developing stand-alone generation technologies commented on the sector’s reluctance to consider different options:

> Alternatives or new techniques are very hard to get accepted, they’re always looking for the engineering issues of why it’s not going to be reliable or whatever else… The first [issue] is control, if it’s outside the control of the industry… they’re not particularly comfortable with that (Interview 23, 19/10/2006).

The PCE’s energy-sector advisor also commented wryly on the pattern of political and sector support for large commercially-managed technological systems rather than decentralised small-scale applications:

> [Major industry actors] were much more comfortable with that model [large-scale windfarms] because then they would have control. They didn’t want a whole bunch of uncontrolled people out there [with independent generation]

[152] The unit price (cents per kW hour) of household scale distributed generation were cited in 2008 as approximately 35 cents for a 15 kW mast mounted turbine, 55 cents for a 2.5 kW turbine, and nearly 80 cents for a 3 kW vertical axis turbine; these prices are much higher than the conventional retail rates of around 21 cents per kW hour (Energy Efficiency and Conservation Authority 2008, pp 1-2).

> contracting with them and setting terms and all that. No, it's much better that [they] go out there, sell the package, and have the final say… nobody likes consumers in control (laughter) (Interview 10, 16/8/2006).

Despite the efforts and enthusiasm of advocacy groups and the few small companies working with local-scale generation technologies in New Zealand, proponents of distributed energy systems remain outsider voices in the sector (Black 2009; Barnett 2010).[153] A Christchurch designer of stand-alone systems observed rather bitterly:

> People are struggling to bring forward new technology and not receiving any support, or very little… it seems an extraordinary uphill battle (Interview 6, 18/7/2006).

And an engineer working on energy alternatives commented on the limited interest from established electricity sector actors and government agencies in the potential benefits of different kinds of systems:

> Not surprisingly they're not and they never have been particularly supportive of renewable distributed generation [or] working out ways to best integrate small scale alternative energies with the network… You have the government sort of saying, "well we'll chuck a little bit of money in the research end there, but we're not going to give it any clout or any power"… so renewable distributed energy, small scale micro-generation is sort of sitting in a limbo (Interview 23, 19/10/2006).

Such uses of wind and other small-scale generation technologies are considered beneath the interest of the large corporate actors. These configurations of wind technologies are developed by smaller companies with a mix of commercial and environmental motivations, led by committed engineer-entrepreneurs. Some research into local generation has been funded, but the engineer leading one distributed technology study suggested that work on such applications was so minimal it was not perceived as offering any serious challenge to the dominant industry paradigm:

> The networks say "yeah, put a bit of money into remote stuff because that's not going to affect us"… overall [work on distributed generation] won't have a big impact, it'll have negligible impact (Interview 23, 19/10/2006).[154]

[153] For example, www.seanz.org.nz , www.powerhousewind.co.nz , www.windflow.co.nz; also www.distributedwind.org.

[154] Research exploring the development of small-scale generation was resourced through the Distributed Generation Fund. However this support was short-lived; established in 2008-09, funding was no longer available in 2010. Projects undertaken included feasibility studies of different sizes and models of turbine for local communities, farms and vineyards (www.eeca.govt.nz/distributed-generation-fund). Other trial projects in remote rural communities in Southern Hawkes Bay and the East Coast have investigated the potentials for off-grid generation including wind, solar and other

The former Chair of Orion Energy described the perception amongst the dominant corporate and policy groups in the sector of work on such environmentally- and socially-oriented alternatives:

> It's seen as a soft, soppy sort of do-goodie, not hard research delivery… the soft options, the fringe stuff, the feel-good stuff, nice to have them there because it salves our conscience… they're thrown little bones to keep them happy, but they're not seen as mainstream (Interview 12, 17/10/2006).

Within the field of electricity generation and energy policy in New Zealand, the dominance of large-scale, centrally-controlled technological system models, and of values frameworks of commercial competitiveness and efficiency, has effectively foreclosed opportunities for independent, locally-focused wind generation. The potential benefits of distributed generation have insufficient weight in sector frameworks to be considered relevant except in limited niche applications for remote sites where the existing technological configuration – transmission lines linking to the national grid – is deemed problematic because of the extreme costs of connection.

Advocates for personal household-level turbine systems and local distributed energy systems have gained little traction for these models of wind technology in New Zealand despite their assertion of diverse benefits from dispersed generation systems. These kinds of benefit are not compatible with the assumptions and orientations of the dominant technological mode in this field. Arguments for the positive outcomes anticipated from such alternative possible uses of wind technology appeal to different frameworks of meaning and value from those shaping the expectations of key political and industry actors. As Christensen (1997, p 16) observes, such disruptive innovations: 'offered a different package of attributes valued only in [other] markets remote from, and unimportant to, the mainstream.'

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technologies (http://www.caenz.com/DistGen/DGdownloads/Gardiner.pdf, http://www.irl.cri.nz/our-research/energy-power/distributed-energy-generation-storage, Interview 23, 19/10/2006).

The weight of the status quo

The introduction of new technologies into well-established sectors has been analysed as a process where the benefits or advantages projected from the innovation must overcome the inertia of existing ways of doing things, and existing assumptions of what can and should be done (Utterback 1994; Gooley & Towers 1996; Christensen 1997; Hargadon 2003; Rogers 2003; Coburn 2006; Montalvo 2006; Van de Ven et al. 2008). Bourdieu's concept of habitus, discussed in Chapter Two – the entrenched, taken-for-granted frameworks of orientation and practice shaping and shaped by group interactions over time – is a way to understand the inertial weight of such reiterated conventions (Bourdieu 1999, 2004; Grenfell 2004).

Like any established field, the New Zealand electricity sector is characterised by participants' acquiescence to hegemonic norms and expectations, frameworks of value and orientation that are perpetuated in institutional and policy structures. Sector actors interviewed for this thesis felt that such conservative patterns have influenced the introduction of new technologies such as wind energy. Past and present systems, and the values and meanings they embody, severely limit the range of possible alternatives that are considered credible or desirable. The PCE's energy-sector advisor observed:

> We still have the incumbents set up and the institutional arrangements set up to maintain and extend the status quo... Technologies that can be applied in a range of scenarios, a range of ways, when they get incorporated into the [system] they get applied just as the old technologies were (Interview 10, 16/8/2006).

And a researcher into stand-alone generating technological systems commented:

> The supply industry sees conventionally that generating in large scale away down the other end of the country, trucking it up the country and expanding all your transmission systems and so on, is good because that's the way we've always done it (Interview 23, 19/10/2006).

Closely intertwined with the inertia of paradigms and expectations, is the inertia of physical artefacts and infrastructure, which is also a significant constraint on the development and diffusion of new technological systems and configurations. Path dependence is a concept that encapsulates the powerful influence of previous development trajectories (Garud & Karnøe 2001b). The inertial weight of established systems and structures results in a narrowing of options (Jacobsson & Johnson 2000, pp 630-633; Sandén & Azar 2005, pp 1559-1560; Sarewitz & Cohen 2009, p 21). As Williams (2005, p 13) explains:

> Prior choices are also important in relation to… large-scale sociotechnical systems, in which powerful 'path dependencies', and reinforcement between the technical features and the broader innovation regime, may result in lock-in to particular technology models. The difficulties of overcoming lock in technologies, once entrenched, and in changing technology regimes [results from] the close coupling between the design of technical components, the institutional context and entrenched operating principles.

The orientation of New Zealand's electricity system around the national transmission grid – transporting electricity from the major generation plants to consumers, running the length of the country and under Cook Strait – is a major factor in the siting of windfarms. This was acknowledged by Meridian project managers as a factor in the development of Project West Wind at Makara near Wellington:

> While New Zealand's very windy, the number of places that are actually suitable for wind turbines is a much smaller set of that… you need to be close to transmission (Interview 13, 18/4/2006).

> Wellington is probably the windiest spot in the world and it's an appropriate place for a windfarm inasmuch as it's close to transmission so you didn't have to build any more infrastructure (Interview 40, 8/12/2006).

The project manager at White Hill windfarm in Southland also acknowledged that:

> …a great advantage to this site is that we've got that Powernet local 66 KV network, the North Makarewa [to] Headon Bush, it comes up through here… It certainly is [important] having close transmission… You have your losses, and the further you are away from transmission to get it into the network, the higher the cost (Interview 26, 21/11/2006).

As well as the implications of the grid network for the location of windfarms, there are issues of capacity in the larger system. In the case of White Hill, this was a constraint on the scale of the development. The project manager admitted that, although the site could accommodate more turbines, without increased capacity in the transmission link future expansion was unrealistic: 'We're limited by the 66 KV network, we can only get 58 MW into that system. Unless that system was upgraded [the number of turbines at White Hill] is restricted' (Interview 26, 21/11/2006).

The constraints of path dependence on large commercial windfarms are primarily technical. However for alternative wind energy applications such as distributed generation, the obstacles inherent in the existing system are more profound. The idea of reconfiguring New Zealand's centralised linear grid network to a distributed local application of small-scale wind generation technologies is very much at the radical, disruptive end of the spectrum of technological innovation (Gooley & Towers 1996; Christensen 1997).[155] The logistics and costs that would be involved in shifting to such a different mode of delivering electricity are a major disincentive. The systemic changes that would be required to accommodate a fundamentally different decentralised generation system would be far-reaching and hugely expensive, requiring rebuilding not only the electricity generation and transmission infrastructure for the whole nation, but also restructuring communities, industry, businesses and economic systems around new modes of energy delivery. The extent of the paradigm shift posed by a locally-focused dispersed system was acknowledged by the PCE's energy-sector advisor:

> The only [truly sustainable] solution is one where we actually radically redesign our society from virtually the ground up, where we say basically everything we've been doing for the last hundred years, well that has to go… and that means that our cities are the wrong design, our businesses are the wrong design (Interview 10, 16/8/2006).

Senior policy managers for the energy sector at the Ministry of Economic Development described the challenges of changing from the present established grid-based network to a dispersed generation model:

> All the networks have been designed to take power from one place and have it flow in one direction, and one direction only, and the prospect of it flowing in the other direction and at different times and going all over the place… It means you have to rethink the whole design of your network to a large extent, and develop new technologies, new control systems. Who wants to pay for that? (Interviews 19 and 60, 7/12/2006).

The pragmatic requirements of integrating new technologies with existing energy infrastructure, system configurations and operational constraints have inevitably constrained the ways wind technologies have been adopted in New Zealand. Wind energy has not been introduced onto a *tabula rasa*, but into a long-established field

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155 The differences between incremental and radical or disruptive technoscientific changes are discussed in Chapter Three.

with deep inertia and extensive sunk investments, and perhaps even more importantly, with solidly-entrenched norms, assumptions and values frameworks limiting the openness of actors and institutions to new options.

The inertia of past and present technological modes is also significant for the strategic performative work of projections of benefit from innovations such as wind energy. The status quo system narrows the applications in which new technologies can be considered acceptable and integrated into ongoing practice, but also asserts a demand for the new technology to offer significant benefits or advantages over existing arrangements – a strong enough 'inducement' for change (Jacobsson & Johnson 2000, p 638). In New Zealand, the satisfactory delivery of electricity via existing systems is taken for granted.[156] Technological innovation, such as the adoption of wind energy, has been justified by its delivering additional benefits answering new frameworks of value and need that cannot be satisfied with conventional technologies. The strategic importance of the looming catastrophe of global climate change, for the acceptance and introduction of wind energy, is discussed further in Chapter Seven.

Conclusion

This chapter has explored the evolution of wind energy technology in New Zealand, looking at the framings of expected future benefit that have been advanced in support of this innovation. A broad diversity of claimed benefits have played their parts in the legitimation and diffusion of different applications of wind energy – environmental sustainability, commercial competitiveness, advantageous market positioning, fulfilling New Zealand's international commitments, and community independence. Each of these registers of benefit appeals in different ways to different societal groups – corporate executives, policy-makers, people building their dream home on a remote coastal site, entrepreneur-engineers, green lifestylers – each with different levels of influence in terms of sector power relations.

[156] Shortages, such as the constraints imposed by dry summers lowering water levels in the Southern hydro lakes, and outages, such as the 2006 Auckland blackouts due to a substation fault, are rare occurrences but provoke major outrage (for example, Canterbury Manufacturers' Association 2006).

A symbiosis between green ideals and the pragmatic demands of technical and commercial commodity-production systems has been supported by the discourses and benefit projections associated with particular applications of wind energy technology. The direction taken by wind generation systems in New Zealand shows the importance – for the introduction and establishment of a new technology – of strategic positioning that aligns with the requirements and assumptions of dominant political and sectoral groups. The form of wind energy that has found most acceptance and become most common in New Zealand is the large corporate-controlled windfarm feeding the national grid. This mode of the technology has achieved legitimacy because of a conjunction of factors – technical advancements in turbine design, commercial and governance structures in the energy sector, and supportive policy frameworks. Environmental values are convertible into political and economic advantage, and this mode of the technology offers benefits that satisfy the expectations of powerful sector interests.

Other configurations of wind energy technologies, associated with projected benefits of little value or credibility within the dominant paradigm, remain on the margins with poor prospects of wider diffusion. The stories of wind energy's divergent trajectories in New Zealand – the success of "Big Wind" and the relegation of distributed small-scale generation to "fringe" applications – illustrate the crucial importance of framing expected benefits from technological innovation that are compatible with mainstream value systems.

Chapter Six

A brave new world[157]

Introduction

This chapter explores the work of projections of anticipated benefit in securing commitment and resourcing for R&D in genetic modification in New Zealand. Support for GM in this country has inevitably been strongly shaped by global framings of this technoscience field and its opportunities and challenges. The chapter surveys the international evolution of GM since the 1970s, tracing the prominence of ideals of commercial profit and competitiveness as drivers for investment. New Zealand GM research has largely followed this orientation, being promoted as crucial to economic growth and the viability of primary production sectors.

The governance arrangements for GM R&D in New Zealand include requirements that such technoscientific innovation activity also delivers public-good benefits for the nation.[158] The formal regulatory processes under the Hazardous Substances and New Organisms Act 1996, while focused largely on issues of risk, also require the expected benefits of the work to be taken into account and comprehensively assessed (s6(e), HSNO Act; Environmental Risk Management Authority 1998a). And the legislation establishing the Crown Research Institutes, the agencies conducting the majority of New Zealand's GM work, imposes the obligation that 'research… should be undertaken for the benefit of New Zealand' (s5(1)(a), Crown Research Institutes Act 1992). However, the stories of the various projects discussed in this chapter suggest

[157] With apologies to William Shakespeare and Aldous Huxley.
[158] These New Zealand statutes have some similarity to the provisions of the Norwegian Gene Technology Act 1993 (ss 1 & 10), which requires that GM organism releases in Norway must satisfy criteria of environmental sustainability and 'benefit to society' (Myhr & Traavik 2003, pp 319, 327; Danish Council of Ethics 2007, pp 47-49; Norwegian Directorate for Nature Management 2011). The practical application of these requirements has been debated, with concerns from biotech industry actors that the concept of 'social utility' is 'imprecise and thus non-operational' (Danish Council of Ethics 2007, p 48); policy analysis considers that evaluations of societal benefits from GM would inevitably be subjective and dependent on the values frameworks and interests of different social groups (Danish Council of Ethics 2007, pp 55-70, 110). Another similar focus on social benefit from biotech R&D was the recommendation of the UK Biotechnology and Biological Sciences Research Council's review of crop science (2004, pp 6, 18, 35-36) for an initiative to promote 'public-good' plant breeding focused on crops and traits not being developed by commercial interests; this was supported with funding of £15 million in 2009 (Wynne 2012b, p 6).

that generic abstracted narratives of economic progress and commercial profitability have been the most powerfully influential frameworks of expectation validating GM developments in New Zealand.

All GM work in this country to date has been confined to lab research and contained field trials; no GM products or applications derived from New Zealand research have yet been released into markets or the environment.[159] The outcomes projected from GM technoscience for New Zealand are therefore of a different order to the actual benefits delivered by wind technology in the form of electricity, revenues and carbon credits associated with climate change mitigation. The principal outputs of GM research in New Zealand thus far have been scientific knowledge, proof of concept for proposed biotech objectives, and optimistic claims about intended downstream developments. The main strategic benefits have been the ongoing funding, prestige and symbolic capital accruing to research institutions and scientists.[160]

The advancement of GM technoscience in New Zealand has another point of difference from the story of wind energy in this country, where a dominant mode of that technology, offering a particular suite of benefits, is now well-established. The corporate-owned industrial-scale windfarm is an application of wind technology that aligns with the value frameworks and requirements of powerful sector groups. But GM research in New Zealand has been focused around a diverse range of possible forms and uses, appealing to heterogeneous interests and advancing a diverse range of intended benefits and improvements. Work has been conducted on vegetable crops modified for resistance to herbicides, pests and diseases, or for enhanced processing and storage characteristics, flavour and appearance. Major projects have developed livestock modified for the production of pharmaceutical proteins and for milk and meat with new characteristics. Other research has focused on exotic forestry species modified for faster growth, and forage plants modified for increased nutrient value

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[159] Possible exceptions (depending on the definition of "GM product") are relatively uncontroversial non-GM products derived from the processing of GM substances, notably insulin for treating diabetes (Royal Commission on Genetic Modification 2001a, p 243). Rolleston (2005) describes purchasing imported cans of chili beans containing GM corn and maize meal from a Woolworths supermarket in Canterbury, arguing that with such (labeled) products approved under New Zealand's food safety regulations, the concept of New Zealand being "GM-free" is purely rhetorical.

[160] The distinctions between exogenous benefits – serving a need or delivering an improvement for external sectors or actors – and endogenous benefits advantaging the technoscience community itself, are discussed in Chapter Seven.

and reduced methane emissions from livestock. No particular application or mode of GM technoscience is clearly dominant in the range of research activity in New Zealand.

Nevertheless, running consistently through the promotion of GM is the narrative of the importance of this technology as an essential component of New Zealand's economic growth and prosperity. Although only in the research stages in this country, GM is legitimated through its rhetorical and political construction as a necessary enabling technology for New Zealand's competitiveness in global marketplaces, via development of lucrative new exports and efficiencies in existing production systems. Belief in the need for New Zealand to maintain active involvement in GM and biotechnology – the Red Queen imperative – runs strongly through policy and sector discourse, and this chapter outlines the influence of these patterns on support for and regulation of research.

The potential development of GM biocontrols for possums is a uniquely New Zealand application of this technoscience. The biocontrols research was primarily driven by ideals of protecting New Zealand's indigenous biodiversity and forest landscapes from this pervasive Australian pest. These environmental priorities were qualitatively different from the goals of agricultural and biopharmaceutical GM R&D, although intended environmental benefits also featured in the promotion of some research on GM crops. This chapter examines the frameworks of value and intended benefit shaping a diverse range of GM projects in New Zealand and motivating the scientists involved. These constructs of expectation show the persistence of powerful narratives of disinterested societal benefit, intertwined with more pragmatic commercial purposes in an increasingly economics-dominated technoscience sector.

***Bigger than physics*[161]**

GM technoscience originated in the early 1970s with the creation of the first recombinant-DNA organisms and, simultaneously, of a new entrepreneurial, unashamedly commercial paradigm for biology (Watson 2003, pp 108-114; Jasanoff 2005b, pp 188-189; Sunder Rajan 2006, pp 4-10). From its beginnings, this elite field oriented itself around the 'economics of technoscientific promise' as a proudly 'promethean' technology (European Commission 2007, p 24; Salleh 2008, p 233; Dryzek et al. 2009, pp 266-267). Analyses of the dynamics of science and technology developments discussed in Chapters Two and Three (for example, Latour 1996; Sarewitz 1996; Christensen 1997; Greenberg 2001; Rogers 2003; Bourdieu 2004) highlight the dominance of economic, institutional and political interests in the evolution of innovation fields. The practices and priorities of global GM are inextricably aligned with and shaped by the expectations of powerful groups (Kleinman & Kinchy 2007, pp 197-198; Hindmarsh 2008, pp 10-12, 35).[162] The science, knowledge and manipulation of genetic materials are framed as sources of unprecedented opportunities – promising commercial returns to developers, investors and industries, prestige and funding for scientific institutions and researchers, and economic expansion and international competitiveness for governments and multinational corporations (Hacking 1986, pp 10-11; Gottweis 1998, Chapter 4; Van Dijck 1998, Chapter 4).[163]

Advocacy for this technology claims a range of projected benefits for agricultural production, health and nutrition, and environmental management, but expectations of financial profit are a dominant theme of GM development: 'At no time in history has a field of basic science been so quickly commercialised' (Krimsky 2008, p xvi). The close inter-relationship of biotechnology with entrepreneurial business interests is a

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[161] This ambitious comparison positions biological technoscience relative to the supremely prestigious science field of the 20th century (Dyson 2007, p 1). Dyson asserts that biotechnology now exceeds physics in terms of budgets, workforces, economic consequences, and effects on human welfare.
[162] Analysing governance challenges in global biotechnology, Forbes (2006, pp 78-81) argues that the industry advances a new 'imperialism'. And Jasanoff (2005b, p 186) critiques GM biopolitics and the assumptions of global interests: 'the modernist, science-promoted vision of progress: one that begins with invention in the labs of wealthy Western nations and then is disseminated by multinational corporations, through mechanisms such as high-input industrial agriculture, to the rest of the waiting world'.
[163] This has been dependent upon the establishment of new regimes of intellectual property rights and private ownership of genetic resources (Rifkin 1998, Chapter Two).

distinctive characteristic of this sector relative to other science fields (Pisano 2006, pp ix, xii-xiii, 1-4).[164] This is based in GM's promise of knowledge, products, substances and living entities with unprecedented earning potential (Hacking 1986, pp 9-10; Gaisford et al. 2001, p 6; Sunder Rajan 2003, pp 91-92, 96; Watson 2003, pp 109-110, 122-123; Senker & Chataway 2009, p 184). The extraordinary revenues earned, even as biotechnology companies were first launched, ensured a strong commercial orientation (Rifkin 1998, pp 15, 68-70; Lyons et al. 2004, p 96; Glover 2008, p 11; Hindmarsh 2008, pp 4, 38). Watson (2003, pp 114, 117) sums up the incentives shaping the field:

> Biology was now a big-money game, and with the money came a whole new mind-set… [an] evolution from a purely academic mind-set to one adapted to the age of big-bucks biology.

Underpinning the development and application of GM are a range of narratives, discursive patterns, and positioning strategies (Gottweis 1998, pp 154-155; Sunder Rajan 2003, p 110; Kitzinger et al. 2007, pp 204-207; Kleinman & Kinchy 2007, p 197; McNally & Glasner 2007, p 273). An obvious pattern is the regular reliance, in rhetorical and political construction of GM, on generic affirmations of beneficence. Such confidently optimistic assertions are often vague, sweeping statements with little detail or evidentiary substance; nevertheless, they have considerable strategic force (Forbes 2006, p 80; Pisano 2006, pp xi, 129; Davies 2007, pp 221-222; Levidow & Carr 2007, p 410; Vanloqueren & Baret 2009, p 981). Van Lente (1993, pp 150-152) highlights the advantageous flexibility of such loose discursive constructs in the promotion of new technologies. Leitch and Davenport (2007, pp 44, 59) analyse the strategic use of ambiguity to assert apparent consensus around particular policy or organisational value frameworks. GM is constructed as the means to a broadly idealistic future, described by Hindmarsh (2008, p 4) as 'persuasive bioutopian narratives or visions of a genetically engineered cornucopia'. Such discourse, shaped by glowing scenarios of a new "Golden Age", encompasses a comprehensive diversity of human and societal needs and desires (Dyson 2007, pp 6-7).

[164] The hegemonic acceptance of this commodification of science is however not unchallenged (for example, Hindmarsh 2000; Goven 2006; Kitzinger et al. 2007; Kleinman & Kinchy 2007; Dryzek et al. 2009; Herring 2010). Sunder Rajan (2003, p 97; 2006, pp 4, 117) highlights the ways that the corporatisation of biotechnology is contested, 'frictioned' and capable of 'denaturalisation'.

The suite of inter-related narratives typical in the promotion of GM technoscience includes claims of the power to transform nature in ways previously impossible (Danish Council of Ethics 2007, p 21); as Sunder Rajan (2006, p 114) suggests, 'the magic of [biotechnology] is… the magic of being able to pull rabbits out of hats'.[165] The metaphor of a 'biotechnology revolution' assumes a process of dramatic change as new knowledge and powers overwhelm existing technologies, practices and ideas (Rifkin 1998, pp 1-8; Hindmarsh 2000, pp 541, 544; Nightingale & Martin 2004, pp 564, 567; Pisano 2006, pp 4, 21-22; Hopkins et al. 2007, pp 566-567).[166] Such conceptualisations of GM serve to foster perceptions of the field as exceptional, dynamic, and thus worthy of investment and political support (Nightingale & Martin 2004, p 568).

Closely linked with the bio-revolution narratives are confident constructions of GM as offering extraordinary power over nature, enabling technoscience to triumph over the limitations of ordinary reality and remake the world (Krimsky 2008, p xviii). Hindmarsh (2008, p 21) summarises the appeal of these grand claims:

> Life is redesigned and also re-created according to human notions of order, hopes and aspirations, ideologies, and images for sale, of perfection and control over nature... The portrayed BioUtopia is free from disease, hunger, resource scarcity and ecological degradation.

The origins of these concepts of human mastery over nature are traced back to the scientific ideals and methods of Francis Bacon (Rifkin 1998, p 170; Hindmarsh 2008, pp 24-26), and earlier still to the work of medieval alchemists (Rifkin 1998, pp 32-35; Hindmarsh & Lawrence 2004b, p 29; Kirkham 2008). Improving upon the world's imperfections is presented in GM discourse as satisfying the ultimate goal of scientific endeavour: 'The Biotech Century promises to complete the modernists' journey by "perfecting" both human nature and the rest of nature, all in the name of progress'

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[165] The sexiness of GM as an elite "cutting-edge" field that will recreate ordinary realities has more recently been overtaken by nanotechnology, about which many of the same issues apply, including unknowns and risks, public engagement, and a lack of scrutiny of promotional hype (Sarewitz & Woodhouse 2003; Wilsdon & Willis 2004; Macnaghten et al. 2005; Kearnes et al. 2006).

[166] However a counter-narrative – of GM as merely an evolution or continuation of long-familiar interventions in the natural order – positions this technoscience as no more controversial than brewing, baking or farmers' selection of the most productive crop varieties (Conner & Jacobs 1996, pp 223-224; Conner 1997; Hedgecoe & Martin 2008, p 820). This more reassuring framing of GM developed in response to public unease about the risks of the new technology, and the industry's desire 'to better align society culturally to the biotechnology text… [and] to close the controversy over the nature of genetic engineering as "a reductionist transgression of nature"' (Hindmarsh 1994, p 187).

(Rifkin 1998, p 171). Gottweis (1998, pp 156-157) identifies a 'discourse of deficiency' corresponding to this framing of GM; natural unmodified reality is conceptualised 'in terms of "absences" and of "areas of improvement" in need of the intervention of genetic technologies'.

Assertions of broad-ranging confidence in GM technoscience as the solution to problems – in farming and food production, health and medicine, and environmental management – are a common pattern in the discourse (Rifkin 1998, pp 15-23; Lyons et al. 2004, p 103; Birch 2006a, pp 173-175). Presenting GM as the answer to otherwise intractable difficulties, this positioning illustrates the strategic co-construction of problem and solution, linking the imperative and the innovation in a performative symbiosis.[167] The concept of 'salvation' encapsulates a sense of technological innovation as miraculous rescue (Sunder Rajan 2006, p 35, Chapter 5; Davies 2007, p 221; Birch 2007a, p 94; Senker & Chataway 2009, p 171). Jasanoff (2005b, pp 187-190) analyses themes of 'crisis' and corresponding 'salvation' in the discourse around Golden Rice.[168] The (in)famous claim that GM will solve food shortages in the Third World demonstrates this rationalisation (Froggatt & Rankine 1999, p 465; Hindmarsh 2000, p 543; Gaisford et al. 2001, p 26; Hunt et al. 2003, p 20; Carter 2007; Glover 2008, pp 20-21; Hindmarsh 2008, p 48). Despite sustained challenges, this claim remains 'pervasive' in industry promotions (Brooks 2005, pp 360, 367, 373); according to a Monsanto advertisement: 'Worrying about starving future generations won't feed them. Food biotechnology will' (quoted in Senker & Chataway 2009, p 175).

In their sweeping confidence in the capacities of GM to solve problems and satisfy human requirements and desires, these narratives provide a seductive resource for the advancement of this field and for its proponents to secure the funding and political and social support needed for R&D (Evans et al. 2009, pp 46-47, 53). The ambitious visions and imaginaries that have been spun around the potentials of GM from its inception are in themselves a valuable asset for the field. Sunder Rajan (2006, p 34)

[167] The significance of such associations is explored in Chapter Seven.
[168] Golden Rice is genetically modified to produce beta-carotene, which converts to vitamin A in the body. It is claimed to help solve the problem of blindness due to widespread vitamin deficiency in the developing world (Jasanoff 2005b, pp 183-184; Yonekura-Sakakibara & Saito 2006; Senker & Chataway 2009, p 183).

analyses 'the conjuration of corporate promissory futures as… a game that is constantly played in the future in order to generate the present that enables that future'. These constructs are a benefit *for* GM, as well as ostensibly describing the benefits that will flow *from* GM. They are both normative and performative; they create momentum and establish hegemonic acceptance in science research, industry, political and public domains. Their context is the narrative discussed in Chapter Two of technoscience as the irresistible driver of progress, an enduring myth that presumes the desirability and effectiveness of innovations (Bingham 2008, pp 112-113).

The promise of GM is often framed in terms of the evolution of this technoscience over time.[169] The predominant "first-generation" GM applications are a narrow range of bulk-commodity crops modified for herbicide- and pest-resistance (Pimentel et al. 1989, p 606; Boulter et al. 1990; Paoletti & Pimentel 1996, pp 666-667; Duke & Powles 2008; Vergragt & Brown 2008, pp 784-785).[170] These are acknowledged as offering agronomic benefits primarily to large-scale growers and the companies holding patents (Gamble et al. 2000, pp 13, 19, 21; Gaisford et al. 2001, pp 9-11; Brooks 2005, p 367; Glover 2008, p 26; Herring 2008, p 459).[171] As Senker and Chataway (2009, pp 172-173) explain:

> Early applications of biotechnology were designed to appeal to farmers rather than consumers. The lack of demonstrable advantages for consumers contributed to the difficulties of marketing the technology in Europe… The public wanted to see some benefits to society, not just increased profits for [multinational corporations].

[169] The metaphor of "generations" encourages a concept of the technology as a natural, organically sequential process rather than a strategic political and commercial construct.
[170] Herbicide-resistant crops are the most prevalent application of this technology, comprising 75% of GM crops worldwide in 2002 (Birch 2007a, p 106); a review five years later reported that 71% of global GM crops were modified for herbicide resistance, 18% for insect resistance, and 11% for both herbicide and insect resistance (Danish Council of Ethics 2007, p 23). A commercial review of GM crops from 1996-2004 estimated returns of US$27 billion, with 60% of soybean, corn and canola farmers in the US planting GM crops (Rolleston 2006). The "big four" commodity species – herbicide- and pest-resistant soy, canola, maize and cotton – now comprise 99% of global acreage of GM crops (Howard 2012, p 4).
[171] GM's orientation around applications which benefit the interests and profits of corporate-controlled agriculture has been criticised as part of a wider dynamic of economic dominance over nature, food production and traditional rural relationships with the environment (Rifkin 1998, pp 82-90; Danish Council of Ethics 2007, pp 33-35; Senker & Chataway 2009, pp 173-176). As Tudge (2000, pp 306-307) observes, these crops: 'reinforce a system of agriculture that is increasingly monocultural… reducing the farmers to subcontractors and focusing profits in fewer and fewer hands… part of a broad strategy to make agriculture even more industrial and to bring it ever more under the control of big business'. And Wynne (2012b, p 10) argues that 'weed-resistance to herbicides like glyphosate [was] designed into GM for market-share and patent-extension, ie concentrated commercial control'.

These applications of GM are distinguished in sector discourse from projected "second-generation" products which are intended to deliver direct benefits for consumers and publics. The products intended from "second generation" GM include foods with improved taste or nutritional content; medicines, chemicals or energy derived from GM crops and animals; and crops capable of surviving harsh conditions via drought or salt resistance (Wolfenbarger & Phifer ; Wall et al. 1997; Gaisford et al. 2001, pp 5, 11-13; Loureiro & Bugbee 2005; Yonekura-Sakakibara & Saito 2006; Dyson 2007, pp 6-7; Blasco 2008, pp 195-199; Herring 2008, pp 458, 462; Ortiz 2008; Colson et al. 2011). Public opinion surveys show consistently that GM is more acceptable for medical purposes than food production (Hunt et al. 2003, pp 19, 122; Cook et al. 2004, pp xiii, 66; Ministry of Research Science and Technology 2005c, p 14; Kaye-Blake et al. 2007, pp 17-18; Herring 2008, pp 458, 460; 2010, p 620).[172]

The actual delivery of the promised "cornucopia" of benefits from GM has, however, been strongly challenged. The extravagant rhetoric is found to be unrelated to significant change or innovations, or to the projected financial returns:

> [T]he empirical evidence does not support the existence of a biotech revolution. Nor does the data support the widely held expectation that biotechnology is having a revolutionary impact on healthcare or economic development (Hopkins et al. 2007, p 566).

Studies of the performance of the biotechnology industry find a major disjunction between the grand claims and expectations, and disappointing realities (Hacking 1986, p 8; Froggatt & Rankine 1999, p 464; Pisano 2006, pp x-xi, 5-6, 116-118, 184-185; McNally & Glasner 2007, pp 263-264, 271; Birch 2007a, pp 94, 107; Howard 2012, pp 13, 20). Low actual success rates are attributed to the complexities and uncertainties inherent in research, the lengthy timeframes for development, production and marketing of innovations, and the impositions of regulatory processes (Tudge 2000, p 238; Rasnick 2003, p 355; Nightingale & Martin 2004, p 568; Howard 2012, pp 1-4, 7). In agricultural biotechnology, the differences between the

[172] The importance of urgent drivers for acceptance of technoscientific innovation is discussed in Chapter Seven. Reasons for the higher acceptability of medical applications of GM would include the logic that a disease or debilitating condition establishes a strong imperative to seek and achieve relief. People with illness and pain have a greater need for solutions, or even for alleviation. The international biotech industry is strongly focused on developing new pharmaceuticals, diagnostics and foods for disease prevention (Hedgecoe & Martin 2003; Goven et al. 2008, pp 11-15; Hedgecoe & Martin 2008, pp 823-826).

benefits projected by GM developers and the areas of actual achievement have raised sceptical concern (Brooks 2005, p 367; Glover 2008, pp 2-6, 33). Senker and Chataway (2009, pp 172-3) identify the gap between rhetoric and reality as a key factor in public opposition to GM crops:

> The mythology about the revolutionary potential of the technology for feeding the world did not match the reality of products which seemed to extend rather than transform the chemical inputs era of agriculture.

However, the actual delivery of beneficial, marketable, effective products is only part of GM's commercial appeal. Sunder Rajan (2003, pp 110, 114) explains the 'market logic' of biotechnology in terms of the symbolic capital underpinning the industry and research communities. Two inter-related frameworks of value are identified: commodity capital, determined by the value of products; and commercial or speculative capital, which recognises value in economic activity and institutions regardless of actual outputs (Sunder Rajan 2006, pp 8-10, 14, 111-112). This second dimension of the economic framing of GM technoscience affirms an importance in maintaining R&D activity in its own right – a strong dynamic in the New Zealand biotech sector. Development is driven by:

> … not just the production and exchange of commodities… [but] commercial activity as an end in itself… providing it with its own self-perpetuating, self-sustaining logic… forms of valuation having not to do with tangible material indicators of successful productivity, but with intangible abstractions (2006, pp 8-9, 18).

The concepts of societal benefit and avowals of good intentions that are deployed in the advancement of GM may be at some remove from actual outcomes and practice of the biotechnology industry. But optimistic framings of GM – as solution, as alchemy, as provider of abundance, and as economic bonanza – continue because they serve useful services for the field. These constructs are vital symbolic capital for securing the prestige, resourcing and support necessary for continuing research activity. Such idealised projections of benefit and beneficence have been profoundly influential in GM's promotion in New Zealand's policy and science arenas, establishing significant advantages for the field in terms of political and financial backing, regulatory facilitation and institutional commitment.

"Big-bucks biology" in New Zealand[173]

Most New Zealand research in GM, and initiatives in the wider field of biotechnology, are politically and discursively framed within a narrative of economic growth and competitiveness – the "Golden Goose" myth of technoscientific innovation as the key to profits and prosperity, discussed in Chapter Two.[174] This framing of the opportunities of GM both reflects and contributes to a broader (and ongoing) pattern of policy evolution over the years covered by this thesis, where New Zealand's science and innovation systems have been consistently oriented towards economic objectives (Cartner & Bollinger 1997, pp 776, 783-784, 788).[175] Leitch and Davenport (2005, pp 891-893, 896-902) describe the 'marketization' of New Zealand R&D through a series of purposeful policy shifts, institutional restructuring, and discursive strategies. Successive governments, seeking to create a competitive 'knowledge economy' based in the lucrative potentials of technoscientific innovation, have emphasised goals of wealth creation and transformation of New Zealand's economy. Goven (2006, pp 567, 582) argues that New Zealand science has been 'reshaped by the increasing importance of commercial actors and goals' as research priorities focus on 'imperatives of commercialization and commodification'. New Zealand's science funding systems, with criteria for research grants based on potential marketability of the work, reflect and contribute to such marketization trends – as does the statutory requirement that the CRIs operate as commercial entities.[176]

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[173] A description of the biotechnology industry from James Watson, one of the scientists responsible for the "discovery" of DNA and the development of genetic science (2003, p 117).

[174] The relationships between GM and biotechnology – as discursive terms, as fields, and as technical approaches – are complex and often strongly political. The elision of GM and wider biotechnology is a common pattern in policy and sector discourse in New Zealand. This can be a result of GM being consciously positioned as merely one aspect of the ostensibly less risky, more conventional domain of biotechnology. As emphasised in some sector interviews for this thesis, specific GM research work is less likely to attract public controversy and opposition when it has a lower profile under the broad umbrella term "biotechnology" (Interview 51, 24/7/2006; Interview 54, 9/5/2006). This term, and the still wider framings of "innovation" and "science", are often used in sector and political rhetorics as generic symbols of modernity. However this blurring of terminology and categories can cause confusion, and render relatively opaque the actual extent of GM R&D being undertaken.

[175] The 2011 creation of the Ministry of Science and Innovation, and ongoing shifts in policy, continue this focusing process. In March 2010 the Hon Wayne Mapp, Minister of Research, Science and Technology addressed the annual NZBio conference: 'Science and innovation are one of the six main policy planks that will be at the heart of lifting New Zealand's economic performance… Our future growth depend[s] to a large extent on generating and using new ideas' (http://www.beehive.govt.nz/speech/2010+year+science+speech+nz+bio+conference).

[176] Through the time covered in this thesis, most R&D was resourced through the competitive bidding systems of the Foundation for Research, Science and Technology (FRST). Its requirements included a strong emphasis on the 'path to market' and the endorsement of 'end users' of the research (Interviews

Confidence in technoscience as the driver of economic rejuvenation – and in economic growth from science and innovation ensuring societal wellbeing and other qualitative outcomes – runs strongly through the policy and sectoral discourse, reflecting the basis of such positions in the ideology of dominant political and business groups (Cartner & Bollinger 1997, pp 788, 798; Kelsey 1997, p 11; Goven 2006, pp 574-576, 585).[177] The assertion of benefits is often sweepingly broad, reiterating taken-for-granted assumptions. To give just two examples of the typical generalisation: a 1996 *Strategic Overview* for the science sector (New Zealand Government, pp 2-3) develops from wide claims reminiscent of Vannevar Bush:

> [E]nhancement of New Zealand's future quality of life will be increasingly reliant on scientific knowledge and technological know-how… [research, science and technology] are important to the achievement of prosperity and well being for all New Zealand.

And more recently, a 'summit report' of opportunities in the 'bioeconomy industry' opens with a quote from Prime Minister John Key:

> It's my view that we need to put science at the heart of this National-led Government. If we don't do that we are simply not going to get the economic gains that New Zealand needs and we won't have the standard of living that we deserve. And it's not a lot more complicated than that (NZBio 2009, p iii).

Some policy does acknowledge non-monetary aims and outcomes alongside the economic focus. The *Strategic Overview* recognises science's contributions to social and environmental goals, as well as economic advancement and benefits to industry (New Zealand Government 1996, pp 3, 6, 10). A range of goals are acknowledged in a formal clarification of the statutory requirements that publicly funded research must

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7 and 47). The Crown Research Institutes Act 1992 (ss5(2)&(3)) require CRIs to maintain financial viability and generate an adequate rate of return for shareholders.

[177] This orientation of New Zealand's science and technology systems has been contested and resisted by many within research and policy communities (Hunt 2003; Leitch & Davenport 2005, pp 904-905). Some economic research has specifically contradicted the typically optimistic claims for the economic outcomes of technoscience development. Nevertheless the 'deep ideological divisions' within New Zealand R&D domains are not reflected in the enthusiastic confidence of the policy documents predicated upon the primacy of economic objectives (Leitch & Davenport 2007, pp 43-45, 57). Analysis of the increasingly instrumental framing and positioning of R&D notes that although questions have been raised in policy debate that challenge such assumptions, these remain unresolved and are 'largely masked or rendered marginal' in sector discourse, with little impact on the momentum of the prevailing mainstream narratives (Cartner & Bollinger 1997, pp 776-777, 789, 796). Macdonald et al (2011, pp 9, 12, 21) assess dialogue initiatives around social concerns about biotechnology and their failure to influence policy and industry developments driven by an 'ideology of marketization and commodification'.

be 'for the benefit of New Zealand'.[178] This identifies (undefined and generically vague) benefits to society and the environment alongside income generation, competitiveness, high value exports and increased innovation capacity (Ministry of Research Science and Technology 2005a, pp 3-5). Other policy, however, focuses more narrowly on economic value frameworks. Support for R&D and innovation is consistently promoted as essential to rejuvenate the New Zealand economy by delivering rapid growth, developing new products and sectors, and revitalising existing sectors (for example, Ministry of Research Science and Technology 2000, 2001; OECD 2007).[179]

The place of GM and biotechnology in this larger mission was made specific with a series of political and policy initiatives through the late 1990s and early 2000s. The report of the Royal Commission on Genetic Modification (2001a, p 3) based its conclusions in the perceived importance of GM for New Zealand:

> Technology is integral to the advancement of the world… the human race has ever been on the cusp of innovation. Currently, biotechnology is the new frontier. Continuation of research is critical to New Zealand's future.

The RCGM considered a spectrum of claims, advanced in the submissions of interested parties, of expected benefit from development and use of GM. These ranged widely across agronomic, health and medical, and environmental benefits (Royal Commission on Genetic Modification 2001c, pp 49-61, 151-153, 230-236). Underpinning most of these projections, and running strongly through the Commission's conclusions, was a driving sense of the commercial returns and competitive advantages predicted to flow from GM (2001a, pp 42, 76-80, 108-109, 139-142; 2001c, pp 55, 257-260). The Commission highlighted the importance of 'a robust economy' for the achievement of community wellbeing: 'Economic and social goals are not mutually exclusive. They are, in fact, symbiotic' (2001a, p 12).[180]

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[178] The Crown Research Institutes Act 1992 establishes general purposes and principles of operation for the CRIs, but does not include definitions or explanations of key terms. For example, s5(1)(a) merely requires that 'research… should be undertaken for the benefit of New Zealand'; subsequent sections establish more specific criteria for CRIs' commercial performance (as outlined in Footnote 174 above).
[179] The OECD review of New Zealand's innovation systems urged that the over-riding objective for innovation policy should be to foster 'market-pulled innovation', and insisted that knowledge must 'contribute effectively to increasing value added in resource-based sectors' (OECD 2007, p 15).
[180] This elision of commercial and societal dimensions was explained as characteristic of the worldviews expressed in submissions to the RCGM: 'Most submitters saw New Zealand's overall wellbeing as being dependent on its ability to sustain a competitive and innovative knowledge-based

A series of policies through the first decade of the 21st century reiterated and reinforced the narrative that GM and biotechnology are essential for New Zealand to generate the economic benefits that would in turn ensure other kinds of qualitative societal benefits. The influential Growth and Innovation Framework (New Zealand Government 2002, p 5) assumed an interdependence between economic growth and generic societal outcomes; technological innovation would 'build the momentum for an economic success story delivering for all New Zealanders the standards of living to which we aspire'. Biotechnology was prioritised as a key area for government support on the basis of its perceived growth potentials and influence across the economy (2002, pp 49, 51).[181] The following year, the Biotechnology Taskforce recommended ambitious sector expansion to boost productivity and export earnings and develop lucrative new products (New Zealand Government 2003, p 5). The Taskforce acknowledged the need to balance economic goals with social and environmental considerations (2003, pp 38-39), but emphasised commercialisation and collaboration between science and business (2003, pp 6, 24).

The government's *Biotechnology Strategy* (New Zealand Government 2003) reiterated expectations of innovation as the route to improved economic performance. The Strategy's guiding principles include a commitment to 'focus on outcomes from biotechnology that benefit the wealth, health and environment of New Zealanders', and to harness the industry for 'our economic, social and environmental well-being' (2003, pp 4, 6). These loosely-defined goals were framed as achievable by focusing on commercial development and efficiency in existing sectors (2003, pp 5-6).

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economy' (Royal Commission on Genetic Modification 2001c, p 33). The RCGM's endorsement of these dimensions of expectation has been analysed in terms of such inquiry processes as legitimation exercises which 'maximise gains for key interests'; the support of major lobby groups such as Business New Zealand and Federated Farmers for the RCGM's conclusions is noted (Rogers-Hayden & Hindmarsh 2002, p 43). Commenting on the neoliberal worldviews shaping the RCGM's processes and findings, Goven (2006, pp 576-578, 587) argues that their equation of the 'wellbeing of all' with economic growth has the effect of silencing alternative voices and visions of desirable futures, and obscuring the political nature of technoscience trajectories.

[181] The other two technologies privileged for intensive development were ICT (information and communication technologies) and the creative industries (film-making and special effects) (New Zealand Government 2002, pp 7, 49, 51).

Economic dimensions are also highlighted in trade and exports policy (New Zealand Trade and Enterprise 2005, n.d.), and in policy for scientific research priorities. A "Futurewatch" analysis of biotechnology opportunities and trends assesses various GM applications, the likelihood of commercialisation and profitability, and timeframes for market entry (Ministry of Research Science and Technology 2005b). A review of plant biotechnology emphasised the commercialisation of products, and recommended increased government investment in the field on the basis of the technology's claimed importance for the New Zealand economy (Foundation for Research Science and Technology 2006a, pp 5-10). A broader review of New Zealand's 'biotechnology research landscape' justified the government's strategic approach and funding increases in terms of economic returns:

> [Support is] primarily directed towards outcome focused research that contributes to the New Zealand economy today or will help to grow and diversify it in the future… [including] investments assisting the commercialisation of biotechnology research (Ministry of Research Science and Technology 2006b, p 8).[182]

These priorities continue through the 'roadmap' strategy for biotechnology research in New Zealand (Ministry of Research Science and Technology 2007, pp 14-16, 21,30, 49-51). The orientation and expectations for R&D are clearly signalled:

> The bulk of the government's research investments are directed towards achieving economic outcomes – fuelling competitive advantages within existing industries and building completely new industries (2007, p 27).[183]

Commercial value frameworks dominate the discourse of the New Zealand biotechnology sector (Macdonald et al. 2011, pp 12-13, 18-19). The industry organisation, NZBio, is assiduous in promoting the sector's achievements and commercial opportunities (NZBio 2005b, 2006b, 2006c, n.d.).[184] NZBio's priorities

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[182] The 'landscape' report noted proudly that just over $195 million was invested by government in biotechnology research in the 2004-05 year; approximately half this was spent on targeted and non-targeted basic research, the other half on outcome-focused research and support for commercialisation. The research areas were: biomedical and drug discovery: 34%; animal-based biotechnologies: 15%; plant biotechnologies: 21%; and environmental biotechnologies: 10% (Ministry of Research Science and Technology 2006b, pp 6-7).

[183] The vocabulary of these policy documents is salutary; the term 'investment' implies an expectation of financial returns, compared to other terms that might describe science funding such as 'grant' (Leitch & Davenport 2005, p 899).

[184] NZBio (www.nzbio.org.nz) was established in 2003 to represent and foster the biotechnology industry in New Zealand. Replacing the former Life Sciences Network, NZBio's activities are strategically focused on supporting the industry, working to assist the sector's expansion and

are determinedly oriented around business growth for the sector and the nation, as emphasised in an interview with the CEO:

> From an economic perspective if we want to have a society that's prosperous in the future we have to be open to accepting new technologies, making the most of innovation… So [NZBio's focus is on] things like what is the best way to increase productivity, generate valuable intellectual property, improve technology transfer [and] increase investment (Interview 54, 9/5/2006).

Sector advocacy and promotions consistently emphasise the economic value generated by and expected from the field (Ahn et al. 2008, pp 3, 6-8; NZBio 2008b, pp 5, 16; Boven 2009, pp 2, 14-15, 27, 60-61; NZBio 2009, pp 5-8, 13).[185] A sector review (NZBio 2006a) highlights growth in investments, numbers of companies and employees, export revenues, and the earnings of New Zealand's primary production industries.[186] A follow-up review (NZBio 2008a) praises further commercial growth, endorsed by the Minister of Research, Science and Technology as imperative for the creation of a "bioeconomy".[187] Sector activities, such as the annual NZBio conferences, have a strong focus on the business aspects of science (for example, NZBio 2008c).[188] The promotions of investment brokers and venture capital companies also frame GM technoscience and biotech as attractive propositions for significant profit-making.[189] This emphasis on the economic dimensions also characterises the positioning of New Zealand's Crown Research Institutes engaged in

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consolidation of a conducive operating environment for a diverse range of biotechnology companies and institutions (NZBio 2005a, pp 3-8, 17-18).

[185] One industry review report opened with the proud assertion that: 'The OECD has estimated the potential contribution of the Bioeconomy to New Zealand's GDP at up to NZ$18.2 billion… in 2030' (NZBio 2009, p iii).

[186] The review summary records: 'expenditure on biotechnology increased by more that 20 per cent between 2004 and 2005, now totally more than $640 million; biotechnology export revenue increased more than 30 per cent in the same period; biotechnology contributes $300 million to $400 million per year to the New Zealand economy through the primary sector… biotechnology now employs more than 2200 people in New Zealand, in 126 private and public sector entities' (NZBio 2006a).

[187] The 2008 review records direct government investment of almost $250 million, up from $200 million in 2005. Overall biotechnology funding from the Foundation for Research Science and Technology in 2008 was $785 million in contracts plus additional capability-supporting contracts worth $347 million over their terms. Private sector funding was over $100 million. Industry growth over 2005-2007 was highlighted: the number of organisations working in biotech increased by 33% to 168; the number of employees increased by 78%; the net profits of the sector almost doubled; export revenues grew by over 35%; and the total sector income grew by 23% to $276 million (NZBio 2008a).

[188] The NZBio conferences typically feature sessions on patenting and IP law, licensing, collaborating off-shore, business partnering, marketing, and strategic financing (NZBio 2008c).

[189] For example, the Pacific Channel investment group explains that the life sciences projects in their portfolio must offer eventual markets for the biotech products under development of between $5million and $500million per year (http://www.pacificchannel.com/WhyInvestinLifeSciences/tabid/56.aspx).

GM and other biotechnology work.[190] For example, scientists from the (then) Crop & Food Research institute highlighted the potentials in producing ‘high-value peptides with medical applications’ from GM potatoes: ‘some high-value proteins are currently worth $1million per gram’ (Conner et al. 2003, p 13).

Not surprisingly, sector actors interviewed for this thesis reflected these frameworks of expectation for the benefits of their work. A venture capital executive arranging finance for technology startups stressed the primary criterion of commercial marketability as determining an R&D project’s worthiness:

> Products that sell provide benefit, and I don’t know what the benefits are necessarily, it will depend on each person what the benefits are… but most products are actually beneficial in some way, shape or form, otherwise they won’t sell (Interview 36, 1/12/2006).

This rationale was echoed by the CEO of NZBio:

> Unless there’s a consumer benefit in a technology there’s not a market… There’s not a disconnection between consumer benefits, public benefit and company benefit; they’re all very intertwined, because otherwise there’s no demand for the technology… Science is just a science until there’s an identified need for a particular technology which is commercialised from the science (Interview 54, 9/5/2006).

While other factors such as the satisfaction of being involved in projects for new medical treatments or environmental sustainability were part of the motivations for investment in science, these dimensions were seen as ‘secondary considerations’ to the driving purpose of building successful biotech businesses (Interview 36, 1/12/2006). Within the government financing agencies there were similar priorities.[191] Policy managers at FRST and MORST emphasised the need for research proposals to be credibly and closely linked with the requirements of end-users of the knowledge or innovation. Applications have to demonstrate an ‘expected return to

[190] For example, AgResearch (2010a) describes its mission as ‘to create sustainable wealth in the pastoral and technology sectors through science and technology’, a role it claims is crucial for the nation’s economic viability: ‘AgResearch’s activities are critical in ensuring the prosperity, security and sustainability of New Zealand’s pastoral and agri-food sectors. These sectors are the backbone of our economy and their continued success is essential to this country’s living standards.’ The CRI projects expected earnings in excess of $150 million per annum.

[191] The principle of orienting research towards economic goals and marketable products extends to government facilitation of science-business interactions; initiatives mentioned in the interviews with FRST managers include commercialisation workshops for scientists, schemes to embed business studies interns in labs, and requirements in ongoing project monitoring to ensure market relevance.

the economy' and a clear 'pathway to market' (Interview 45, 9/5/2006; Interview 7, 18/4/2007; Interview 47, 26/4/2007).[192]

The ultimate goal of GM within such frameworks of value is the (in)famous "killer app", the hypothetical technoscience application that will be so irresistibly desirable and widely marketable that vast fortunes will be earned. This grail of GM R&D was (sometimes rather wistfully) conjectured in some interviews. A MORST biotech policy manager argued that the introduction of a "killer app" with 'very clearly laid out advantages to the consumer', rather than only benefiting industry, would provide a tipping point in public attitudes to GM (Interview 45, 9/5/2006). A policy manager for the horticulture industry highlighted possible health benefits from GM vegetables as offering this kind of appeal:

> If I can make a health claim and say, if you eat 500 grams of these potatoes a week, I can 99% guarantee you won't get bowel cancer or breast cancer or prostate cancer, wheeeew [whistles], you watch consumption (Interview 22, 20/4/2007).

But a research manager at Crop and Food suggested rather ironically that more superficial attributes might also generate sufficient market acceptance:

> How about a potato that makes you thinner when you eat it, tastes fantastic like the best McDonalds fries, and has the properties of Viagra, and gives you wonderful skin – you know, if you have beauty, sex, and problems with obesity, health problems, if you could design that [laughter] (Interview 2, 26/5/2006).

Overall, the dominant narrative of GM as 'big-bucks' science, valued instrumentally for the anticipated commercial returns, has strongly shaped the framing of this research field in New Zealand, and legitimated ongoing resourcing and political and sectoral support. But this confidence in the economic benefits of GM technoscience has not gone unquestioned. Some analyses, from both economic and sociological perspectives, have sharply challenged the prevailing optimistic narrative.

[192] The Foundation system evaluated and ranked proposals against four key criteria: 'benefits to New Zealand' including financial returns and other business benefits such as regional development and employment; marketability of the products or knowledge to be generated by the research; science and technology benefits to New Zealand, the 'technical stretch' or the quality of the science; and ability to deliver, or the skills and capacities of the researchers and institutions (Foundation for Research Science and Technology 2006b).

Modelling of actual market prospects for GM products is perhaps most disruptive of the enthusiastic narratives of "transforming the economy". Several analyses develop highly sceptical evaluations of the optimistic projections for this technoscience and the actual marketability and earning potential of its products. Studies highlight ongoing resistance to GM products of global consumers, major supermarkets and food retailers, and the potentially damaging effects of adoption of GM technology on New Zealand's existing exports and international "clean, green image" (Campbell et al. 2000; Sanderson et al. 2003; Saunders et al. 2003; Howard 2012).[193] Kaye-Blake et al (2007) scrutinise claims advanced for GM medicinal substances and foods, and conclude that, although GM may be 'touted as the next major development in both farming and pharmaceutical production', information to assess such products' eventual performance is not available (2007, pp ix, 3, 8). The example of recombinant human lactoferrin, produced in the milk of GM cows, is salutary; the limited global potentials for this product are set against predicted losses to New Zealand's dairy and tourism industries from negative reactions to GM production:

> [I]ntroducing a GMO into the New Zealand dairy sector has a potential to cause a minimum of NZ$539.6million in losses to the dairy and tourism industries. Thus, such a biopharming endeavour would need to offset those losses before it could be viewed as a net positive for the New Zealand economy. Given that worldwide sales of lactoferrin are currently in the tens of millions of US dollars, offsetting hundreds of millions of NZ dollars of lost exports seems unlikely in the short to medium term (2007, pp 32-33).

Other studies critique the dominant framings of GM and biotechnology and their projected economic benefits for New Zealand in terms of their discursive and political dimensions. The purposeful creation of discourse strategies to legitimate GM – and to position it as positively as possible in public, political and sectoral debates – is described by Weaver and Motion (2002, p 327) as 'the engineering of public opinion on the issue of genetic engineering in New Zealand'. Analysis of the tactics and typical framings of GM discourse reveals the consistent efforts of proponents of this technoscience to sustain a Foucauldian 'regime of truth' consistent with the values and expectations of powerful actors (Motion & Weaver 2005, p 50). The construction of particular meanings for GM and particular visions of its future is explored as a

[193] The economic value of international perceptions of New Zealand as a "clean green" environment has been strongly endorsed (Ministry for the Environment 2001a, 2001b). These perceptions are important for our export markets and for the tourism industry, which promotes New Zealand as "100% pure" (www.tourismnewzealand.com).

rhetorical process that serves the interests of dominant groups (Rogers-Hayden & Hindmarsh 2002; Weaver & Motion 2002; Leitch & Davenport 2005; Henderson et al. 2007; Leitch & Davenport 2007; Davenport & Leitch 2009; Macdonald et al. 2011).[194] Cronin (2008, p 294) describes the hegemonic acceptance of 'strategic and normative assumptions about the role of biotechnology, now intrinsically tied in to future economic development in a knowledge economy'. And Wynne (2003, pp 6, 24) identifies the commercialisation of science, and governments' promotion of claims of economic outcomes from technologies such as GM, as dominant influences deserving closer attention.

Despite such critique, the privileging of GM R&D and promotion of genetic technoscience continued in policy, sectoral and public discourse through most of the first decade of the 21st century. The persistent dominance of framings of GM as an essential dimension of New Zealand's economic viability reflects the alignment of this optimism with the interests and agendas of powerful sectoral and political actors. The next section of this chapter looks at another technoscience myth that contributes to GM's promotion by economists, politicians and research institutes – the Red Queen imperative. This narrative helps sustain a sense of necessity for active New Zealand engagement in GM, and provides a justification for R&D in this field regardless of any actual deliverables beyond the lab or field trial perimeter fence.

GM and the Red Queen

Biotechnology developments in New Zealand have been strongly influenced by the conceptual framing of this technology as a rapidly-moving domain of fierce global competition. This construct is a common pattern in many R&D fields, especially in the early stages of evolution of new technologies and new paradigms (Burnett et al. 2009, p 187). As discussed in Chapter Two, technoscience is perceived as a contest, a desperate race where even to participate demands huge commitment, striving and

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[194] Other analyses of GM discourse and the institutional and political framings of technoscience highlight these dimensions from the perspective of public participation; studies have focused on the processes and conclusions of the Royal Commission of Inquiry (Rogers-Hayden & Hindmarsh 2002; Goven 2006; Rogers-Hayden & Jones 2007; Hindmarsh & Du Plessis 2008), and the role and approaches of the Environmental Risk Management Authority (Cronin 2003b, 2008; Wright & Kurian 2009; Kurian & Wright 2010).

ruthless competitiveness (Winner 1986, p 46; Rappert 1999a, pp 5-6; Kearnes et al. 2006, p 35). The analogy with Lewis Carroll's fictional Red Queen – rushing Alice at top speed across the landscape only to maintain their present position – encapsulates the urgency and frantic pace central to this framing of technoscientific research and innovation (Carroll 1939 (1871), pp 141-143).

From its origins in the 1970s, GM has been heavily influenced by the Red Queen imperative. The competitive drive for primacy in discovery and product development, described by Rifkin (1998, p 79) as a 'scramble for fame and fortune', was fuelled by projections of immense commercial profits and glamorous stellar careers. Intensive publicity around the "race" to sequence the human genome framed the creation of scientific knowledge as a contest between research teams (Sunder Rajan 2003, pp 95-98; Watson 2003, pp 181-195; Sunder Rajan 2006, pp 2, 16). The enormous expectations constructed around genetic technoscience created a powerful sense of urgency to be at the forefront of developments, or at least not to fall behind and lose access to the promised returns (Birch 2007a, pp 95, 107). As Kahane (2009, p 54) observes, major waves of technological innovation, once they gather momentum, 'become too big to be missed'. Claims that existing technologies and production processes would be rendered obsolete, combined with the fear that competitors would secure the benefits and profits of the new science, built GM into an irresistible priority. For corporations, the drivers were commercial: '[multinationals] could ill afford to miss out on what recombinant DNA technology represented, namely the very future of pharmaceutical production' (Watson 2003, p 113). A Monsanto spokesman summed up the compulsive urgency spurring GM R&D: 'The biggest mistake that anyone can make is moving slowly, because the game is going to be over before you start' (quoted in Bingham 2008, p 111). Governments worldwide established policies, funding and supportive regulatory systems, 'investing heavily in biotechnology and genomics in order to establish a foothold in what is seen as a key part of the New Economy' (Nightingale & Martin 2004, p 565). Dryzek et al (2009, p 267) describe the compulsion for governments to facilitate technoscientific innovation and diffusion 'to ensure economic competitiveness in a globalizing world'.[195]

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[195] Most First World and many developing nations have given high priority to biotechnology and GM research in their science and technology policies. As Hacking (1986, p 11)explains: 'Most governments have a positive attitude to the development of new biotechnology… nations are aware

The Red Queen imperative for GM and biotechnology is closely linked with the inequities of global power relations (van Vliet 1998, pp 1-2; Froggatt & Rankine 1999, p 466; Brooks 2005, pp 362, 364; Birch 2007a, pp 94-95; Herring 2008, p 461). Gottweis (1998, pp 51-53, 161-162, 196-197) follows political narratives that frame biotechnology as a contest between nations. Accusations of 'backwardness' relative to GM 'leaders' such as the US and Japan justified British and European policies to foster increased support for R&D; biotechnology was claimed to be 'essential to socio-economic development and to surviving the "international high-tech race"' (Gottweis 1998, p 157).

The Red Queen imperative is powerfully influential in the frameworks shaping GM research in New Zealand, at least in the programmes oriented towards commercial profits via production of vegetables, crops or livestock with new characteristics.[196] The driver of relentless competitiveness is manifested in the strong belief, through policy agencies, research communities and sectoral bodies, that it is essential for New Zealand to maintain an active capacity in GM. Such capacity – in R&D institutions and infrastructure, and in the expertise and skills of individual researchers – is considered an important benefit in itself that justifies investment in this new technology.[197] This reflects the imperative of 'speculative capital' identified by Sunder Rajan (2006, pp 8-9) and discussed in the preceding section of this chapter; the belief that sustaining ongoing activity in biotechnology is desirable for its own sake, regardless of other outcomes that might (or might not) be achieved.

These frameworks of value were firmly established in the findings of the Royal Commission of Inquiry on Genetic Modification, which insisted on the necessity of building strong research capacities as 'basic to the establishment of a knowledge

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that early participation in new technologies is axiomatic for maintaining a leadership and thereby creating future wealth and employment… The potential applications of biotechnology are so wide that no-one wants to be left on the starting line'.

[196] However the Red Queen narrative does not feature in the frameworks of purpose and value underpinning the New Zealand research on possible GM biocontrols for possums, discussed later in this chapter.

[197] This pattern is in marked contrast to the electricity sector, where apart from a few small companies developing their own turbine designs, it is widely accepted that the most appropriate role for New Zealand wind energy technologies is to be a "fast follower" and importer of overseas innovations. This difference in expectation will be discussed further in Chapter Seven.

economy' (2001a, p 333).[198] Government policy for GM in New Zealand is predicated on the belief that 'standing still is not an option' (New Zealand Government 2003, p 9). Priorities are to 'grow' the biotech sector, strengthen capabilities and build critical mass in New Zealand to keep pace with global developments (New Zealand Government 2003, pp 3, 5, 16-24; Ministry of Research Science and Technology 2007, pp 8-11, 27-31; McGuinness et al. 2008b, pp 8-9).

The Red Queen imperative also runs strongly through the discourses of New Zealand's research community and interested sectors. Active participation in GM is promoted in terms of New Zealand's economic viability and scientific credibility. A 2003 report on future potentials commissioned by Industry New Zealand encouraged GM development to 'signal to the world that New Zealand is a meaningful global player in biotechnology' (Beckman & Goldberg 2003, p 8).[199] Sector actors interviewed for this thesis in 2006 expressed an acute sense of the demands of competitiveness. The manager of biotechnology research at Crop & Food insisted: 'For us to have a part in [GM science] is very important for the whole aspect of New Zealand and its reputation as a player in the global market' (Interview 2, 26/5/2006). The CEO of NZBio endorsed the belief that biotechnological innovation is essential for New Zealand's future, 'and to lock that out, to me it doesn't seem sensible' (Interview 54, 9/5/2006).

As well as the promised benefits, the perceived threat of New Zealand science and production sectors being "left behind" in global technology innovation contests is a powerful negative incentive inherent in the Red Queen imperative. The fear of "missing out" on the opportunities and benefits projected from work in GM is deeply ingrained. These themes ran strongly through the submissions of many sectoral interest groups to the Royal Commission on Genetic Modification (2001c, pp 55-60, 220-222). For example, the NZ Biotechnology Association argued that:

[198] The option of a GM-free New Zealand was rejected on the rationale that this would cause the economy to contract, and our science and industries would not be internationally competitive (McGuinness et al. 2008b, p 12).
[199] Industry NZ was the government's economic development agency, supporting and fostering a wide range of business sectors; in 2003 it was merged with Trade NZ to become NZ Trade and Enterprise www.nzte.govt.nz/About-NZTE/Pages/Our-history.aspx).

> …if we turned away from genetic modification our country would lose ground to the developed nations of the world, and we would all be subjected to a decline in our quality of life (Royal Commission on Genetic Modification 2001a, p 79).

Other submissions raised similar concerns, advocating that New Zealand must be 'technologically ready' to maximise future commercial opportunities (2001a, pp 82-84). The threat of other countries' products 'beating us to the market' was a powerful incentive: 'We will get rapidly behind if we don't move quickly' (2001a, p 83). The New Zealand Dairy Board insisted that GM technologies were 'essential' to maintain competitiveness for the industry and for the national economy (2001a, pp 85-86); the Board emphasised that global competitors were 'moving fast' to develop GM knowledge and markets, and that New Zealand 'cannot afford not to be in that race' (2001a, p 83).[200] The perception of intense international competition establishes a rationale in which New Zealand's involvement in this technology is argued as an unavoidable necessity. Participants at a 2007 AgResearch workshop asserted that:

> New Zealand agriculture could fall to "Third World" status in 20 years if it doesn't take up genetic modification technology… If we don't adopt this technology we will be left behind… If we do not stay in that science as a nation it will pass us by and we'll never regain that (Timmo 2007).

A senior scientist working on GM vegetables at Crop & Food Research, interviewed for this thesis, used the Red Queen metaphor to describe the pressure to maintain engagement with GM technoscience:

> Ultimately if everyone else is doing something that makes producing a crop easier, more efficient, cheaper or whatever, then if we're not doing it… It's the classic Red Queen hypothesis, from *Alice in Wonderland*, you know, if we don't keep running with everybody else then we're going to fall behind, and there are people out there running flat out, so that is the danger (Interview 17, 17/7/2006).[201]

The threat of global developments outpacing New Zealand was echoed by other interviewees. The Chief Science Strategist at AgResearch insisted: 'if we don't do [GM R&D] we'll get left behind, and that's very bad' (Interview 24, 18/8/2006). The

[200] The New Zealand Dairy Board managed the international marketing and exports of New Zealand dairy products, and was enormously influential in the primary production sector; by the late 1990s it was the world's largest dairy network. In 2001, following restructuring in the sector, it was merged with the major industry co-operatives to become Fonterra (www.dcanz.com/about-nz-dairy-industry).
[201] The Red Queen actually features in Carroll's sequel *Alice's Adventures Through the Looking-Glass*.

CEO of NZBio emphasised the importance of sufficient resourcing to support professional capacity in GM research in New Zealand:

> [New Zealand biotechnology needs] a critical mass, it needs a decent amount of investment… so that you can establish a position in it. The risk is that if you fail to do that then the opportunity's lost (Interview 54, 9/5/2006).

The manager of a product group at Horticulture New Zealand also highlighted the risks of not keeping an active role in GM:

> We've got to be there because there's no use being a backwater in New Zealand… we funded [research on GM veges] because we wanted to ensure that our scientists had the capability, otherwise if we don't have the capability we're in deep trouble when it becomes acceptable (Interview 22, 20/4/2007).[202]

The conceptualisation of GM as driven by rapid advance and ruthless competition is widespread through policy and sectoral domains, and creates an inescapable requirement for New Zealand's science institutions. Credible and active engagement with GM is seen as absolutely necessary to ensure that New Zealand science and production sectors will benefit from the projected advantages of biotechnology and remain competitive in global markets. This narrative of compulsion is a significant strategic benefit for the CRIs undertaking research in GM crops and livestock – in a conveniently circular logic, their work is supported on the grounds of the necessity of support for such work. The sectoral benefits from this rationale for GM technology, endogenous benefits derived by practitioners in this field of research and innovation, rather than exogenous benefits to end-users, society or the environment, are discussed in the following chapter.

The Red Queen imperative has also been influential in the regulatory processes for GM projects in New Zealand. In the years during which the GM projects addressed by this thesis were undertaken, any research, development work or field trials using genetically modified organisms in New Zealand required approval from the Environmental Risk Management Authority (ERMA) under the Hazardous Substances and New Organisms (HSNO) Act 1996.[203] The purpose of the Act is

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[202] This industry group represents New Zealand's 7000 commercial fruit and vegetable growers, providing strategic direction, promotion and sector advocacy (www.hortnz.co.nz).
[203] See http://archive.ermanz.govt.nz/no/index.html . As of 1 July 2011, ERMA was restructured and its functions amalgamated within the newly formed New Zealand Environmental Protection Authority

firmly oriented towards risk, being to prevent or manage adverse effects of new or potentially hazardous phenomena such as GM organisms (s4, HSNO Act). However, consideration of GM proposals also requires that the anticipated economic and related benefits from the proposed new organisms are taken into account (s6(e), HSNO Act), and the formal assessment processes include recognition and evaluation of benefits as well as risks and costs (Environmental Risk Management Authority 1998a, Clauses 9, 13, 14, 22, 26, 27).

As outlined above, New Zealand CRIs' GM work was justified under a diverse range of anticipated benefits and outcomes. However the HSNO process guidelines warned applicants that wider objectives – the hopes for eventual future benefits or products, dependent on successful development and trialling of the organism, and on further approval for release or commercialisation – would not carry significant weight in the assessment process for specific trials (Environmental Risk Management Authority 2000a, pp 22-27, 30). This discounting of longer-term goals was explained as necessary due to the inherent contingency of such projections: 'at the research stage, end-use benefits are often very speculative' (Environmental Risk Management Authority 2004, p 31). The distinction between such intended outcomes and the immediate research was strongly emphasised by the manager of ERMA's GM approval procedures, interviewed for this thesis:

> When applicants come to us they normally come with a very far-looking, far-reaching, you know, well if all this research pans out then the benefits will be we're going to solve cystic fibrosis… fantastic things are going to come out of this. And we [ERMA] actually have to knock all of that out of our analysis and say: yes, but this particular piece of research… isn't going to get you to that benefit that you're claiming you're going to achieve. You've still got alot of steps along the way before you get to that ultimate benefit (Interview 30, 16/8/2006).[204]

Only outcomes specific to the particular research project could be given weight in ERMA's evaluations. Two main kinds of outcome were recognised (examples of which are detailed in the following paragraphs). The first comprised new scientific

(EPA), an independent Crown agency responsible for regulation of New Zealand's environmental management; see http://www.epa.govt.nz/new-organisms/Pages/default.aspx .

[204] This interviewee illustrated her explanation with a whiteboard diagram of a classic linear-model process for R&D, headed "Pipeline" and moving from "Proof of concept" through "Lab", "Outdoor development" and "Conditional release" to the last stage of "Product to market".

knowledge in areas relevant for further advances in GM work, such as transgenic techniques, gene function, protein expression in milk, and the performance and environmental effects of GM plants. The second area of recognised outcomes was the maintenance of capacity and expertise in GM, to support the competitiveness and international standing of New Zealand science. The Red Queen imperative emerges as a fundamental rationale for the regulatory agency's approval of GM research proposals. The priority of sustaining New Zealand capabilities in this technoscience serves as a justification of the value of CRIs undertaking such work. Whether or not the "downstream" outcomes projected from the research actually come to fruition or not is irrelevant to the evaluation process; the Red Queen provides a hegemonically inarguable framework of value under which the work may be sanctioned.

Despite the constraints imposed by the formal exclusion of contingent future projections, and the emphasis on risk mitigation and management, the CRIs' applications were an opportunity to highlight the intended benefits and positive outcomes of proposed work.[205] Typically, applications optimistically outlined as many potential benefits as possible; the application forms' structure allowed such claims to be reiterated and expanded upon at different points. For example, AgResearch's 1998 application for work on GM cattle aimed to develop enhanced dairy products with improved processing characteristics, greater nutritional value and reduced allergenicity, and proteins to be used in drugs to treat multiple sclerosis (AgResearch 1998, pp 3, 6, 14, 27-28). But the Authority drew a careful distinction between the research itself and these longer-term objectives: 'at this point it would be premature to speculate on what those benefits might be' (Environmental Risk Management Authority 1999b, p 12). The formal appraisal is coolly dismissive:

> The applicant has focussed on the potential benefits that are likely to accrue if the desired outcomes from an exploratory contained experiment are realised… The health benefits are theoretical since transgenic cattle have yet to be developed (Environmental Risk Management Authority 1999a, p 37).

[205] ERMA's advice to applicants encourages comprehensiveness and lateral thinking to include as many anticipated outcomes as possible: 'Identification of risks, costs and benefits involves examining all sources of effect [and] potential areas of impact... The aim is to undertake a systematic and wide-ranging review' (Environmental Risk Management Authority 2004, p 10). Specific advice covers such considerations as timing, distribution, and whether the expected benefits of the GM organism accrue directly or indirectly to different groups or sectors (Environmental Risk Management Authority 2000a, pp 11-13; 2004, pp 17-25; 2005a, pp 9-10, 16-18).

Nevertheless, ERMA recognised the value of the scientific knowledge to be gained, and the need for New Zealand science to support economic competitiveness:

> The Committee accepts that given the significance of the dairy and wider pastoral industries in New Zealand, its research institutions should be at the leading edge of research into the genetic factors which control and regulate milk production… and of associated biotechnological innovation, including recombinant research… The issue is not so much whether the long term benefits outlined will be achieved, but whether research leading to those potential benefits is a legitimate and valuable scientific endeavour (Environmental Risk Management Authority 1999b, p 12).

The trials were approved on the basis of the intended benefits to technoscientific research, and the goal of maintaining capacities in an field deemed necessary for the future performance of a production sector critical to New Zealand's economy.[206]

The Red Queen imperative was advanced by AgResearch itself in a later application for field trials with GM livestock. This positioned the research in relation to the CRI's stated mission of supporting and improving wealth creation in New Zealand's pastoral sector.[207] AgResearch's plans for a range of GM species targeted research objectives as well as 'breeding and the production of antigens, biopharmaceuticals, enzymes, hormones and other products with commercial applications' (AgResearch 2007a, p 4). Arguing that '[t]he pastoral sector is the backbone of New Zealand's economy and its continued success is essential to this country's wellbeing', AgResearch justified its work as necessary for the sector's ongoing profitability:

> AgResearch has now developed a world leading capability in transgenic livestock research and development… This positions AgResearch and New Zealand to take a leading international role in commercial applications of transgenic livestock… It is important that New Zealand is positioned firmly at the forefront of the international biotechnology sector, and provides innovative products for the dairy industry (AgResearch 2007b, pp 8, 83).

International competitiveness and the perceived rate of GM developments overseas were highlighted in justification of working with multiple species:

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[206] The approval was, however, appealed to the New Zealand High Court, which reversed ERMA's decision on technical grounds and required a reconsideration (*Bleakley v ERMA* [AP 177/00]). ERMA later re-approved the work (Satterfield & Roberts 2008, p 203; McGuinness et al. 2008b, p 32).

[207] AgResearch's *2020 Science Strategy* outlines an ambitious vision for technoscientific prosperity for the pastoral sector and the nation, including doubling the value derived from dairy production, and developing valuable new product opportunities beyond food and fibre commodities (AgResearch n d).

> [T]he pace of global research and development using different transgenic animals is rapid. To keep up with global research directions and to take advantage of commercial opportunities, AgResearch needs to have regulatory approvals in place for a broad range of animal candidates (AgResearch 2007a, p 13).

The effects of the Red Queen imperative are also clear in New Zealand work on GM vegetable crops. For example, Crop & Food Research's 2003 application for a field trial of glyphosate-resistant onions projected ambitious future commercial returns to the horticulture industry, and benefits to the environment in reduced agrichemical use (Crop & Food Research 2003, pp 8-11, 43). But ERMA dismissed these intended outcomes as beyond the scope of the particular field trial (Environmental Risk Management Authority 2003, pp 55-56, 86). The longer-term intentions were not considered credible as justification for the trial: 'many of the indirect benefits identified are speculative, and contingent on the possible development and commercial application of this project' (2003, p 51).

The Roundup-ready onion trial was approved, nevertheless, on the grounds of the usefulness of the scientific knowledge that would be gained (2003, pp 51, 75, 82, 86). Crop & Food's application emphasised the importance of a range of goals including new information useful for future research (Crop & Food Research 2003, pp 7-13, 48). Expected advantages for Crop & Food as an institute were highlighted, with reference to years of work creating 'a niche that is "onion biotechnology"', and broader national benefits were also claimed in 'help[ing] New Zealand researchers stay at the forefront of this particular technology' and contributing to 'the expansion of New Zealand's biotechnology capabilities… in order for New Zealand to remain competitive in the global economy' (2003, pp 42, 44-45).

These typical examples of the frameworks of value justifying approval of GM R&D in New Zealand illustrate the importance of the Red Queen imperative for this country's research institutions. The regulatory processes rule out many of the projections of future benefit from GM work – intended outcomes for societal or environmental good that might justify undertaking such research. However, framing biotech activity and capabilities as worthy and necessary objectives in themselves serves to validate GM work. The implications of such legitimation of endogenous sectoral benefits – while exogenous societal benefits are simultaneously advocated and dismissed – are discussed further in the next chapter.

Greening GM

Much of the GM research undertaken by New Zealand's science institutes has been oriented around commercial values and economic competitiveness, as outlined above. Scientific knowledge and innovation are valorised and supported for their presumed contribution to the economy and the nation's prosperity. However other frameworks of value are also evident in the discursive and strategic construction of GM technoscience in New Zealand. As with the positioning of wind energy in the context of global climate change, discussed in Chapters Five and Seven, the ideals and requirements of environmental protection have been deployed to validate biotechnology R&D. Such "green benefit" framings are associated with three areas of GM research in New Zealand: vegetables modified for resistance to pests, disease or herbicide; forage grasses modified for reduced methane emissions from ruminant livestock; and biocontrols for possums.

Research projects on GM vegetables were undertaken by the (then) Crop & Food institute from the late 1990s to the late 2000s. The environmental benefits envisaged from the use of these crops were framed in relation to current agricultural production systems and practices.[208] The GM vegetables were promoted as a means to limit harmful effects and reduce the environmental footprint of contemporary industrial growing methods. Crop & Food's proposals to field test GM potatoes, onions and brassicas highlighted intended improvements via reduced chemical loadings on soils and groundwater, as well as other projected benefits such as reduced tillage impacts (Environmental Risk Management Authority 1998c, p 30; Crop & Food Research 2003, pp 8-9; Environmental Risk Management Authority 2006, pp 19, 64-67).[209]

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[208] Chapter Seven discusses the co-construction of projected future benefits along with the present-day problems for which the technological innovation is advanced as the solution – such as intensive chemical use in large-scale agricultural production.

[209] Crop & Food projected that herbicide-resistant onions would reduce herbicide loadings by 70% with significant cost advantages for growers: 'From an economic viewpoint this saving equates to about $500 per hectare of herbicide or about $2.6 million across the country per year' (Crop & Food Research 2003, p 11). But such claims of reduced agrichemical use from the introduction of GM crops have been strongly contested, with evidence that herbicide applications have actually increased as a consequence of these crops' use (Danish Council of Ethics 2007, p 32). Outwater (2012) reports that in

Work on GM forage species, developing transgenic clover and ryegrass, has been undertaken by research consortiums involving AgResearch and other major companies in New Zealand agriculture.[210] There were dual aims for this research – to increase nutritional value and thus milk production in the cows grazing on the 'super-grass', and to reduce the methane emissions from grazing livestock, a major component of greenhouse gas emissions contributing to global warming (Atkinson 2010; James 2010; Royal Society of New Zealand 2010; NZ Press Association 2010a, 2010b, 2010c).[211] However, there were strong concerns about the environmental risks of even a field trial of these new grasses, and commercial risks with potential adverse impacts on New Zealand's "clean green" image and export markets. AgResearch decided to limit the forage projects to overseas research facilities, citing a lack of acceptance of GM, and difficulties gaining approvals under the regulatory processes in New Zealand (AgResearch 2010b, pp 39-40; NZ Press Association 2010d).

The intended environmental management benefits among the suite of objectives of GM R&D projects were emphasised by many of the biotech sector actors interviewed for this thesis. Some interviewees expressed their strong belief that GM could make significant contributions to environmental sustainability, and expressed regret that such potentials were not appreciated by the public and ecological advocates. As a Crop & Food scientist explained:

> I was very disappointed to be challenged by environmental groups… yeah, and the organic farmers in particular, because what we do, if it could be accepted by organic farming it could do so much to help them, so they've got other ways of controlling pests and diseases, that's what it was all about…

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the USA, 'rates of glyphosate (in the herbicide Roundup) use on corn, soybeans, and cotton have increased by more than 10 percent per year. It is estimated that GM crops in the United States have increased the use of herbicides by 240 million kilos more than what would have likely been used in the absence of genetic engineering… This trend is confirmed by 2010 United States Department of Agriculture pesticide data, which shows skyrocketing glyphosate use, accompanied by constant or increasing rates of use for other, even more toxic, herbicides… [as] seeds genetically modified to resist herbicides have produced weeds resistant to glyphosate'.

[210] Seed company PGG Wrightson contracted Australian science research on GE ryegrass; AgResearch, dairy giant Fonterra and other New Zealand agricultural interests formed the Pastoral Genomics Group to investigate GE clover and ryegrass (Atkinson 2010; NZ Press Association 2010a, 2010b).

[211] The issues around the methane emissions from New Zealand livestock have been a highly controversial dimension of the country's response to global climate change: 'Livestock "burps" produce about 90 percent of the methane that makes up 43 percent of NZ's greenhouse gas emissions' (NZ Press Association 2010d).

> and I find that [opposition] rather ironic, yeah, and frustrating (Interview 11, 8/11/2006).

Researchers working on GM crops described their strong personal commitment to sustainability, and the societal benefits of improving New Zealand's environmental management. These values were central to their work and their identity as scientists:

> What really motivates me is the reduction of pesticide use for the environment, benefits to the environment, which should benefit everyone as society, as New Zealand in general… It's not an economic thing, it's a societal thing, looking after our environment, and that's what motivated me to get into this in the first place… It wasn't so much to help Joe Bloggs farmer, it was what I could do for the production system as a whole to make it more environmentally sustainable (Interview 11, 8/11/2006).

> Most people here who are involved in genetic engineering came from a background of wanting to do good things for the environment, even card-carrying members of Greenpeace, you know (Interview 2, 26/5/2006).

> Any person that I know in plant biotechnology has got into it because they want to do good, they want to try and improve things (Interview 17, 17/7/2006).

For these scientists, green idealism and goals of improving the environmental impacts of agricultural systems were not inconsistent with the economic frameworks of commercial competitiveness underpinning policy and institutional expectations of GM technoscience. As seen in the concepts of benefit driving the electricity industry and company branding strategies in New Zealand (discussed in Chapter Five), the two modes of orientation seemed happily compatible to these sector actos. A Crop & Food scientist argued that while research agencies 'have the responsibility to their shareholders to make a profit, the best way you do that I would think is… to actually do good and produce good things' (Interview 17, 17/7/2006). The CEO of NZBio also endorsed the close interconnectedness of social benefits and marketable products for business (Interview 54, 9/5/2006).

The claimed environmental objectives of R&D for GM crops in New Zealand reflect increasing awareness of the need for sustainability in agriculture (Parliamentary Commissioner for the Environment 2004a). But as discussed in the Prologue, the story of biotechnology in New Zealand also features a unique application of GM technoscience, focused on completely different kinds of goals from the work on crops and livestock. More than a decade of research concentrated on GM techniques intended primarily to achieve non-monetary benefits for the public good – protecting indigenous biodiversity and natural ecosystems by helping to control one of New Zealand's most destructive animal pests, the voracious Australian brushtail possum (*Trichosurus vulpecula*).[212]

Several research streams and technical options were pursued by the two CRIs with interests in environmental management, AgResearch and Landcare Research, and university collaborators in New Zealand and overseas.[213] The major focus of the research was on techniques to disrupt fertility and breeding processes in possums (Eckery 2007).[214] Such methods as a GM immunocontraceptive were seen as more humane and were more acceptable to the public than other possible interventions (Parliamentary Commissioner for the Environment 2000, pp 41, 46, 84; Wilkinson & Fitzgerald 2006, pp 17-19, 24-26, 37; Ji 2009, p 22).[215] Related strands of research investigated the crucial question of how best to disperse the biocontrol into wild possum populations. Potential delivery methods studied included conventional bait drops, GM plants, a spray device, or a self-disseminating vector, the possum-specific nematode worm *Parastrongyloides trichosuri* (Cowan et al. 2005; Cowan et al. 2006, pp 287-288; Cowan et al. 2008; Walcher et al. 2008; Duckworth et al. 2009; Ji 2009, pp 22-23; Cui et al. 2010a; Duckworth et al. 2010; Duckworth et al. 2011).

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[212] Introduced between 1837 and the 1920s with the aim of establishing a fur trade, possums have no natural predators in New Zealand and spread rapidly to now infest more than 95% of the country. Their ongoing impacts on forest ecosystems, indigenous wildlife and forestry are well documented (Parliamentary Commissioner for the Environment 2000, p 11; Environmental Risk Management Authority 2007a, pp 5-6; 2007b, pp 11-12; Ji 2009, p 20). As carriers of bovine tuberculosis, they also pose a major risk for New Zealand's dairy and meat industries (Coleman & Fraser 2005, p 81; Environmental Risk Management Authority 2007a, pp 6-7; Animal Health Board 2008, pp 4-5, 10).

[213] Administration of the overall programme was coordinated through the National Research Centre for Possum Biocontrol, a partnership between the CRIs and key end-user organisations (Animal Health Board, Department of Conservation, Ministry for Agriculture and Forestry, and Regional Councils). It was funded by FRST under the Public Good Science Funding category as an outcome based investment (OBI). The OBI objectives included strategic coordination of the overall programme, setting research directions and priorities, and providing a focus and communications framework for the various parties involved (http://possumbiocontrol.agresearch.co.nz/mediawiki/index.php/Main_Page).

[214] See http://www.landcareresearch.co.nz/research/programme.asp?Proj_Collab_ID=8; and FRST research contracts C10X0218: Genetic and Hormonal Control of Reproduction, and C10X0501: Biological Management of Possums (AgResearch), at http://www.msi.govt.nz/update-me/who-got-funded/.

[215] GM methods aimed at reducing numbers through infant mortality, by interfering with lactation or the transfer of natural immunity from mother possums to pouch young, were strongly rejected as unacceptably inhumane (Parliamentary Commissioner for the Environment 2000, p 41).

The proposed biocontrols – involving perhaps the general release of a self-spreading GM organism inducing sterility – were intensely controversial (Parliamentary Commissioner for the Environment 2000, pp i, 1, 83-87; Royal Commission on Genetic Modification 2001a, pp 164-165). Concern about public responses to such potentially risky new technoscience underscored the biocontrol team's ongoing obligations to constructive public engagement (Fisher 2006, p 10; Eckery 2007).[216] The pressure to demonstrate safety was intense, but so was the need to secure acceptability for the work in terms of the intended benefits of better possum control.[217] Justification of the potential application of GM technoscience for pest control was advanced via two principal framings of environmental benefit – managing the risks to New Zealand dairy farming from bovine tuberculosis carried by possums, and reducing the effects of possums on native ecosystems and wildlife.

Protection of New Zealand's unique natural heritage is a powerful if intensely contested national ideal.[218] Promotion of these islands as a tourist destination, and of

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[216] Over the years there has been fierce opposition both from local communities and nationally to the widespread use of poisons, notably 1080 (sodium monofluoroacetate), spread mostly aerially across the landscape for possum control. Protest action included the high-profile 1996 occupation by local Maori blockading access to Department of Conservation reserves at Mangamuka in Northland (http://www.royalsociety.org.nz/1996/12/18/protesters-vow-to-stay-put/). Organised opposition to local control projects, and anti-1080 media and information campaigns, continue to the present day (eg, http://www.nzherald.co.nz/nz/news/~10609368, http://www.nzherald.co.nz/nz/news/~10656951). The risk of GM controls generating similar, or even more vociferous responses was an ongoing issue for the biocontrols research programme.

[217] Given that possums are marsupials, the specificity of the proposed biocontrols was a key factor in research around safety. Possum physiology and breeding processes are very different from eutherian mammals, as was emphasised in interviews for this thesis with scientists at Landcare Research and AgResearch (Interviews 16 and 37). Trials were undertaken to test the susceptibility of non-target species to the biocontrols (Duckworth et al. 2008). However the major risk concern was the potential effects on Australian marsupial wildlife, including national icon species such as the kangaroo and koala, if a GM sterility-inducing biocontrol was somehow conveyed across the Tasman (Parliamentary Commissioner for the Environment 2000, p 43; Wilkinson & Fitzgerald 2006, p 22).

[218] New Zealand ratified the international Convention on Biological Diversity in 1993, and subsequently established a wide-ranging *Biodiversity Strategy* to fulfil these commitments and address the well-documented decline of indigenous wildlife, plants and ecosystems (New Zealand Government 2000). Policy for biodiversity protection is predominantly framed in terms of the nation's duty to preserve its extraordinary natural heritage: 'New Zealand's high level of endemic biodiversity makes a unique contribution to global biodiversity and places on us an obligation to ensure its continued existence' (New Zealand Government 2000, Executive Summary). But even under these kinds of policy priorities, economic dimensions are also acknowledged in terms of the importance of the country's "clean, green image": 'Increasingly, New Zealand's international reputation and trade opportunities will depend on our performance in maintaining a quality natural environment, of which biodiversity is a key element' (2000, Executive Summary). Some research has been undertaken on the economic value of conserving New Zealand's landscapes and biodiversity, focusing on regional economic benefits from the tourism industry, and the contribution of ecosystem services such as freshwater filtration and erosion and flood control (Department of Conservation 2006). Nevertheless, the prospects for indigenous biodiversity continue to worsen, with increased numbers of threatened

New Zealand's export products, focuses strongly on our "clean green" brand and features dramatic images of lush forests and rich pastoral landscapes.[219] But the ravages of possums and other environmental pests seriously compromise this cherished national identity (Environmental Risk Management Authority 2007a; Manaaki Whenua Landcare Research 2008, n d-a, b). The biocontrol research objectives were focused around the ambitious goal of 'improved management of possums in New Zealand such that they no longer threaten native biota'.[220] This purpose was evident in the strong personal commitment of all the biocontrols scientists interviewed for this thesis, that protecting biodiversity is an important and valuable purpose – in itself, for the nation and future generations, and in terms of the duty of their research institutions to provide science and technology for the public benefit. As one AgResearch scientist explained:

> Ultimately the reason I'm doing this I suppose is that I'm convinced that possums will destroy what's left of the New Zealand environment if they're not dealt with, and that alone is a very potent motivation for doing something about the problem. So to me it's an absolute imperative… primarily from an ecological point of view (Interview 25, 6/12/2006).

The focus on non-economic goals for the public interest was a matter of no little pride for some biocontrols researchers: 'we're not in it for commercial gain' (Interview 16, 17/5/2006). The distinction between the biocontrols work and other FRST-funded programmes oriented around economic benefits was a strong part of these actors' sense of their identity and mission as scientists: 'they're not viewing it like the Foundation product development portfolios where they're expecting to see millions of dollars in revenue generated' (Interview 18, 7/12/2006).

Working for public-good purposes was seen as a more socially acceptable use of GM than crops and livestock; a technology policy manager described the expected response of key interest groups:

> They will be much more favourably disposed towards GM pest control technology than towards GM food production technology, because … the benefits of GM pest control are to the environment and the public… Usually [the regulatory agency ERMA has] some applicant wanting to plant their GE

species, significant reductions in habitat areas and indigenous vegetation cover, and the risk of extinction in the wild for many icon species (WWF New Zealand 2012, pp 20-23).

[219] For example, www.newzealand.com , www.nzte.govt.nz , www.fonterra.com/wps/wcm/connect/fonterracom/Our+Business/Sustainability .

[220] National Research Centre for Possum Biocontrol website http://possumbiocontrol.agresearch.co.nz/.

> cabbages, and they've got two people in support and 500 against, but this will be slightly different… So I suspect that the arguments around GM possum control might be less difficult than the ones that are currently happening around GM food production (Interview 28, 18/4/2007).

Despite the focus on non-commercial goals, possible future opportunities were identified for applying the knowledge gained in the possum biocontrols research to other animal management problems (Royal Commission on Genetic Modification 2001a, p 162). A university scientist suggested lucrative potentials: 'the technology might be translated to be utilised on the world's other pests… some money could be made in selling that IP' (Interview 18, 7/12/2006). Other marketable applications were noted by a Landcare Research science manager:

> The technologies we've learned will have big applications not only for fertility control but also some of the delivery systems will be just as important for disease control… vaccines particularly have an enormous amount of potential [and] techniques for controlling wildlife health (Interview 16, 17/5/2006).

While the biocontrols research was strongly characterised as an ideals-driven mission working for the benefit of New Zealand's threatened species and native bush, there were significant economic dimensions inherent even in this framework of values. The daunting costs of possum management via existing methods are an ongoing burden, and were a major factor in the initiative to develop alternative techniques via GM.[221] The biocontrols were promoted as improving the efficiency and affordability of pest management: 'the only long-term, cost-effective solution to the possum problem in New Zealand' (Cowan 1996, p 655). Agencies' budget constraints mean that conventional control programmes are restricted to the most urgent priority areas each year.[222] While some biocontrol delivery options would require similar operational approaches to the current aerial drops of 1080 bait, significant advantage was seen in the prospect of a self-disseminating biocontrol that, once introduced, would spread

[221] In the mid-2000s, more than $80 million per annum was spent on aerial and ground poisoning programmes and trapping of possums (Cowan et al. 2006, p 287); by 2008, costs of conventional control programmes were around $100 million per annum (Cowan et al. 2008, p 573). Further government funding for the national bovine Tb eradication programme was around $87 million per annum (Environmental Risk Management Authority 2007a, p 6); possum control costs were the 'biggest single expenditure' annually for the Animal Health Board in the mid-2000s (Interview 28, 18/4/2007). In addition to expenditure by central government and regional councils, significant amounts are spent by farmers, landowners and residents on possum control; in 2000 these costs were estimated at $74.8 million per annum (Parliamentary Commissioner for the Environment 2000, p 11).
[222] Department of Conservation, Head Office policy manager (Harry Broad), pers comm. May 2012.

itself independently in the wild.[223] A Landcare Research science manager highlighted the potential:

> There is the additional benefit, if we can ultimately go to transmissible control, that we can actually control possums over a much wider area than we would ever be able to do otherwise, given that money is the limiting factor on pest control (Interview 14, 23/4/2007).

A further dimension of the beneficial framing of the proposed biocontrols was their compatibility with existing pest management technologies and systems. As with the integration of windfarms into New Zealand's electricity system (discussed in Chapter Five), this innovation was positioned as having the advantage of fitting in alongside current pest control processes. Although the fertility interventions used radical new scientific tools in the form of GM, the benefits were framed as extending the effectiveness of current poisoning methods, as explained by Landcare Research scientists:

> The main use is likely to be in conjunction with large-scale conventional control, so you'd knock possums down with toxins and then you'd use fertility control to keep the populations down (Interview 14, 23/4/2007).

> They'll both complement each other. At the moment you use your toxins, they drop the numbers right down and then numbers gradually, well quite quickly increase, and you have to go back in another four years. With fertility control you might only go back every ten to twelve years (Interview 16, 17/5/2006).

Improving the outcomes achieved with current pest control techniques was also a high priority for the other mode of intended benefit of the biocontrols, reduction of the risks of bovine tuberculosis spread by possums. This goal was determined primarily by economic values, in terms of potential losses to New Zealand's dairy industry and threats to New Zealand's exports and international reputation.[224] The government

[223] Studies demonstrated the successful establishment of a likely vector for GM biocontrols, the gutworm *Parastrongyloides trichosuri*, through previously uninfected possum populations. From a single release site in North-West Nelson, the parasite spread to infect animals over 8000 hectares of forest in just under four years (Cowan et al. 2005; Cowan et al. 2006; Ji 2009). Subsequent research showed that a new *P. trichosuri* genotype successfully 'invaded' a population of possums already parasitised with an earlier form of the worm, and it was concluded that *P. trichosuri* had 'all the attributes of a highly effective vector' for a GM fertility control (Cowan et al. 2008, pp 573, 575).

[224] Potential losses to the meat and dairy sectors from bovine Tb were estimated at up to $1.3 billion annually (Ralston et al. 2002, p 2), or $5 billion over ten years (Environmental Risk Management Authority 2007b, p 11). New Zealand is a member of the Office International des Epizooties (OIE), the world organisation for animal health, which imposes strict requirements for management of bovine Tb; non-compliance with OIE standards could lead to trade barriers against New Zealand exports, or to

agency responsible for managing bovine Tb, the Animal Health Board (AHB), coordinates intensive pest control programmes using conventional poisoning methods: 'Reducing possum population densities in the wild remains the key to maintaining low overall herd infection rates' (Animal Health Board 2010, p 6).[225] However the justification for this work is focused on possums as carriers of bovine Tb, not on the damage they cause to ecosystems and wildlife. While there is considerable practical synergy between the two frameworks of value and intended benefit – biodiversity conservation and protection of dairy and beef herds – there is also a significant disjunction. An AHB manager, formerly a senior advisor for the Department of Conservation, interviewed for this thesis, acknowledged:

> [The two goals] mostly conveniently go side by side, or overlap… [but] in some areas, for example Banks Peninsula, we've got a history there of very effective possum control [and] we've achieved total eradication of tuberculosis, there's no Tb there, none in the livestock and none in the wildlife. So when we reach that point, as far as the Animal Health Board is concerned, that is "problem solved" and we can move on… So that creates a risk that… as the Tb programme withdraws from areas where it's been successful then yes, possum populations will naturally recover (Interview 28, 18/4/2007).

The respective possum control work of the Animal Health Board and conservation agencies such as the Department of Conservation are based in fundamentally different modes of value. Tensions between the different kinds of benefit advanced as the rationale for the same activity – controlling possums – were recognised by some of the scientists researching GM biocontrols. There was a strong sense that priority was given to economic concerns, in policy domains and broader public perceptions of environmental management, relative to more qualitative, ideals-based conservation goals. As a university scientist working with the biocontrol programme explained:

> What's really driving the possum biocontrol [research] is the bovine tuberculosis side of it… The environment is a concern, yes, you can talk about threats to this and that and the other thing, but that doesn't attract very much money. But because there's a threat through bovine Tb to one of the major industries of New Zealand, the dairy industry, then that gets people's attention, yeah… Everybody recognises [the environment] as being an important thing, but you can't put a tangible sort of thing to it, you can't give

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consumer rejection of New Zealand dairy and meat products (Parliamentary Commissioner for the Environment 2000, p 24).

[225] The AHB strategy of targeting priority areas with high densities of infected possums has achieved significant reductions in the levels of bovine Tb infection nation-wide; in local areas, strategic intensive possum control results in the 'disappearance ' of Tb (2010, pp 4, 10, 13, 29).

> it a bottom line. So if we lose all these native birds it doesn't affect Joe Blow's back pocket like the dairy industry does (Interview 18, 7/12/2006).

The research trajectory of GM biocontrols as a potential technoscience innovation in New Zealand's arsenal against possums was shaped by two constructs of perceived or intended benefit. In Bourdieu's terms (as outlined in Chapter Three), the symbolic capital of the economics-driven imperatives of New Zealand's dairy sector was seen by some actors in the field as exerting stronger influence than other frameworks of social and environmental value. The relative forcefulness of different narratives of benefit in key policy and sectoral domains, where decisions are made and directions set for technoscience R&D, is discussed in Chapter Seven below.

In the end, pragmatic cost-effectiveness was a major factor in the closure of the possum biocontrols work in October 2010 (Green Party of New Zealand 2010; Wallace 2010). The programme came to an end due to changed funding criteria; resources were prioritised to research into control methods targeting multiple pest species simultaneously, with the aim of getting more impact for the money invested (Foundation for Research Science and Technology 2010). The withdrawal of support for GM biocontrols research highlights important questions around the frameworks of expectation and need underpinning technoscience innovation, and the justificatory benefit projections validating other GM research in New Zealand. These issues are explored in the next chapter.

Conclusions

The extraordinary claims advanced for GM, as a technoscientific field that will deliver radically new products, techniques, knowledge, substances and living organisms, have established an irresistible appeal for many political, business and sectoral groups. The persuasive power of this Promethean technology is asserted both in its capacity to intervene directly in the fabric of existence, creating new entities that would not be possible with ordinary scientific or production methods, and in its promise of enormous commercial profits.

From its inception GM research and the products and processes intended to be derived from it have been strongly associated with economic benefits – on a scale far beyond the resources available to many science research fields. Not surprisingly, GM is positioned in policy, high-level strategic inquiry processes, and sector discourse and promotions as a necessary requirement for the growth and advancement of the nation's economy. The imperatives of international competitiveness, encapsulated in the analogy with Lewis Carroll's Red Queen, only strengthen the perceived necessity for New Zealand engagement in this field.

However, the benefit framings associated with GM are not solely oriented around commercial values. Other purposes and intentions are significant in the shaping of this technoscientific field, including health and environmental benefits. The unique focus of New Zealand's research programme working on possible biocontrols for possums emphasised the potential of GM methods and knowledge to be applied for very different kinds of objectives from the economic priorities that predominate in the dominant modes of this technoscience. Nevertheless, pragmatic concerns of costs and the protection of New Zealand's primary production industries were inextricably intertwined with the more ideals-based, qualitative projections justifying GM research in this country.

Chapter Seven

Patterns of association

Introduction

This chapter explores some of the underlying patterns and implications of the work of benefit claims in technoscience. The two preceding chapters focused on the benefit projections advanced for GM and wind energy in New Zealand, and the influence of expectations on research and innovation trajectories in these fields. A focus on benefit claims highlights the close relationships between abstract constructs of intended future states and the present-time requirements of the electricity and biotech industries and New Zealand technoscience. These sectors are the contexts within which claims for R&D and new technologies are embedded and deployed, and where expectations have symbolic and performative salience. These domains are, moreover, competitive arenas where benefit projections are central to actors' efforts to establish and maintain perceptions of the desirability, utility and worthiness of particular technology applications and of technoscience in general.

This chapter investigates some of the underlying questions about technoscience paradigms and processes that run through the promotion of GM and wind energy in New Zealand. What is the key to a "successful" benefit claim? Chapters Five and Six have shown some constructs of expected future benefit exerting considerable appeal and persuasive influence in contested sociotechnical fields. However, the projected beneficial outcomes of other potential technoscience applications have gained less traction in securing acceptance and support for those innovations and their diffusion. Biotech advocates dream of the "killer app", a product of genetic science offering benefits that are so irresistibly compelling it will sweep the market and make fortunes. But what kinds of expectation – and what kinds of needs, imperatives, priorities and desires – generate the necessary momentum and ongoing commitment for R&D and uptake of new technologies? What are the linkages between projected benefits from research and innovation, and the problems and demands for which technoscience is positioned as the answer?

The development trajectories of GM and wind energy in New Zealand show the importance of suitably compelling problems, failings or needs as drivers of R&D and innovation. In discourse, policy, and the strategic dynamics of technoscience fields, these imperatives are the "other side" of benefit projections. A range of negative scenarios are referenced as incentives for research and new technologies – from the vast scale and complexity of looming global environmental change to specific local threats to biodiversity, from the demands of international economic competition to the personal needs of individuals with debilitating diseases. Such problems are useful strategic resources for the promotion and uptake of R&D and innovation, asserting a "problem push" to boost the appeal of a technoscientific "benefit pull". This chapter explores the significance of different framings of need, difficulty, lack and inadequacy in relation to the corresponding benefit claims in the legitimation of new research and technoscience options.

Consideration of these dimensions of benefit projections also draws attention to the diverse registers of value that underpin the framing of anticipated outcomes from R&D and new technologies. Advocacy and justification for technoscience can be oriented around fundamentally different priorities and criteria. An obvious instance of this are the tensions between promotion of economic or commercial objectives, and a focus on non-monetary public-good goals. But the mix of benefit constructs is often more nuanced and complicated than simple contrasts or dichotomies, and multiple value frameworks can coexist and overlap. This chapter explores the heterogeneity of the narratives of benefit and need advanced for GM and wind energy in New Zealand. The development trajectories and strategic positioning of innovation in these two fields show the significance of different modes of expectation. A major distinction is between outcomes intended for the benefit of external stakeholders or society at large, and research objectives focused around technoscience communities and institutions themselves. This pattern is evident in the respective approaches of the two sectors to R&D, and the strong priority given to maintaining active involvement of New Zealand researchers in GM.

Any prediction or projection into the future can only express actors' intentions and assumptions. Projections of benefit from technoscience research and innovation may prove to be less compellingly persuasive than advocates would hope; needs, contexts and assessment criteria may change; and actual events may turn out to be something quite unexpected. Nevertheless, technoscience discourses typically assert a confident inevitability. The desirability and advantages of a new technology or application are unquestionable in its representation in R&D policy and sectors' strategic positioning and advocacy. It is taken for granted that the benefits will eventuate, will be recognised and appreciated, and will inexorably carry the innovation forward to successful uptake and diffusion. But the stories of GM and wind energy in New Zealand include many research programmes and development proposals where, over just a few years, the momentum was not sustained – usually fading quietly away in comparison to earlier enthusiastic projections. In both fields, innovation projects were closed down, not renewed past the initial term, or never actually implemented despite receiving regulatory approval. This chapter concludes with a brief assessment of such failures. They reinforce the understanding that the principal importance of constructs of future technoscience benefit is not actually in any relation to future outcomes. The primary purpose of benefit claims (and needs framings) is to provide leverage and legitimation for present-time R&D activity.

The "dark side" of benefit claims

The projection of attractive future benefits from technoscientific R&D and innovation is crucial to secure the support, resourcing and societal acceptance necessary for ongoing research work and uptake of new technologies. But the visions and scenarios of expected benefits are often given additional persuasive impetus by their opposites – the problems, failings and inadequacies which the innovation is intended to address. A strategic symbiosis is established between problems of various kinds and their projected solution through technoscience (van Lente 2000, p 55; Michael 2000b, p 22). Sturken and Thomas (2004, p 9) describe a pattern where 'responses to new technologies are… shaped by both a sense of lack and loss and a hopeful investment in the possibility of resolving that lack and loss in the future'.

Dysfunction or constraints may be evident in current technologies, systems and products, but anticipated future difficulties can also exert pressure for change to new modes, as discussed in Chapter Three. Problems highlighted as the "other side" of the drive for technoscientific innovations and improvements may be framed as severe and intractable, urgent and unavoidable – the crisis or major failure emphasised by Kuhn (1996) and Perez (2002) as necessary to generate a shift to a new paradigm. Often, however, the momentum comes from a more loosely-defined construct of chronic inadequacy or limitation, as described by van Lente (1993) and Constant (1987). The compulsion for technoscientific change may be found in a generic insecurity or fears of possible future decline, as in the patterns described in Chapter Two as the Red Queen imperative. Whether specific or broad, urgent or creeping, problem constructs are important for an understanding of the discursive and strategic framing of the intended benefits of R&D and innovation. The trajectories of GM and wind energy in New Zealand show the full range of different kinds of problem constructs, from the immediate to more distant far-term issues, and from the direct demands of particular situations to more diffuse concerns.

Many of the technoscience actors interviewed for this thesis acknowledged the value of sufficiently significant problems as imperatives to justify investment in research and technological change. A biotechnology policy advisor at the Ministry of Research, Science and Technology admitted the usefulness of such incentives: 'Yep, that would certainly help… absolutely, a really serious problem… The "burning platform" they call it in policy-speak… facing disaster' (Interview 45, 9/5/2006). An AgResearch scientist noted ruefully that: 'unfortunately it often takes crises before people come to any understanding, till they see things clearly and are willing to make a move or do anything' (Interview 46, 8/3/2007). Benefit claims and the difficulties demanding solution can be seen as two sides of the same scenario. The inseparable nature of problem and answer was argued by the CEO of a Canterbury wind energy firm: 'The benefit is part of the dichotomy. You have to compare it with something, you know, everything needs contrasts, yin and yang, black and white' (Interview 31, 28/4/2006). This kind of duality is evident in both the GM and wind energy sectors and wider technology policy in New Zealand, linking problems or crises with corresponding benefit claims, to promote the need for change and justify investment in research and new systems.

The answer is blowin' in the wind[226]

The unavoidability of major new environmental challenges requiring innovative technological responses is a central strand in the story of wind energy in New Zealand and internationally. Over the last twenty years, global climate change due to the effects of human activity has become generally recognised as a reality that demands appropriate action and change (Ereaut & Segnit 2006; Stern 2006; Dawson & Spannagle 2009; Quaschning 2009; European Renewable Energy Council 2010). "Green" has become an active verb, with diverse creative initiatives intended to shift production systems, agriculture, infrastructure, buildings, energy and transport to more environmentally sustainable modes (Parliamentary Commissioner for the Environment 2002, 2004a, 2007; McNeil 2009; Parliamentary Commissioner for the Environment 2011a; Mulcare 2012; Pure Advantage 2012).[227] As outlined in Chapter Five, New Zealand is a signatory to the Kyoto Protocol, and has established legislation and policy recognising climate change and instituting measures to address national greenhouse gas emissions.[228]

For the electricity sector, this has brought an increased emphasis on renewable energy that does not depend on fossil fuels. The technical challenges of maintaining security of supply and satisfying growing demand for electricity could be addressed by building more coal or gas fired generation plants in New Zealand.[229] But the official

[226] With apologies to Bob Dylan. This slogan featured prominently in the reception area of the Christchurch offices of turbine design and construction company Windflow Technology Ltd, visited in 2006.
[227] Numerous campaigns and companies are enthusiastically promoting new technology options; for example the UK's Zero Energy Design (www.zedfactory.com), Australia's the Shaper Group encouraging sustainable business practices (www.shapergroup.com), and New Zealand collaborations such as the Sustainable Business Network (www.sustainable.org.nz), the Sustainable Design Group (www.sustainabledesign.org.nz), and the Sustainability Society, a technical group fostering sustainable engineering (www.thesustainabilitysociety.org.nz).
[228] These include the New Zealand Energy Strategy (New Zealand Government 2007, 2010, 2011a); initiatives around energy efficiency and sustainability such as the National Energy Efficiency and Conservation Strategy (New Zealand Government 2001); and an amendment to the Resource Management Act (section 7(ba), (i) and (j)), adding the requirement that environmental decision-makers must "have particular regard to… the effects of climate change" and "the benefits to be derived from the use and development of renewable energy" (Climate Change Response Act 2002).
[229] The National government's revision of the country's Energy Strategy (New Zealand Government 2010, 2011a) was notable for its emphasis on New Zealand's coal and gas industries; this policy shift is discussed in Chapter Five.

recognition of climate change introduces new criteria; using fossil fuels to produce electricity is reframed as part of the problem.

Wind energy technology delivers a wider mix of benefits than other modes of generation, as outlined in Chapter Five. The environmental benefits also translate into economic credits, and satisfy the requirements of New Zealand's policy and Kyoto commitments. Advocates for wind generation have maximised leverage from the political and environmental demands of climate change to position this technology as a key part of a shift to new eco-friendly energy systems (Meridian Energy 2005a; Parliamentary Commissioner for the Environment 2005a, 2006c; Pyle 2012). Sector actors interviewed for this thesis endorsed wind energy's contributions (Interviews 9, 13, 26, 33, 41, 43, 44, 48; 2006). Consciousness of the scale and severity of possible impacts of environmental change was a key driver for many interviewees' involvement in this technology. The CEO of a small turbine company described his horror at Europe's heavy air pollution as motivating his advocacy for renewable energy (Interview 31; 28/4/2006). The Parliamentary Commissioner for the Environment's energy policy advisor posed apocalyptic climate change scenarios as an incentive for innovative thinking and societal change:

> If in the future the water's up to halfway up Bowen Street here, which it most probably will be in a century or so, and we can't grow the crops that we used to grow, and we've lost the kauri… yes it *is* life-threatening (Interview 10; 16/8/2006).[230]

The dialectical nature of problem and solution runs through a range of contexts and discourse in New Zealand's energy sector. Some policy documents place strong emphasis on the severity of climate change and the urgency of taking action. To give just two examples: the Parliamentary Commissioner for the Environment's assessment of the sector's environmental performance is framed within 'the shadow of this enormous global challenge' (2006b, p 6); and the energy and efficiency strategies developed by the previous Labour government (New Zealand Government 2001, 2007) highlight the new global context as an unavoidable societal imperative:

[230] The Bowen Street building in Wellington housing the PCE offices is (at present) 17 metres above sea level (http://www.daftlogic.com/sandbox-google-maps-find-altitude.htm). The iconic kauri tree (*Agathis australis*) has a limited geographical and climatic range in northern regions of New Zealand (www.doc.govt.nz/conservation/native-plants/kauri; www.kauridieback.co.nz/home/about-kauri/kauri-ecology.aspx).

> The quest for sustainability is a defining issue of the 21st century… Tackling climate change will require each and every one of us to do what we can, with all sectors playing their part… the predicted costs and risks of inaction would prove to be unacceptably high (New Zealand Government 2007, pp 5, 14).[231]

Climate change features in such official discourse, and also in the application of policy in the decision-making for particular wind energy projects. The spectre of climate change, and the need to uphold New Zealand's Kyoto obligations, provide justification for approval of windfarm proposals. An example is Meridian Energy's Project West Wind at Makara near Wellington. The original consent and the later Environment Court appeal judgement both relied on arguments for the advantages of wind energy technology as a response to the problems of global sustainability.[232] The project's benefits are assessed in relation to climate change as an environmental, political and moral imperative:

> [N]ot only do wind farms assist with the contribution to national energy renewable targets, they also assist with the country's climate change obligations under the Kyoto Protocol… Project West Wind… would provide 10% of the national renewable energy target… Development of wind farms is an environmentally responsible way of both fulfilling the economic needs of the community while protecting the planet for future generations (*Wellington City Council v Meridian Energy Ltd,* Joint Hearings Commissioners Wellington SR 131428, 21 December 2005, pp i, 7, 43).[233]

Such imperatives have been influential in the consent processes for other windfarm applications. For example, the Environment Court appeal decision for the proposed Awhitu windfarm south of Auckland includes discussion of the benefits of renewable energy in terms of New Zealand's international commitments (*Genesis Power Ltd v Franklin District Council* [A 148/2005]).[234]

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[231] The 2007 Energy Strategy moves from an explanation of global climate change (New Zealand Government 2007, pp 15-16) to a strongly prescriptive position in favour of renewable energy, with a target for 90% of New Zealand's electricity to be from renewables by 2025 (2007, pp 19, 22, 37).

[232] These approvals were made under the 2004 amendments to the Resource Management Act s7, which require decision-makers to 'have particular regard to the effects of climate change [and] the benefits to be derived from the use and development of renewable energy' (*Meridian Energy Ltd v Wellington City Council,* Environment Court Wellington, W031/2007, 14 May 2007, p 92).

[233] The Makara appeal decision endorses these principles. It includes a lengthy summary of evidence presented to the hearing by the Intergovernmental Panel on Climate Change, and offers a calculation of the greenhouse gases that would be produced in generating West Wind's projected output by fossil fuel driven generation: 'If that amount of electricity was instead produced by burning coal, something like 540,000 tonnes of CO2 would be emitted to the atmosphere, per annum' (*Meridian Energy Ltd v Wellington City Council,* Environment Court Wellington, W031/2007, 14 May 2007, p 105).

[234] The Awhitu windfarm proposal received official consent but has not yet been constructed (http://windenergy.org.nz/nz-wind-farms/proposed-wind-farms/awhitu , http://www.genesisenergy.co.nz/genesis/about-us/company-information/history).

Controversy around the Makara windfarm highlights another dimension of the strategic co-construction of benefits and problems in the justification of technological developments. Meridian faced fierce opposition from the small Makara community, who sought to preserve the rural landscape and tranquil backwater character of their valley beneath the giant turbines.[235] But the company's promotional campaign emphasised benefits and values on a much grander scale – the imperatives of global sustainability and reducing greenhouse gas emissions (for example, Meridian Energy 2005b, pp 5, 11).

Michael (2000b, pp 26-27) identifies the 'different rhetorical functions' and relative influence of individual subjects as opposed to collective interests in technoscience discourse, and this imbalance was played out at Makara. The residents' opposition was countered by framing local concerns in contrast to larger regional, national and global benefits. Meridian's project manager explained the tactical isolation of the protest group:

> There seems to be alot of reluctance of people to accept things that may impose on their lifestyle for the public good, the national good… We did a much wider campaign to educate the whole community about wind energy and the benefits… The objective of that really was to try and marginalise the people at Makara… We wanted to get the silent majority to stand up and say "yeah, we all think it's a great idea, what are you people at Makara whingeing about?" (Interview 13, 18/4/2006).[236]

Global environmental priorities had crucial significance in the formal consent and appeal processes for Project West Wind. The consent decision acknowledged the 'conflict between the national benefit and the local costs' but concluded that 'the global and national benefits outweigh the local costs' (*Wellington City Council v Meridian Energy Ltd*, Joint Hearings Commissioners Wellington SR 131428, 21 December 2005, p ii). The appeal process also focused on the appropriate weighting

[235] The windfarm's physical scale is detailed in Chapter Five.

[236] This strategy was acknowledged by others in the sector. The CEO of a Christchurch turbine company, commenting on the issues for projects challenged by local interests, noted the advantages of mobilising broader public support for wind technology as an environmentally friendly means of producing electricity: 'What Meridian have done with Project West Wind will become more common I think, where it will be a bit of a popularity contest, where you… get lots of people to write in and support it, because the majority of people do [understand the environmental benefits of wind energy]' (Interview 31, 28/4/2006).

to be given to the broader sustainability benefits (*Meridian Energy Ltd v Wellington City Council*, Environment Court Wellington, W031/2007, 14 May 2007, p 124).[237]

These decisions endorse the importance – strategic, procedural and political – of a sufficiently major problem to justify new technology developments. In the policy and discourse of the New Zealand electricity sector, the co-construction of climate change as an imperative, and wind energy technologies as an answer, has supported the introduction of this innovation. Recognition of global climate change, and the statutory and moral obligations to minimise its effects, have established a powerful legitimation for wind energy in New Zealand.

Finding a "killer app"

Such patterns in the electricity sector have the advantage of a single, universally relevant problem for which wind generation and other renewable energy technologies are positioned as solutions. Global climate change may be wickedly complex, multifarious in its implications, and persistently contested, but it is one major, well-recognised phenomenon with potential impacts across all levels of society. In the strategic discourse of the biotechnology sector, the problems which GM is positioned to address are more heterogeneous, and more the concerns of particular groups and interests. The benefits projected from proposed applications of the GM research undertaken in New Zealand span a range of priorities – health, agricultural efficiency, biodiversity protection, new food products – as well as generic societal and sectoral objectives such as economic growth or the competitiveness of New Zealand's science institutions. In contrast to the wind energy story, where the problem-solution dialectic is focused primarily on climate change, GM technoscience is linked to multiple modes of presumed need and benefit.

The potential of GM to provide solutions to the medicinal requirements of sufferers of chronic diseases features strongly in New Zealand's transgenic livestock research. Project proposals emphasise the difficulties faced by individuals afflicted with gruesome conditions for which treatments might be developed from the milk of GM

[237] The appeal was rejected, with some negotiation of turbine siting in mitigation of the residents' concerns.

animals. An early example is the 1998 field test of sheep modified to secrete the human protein alpha-1-antitrypsin (AAT) in their milk. The primary intended benefit was the production of a biopharmaceutical for treating cystic fibrosis, congenital AAT deficiency, and other conditions.[238] The severity of these diseases was made clear:

> Cystic fibrosis is the most common life-threatening genetic disorder… morbidity and mortality from CF primarily result from the effects of chronic pulmonary inflammation and infection… life expectancy is about half of that of unaffected individuals… Congenital AAT deficiency is an autosomal recessive disorder [which] predisposes affected individuals… to early onset of severe emphysema and premature death (Environmental Risk Management Authority 1998b, p 4).

The rationale for research into GM options was based on claimed inadequacies in the existing means of production of medicines, including limited supply and the risk of disease from plasma-derived products (1998b, p 4).

Other project applications for GM livestock work in New Zealand highlight the conditions for which biopharmaceuticals and new foods might be developed from transgenic products, and the potential commercial returns of the medicinal markets. AgResearch's first application to develop GM cattle targeted multiple sclerosis and allergenicity to dairy products (AgResearch 1998, pp 3, 6, 14).[239] AgResearch emphasised the debilitating effects of MS and the inadequacies of current therapies:

> MS is a chronic demyelinating disease of the human central nervous system that occurs in one in every 1,000 people, and is associated with clinical neurological signs of paralysis… At present the only approved therapies for the treatment of MS are adrenocorticotropic hormone and IFN-β. Rather than relying on systemic immunosuppression, methods that result in unresponsiveness of specifically autoreactive cells would be a valuable addition to treatment strategies for MS (1998, p 6).[240]

Subsequent AgResearch projects also stressed the medical problems which its GM work aimed to treat. Its 2002 application for further research with GM cattle focused

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[238] ERMA's evaluation of these benefits included an estimation of the company revenue, based on the costs of similar pharmaceutical products multiplied by the number of patients globally, as $NZ1.1B for cystic fibrosis and $NZ900M for congenital deficiency (Environmental Risk Management Authority 1998b, p 38).

[239] ERMA's evaluation of this proposal included a summary of global research into treatments for multiple sclerosis, describing trials with bovine myelin and noting that results were inconclusive, despite AgResearch's enthusiasm (Environmental Risk Management Authority 1999a, pp 39-40).

[240] When ERMA's initial approval of this work was appealed (*Bleakley v ERMA* [AP 177/00]), AgResearch issued a media release emphasising the medical intentions of the research and suggesting that the appeal decision 'will be frustrating for MS sufferers' (McGuinness et al. 2008b, pp 32, 55).

on the ‘expression of large amounts of functional human and other therapeutic and bioactive proteins in milk’ (AgResearch 2002, p 7). The need for this science was argued in relation to the scarcity and high value of the desired proteins (2002, p 8). An email was attached to the application from the Research Director of the New Zealand Multiple Sclerosis Society, endorsing the project as ‘central to resolving the problem of MS’ (2002, p 69).[241] AgResearch’s 2007 application for work with a range of GM animals identified a range of agricultural and technoscientific opportunities, but again focused strongly around production of therapeutic proteins, antigens, enzymes and hormones in milk (AgResearch 2007a, pp 4-5; 2007b, pp 77-78).[242] Inadequacies in the current availability of these substances were argued as justification for investigating GM methods:

> [These proteins] are either difficult to produce in economically viable quantities using conventional systems (e.g. cell cultures) or cannot be produced in a biologically functional way using any other method [than transgenic livestock] (AgResearch 2007b, p 9).[243]

Research work with GM livestock in New Zealand has been positioned in relation to the desperation of sufferers of painful, incurable diseases. The purposes and projected benefits of the transgenic animal trials are strategically associated with problems for which existing medicine can offer little hope. This positioning is supported by the discursive framing of GM as a “miracle” technology, enabling breakthroughs that would otherwise be impossible, discussed in Chapter Six.

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[241] The MS Society also acknowledged the commercial potentials, enthusing that: ‘control of the supply of a standardized functional human myelin basic protein would place an organization in an extremely strong scientific position… the opportunities ahead for the innovative groups are real’ (AgResearch 2002, p 69).

[242] Other potentials included dairy products with lower fat and reduced allergenicity, and “designer foods” intended to reduce obesity-related health problems such as heart disease and diabetes (AgResearch 2007b, pp 27, 76).

[243] The scale of these opportunities was realistically assessed as a niche market, potentially involving only a few New Zealand farmers and sites, as ‘[t]hese proteins are required in volumes that can be produced easily by small numbers of specially bred animals which will be kept in containment’ (AgResearch 2007a, p 8). Nevertheless AgResearch claimed significant economic returns from new agriculture based biotechnology industries, including processing (2007a, p 35). Revenue from one currently approved biopharmaceutical product was cited as ‘more than USD$23 billion in 2006 estimated to grow to USD$36 billion by 2012’ (AgResearch 2007b, p 84). AgResearch argued the necessity for New Zealand farming to move from ‘a strategy based on low costs of production’ to the increased returns anticipated from biopharmaceuticals and nutraceuticals (2007b, p 9). However the claimed economic benefits from biopharming in New Zealand have been strongly contested; projected profits do not compare well with the projected losses in agriculture and tourism revenue, as outlined in Chapter Six (Sanderson et al. 2003; Kaye-Blake et al. 2007; Goven et al. 2008).

Like wind energy technology, the New Zealand research into GM vegetables and biocontrols (detailed in Chapter Six) was strategically positioned as helping to fix major environmental problems. Here, however, the R&D was framed in relation to difficulties in current agricultural production and pest management methods, rather than distant future threats. Work on crops resistant to herbicides, pests and diseases was justified as addressing problems of intensive chemical use in industrial-scale agriculture.[244] A scientist researching GM vegetables at Crop & Food highlighted the impacts of conventional commercial growing systems:

> In most countries they'll put on thirteen applications of pesticide a year to control the disease [potato blight], just do it routinely all through the growing season. In New Zealand it's usually about six or seven applications in most places, but up to twelve or thirteen in Pukekohe which is much more humid and warmer (Interview 11, 8/11/2006).

The intended reduction of agrichemicals, pesticide residues in soils and ground water, and production costs, are key benefits argued in Crop & Food's applications for field trials of GM vegetables (Environmental Risk Management Authority 1998c, p 30).[245] The proposals outlined the extent of the problems with existing growing methods:

> In New Zealand the application of 10 to 15 different, mainly toxic and persistent herbicides, to one crop during one season is not uncommon. The use of these herbicides and other pesticides on onion crops has been identified by MAF as a major sustainability challenge for the New Zealand industry… Data indicate that New Zealand onion exporters use up to 16 L/ha of formulated herbicide ingredient per season to control weeds (Crop & Food Research 2003, pp 8-9).[246]

The goal of developing solutions to major environmental pollution problems was also highlighted as a strong personal motivation for the scientists. Researchers at Crop &

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[244] The claims of developers of GM crops that chemical applications will be reduced have been contradicted by actual experience (for example, Nestle 2012).

[245] Benefits for soils were also claimed from reduced tillage, and it was anticipated that growers would save on machinery use and fossil fuel from fewer herbicide application passes (for example, Crop & Food Research 2003, p 9). Related pest control problems, such as thrips in onion production, were also identified as potentially being reduced via more efficient herbicide management with glyphosate-resistant GM crops (2003, p 10).

[246] The GM onion research proposal projected savings for New Zealand growers of 11 litres of herbicide per hectare per season, amounting to 'a 70% reduction in herbicide usage… From an economic viewpoint this saving equates to about $500 per hectare of herbicide or about $2.6 million across the country per year' (Crop & Food Research 2003, p 11). MAF was the Ministry of Agriculture and Fisheries, now restructured to become the Ministry for Primary Industries (www.mpi.govt.nz).

Food, interviewed for this thesis, emphasised their focus on the benefits of reducing toxic chemicals in the environment (Interviews 2 and 11); one scientist explained:

> I originally got into it [GM science] from an environmental perspective… I spent alot of time working on my uncle's farm when I was a child and I got to know about the inputs. And just the books of our generation, such as Rachel Carson's *Silent Spring*… and you read those books and you get influenced by them. And then as a geneticist you see the power of this technology to actually be able to alleviate some of those issues (Interview 17, 17/7/2006).

Concerns about the widespread application of noxious poisons were also a major focus for the New Zealand research into GM biocontrols for possums, discussed in Chapter Six. The regular aerial dispersal of 1080 baits to kill possums is a fiercely contested practice, despite regulatory agencies' assurances of its safety and effectiveness (Environmental Risk Management Authority 2007a, 2007b; Parliamentary Commissioner for the Environment 2011b). Furthermore, as noted by biocontrol researchers interviewed for this thesis, the results of 1080 drops are of limited duration, and control operations must be repeated after a few years to prevent repopulation (Interviews 14, 16, 18, 28). As an AgResearch scientist explained: 'the basic premise is that the current methods of possum control are not sustainable' (Interview 25; 6/12/2006). The biocontrols research was strongly associated with the environmental and societal benefits of minimising the need for 1080 applications (Royal Commission on Genetic Modification 2001a, p 110). A biocontrols scientist argued that: 'the benefit is reducing the use of those sorts of poisons, hopefully quite substantially, and there is also the lessening of the non-target effects' (Interview 18; 7/12/2006).[247]

New Zealand GM research has been strategically positioned as focused on finding answers to ongoing environmental and health problems. The benefits projected from this research are constructed in a dialectical relationship with dramatically negative scenarios. However, as outlined in Chapter Six, New Zealand's regulatory systems exclude such longer-term outcome projections from the assessment process for GM proposals; only the specific outputs of the research project itself can be taken into account (Environmental Risk Management Authority 2000a, 2004). Research is

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[247] Protests about 1080 often focus on its impacts on non-target species, including the native birds which possum control operations are intended to protect (www.stop1080poison.com/Page10.html; www.safe.org.nz/Campaigns/Ban-1080; www.thegrafboys.org/poisoning-paradise.html).

justified under claims of the value of scientific knowledge, and maintaining expertise in biotechnology. But these project-focused benefits derive much of their importance and legitimacy from their claimed instrumentality – knowledge and expertise are valued for their intended contributions to New Zealand's economic objectives and wider societal goals. In turn, these wider generic justifications are given additional impetus by association with broader-level problems or threats. As discussed in Chapter Two, the counter-argument to the Red Queen imperative is a chronic fear of economic decline and lost competitiveness. A typical example of this pattern is the argument of the biotech industry (NZBio 2008b, p 3) that New Zealand should develop a "bioeconomy":[248]

> New Zealand's economy has been based on the primary sector for the last 150 years. In the past few years however… it has not been enough. New Zealand's GDP per capita and economic growth has been falling steadily in the OECD rankings… If our economy is to grow it needs to diversify.

NZBio frames these imperatives for New Zealand within the OECD's judgement that:

> Those countries able to muster resources to invest in R&D and human capital formation… will move ahead, creating wealth within their societies and becoming leaders in innovation globally. Those who fail to keep pace with these changes risk losing new global markets and compromising growth at the national level (cited in NZBio 2008b, p 3).[249]

Such negative projections, and the dire consequences projected from a lack of commitment to new technoscience, assert a powerful impetus for research and innovation. Benefit projections from R&D and new technologies are only half of the equation. Both GM and wind energy initiatives gain legitimacy and momentum through the symbiotic association of their expected benefits with needs and difficulties of diverse kinds – the ravages of possums on native forests, the agony of those suffering from incurable diseases, the impacts of global warming, or the drive to lift the nation's economic performance. These imperatives range from the immediate to the remote, including both current difficulties and future potentials, urgent and

[248] This term is an example of the common prefixing of "bio" to denote an instrumental dependence on genetic technoscience. The concept of a "bioeconomy" encapsulates an ambitious economic renaissance driven by biotechnology, particularly the development of new medical and agricultural applications (for example, OECD International Futures Project 2009). Some critiques offer more sceptical "bio" terms, such as Van Dijck's discussion of "Biobucks and Biomania" (1998, Chapter 4).

[249] This dialectical co-construction of generic economic promise and threat is very common through sector and policy documents, speeches, conference presentations and media statements, both in New Zealand and internationally – as Leitch and Davenport (2007, p 46) observe, these discourses are 'highly formulaic'.

incremental conditions, specific local issues and global developments. But all the various narratives of dysfunction share a key rationale – to strengthen the appeal of technoscience as the solution to society's problems, and to ensure ongoing support and resourcing for R&D activity.

Mixed benefits

Innovation and R&D in GM and wind energy in New Zealand are promoted and justified through a range of diverse benefit projections where economic and non-monetary value frameworks are continually intermingled. Aims of commercial profitability and competitiveness are upheld alongside more altruistically-oriented public-interest objectives, commonly environmental or health benefits. There are fundamental qualitative differences between the goals of making money and making the world a better place – the two basic registers of positive intention that underpin benefit claims for technoscience and innovation. Yet in the discourses, policy and strategic positioning of actors and institutions in these fields, such differences are often blurred, and the two modes of expectation overlap, intertwine and support each other. This section of the chapter explores some of the ways that this duality plays out in the stories of GM and wind energy in New Zealand.

The co-existence of economic and public-good objectives is enshrined in the statutory and governance structures. Technoscience research and the introduction of new technologies for essential services have primarily been undertaken in New Zealand by the Crown Research Institutes (CRIs), such as AgResearch, and State-Owned Enterprises (SOEs), such as Meridian Energy.[250] As outlined in Chapters Five and Six, the legislation governing these government-owned entities asserts dual objectives for their operations – they must be successful businesses, efficient and financially profitable, while also acting in the interests of the community and working for the benefit of New Zealand.[251] Policy for both the biotech and electricity sectors, and for New Zealand science, technology and innovation generically, establishes multiple

[250] New Zealand's relatively low proportion of private sector investment in science and technology R&D, and the heavy weighting of research funding from government, is an ongoing concern in policy and sector discourse (for example, OECD 2007, p 12).
[251] State-Owned Enterprises Act 1986 ss4(1)(a) and (c); Crown Research Institutes Act 1992 ss5(1)(a), 5(2) and (3).

objectives for R&D and the diffusion of new technologies. For example, the government's high-profile Growth and Innovation Framework (2002, p 6), intended to boost research and new enterprises, recognises the importance of policies for 'a modern cohesive society, a healthy population… [and] sound environmental management' as well as economic objectives. The successive versions of the New Zealand Energy Strategy (New Zealand Government 2007, pp 8, 26; 2011a, pp 1, 3, 8-9) highlight societal priorities including energy efficiency, community initiatives and environmental sustainability alongside market management, investment incentives and the commercial impacts of emissions pricing. The Biotechnology Strategy (New Zealand Government 2003, pp 1-4) includes recognition of the need for research to benefit health, the environment and biodiversity protection, as well as emphasising economic goals as outlined in Chapter Six. The parameters set for the Royal Commission of Inquiry's assessment of New Zealand's potential development of GM were similarly wide-ranging (Royal Commission on Genetic Modification 2001a, Chapters 3, 4 and 5).

New Zealand's regulatory systems for technologies and innovation also impose multiple requirements on new developments in the two fields. The Electricity Commission had responsibility for managing pricing structures, ensuring the stability of an arcanely complicated electricity market system, and maintaining incentives for investment; at the same time the Commission was required to ensure the environmental sustainability of the industry and its contribution to the nation's climate change commitments.[252] Regulation of GM research also combines economic and other kinds of criteria; evaluations of proposals for new organisms research must consider anticipated economic benefits alongside expected impacts on the natural environment, public health, social and community matters, Maori cultural dimensions, and New Zealand's international obligations (Hazardous Substances and New Organisms Act 1996 ss 5 & 6; Environmental Risk Management Authority 1998a, Clauses 9, 13, 14, 22).

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[252] Government Policy Statement, May 2009, www.electricitycommission.govt.nz/rulesandregs, www.med.govt.nz/templates/MultipageDocumentTOC_40723.aspx. The Commission was restructured in 2010 to become the Electricity Authority.

As seen in Chapters Five and Six, discourse and strategic positioning of agencies and companies in the two sectors associate technoscience innovation with an eclectic variety of benefit goals. Even with research initiatives that are ostensibly aimed primarily towards idealistic public-good goals, the intended economic benefits are also highlighted. The work on possum biocontrols was driven strongly by the imperatives of biodiversity protection, but the ongoing costs of existing pest management methods were a significant factor in the drive to develop alternative control technologies.[253] Biocontrol scientists interviewed for this thesis described the intense pressure from environmental management agencies and interested sectors such as forestry to deliver new more cost-effective control tools (Interviews 14, 16, 18 and 25). The goals of saving indigenous ecosystems and wildlife from the depredations of possums are intertwined with the priorities of the New Zealand dairy industry; for farmers, possum control is a matter of economic risk, with the dangers of possum-borne bovine Tb measured in potential lost earnings and damage to New Zealand's international reputation and export markets.[254] And, as outlined earlier in this chapter and in Chapter Six, the apparently altruistic purposes of research on GM livestock, aiming to produce proteins and other substances as the basis for pharmaceutical treatments for devastating diseases, are also combined with grand commercial ambitions. Sector discourse and project proposals highlight the scale of international markets for the proposed pharmaceuticals, and emphasise the economic benefits to New Zealand agriculture of shifting from current commodity markets to such lucrative products.[255]

Analysis of the diverse modes of expected benefit advanced for R&D and innovation in the two New Zealand fields shows agencies and research institutions deploying a kind of bricolage approach, bringing together disparate frameworks of reference in a patchwork of persuasiveness. In both sectors' discourses, and in policy and regulatory assessment processes, research activity and new technology options are linked not to any single objective but to multiple overlapping goals and benefit

[253] As noted in Chapter Six, possum control cost New Zealand around $100 million per annum in the late 2000s (Cowan et al. 2008, p 573). The national bovine Tb eradication programme cost an additional $87 million per annum (Environmental Risk Management Authority 2007a, p 6).

[254] A manager at the Animal Health Board, the agency responsible for managing New Zealand's bovine Tb problem, expanded at length in his interview for this thesis on the huge costs and complex logistical problems faced by farmers when Tb is found in their herds (Interview 28, 18/4/2007).

[255] Claims of the economic opportunities of GM have been strongly contested, as noted in Chapter Six.

projections. The strategic importance, for new technoscience initiatives, of establishing alliances and alignment with powerful and influential interests is discussed in Chapter Three. Theorists of science and technology such as Latour (1987, 1996), Bijker (1995) and Kaplan and Tripsas (2008) stress the necessity for such connections between a project or research field and the social, sectoral and political support that will provide it with legitimacy, momentum and a raison d'etre. The trajectories of GM and wind energy innovation in New Zealand demonstrate the usefulness of maximising such positive associations, and building supportive links in as many directions as possible, as these sectors assert the utility, importance and desirability of their work.

Although the legislative, institutional and policy frameworks establish multiple objectives and expectations for R&D and innovation, one orientation is widely valorised, accorded hegemonic priority, and automatically accepted as an inarguable rationale for new technoscientific ventures. The increasing dominance of economic framings of purpose and benefit for R&D and new technologies has had enormous influence on innovation trajectories (Cartner & Bollinger 1997; Leitch & Davenport 2005; Motion 2005; Goven 2006; Cronin 2008; Macdonald et al. 2011). Motion and Weaver (2005, p 64) analyse the promotional framing of biotechnology, strategically 'rearticulated as an economic discourse in order to align GM with the "superordinate" agenda of mainstream New Zealand politics'. As Henderson (2005, p 130) observes:

> [D]iscourse about science and technology has been colonized by economic discourse… reflect[ing] the concerns of organizations whose identity is associated with, and prioritizes, economic discourses centering on growth, profit, and market share.[256]

As discussed in Chapter Two, science and technology have long been conceptualised as necessary drivers of commercial profitability and progress, closely intertwined with Whiggish development teleologies. These beliefs are reinforced by the frequent

[256] Even the science research conducted with funding from the Marsden Fund, the government's allocation of resourcing for "pure" or "blue-skies" research, is considered useful in terms of the marketable IP and new applications and products that can be developed from such work. The criteria for the fiercely competitive Marsden funding focus primarily on the excellence of the science proposals and the contribution of new knowledge. However, the CEO of the Royal Society of New Zealand, interviewed for this thesis, explained that 'there's as much commercialisable stuff coming out of Marsden good ideas as there is coming out of targeted research ideas', and expanded on the serendipity principle for research discovery (Interview 49, 6/5/2006).

elision, in policy and sectoral discourse for technoscience and innovation, of economic growth with the achievement of other societal benefits. This pattern is based in the assumption that qualitative outcomes – in public health, environmental sustainability, or general social wellbeing – will flow from financial prosperity and a strong economy. As noted in Chapter Six, the Royal Commission on GM presumes a ‘symbiotic’ relationship between economic and social goals (2001a, p 12). Weaver and Motion (2002, pp 329, 330, 340) point out that:

> In a market-driven political economy the public interest and the market are constructed as one and the same… [New Zealand’s research institutes] interpret ‘benefits’ as contributing to the nation’s economic competitiveness… the ‘public interest’ has been subsumed by corporate and market interests.

Government policy consistently position R&D and technological innovation as prerequisites for economic growth and competitiveness, as noted above and in Chapters One and Six.[257] The successive restructurings of New Zealand’s government agencies responsible for technoscience development reflects the increasing prioritisation of commercial objectives. Over the time period covered by this thesis, the titles of the ministries show this trend: from the Ministry of Research, Science and Technology, to the Ministry of Science and Innovation set up in 2011, to the new “super-ministry” of Business, Innovation and Employment announced in 2012. However, technoscience communities’ responses to the imposition of such reorientation are salutary, indicating that the dominance of economic priorities is not absolute (Hunt 2003; Fisher et al. 2005; Small & Fisher 2005; Small & Mallon 2007). The reactions of New Zealand scientists to the formation of the new super-ministry provide a small illustration of the tensions. The Royal Society of New Zealand initially welcomed the creation of the new agency on the grounds that it ‘recognises the central importance of science and research and innovation in stimulating innovation and wealth creation’ (RSNZ media release, 15 March 2012); but the RSNZ media statement also urged government acknowledgement of ‘the broader role of this country’s science, research and knowledge expertise… [and] the essential contribution that environmental, social, humanities and health research must make to

[257] New Zealand policy assumptions are reinforced by economic thinking and processes at international levels, such as the OECD review of New Zealand’s systems for innovation (2007, pp 15-16), which recommends: ‘fostering market-pulled innovation throughout the economy… mak[ing] the business environment more supportive of R&D and innovation… [and] removing obstacles to increased entrepreneurship and growth of small high-technology / high value-added businesses’.

the wellbeing of New Zealand.'[258] A week later, following expressions of concern from its membership, the RSNZ publicly released its letter of protest to the Minister responsible, criticising 'the absence of the word "Science" or "Research" in the title' of the new agency. The RSNZ argued that:

> Undoubtedly, science and research are very important to New Zealand in stimulating innovation & [sic] wealth creation. There are, however, many other reasons for the public investment in research, including protecting public health, sustaining land-based industries, managing our natural resources and informing evidence based policy… the absence of the word "science" could send an unfortunate signal giving the impression that science and research may somehow be overlooked (22 March 2012, letter from Dr Garth Carnaby, President of the Royal Society of New Zealand, to Hon Steven Joyce, Minister of Science and Innovation).[259]

The assertion of economic framings of meaning and value as a primary rationale for technoscience R&D in New Zealand has had significant effects on the trajectories of research and innovation in GM and wind energy. Chapters Five and Six outline the dominance of business and commercial projections in the benefit claims that justify new developments in these fields. Assumptions of profit and improved sector competitiveness are prominent in the promotion of GM innovation, both in New Zealand and internationally, as detailed in Chapter Six. Business priorities are evident in the expectation that wind energy technology will only be adopted in configurations that are compatible with the commercial bottom lines of generation companies – the "Big Wind" model discussed in Chapter Five. But, as outlined earlier in this section, the intended economic outcomes from R&D and innovation are not the only modes of appeal that are advanced in the performative work of benefit claims for technoscience. As the RSNZ's defence of New Zealand research indicates, other kinds of value and other societal priorities are also crucially important.

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[258] See www.royalsociety.org.nz .

[259] Nevertheless, the Royal Society also actively promotes the economic benefits of science research and technological innovation, through such initiatives as the 2012 Transit of Venus summit, including a high-profile session on 'Science and Prosperity' (www.royalsociety.org.nz/events/2012-transit-of-venus-forum-lifting-our-horizon/), or a panel discussion on Radio NZ (12 August 2012) where Sir Peter Gluckman, Chief Science Advisor to the Prime Minister, and prestigious representatives of business, economics and academic research institutions debate the role of science in providing 'an answer to New Zealand's economic problems' (*RSNZ Alert*, Issue 729, www.royalsociety.org.nz/category/alert-newsletter/).

The heterogeneity of the different benefit projections that create meaning and legitimacy for research activity and the introduction of new technologies in New Zealand can be seen in itself as evidence of the limitations of economic value frameworks. Associating an R&D project or technoscience field with altruistic public-good ideals offers significant advantages in terms of creating meaning for that innovation and establishing positive symbolic value. These dimensions matter not only for publics and societal groups with a particular interest in the issue, such as the patient advocacy organisations who supported research aiming to develop new pharmaceuticals. Perceptions of the worthiness of a technoscience field, and of the ethical importance of the problems research is intended to address, are also central to the motivation and identity of practitioners, and to the corporate branding of agencies and firms. For example, Meridian's strong positioning as an environmentally conscious provider of renewables-derived electricity is embodied in its innovative sustainable office building, described in Chapter Five. The scientists working on possum biocontrols and GM vegetables are driven by a commitment to environmental protection, as detailed in Chapter Six.

Projections of qualitative and ethics-based societal benefits from R&D and innovation provide, in Bourdieu's terms (discussed in Chapter Three), powerful symbolic capital for projects and fields. Although Bourdieu acknowledges the convertibility of different forms of symbolic capital, the framings of non-monetary benefit that are part of the strategic advancement of GM and wind energy in New Zealand serve a distinct purpose in the legitimation and promotion of these innovations. The value of these qualities is not entirely covered by their translation into the corresponding economic value, such as increased market share from the appeal of a "green" brand, revenue from carbon credits under the emissions trading scheme, or research funding secured via the lobbying of patient advocacy groups. The qualitative intangible benefit constructs offer satisfaction of deeper human and societal needs for purpose, worthiness and relevance, that the reductive quantitative frameworks of the "dismal science" simply cannot deliver. These ideals-based benefit frameworks give technoscience and innovations a kind of credibility, a rationale that is more than just a balance sheet or profit calculation.

Theorists of science and technology have developed models of the dynamics of processes and structures in fields where the gestalt is created or comprised in a fundamental duality – two different aspects or qualities interacting, each defined in a symbiotic dialectical relationship with the "other". Latour (1987) offers a series of "Janus-faces" to explain the coexistence of radically polarised meanings, norms, assumptions and principles in the practice and representation of science; he argues that to understand the workings of research and technology fields, 'we will have to learn to live with two contradictory voices talking at once' (1987, p 13). Latour shows how – through various discursive, epistemological and strategic aspects of the legitimation and development of R&D activity and new knowledge – both sides of the "Janus-face" are useful and important in the overall processes and construction of technoscience. Rip (1992, pp 231-233, 252) uses a metaphor of science and technology as 'dancing partners', stepping forward and backward together in a dynamic tension to give each other momentum; he describes the two domains as inextricably complementary, 'intertwined and form[ing] a complex'. Van Lente (1993, pp 154-157) analyses technology discourses in terms of ideographs, or broad symbolic constructs of meaning and value. He outlines the ways these flexible concepts are 'defined in relation to each other' – either positively strengthened, or attacked, weakened and compromised, in processes of mutual positioning or 'horizontal strategies'.[260]

These analogies can be adapted to help understand the coexistence of economic and ideals-driven benefit projections in the promotion and legitimation of R&D and new technologies. This duality indicates the necessity for technoscience to establish its beneficence, desirability and worthiness across many fronts simultaneously to ensure ongoing acceptance and support in chronically uncertain, contested fields. Both kinds of benefit claim are necessary; each gains meaning and momentum from its not being its opposite. Each appeals to different audiences and interests in the heterogeneous domains of technoscience innovation – business managers, investors, farmers, environmentalists, mothers of sick children, or politicians looking for a photo opportunity or a regional rejuvenation programme.

[260] Van Lente contrasts these relational strategies with 'vertical strategies' where an ideograph's meaning is determined in associations with past historical events and conditions (1993, pp 152-154).

Despite the confidence and presumed inevitability typical in policy and sectoral discourse, this "Janus-faced" pattern reflects an underlying vulnerability, uncertainty or fragility of benefit claims. Van Lente (1993, 2000) models the progression of confidence through technoscience development processes, building from expectation to promise to requirement and commitment. But the performative forcefulness of benefit projections is not necessarily always so reliable. The final section of this chapter will explore some examples in the stories of GM and wind energy in New Zealand where the arguments of need and intended benefit were not sufficiently convincing, or not sustained, and the research or technological projects were not continued. But before that discussion, the next section looks at another dimension of these patterns' influence on the development trajectories for GM and wind energy in New Zealand, where narratives of need and solution have taken technoscience programmes in very different directions.

Made in New Zealand?

The idea that GM technoscience is a crucial requirement for New Zealand's economic prosperity, contributing knowledge and new "value-added" products to drive the nation's future growth, has itself provided significant benefits for the biotechnology research community and institutions in this country. Belief in the necessity of GM to lift performance in production sectors and develop new health-focused industries has legitimated the provision of significant government funding and other support, as well as prestige and influence, for actors and agencies engaged in this research.[261] These forms of Bourdieu's symbolic capital can be distinguished as endogenous benefits to technoscience communities, relative to the exogenous benefits projected for other groups or sectors, such as the expected customers or users of the technology and products derived from it, or the wider societal, environmental and intergenerational benefits also claimed for GM.

[261] The prominence of genetics-related research in New Zealand's science portfolio is proudly reported in a government research strategy document (Ministry of Research Science and Technology 2007, p 3): 'The importance of biotechnology research to New Zealand is reflected in the proportion of government research funding spent on it. At 25% of total government R&D investment (or around $195 million per annum), this is proportionally the highest share of government-funded biotechnology research in the OECD'. This total includes biotech work that might not necessarily involve GM per se.

The assumption that New Zealand must maintain a credible active involvement in this technoscientific field goes back to the report of the Royal Commission on Genetic Modification (2001a, 2001c), discussed in Chapter Six. This position was a foundation of the RCGM's recommendation to 'preserve opportunities':

> The Commission considers that a strong research base is essential if New Zealand is to be able to pursue all possible opportunities. The acquisition and application of new knowledge, to develop new technologies and new processes, is basic to the establishment of a knowledge economy. A skilled research workforce contributes to… the growth of the economy in diverse areas. Without a cutting-edge research capability, New Zealand's ability to [undertake GM work] would be limited (2001a, p 333).

As outlined in Chapters Two and Six, the Red Queen imperative runs strongly through policy, industry and science institutions' discourse around GM applications for food production and biopharmaceuticals.[262] The perceived rapid pace and dizzying profit projections of international developments combine to create a field where competitive participation is seen as essential to avoid the ignominy of being "left behind". The focus of much international GM research on agricultural applications, and the dependence of the New Zealand economy on our primary production sectors, left little doubt for many policy and sector decision-makers that active engagement with this technoscience is an unavoidable priority (Royal Commission on Genetic Modification 2001c, pp 33-35, 152; Ministry of Research Science and Technology 2007, pp 3, 25-26, 31, 38-39). The government's Biotechnology Strategy (New Zealand Government 2003, p 17) commits to the goal of 'growing' the sector, insisting that:

> To achieve a world-class biotechnology sector in New Zealand, we must make sure that New Zealand has the underlying capabilities… The needs of a dynamic sector like biotechnology call for high general levels of science, research and commercial skills, as well as specific specialist skills.

[262] These patterns are notably absent from the strategic framing and promotion of the research on GM biocontrols for possums. The biocontrols work was understood as offering benefits primarily for the management of New Zealand's biodiversity and ecosystems, rather than any commercially marketable export products – although the potential to develop innovative control technologies for other pest species was acknowledged, as noted in Chapter Six. This research focused on a uniquely New Zealand problem, and the work could only be undertaken in this country; issues of international science rivalry were not relevant.

Maintaining a strong research base, increased funding, supportive sectoral and institutional frameworks, and active recruitment and retention of scientific talent are highlighted as necessary commitments (2003, pp 17-20). Other policy also asserts the need to foster the sector, but acknowledges that New Zealand is a small country with limited resources relative to global biotech players. The logical policy is to identify niche research areas to keep an international profile in the field (Ministry of Research Science and Technology 2007, pp 6, 14-18). The comparative scale of New Zealand's research is not seen as a reason not to keep actively involved:

> Given that the vast majority of biotechnology research and applications are, and will always be, developed off-shore, New Zealand must maintain research… to remain connected to the global network of biotechnology (2007, p 49).

Sector actors interviewed for this thesis endorsed the importance of sustaining New Zealand's capacities in GM technoscience, however humble. A Crop & Food research manager explained:

> The reason we work with crops like peas and onions and potatoes is… we don't grow much cotton [or canola or soya] in New Zealand… Biotechnology is global, the whole industry, and for us to have a part in it is very important… we're part of that total community (Interview 2; 26/5/2006).

Some interviewees sketched the scenario of a future where GM crops and products are widely accepted and profitable; keeping an active New Zealand role in this technoscience was argued as necessary to have the capacity, if or when such markets obtain, to compete against other countries' exports. A scientist at Crop & Food explained the reasoning behind research on GM vegetables:

> That was the justification for doing it, you know, in the belief that some time in the future we'll need this technology and it'll be acceptable, therefore we should be investing in it now to learn what we need to learn… So it was really making sure we could retain capacity, keeping ourselves usefully doing things in terms of research, maintaining capability in the Institute and the country for this technology, because in time it will be useful, and we don't want to lose the people and the skills (Interview 11, 8/11/2006).

A sector manager for Horticulture New Zealand, the industry body for commercial vegetable growers, reiterated the rationale for maintaining expertise in GM as a kind of insurance against future international market requirements (Interview 22, 20/4/2007). An AgResearch science manager endorsed these principles, arguing that the role of the CRIs is 'to show some sort of scientific leadership' on behalf of the nation, and to anticipate future developments:

> Who knows? – in five or ten years when Switzerland's producing five times more dairy products than New Zealand because of transgenics, we've got to get into a position where we can handle that and remain competitive. So we can't become too Luddite about developing future technologies in case our markets just come round and bloody flatten us, you know – we've got to be there… to do some of this cutting-edge stuff (Interview 24, 18/8/2006).

The arguments for a national science capacity in GM also refer to the need for New Zealand to have knowledge and technical skills to assess the risks and environmental effects of GM, and ensure safety of any introductions of modified organisms into the country (Royal Commission on Genetic Modification 2001a, pp 132-133, 142). Another Crop & Food researcher insisted:

> You've got to know how that technology works… what the potential impacts are, we do have unique flora and fauna, we do have unique conditions… We've got to have skilled personnel to use [GM technology], to work with it, the stewardship issues, the management issues, the control issues, so you've got to have skills available to do all that (Interview 17, 17/7/2006).

These narratives of anticipated need for expertise in GM technoscience establish a framework of benefit for active New Zealand engagement in research in this field. The activity and capacities of New Zealand's researchers are valued in themselves, as important for the reputation and credibility of the nation in international science arenas, and as instrumental support for the benefits GM is expected to deliver to other sectors of the economy. The anticipated eventual acceptance and diffusion of GM is the cornerstone of this framing of the need to maintain capability. This is an interesting twist on Constant's concept of a presumptive anomaly, discussed in Chapter Three (Constant 1987, p 225; van Lente 1993, pp 51, 86-87; Bijker 1995, p 278). Rather than the projection of a future technological inadequacy or limitation providing the impetus for R&D, here it is the assumption that GM will be widely successful that drives the demand for engagement in research.

The introduction of wind energy technology to New Zealand, however, has followed a totally different pattern. Wind turbines are now well established features in many New Zealand landscapes. But the deployment of this technology has largely been based on international knowledge and technical development, with turbines and associated technologies provided by European manufacturers. A few local companies design and make their own small innovative turbines, as noted in Chapter Five. There has been some advocacy for the potential economic benefits of developing cutting-edge alternative energy technologies and fostering a renewables industry here (for example, Parliamentary Commissioner for the Environment 2006c, pp 7-8, 40; Winitana 2008). But the dominant form taken by wind energy in New Zealand – using the latest giant turbines for maximum efficiency and competitiveness – is an unashamed import.

The strategy of being a "fast adopter" of international expertise and products in wind energy technology is rationalised in terms of New Zealand's limitations as a small country with modest resources for R&D in new energy technologies. Policy for the sector recognises these constraints and the importance of following closely behind the international leaders in the field. The Parliamentary Commissioner (2006c, p 65) admits that 'for many of the [new energy] technologies, New Zealand will be in a receiver role, a "technology taker", rather than an instigator or developer'. Research in wind energy innovation focuses on adapting imported technologies to best fit local conditions (Ministry of Economic Development 2006a, p 11.3; 2006c, pp 64-65).[263] The Ministry of Economic Development (2006c, p 65) outlines the logic:

> As a technology taker, New Zealand needs to make the most of its engagement with the international community leading the development of innovative energy technologies and practices… so that we are well placed to rapidly adopt energy technologies for use in New Zealand.

An energy policy manager at the Ministry, interviewed for this thesis, highlighted the relative scale of New Zealand's possible investment compared with global R&D:

> Our general view in terms of new technologies is that we should be fast adopters, rather than really focus on developing new technologies… Whenever we try to do things here in New Zealand… we haven't got sufficient wealth to give it sufficient funding… Overseas they're given millions and things happen a hell of a lot faster (Interview 19, 7/12/2006).[264]

[263] Policy for energy sector research in New Zealand highlights modelling regional meteorological patterns and energy resources and use, and work to support New Zealand adoption of knowledge and technologies from overseas (Ministry of Research Science and Technology 2006a, pp 5-6, 18, 36-40).

[264] The dominance of the established major international wind technology corporations in the industry globally is recognised as related to the scale and technological sophistication of today's systems and a continual drive for improved, more cost-effective turbines (Pernick & Wilder 2008, p 60; Ngô & Natowitz 2009, p 220; Vasi 2010, pp 143-144). Danish company Vestas Wind Systems, supplier of Meridian's turbines, is one of the biggest turbine manufacturers internationally, with (in 2010) 41,000 turbines installed in 65 countries across five continents. Vestas promotes its R&D centre as 'the largest

It is generally accepted in the electricity sector that New Zealand's most realistic course with wind energy is to import the latest turbines and associated technologies from overseas (Parliamentary Commissioner for the Environment 2006b, p 9; New Zealand Government 2010, p 4). New Zealand's major generation companies are pragmatic about the strategic efficiencies of utilising others' designs, knowledge and experience; as a Meridian project manager explained:

> We don't see ourselves as technology developers. We want technologies that already work and are proven, and that we can install and operate in New Zealand… With wind energy now it's a huge international business… and it's just a waste of time trying to [compete], I mean, why bother?… The products are improving every year, getting better and better all the time, bigger and more efficient and more effective, so yeah, we're just riding on the back of that wave (Interview 13, 18/4/2006).

At the smaller-scale end of the wind industry, a few companies, such as Windflow Technology in Christchurch, build turbines to their own designs.[265] But other engineers working with independent turbine installations happily accept the role of "technology taker" as a cost-effective approach. For example, a Canterbury developer of local stand-alone generation systems explained his company's approach:

> [We] use second-hand equipment from Europe which makes it affordable… When we talk about bringing in turbines for small scale community stuff my analogy is: hey, I drive a second-hand Japanese car, and I own a second-hand European turbine, same thing! … It's cheaper and I get exactly the same service out of it, cheaper (Interview 33, 11/5/2006).

New Zealand energy policy, and the majority of electricity companies, sector actors and research agencies involved in wind energy in this country, have no problem with the strategy of following international developments and importing technologies and expertise as required. It is understood that New Zealand just too small to support a significant competitive R&D programme in wind energy. But this does not prevent

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in the world' (http://www.vestas.com/en/about-vestas/profile.aspx). In 2008 the company claimed it was installing an average of one new turbine every four hours (Pernick & Wilder 2008, p 82).

[265] The CEO of Windflow explained the differentiating features of his company's product: 'Our particular solution uses a couple of technologies that are different from the rest of the wind industry… giving a lighter, more cost-effective design' (Interview 31, 28/4/2006). The Windflow turbine uses two blades rather than the conventional three, and features a "teetering" hub to accommodate turbulence and sustain operation at higher wind speeds (*The Windflow 500: Towards a Sustainable Future*, undated pamphlet, Windflow Technology Ltd, Christchurch).

New Zealand from benefiting from innovation in the field, or hinder the use of turbine technologies both in large commercial windfarms and independent sites.

This pattern is in marked contrast to the GM sector, where active New Zealand research activity and capacities are insisted upon, despite local efforts being dwarfed by the relative scale of international research programmes in GM. The two fields have completely different strategies and expectations of the necessity for "hands-on" research to be undertaken in New Zealand. Obviously a range of factors are pertinent; for example, the potential for GM work to be kept "ticking along" in manageably modest niche research programmes on species of low priority for major international science groups. However, I would argue that the respective framings of purpose and benefit of these two innovation fields also have significance for their different approaches to New Zealand-based research activity.

Both fields position their innovation work as providing benefits in the form of new products and services intended to contribute to the growth, efficiency and profitability of other sectors and the New Zealand economy. Each works to ensure support and legitimacy for R&D and new technologies through simultaneous appeals to both economic and public-good frameworks of value, as discussed in the preceding section of this chapter. But the strongest associations of each field – the framings of intention and benefit which are dominant in public, policy and sectoral perceptions – establish fundamentally different expectations of the importance of active participation.

Bijker (1987, 1995) shows how the very meaning of a technology is based in social interactions. And Latour's analysis (1987) of technoscience development processes highlights the networks of linkages with social groups that constitute the trajectories of R&D activity, artifacts and scientific knowledge. These 'heterogeneous chains of associations' create meaning and credibility for the object or practice, although some links are more direct, influential and durable than others(1987, pp 136-144). Latour insists that:

> We are never confronted with science, technology and society, but with a gamut of weaker and stronger associations… The only question in common is to learn *which associations are stronger and which weaker* (1987, p 140; emphasis in original).

Latour's insight is useful in distinguishing the frameworks of meaning and value that are dominant in the purposes associated with the two New Zealand technoscience sectors. In turn, the dominant associations of the respective fields help to explain the different approaches to maintaining research activity in this country. The primary association of GM with projections of economic and commercial benefit is central to the recognition in political, sectoral and regulatory domains of the necessity for New Zealand to sustain active R&D capacity in this field. The prospect of dazzling profits – and the prestige and glamour promised by GM as cutting-edge "high" technoscience that can transform humdrum reality – are justification for official and institutional enthusiasm and investment. The primary association of wind energy with non-monetary value frameworks – the moral principles underpinning societal obligations in response to a remote, uncertain future environmental problem – links this technology with green idealism, the constraints of sustainability, and abstract concepts of duty such as intergenerational equity. The potential benefits of innovative energy solutions are primarily associated with modes of value which, compared to GM's lucrative potentials, have relatively limited leverage for policy and sector decision-makers. The strong and weaker benefit associations of the respective fields are illustrated in Figure 2 below.

Figure 2:

	WIND ENERGY	GM
STRONG ASSOCIATIONS	• Environmental sustainability • Clean renewable energy • Reduced greenhouse gas emissions • NZ's clean green reputation • Duty to future generations	• Economic growth and competitiveness • Commercial profits • Lift performance of primary production sectors • Development of NZ biotech sector • Marketable IP
SECONDARY ASSOCIATIONS	• Business competitiveness and efficiency • Returns to generators • Carbon credits	• Pharmaceuticals to relieve suffering • Improved environmental management

Wind energy has its dominant meaning as an ideals-based "do-good" or "feel-good" option, whereas GM is understood by key groups as primarily offering economic advantages and new industries and exports. The importance of strategic alignment of the projected benefits of R&D and innovation with the interests and assumptions of powerful groups is discussed in Chapters Three and Five. The contrasting trajectories – support for an active New Zealand research capacity in GM, and acceptance of a "technology taker" role in the wind energy sector – are shaped by the strongest framings or modes of benefit associated with the respective fields.

The next section of this chapter looks at some of the consequences when projections of benefit from technoscience and innovation are relatively weak and ineffectual. What happens when benefit claims are unconvincing? Why are some problem scenarios less than compelling as motivation for wider public recognition of the benefits of change and uptake of new technologies?

When benefit claims are not enough

The benefit projections advanced for technoscience and innovation are typically articulated as confident certainties. These narratives frame the beneficial outcomes of R&D as inevitabilities – sweeping aside opposition, alternatives, qualifications, or questions around the implementation and integration of new technologies in complex societal contexts. The task of advocacy and promotional discourse is to affirm not only the desirability of a new research or technology, but also its achievability, effectiveness and acceptability. Mulkay's (1993, pp 724-725) analysis of 'rhetorics of hope' highlights the assurance of 'strong future-claims', even though these optimistic constructs are 'extrapolations that go beyond the existing evidence'. Such discourse is based in the presumption that resistance or scepticism will easily be overcome by the eventual demonstrated benefits of the innovation (1993, p 727). Winner (2004, p 37) observes wryly:

> As is typical in the grand tradition of techno-enthusiasm, the operative verb tense in such projections is *will*. These things *will* happen. If there were ever a comprehensive history of the rhetoric of technological utopia, an appropriate title for it would be "The Triumph of the Will". The very language used to convey the message insists that wondrous blessing on the horizon is ineluctable.[266]

[266] These patterns of the presumed inevitability of the benefits projected from technoscience might seem to echo theories of technological determinism, which conceptualise innovation and diffusion as driven by an uncontrollable momentum (for example, Winner 1977; Smith & Marx 1994; Wyatt 2008). However the ideas put forward in this section, of the confidence typical of benefit claims, are focused specifically on the performative function of those claims.

These patterns of assumption and rhetorical assertion are widespread in the framings of future benefit advanced for GM and wind energy in New Zealand, as outlined in Chapters Five and Six. In policy documents, institutional and corporate statements, and sector promotions the benefits projected from R&D and innovation are often presented as beyond doubt. It is largely taken for granted that the intended benefits will eventuate, will be appreciated by a grateful society, and will justify the risks and the investments. Sector actors interviewed for this thesis expressed their confidence in the recognition of the utility of their technoscience and its products. Researchers and policy actors in the GM field spoke in anticipation of a steadily increasing acceptance of GM products in global markets. Many emphasised the importance of offering direct consumer benefits, rather than benefits to producers, to overcome public resistance and secure wider societal uptake of GM (Interviews 2, 11, 20, 22, 24, 34, 45 and 50). A university scientist suggested a strategic approach for incremental introduction of controversial new technologies: 'Over time people will become more comfortable with genetically modified organisms… the usefulness of them, how to utilise them' (Interview 18, 7/12/2006). And a scientist at Crop & Food predicted:

> [GM is] going to slowly pervade through society, one product at a time… there's probably twelve crops that make up 90% of the world's food, and before you know it those everyday crops will be GM, and so most of the world will be eating GM stuff (Interview 17, 17/7/2006).

Energy sector actors are also confident that the benefits of wind energy will come to be more widely recognised. The CEO of the Wind Energy Association recently projected increases in generation capacities from wind technologies from the present 0.6 GW to reach 3.5 GW by 2030: "Wind generation will expand to at least 20% of [New Zealand's] generation… [This is] definitely achievable' (Pyle 2012). A Meridian executive interviewed for this thesis explained the industry's advocacy efforts for wind energy as 'the future of New Zealand… those sorts of messages are getting through, generally people are very supportive of wind energy' (Interview 13, 18/4/2006). The manager of a Meridian windfarm described responses to the company's display at the rural field days: 'Nearly every farmer in [the region] was there, and every second farmer was: "hey, how do I get one of these on my property?"' (Interview 26, 21/11/2006). The Parliamentary Commissioner for the Environment included information on the Swift turbine, a UK household-scale design, in his audit of New Zealand's electricity system (2006b, p 46); the PCE's energy advisor described the enthusiastic reaction:

> Where we got the most takeup [of the ideas in the report] was on the Swift turbine… I'm still getting emails from people wanting me to sell them a Swift turbine, I feel I should be on a franchise to the Scottish company that makes them… there's obviously a huge demand (Interview 10, 16/8/2006).

However, the stories of GM and wind energy in New Zealand include many situations where the narratives of need and benefit advanced to promote technoscientific innovation have limited appeal. Interviewees in both sectors were frank about the lack of persuasiveness or traction of some benefit framings for many people. A key factor is the relative immediacy of the projected benefit – or the associated problem that the technology is positioned to answer. This demonstrates Michael's argument (2000b, pp 24-25) of the differing performativity of closer or more remote futures.

The strategic usefulness of environmental crisis in providing legitimation of wind technologies, via formal policy, statute and international treaties, was acknowledged by energy sector actors interviewed for this thesis. But some argued that (at that point in time, the mid-2000s) the projected impacts of climate change were not seen by most New Zealanders as an urgent enough problem to generate sufficient momentum and political leverage for more widespread uptake of renewable energy technologies. A policy analyst at the Energy Efficiency and Conservation Authority commented:

> Alot of people don't actually value the climate change benefit enough for the government to be able to put that funding into [renewable energy technologies]. So when the real pull or push comes from people saying "we want more of this," then that funding would be made available… You need that balance of people wanting it (Interview 43, 6/12/2006).

A Meridian wind energy project manager suggested that raising public awareness of climate change would take time; political and sector commitment for investment in new green technologies would require wider recognition and pressure:

> It's just going to take a whole bunch of evidence, and a whole bunch of different events and occurrences, which gets Joe Blow in the street to raise their head up and go: "oh, this is actually a problem." And then once Joe Blow understands it as a problem, then most of the decision-makers will go: "oooh, we actually need to do something about this." And so it does have to build a sense of momentum (Interview 40, 8/12/2006).

Some interviewees' experience of broader public and political perceptions of climate change was that this problem was seen as too vague, remote and distant in time, and too uncertain in its effects, to have much influence on energy technology choices. As the EECA policy analyst explained:

> It is a real challenge for renewables though. The cost hits us now, the benefit really happens in avoiding something that could happen down the track in fifty years, a hundred years' time (Interview 43, 6/12/2006).

An AgResearch scientist summed up perceptions of the broad, 'amorphous' character of problems on the scale of climate change, limiting its effectiveness as a driver for innovation uptake and public commitment:

> You can't see any direct causal connection between your own behaviour and the end result, and in fact you can't even see the real crisis, and unfortunately the timespans in which our consciousness functions aren't appropriate for the ecological events (Interview 46, 8/3/2007).

The CEO of Orion Energy suggested that many people have far more immediate and pressing concerns than far-away future environmental problems:

> If you're a mother at home with two small kids and you're living in a cold damp house that faces south, what sort of a life are you going to have? You know, we can talk about saving the planet, but if you can't get your kids to eat and they've got continual asthma, who gives a shit about saving the planet? (Interview 48, 18/7/2006).

The relative urgency of economic criteria was considered a more significant driver for the public's energy choices than far-off abstract issues such as climate change. A consultant engineer found that cost was the principal determinant of technology decisions for his clients: 'When push comes to shove, people's behaviour will be governed by their wallet much more than feel-good factors' (Interview 33, 11/5/2006). And the PCE's energy-sector advisor asserted that: 'Climate change, at a gut level, won't work [to change public attitudes about energy sustainability]. What will work is peak energy. Nothing hits people harder than in their pocket' (Interview 10, 16/8/2006).[267]

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[267] Bourdieu's recognition of the dominance of frameworks of economic value underpinning other kinds of qualitative symbolic capital, discussed in Chapter Three (Lash 1993, pp 200-201; Bourdieu 2004, p 55; Grenfell 2004, p 113), takes a slightly different twist here. As discussed earlier in this chapter, qualitative, ideals-based criteria – the long-term benefits of environmentally-friendly energy technologies, and our obligations to future generations – are often outweighed by pragmatic monetary calculations. Even when framed in association with powerful moral imperatives and global-scale

Another argument running strongly through sector discourse and the interviews was that motivation for innovation in the electricity industry would need the impetus of some dramatically catastrophic failure event with more inescapably obvious impact (Interviews 9, 12 and 53). The prospect of loss of electricity supply to major centres, and the impacts on communities and business, are major concerns (Canterbury Manufacturers' Association 2006).[268] People suffering in cold winters without heating is a powerfully evocative scenario; as a consultant for independent wind technologies suggested:

> Change will be invoked by some sort of crisis which will be negative in its connotations… Someone somewhere doesn't want to turn on their heater and dies one cold night, or there is a brownout or a blackout because of a lines failure, that sort of thing. Then there will be an enormous outcry (Interview 33, 11/5/2006).

The issues of motivation for change to more sustainable innovative technologies in the energy sector appeal to distant ideals rather than the immediate societal contexts. Similar dissociations between projected benefit and problem were identified as limiting the influence of some arguments for GM research. The work on GM vegetables focused on the reduction of pesticides and herbicides in conventional agricultural regimes, as discussed earlier in this chapter. However sector actors interviewed for this thesis considered that the majority of the public were not aware of the scale of the problems with agrichemicals; this raises a further issue in the reluctance of the horticulture industry to highlight the present application levels and potentially compromise public perceptions of their products and environmental practices. A research manager at Horticulture New Zealand, the industry body for vegetable growers, commented on the complications of trying to promote Roundup-ready onions on the basis of the benefits of reduced pesticide inputs (Interview 57, 20/4/2007). As a science manager at Crop & Food explained:

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problems, benefit projections for technological innovation can have weaker influence than the simple economics of the immediate context.

[268] The economic effects of energy shortages or failures are highlighted in Meridian's advocacy for the Makara windfarm: 'New Zealand's energy shortage in the winter of 2001 is estimated to have resulted in a loss of more than $200 million, while the power crisis in California during 2000 – 2001 cost the American economy between US$16 billion and $18 billion. The blackout that hit the eastern United States and Canada in August 2003 cost New York City US$500 million and Michigan employers US$700 million in lost output and revenues in just three days' (Meridian Energy 2005b, p 12).

> People are amazingly ignorant of what goes on in agriculture… and the thing is, the growing industry doesn't want to tell them: "well yes, that onion there has had fourteen sprays of chemicals" (Interview 2, 26/5/2006).

The relative remoteness for many New Zealanders of the impacts of possums created similar difficulties for promotion of the research into GM biocontrols. Scientists working in this field found that the majority of the ordinary public had limited awareness or interest in the problems of pest management, protection of indigenous biodiversity, or the risks to the dairy industry posed by possums. A Landcare Research manager explained:

> It's part of the general disconnect between urban communities and rural… For most people who live in towns, [possums] don't exist. For some people they're a nuisance but the fact that they threaten New Zealand's meat and dairy export trade is not even on their horizon (Interview 14, 23/4/2007).

A senior science advisor at AgResearch also argued a lack of public awareness of the extent of the damage caused by possums, as a limitation on the usefulness of this problem as justification for research into new biocontrol tools:

> You're looking at possums and bush despoliation, but how many people really are close enough to the bush to realise what's happening? When you look at urban populations they have an intellectual or kind of imagined outrage about what's going on, but not that many people really see that, really understand it. So the degree of engagement around the importance of transgenic biocontrol agents for possums is pretty theoretical (Interview 24, 18/8/2006).

Technoscience research and innovation are strategically associated with problems such as global climate change, agrichemical pollution or biodiversity losses, as constructs of need that require solution through the R&D or new technologies. But these dialectical relationships between projected benefits and pressing problems are not necessarily widely persuasive. The problems identified as targets for innovation work may be formally recognised in legislation and policy, and bring considerable leverage at those levels. But sector actors acknowledge that, for many New Zealanders, such issues are far from compelling, and unlikely to exert much momentum for attitude shifts or levels of support for new technologies. The benefit-problem nexus may strengthen the performative influence of benefit claims, but it can also be relatively ineffectual when the issues at stake are low in publics' priorities or remote from everyday realities.

The stories of the work of benefit projections in the promotion and diffusion of GM and wind energy technologies in New Zealand offer ample evidence of the fragility of the effects of these discourses and strategic claims in the ongoing dynamics of contested fields. Social and sectoral acceptance of the need for change, and the benefits of new technoscientific options, is neither absolute or enduring; the appeal of innovation may seem strong for a time, only to fade away or be overtaken by other issues or developments (Konrad 2006; Konrad et al 2012). This section closes with a brief assessment of how benefit constructs can fizzle and fail.

In both innovation fields there are salutary cases of projects discontinued, scaled down or never even begun. The decision of Meridian Energy to withdraw its controversial proposal for the large Hayes windfarm is one example of the numerous wind energy projects where approval has been granted but the actual construction deferred.[269] But the most dramatic falling-away of confident benefit projections is in New Zealand's GM research. Strong sector activity at the time of the Royal Commission has significantly declined, as outlined in a recent report from the Sustainability Council (Howard 2012). In 2001 New Zealand institutions were conducting 48 field trials of 15 GM species, but by 2012, only two research programmes remain – trials of GM pine trees at Scion, the forestry-sector CRI, and AgResearch's biopharm livestock work (2012, p 6). Although some biotech industry advocacy attributes this pattern to the claimed disincentives of regulatory constraints, there is increasing recognition that the projected benefits have simply not eventuated:

> Explanation for the lack of commercial success from New Zealand's state-funded agricultural GM R&D effort is certainly needed. Since the 1980s, tens of millions of dollars of public science funding has been invested in the development of GMOs… Yet despite promises of major economic returns and imminent or certain commercialisation, not a single GM crop variety has reached the market or is likely to do so within the next decade (2012, p 13).

Optimistic benefit projections have sustained the GM technoscience sector for many years, as discussed earlier in this chapter and in Chapter Six. But GM's under-

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[269] Meridian's CEO explained the withdrawal as the consequence of a company review which led to other projects being given greater priority (www.meridianenergy.co.nz/company/news/media-releases/community/meridian-withdraws-resource-consents-for-project-hayes/ , 19 January 2012). See also www.odt.co.nz/regions/central-otago/194989/meridian-ditches-project-hayes , 20 January 2012. A list of proposed and consented windfarm projects not yet undertaken is at www.windenergy.org.nz/nz-wind-farms/proposed-wind-farms/ .

performance on those promises reflects a fundamental disjunction between the frameworks of the industry and policy-makers, and actual publics. Howard (2012, pp 6-19) details many New Zealand GM research projects that failed to find support from the relevant sectors (pastoral farming, forestry and horticulture) or from the intended markets. The general lack of consumer acceptance for GM products is an unavoidable obstacle; major international food industry groups such as retailers and food processors have established policies to keep their products GM-free. Another recent study on public attitudes to innovation in food production (Cronin et al. 2012, p 18) also finds a rejection of GM: 'Opposition to GE sits upon a cluster of deeply held values underpinned by risk aversion, environmental safety and sanctity, and concerns of human health impacts'. Howard (2012, p 19) concludes that GM research is 'out of step with… the wider community from whom it must gain [its] license to operate'. Or as Froggatt and Rankine (1999, p 466) observe:

> The arguments that the biotech industry is the industry of the future fail to take into account the significance of the lack of public demand for the end products of this industry in the markets of the UK and Europe… Even Dan Glickman, the US Agriculture Secretary, one of the most bullish supporters of the GE industry, recently stated: "Ultimately, if the consumer doesn't buy, the technology isn't worth a damn".

Failure to deliver usable and saleable products was also implicated in the closure of the possum biocontrols research programme (Green Party of New Zealand 2010; Wallace 2010). The Foundation for Research, Science and Technology, the principal funder of this work, announced a shift in focus in its 2009/2010 Request for Proposals for environmental pest management research (Foundation for Research Science and Technology 2010).[270] Work on single-species control tools, and on GM biocontrols for possums, was explicitly excluded (2010, p 7). This new orientation was explained as due to the lack of new products from the years of work on possum control options; the importance of delivering 'tangible outcomes' was firmly asserted: 'a focus on controlling a single target species (possum) will not meet the needs of a broad spectrum of end users' (2010, p 5). Funding would be available only for studies into control methods applicable to multiple pest species.[271]

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[270] The Request for Proposals processes (RfPs) were the means by which FRST (subsequently restructured into the Ministry Science and Innovation) signalled government's research priorities, goals and criteria to New Zealand research institutions.

[271] The range of pest species impacting on New Zealand's natural ecosystems and biodiversity include stoats, ferrets, rabbits, wild cats, deer, pigs, rats and mice, as well as possums. Research into non-GM

The biocontrols research programme had demonstrated the effectiveness of GM immunocontraceptive methods (Duckworth et al. 2004; Duckworth et al. 2005; Duckworth et al. 2007; Walcher et al. 2008; Duckworth et al. 2009; Cui et al. 2010b), and of different delivery options (Cowan et al. 2006; Cowan et al. 2008). Positive results from the research were enthusiastically highlighted in the media as a breakthrough for New Zealand's possum problem (Eckery 2007; Easton 2009; Keene 2009; TV One 2009). But progress towards an actual marketable management product was slow; furthermore, as explained in interviews with project scientists, the necessary trials and comprehensive safety testing for a proposed GM biocontrol would have taken years of further work (Interviews 14 and 18).

The trajectory of New Zealand's research programme on GM biocontrols for possums ended in a fundamental disjunction of expectations of benefit from the work – between the science team's focus on steady scientific advance, and the short- or medium-term demands of funding agencies and projected users. Without something applicable to present needs, the projected eventual benefits of the biocontrols research were not sufficiently compelling to sustain support over the long term.

Conclusion

This chapter has investigated the dynamics of technoscience benefit claims in the strategic positioning of research and new technologies in complex, contested fields. The diverse demands of funders, technology consumers and users, commercial markets, production sectors and policy domains all impose considerable pressure on R&D proponents. Linking projections of technological benefits with societal needs, problems and difficulties, in a dialectic of positive and negative futures, helps to establish a sense of necessity for the innovation work. Such imperatives may be direct and immediate, or remote and uncertain, but the stories of GM and wind energy

control methods, toxins, and cost-effective application strategies for multiple pest species has been undertaken by Landcare Research from the early 2000s, concurrently with the GM biocontrols work, and is ongoing (www.msi.govt.nz/update-me/who-got-funded/ projects CO9X0910, CO9X1007, CO9X1008, CO9X0505, CO9X0507, CO9X0209).

in New Zealand both show technoscience promotions appealing to scenarios of a "problem push" as drivers for change to strengthen the "benefit pull".

In order to secure acceptance and to sustain support and momentum for research and innovation activity, the projected outcomes and intended benefits must satisfy the expectations and needs of multiple groups. Both exogenous benefits, intended to accrue to external users of technologies and their products, and endogenous benefits supporting the ongoing work and symbolic capital of practitioner communities, are key assets in securing acceptance and investment. Alignment with the interests of dominant sectors is crucial, and this chapter has explored the importance of economic framings of future benefits in positioning research and innovation programmes favourably in relation to key policy and business groups. However, New Zealand's GM research and wind energy developments are also strongly associated with purposes intended to benefit the public interest, notably the efforts towards environmental sustainability and the minimisation of greenhouse gas emissions in response to global climate change. Both registers or modes of intention are valuable in the performative work of benefit claims in generating and maintaining confidence in the desirable benefits of R&D and innovation.

However, as seen in the last section, there are limitations to the appeal and momentum of projections of need and benefit that are deployed in discourse and strategy to justify technoscience. Some benefit framings are stronger than others, and the downward trajectories of some initially confident claims demonstrate the vulnerability of these abstract constructs to the demands and pragmatic realities of markets, business, interested sectors and publics.

Chapter Eight

Somewhere over the rainbow?[272]

The future is a locus of human dreams and aspirations, the place where our good intentions can be made into realities, and where the various dissatisfactions of the present can be resolved or overcome. Although we live in the here and now, we are continually projecting ahead (and also reviewing behind). The irresistibly seductive appeal of tomorrow is that it might – if things go well and the gods are kind – be better than today. Of course, there is also the potential for negative futures to occur, and the exponential rise of the risk analysis industry in recent decades is evidence of society's consciousness of the importance of preparing for difficulties and disasters of various kinds. The experience of living through the series of major earthquakes that devastated Canterbury, New Zealand, in 2010 and 2011 has given a particularly acute focus to the future's inherent unpredictability. But the need to plan, to anticipate, to imagine and to improve is a fundamental human characteristic – and science and technology are very often central to such forward-focused activity.

This thesis explores the workings of projections of future benefit in the advancement of technoscience innovation in two New Zealand fields. The stories of wind energy and GM development in this country provide a rich array of constructs for analysis – scenarios of the outcomes expected to be delivered by particular R&D programmes and new technological applications. These claims are created and deployed in discourse, sector advocacy and policy; they exist in the realms of rhetoric and the strategic positioning of actors, projects, interest groups and institutions; and they reflect and perpetuate the values and norms that prevail in those social contexts. Chapter Two discussed the ways that benefit projections are products of their environments, reifications of the ideals upheld as important and worthy by that community. The meanings of technoscience – whether research knowledge, a product or artifact, or a comprehensive technological system – are forged in the practice of fields, and in the broader assumptions and beliefs of the people who design, build, manage and use those technologies. Expectations of the benefits of science and

[272] With apologies to Judy Garland.

technology are embedded in the ideological frameworks of particular groups, professions and wider society, and deeply internalised in the identities of actors and institutions. Such patterns are effectively rendered subliminal in discourse and practice, thoroughly naturalised in the objectives and purposes towards which activity is oriented, and taken for granted as desirable, worthy and appropriate. This normalisation is part of the influence such frameworks of assumption exert on the development trajectories of science research fields and new technologies. Policies, sector strategies, funding provisions, regulatory systems and public perceptions of technoscientific innovation are all shaped within the narratives of possibility and utility that comprise Bourdieu's habitus (1990, 1999, 2002, 2004) or Foucault's regimes of truth (1972, 1980, 1994). This thesis has frequently identified such hegemonic patterns in the meanings and benefits commonly attributed to R&D and innovation, in discourse and policy for GM, energy and technoscience generically, and in the interviews conducted with sector actors.

Many narratives about the benefits, beneficence and qualities of science and technology have achieved the status of myth, widely accepted as both explaining and guiding orientation and development (Winner 1986; Sarewitz 1996). Chapter Two describes three such myths that both enable R&D and innovation and constrain them into certain pathways. The old tale of the Golden Goose frames science and technology as the sources of societal prosperity, wellbeing, wealth and abundance. Lewis Carroll's neurotic character the Red Queen sets R&D on a frantic race to avoid being left behind and missing out on that prosperity. And (shifting the metaphors to classic country-rock music) Johnny Cash provides the analogy of "walking the line", where technoscience is framed as a reliably rational linear progression towards teleological goals. These narratives are strongly influential in the promotion and positioning of GM in New Zealand. Chapters Six and Seven follow advocates' framing of research into potential GM applications, and the maintenance of expertise in this field, as necessary requirements for the country's economic growth and international competitiveness. Appealing to such projected benefits of GM technoscience has in turn benefited the New Zealand biotechnology sector, helping to secure significant government funding, supportive regulatory frameworks, and political recognition.

Technoscientific innovation domains such as the GM and wind energy sectors in New Zealand are, moreover, fraught with contestation and competition, besieged by protest and opposition, and stalked by chronic insecurity and uncertainty. Chapters Three and Seven address the strategic dimensions of R&D and innovation processes in fields characterised by fierce ongoing struggles for credibility, acceptance, funding and authoritativeness. Chapter Three focuses on the performative work of benefit projections in establishing the grounds for societal support for research work and the diffusion of new technologies (van Lente 1993; Brown et al. 2000a; Brown et al. 2003; Borup & Konrad 2004; Sturken et al. 2004; Sunder Rajan 2006; Dattée & Weil 2007; European Commission 2007; Vanloqueren & Baret 2009). Suitably persuasive and plausible benefit claims are, in Bourdieu's terms (2004), valuable symbolic capital – crucial strategic resources for actors, institutions and projects to establish legitimacy and maintain a positive profile. The projected benefits of research work and new technologies are articulated as the rationale for supportive policy and legislation, generous funding, institutional status, and the presumed public acceptability of unproven, heavily contingent R&D programmes.

Analyses of the dynamics of technoscience development highlight the importance of strategic alignment of a project or field with the interests and value frameworks of significant groups (Bijker 1995; Latour 1996; Kaplan & Tripsas 2008). The need to accommodate research and innovation within the expectations of powerful sectors leads to the dominance of a particular form or application of the technology that satisfies the requirements of key users or decision-makers. This is similar to the negotiation of closure of scientific controversy and the often painful process of a paradigm shift as theorised by Kuhn (1996). The dominant mode, and the suite of benefits associated with it, become the norm, soon leading to inertia in the field, and lock-in of R&D approaches around the established frameworks of expectation (Utterback 1994; Gooley & Towers 1996; Garud & Karnøe 2001b; Rogers 2003; Van Merkerk & Van Lente 2005; Van de Ven et al. 2008).

Possible alternatives that are perceived as radical or disruptive gain little recognition, despite offering other kinds of benefits and returns (Latour 1996; Christensen 1997; Franklin 2003; Rogers 2003). These patterns are strongly evident in the trajectory of wind energy in New Zealand, detailed in Chapter Five. The mode of this technology that has found wide acceptance and uptake is the large commercial windfarm feeding the national grid – the form of wind utilisation that is most compatible with existing infrastructure and sector requirements. Possible alternative ways of using wind technologies, such as distributed networks of independent small-scale generation or local community-based systems, have been dismissed as unrealistic or relegated to minor fringe applications that do not threaten the mainstream paradigm.

The anticipated benefits of new research and technologies are often associated with a contrasting problem scenario to enhance their persuasive force and generate a momentum and motivation for change. Chapters Three and Seven outline the imperative of imperatives – the importance of strategic leverage achieved via a suitably urgent need or looming disaster for which research and technoscientific innovation are positioned as solutions. This pattern plays out in revealingly different ways in the respective stories of wind energy and GM in New Zealand. The advancement of wind energy technologies is framed in relation to the necessity of an active response to the threat of global climate change, an obligation formally recognised in legislation and New Zealand's international commitments. Chapter Five shows the close justification, in government policy and sector discourse, of the benefits of renewable electricity generation in terms of the demands of this enormous environmental challenge. GM research in this country, however, has been legitimated in relation to a diverse spectrum of needs, discussed in Chapters Six and Seven. Objectives of finding GM solutions to medical and environmental problems are important in the strategic positioning of the work, but must be disregarded in New Zealand's regulatory processes for new organisms research; projects are approved on the basis of claimed generic benefits for the economy and the improved performance of our export sectors. This rationale, and the maintenance of active New Zealand capabilities in this field, are framed in relation to the Red Queen imperative of the need for competitiveness in ruthless international technoscience contests.

The heterogeneity typical of the benefit claims advanced for research and innovation in the two New Zealand sectors is an indication of the diverse range of interested groups and parties involved in development and diffusion processes. Chapter Five follows the discursive construction of wind energy technologies in relation to an eclectic mix of benefits – protecting the long-term future of the planet, demonstrating the government's commitment to its Kyoto targets, giving independence and satisfying personal green principles for environmentally conscious individuals, avoiding the prohibitive costs of grid connection for homeowners in remote locations, bringing in revenue for the generation companies as a nil-input source of electricity and in the form of carbon credits, and offering significant consumer appeal and increased market share for those companies with attractive green branding strategies. The range of benefits projected from the potential applications of GM is similarly diverse, including health, environmental and biodiversity protection benefits and commercial profits from new high-value products. However, GM work in New Zealand has so far been confined to laboratory research and contained field trials and therefore the benefits promised for this field remain conjectural.

The typical association of research and innovation with multiple overlapping framings of expected benefit and need also indicates the inherent fragility and contingency of these future constructs. Technoscience advocacy must assert positive associations with key interest groups, and positive frameworks of meaning and intent, to secure the necessary support and legitimacy for their activities (van Lente 1993; Latour 1996; Sarewitz 1996; Greenberg 2001; Rogers 2003; Van de Ven et al. 2008). The diverse arrays of benefit claims advanced for GM and wind energy in New Zealand reveal a basic duality or dialectic between economic or commercial goals and ideals-based, societal-interest objectives. The dominant prioritising of economic framings of anticipated benefit from R&D and new knowledge and technologies is rarely questioned in policy and sector discourse. But it is salutary that technoscience fields and projects also assert a range of altruistic, public-good goals in justification of the worthiness and beneficence of their work, seeking to appeal in different ways to different groups and publics.

Research and innovation are deeply uncertain processes, and the effectiveness, safety, marketability and diffusion of new technologies and products can not be guaranteed despite the most confident projections at the outset of the development programme (Tenner 1997; Collins & Pinch 1998a, 1998b; Geels & Smit 2000a, 2000b; Franklin 2003; Rogers 2003). The fields of GM and wind energy in New Zealand include many examples where the initial momentum could not be sustained, and the research programmes were not continued – including, notably, the work on possible GM biocontrol methods to combat the plague of possums infesting New Zealand forests, the starting point for this thesis as outlined in the Prologue. This vulnerability of benefit projections, and the ignominious fading away of the original enthusiasm and claims, indicates that the real work of future claims for technoscience is not actually in relation to the future. These optimistic constructs have their main relevance in the present-time strategic requirements of R&D communities and the demands of survival for new ideas and development initiatives in chronically contentious and under-funded fields.

What is the significance, for interested groups and actors in technoscience fields, of the findings drawn from this analysis of the promotion and evolution of two innovations in New Zealand? There are several ways forward – both in scholarship, and in the possible application of the lessons of the GM and wind energy stories to innovation processes in other fields and real-world situations.

The attractions of various theoretical models as potential ways of deconstructing the intricacies of my two case study fields are mentioned in Chapter Four. While following the methodologies that I decided were most appropriate for the material, it was clear that there would also be rich opportunities in other conceptual approaches. In particular, the tools of Actor Network Theory offer a perspective on technoscience processes that could be productively applied to the critical analysis of constructs of expected benefit and their complex associations with R&D actors, epistemological and natural phenomena, artifacts and physical entities (Latour & Woolgar 1979; Latour 1992; Law 1992). Such a study might range from huge turbines to domestic appliances designed for greater energy efficiency, from the arcane dynamics of international food markets down to the molecular level of the reconfigured DNA of GM vegetables, and from global environmental change down to the tiny crustaceans impacted by agrichemical leachates from a coastal farm and the business models of that farming community.

Other avenues for possible further development of this research might consider the significance of benefit claims in the promotion and legitimation of other new R&D fields. Nanotechnology is an obvious candidate for such scrutiny (Sarewitz & Woodhouse 2003; Wilsdon & Willis 2004; Macnaghten et al. 2005; Kearnes et al.

2006). The projections of intended environmental benefit advanced on behalf of innovative green technologies might also provide interesting material for an assessment of the relative forcefulness of non-monetary objectives relative to economic frameworks in positioning new areas of R&D. The insights drawn from this study's analysis of the work of expectations in the evolution of GM and wind energy technologies in New Zealand would be a possible starting point for academic critique of development processes and sector rhetorics in other innovation fields.

There are other ways the findings of this thesis might be taken forward, particularly with respect to the practical challenges of implementation and application of new technologies and the design and promotion of new research. The rationale for this thesis, as discussed in the Prologue and Chapter One, is that there has been a lack of critical scrutiny and understanding of the "upstream" origins of technoscience trajectories. Relatively limited attention has been given to the influence of projections of future beneficial outcomes from R&D and new technologies, or the implications of benefit framings for innovation processes and the kinds of products, systems, knowledge and practice they deliver. I contend that in order for technoscience to be made truly effective, relevant and meaningful, and for R&D to productively address real societal needs and priorities, we need a more thorough critical understanding of the ways technoscience is framed in discourse and sector strategy, and the patterns of assumption, expectation and priority that shape and constrain these framings. This will involve proactive, informed engagement with technoscience processes and the relevant policy and institutional domains. I would like some of the insights from this thesis to contribute to improving such interactions and helping both interested groups and sector actors to work thoughtfully towards better outcomes from science and technological innovation.

To come back to the physical location of my research, there are immediate opportunities for the findings of this thesis to be useful right here at home in Canterbury. The daunting technical requirements and complicated social and political issues of the post-earthquake reconstruction process are already strongly influenced by frameworks of expectation and assumptions of the desirability and benefits of various technological modes. With the loss of most of central Christchurch's buildings and infrastructure, there are extraordinary potentials for innovation –

indeed, for a Kuhnian paradigm shift for the whole city. There is energetic advocacy for new green technologies to be creatively deployed in the rebuild, including such radical possibilities as shared energy systems where efficiencies are gained by street-scale networking between buildings.[273] However, the multiple contending interests and values involved, and the enormous costs, create significant challenges for innovators and decision-makers. Determining the best way forward for Christchurch and greater Canterbury will require a deep and comprehensive understanding of the social and strategic dynamics, and the opportunities, of technoscience. The lessons drawn from this thesis's exploration of the benefit claims advanced for GM and wind energy are a contribution to that learning process, and to the negotiation of multiple expectations, ideals and possibilities in the construction of new futures.

[273] See www.café.gen.nz/projects, www.stuff.co.nz/the-press/christchurch-earthquake-2011/city-blueprint, www.scoop.co.nz/stories/BU1206/S00640/energy-design-grants-for-christchurch-rebuild .

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Appendices

Appendix 1: Interviews

As outlined in Chapter Four, the confidentiality of individual interviewees has been protected in the interests of their positions in their respective fields. Interviewees are identified here by their role and organisation.

1.	Science & technology policy	Ministry of Research, Science and Technology	6/12/2006
2.	Research manager – GM crops	Crop & Food Research	26/5/2006
3.	Distributed wind energy systems	Orion Energy	6/10/2006
4.	Energy policy & innovation	Energy Efficiency and Conservation Authority	SCOPING – early 2006
5.	Regulatory policy – GM foods	Food Standards Australia NZ	24/4/2007
6.	Distributed wind energy systems	Independent Consultant	18/7/2006
7.	Science funding policy & processes	Foundation for Research, Science & Technology	18/4/2007
8.	Science communication	AgResearch	8/3/2007
9.	Energy sector policy & regulation	Electricity Commission	31/10/2006
10.	Energy sector policy & wind energy	Parliamentary Commissioner for the Environment	16/8/2006
11.	GM science research – vegetables	Crop & Food Research	8/11/2006
12.	Energy sector policy & wind energy	Orion Energy	17/10/2006
13.	Wind energy strategy & project management	Meridian Energy	18/4/2006
14.	GM biocontrols research	Landcare Research	23/4/2007
15.	Environmental & energy policy	Green Party of New Zealand	8/12/2006
16.	GM biocontrols research	Landcare Research	17/5/2006
17.	GM science research – vegetables	Crop & Food Research	17/7/2006
18.	GM biocontrols research	Victoria University	7/12/2006

19.	Energy sector policy & innovation	Ministry of Economic Development	7/12/2006
20.	GM science research – foods & pharma	Auckland University	7/3/2007
21.	Environmental risk management policy	Ministry for the Environment	SCOPING – early 2006
22.	GM science research – vegetables	Vegfed / Horticulture NZ	20/4/2007
23.	Distributed energy systems	Industrial Research	19/10/2006
24.	GM science research & policy	AgResearch	18/8/2006
25.	GM biocontrols research	AgResearch	6/12/2006
26.	Wind energy project management	Meridian Energy	21/11/2006
27.	Biotech research – innovation	AgResearch	8/3/2007
28.	Policy for NZ dairy sector – biocontrols research	Animal Health Board	18/4/2007
29.	GM policy and regulation	Environmental Risk Management Authority	16/8/2006
30.	GM policy and regulation	Environmental Risk Management Authority	16/8/2006
31.	Distributed energy systems	Windflow Technology	28/4/2006
32.	Innovation in energy systems	Canterbury University	1/12/2006
33.	Distributed wind energy systems	Energy 3	11/5/2006
34.	GM science research – livestock	AgResearch	8/3/2007
35.	Innovation and entrepreneurship	Canterbury Employers' Chamber of Commerce	15/2/2007
36.	Venture capital investment	Endeavour Capital	1/12/2006
37.	GM biocontrols research	AgResearch	22/11/2006
38.	Innovation in energy systems	MainPower	20/4/2006
39.	Science policy & communications	Ministry of Research, Science and Technology	24/4/2007
40.	Wind energy policy & project management	Meridian Energy	8/12/2006
41.	Wind energy policy & regulation	Electricity Commission	7/12/2006
42.	GM policy and regulation	Environmental Risk Management Authority	16/8/2006

43.	Energy policy & innovation	Energy Efficiency and Conservation Authority	6/12/2006
44.	Alternative energy innovations	Independent sector lobbyist	20/4/2006
45.	GM policy and regulation	Ministry of Research, Science and Technology	9/5/2006
46.	Science communities & innovation	AgResearch	8/3/2007
47.	Science funding policy & processes	Foundation for Research, Science & Technology	26/4/2007
48.	Energy systems & innovation	Orion Energy	18/7/2006
49.	Science & technology research sector	Royal Society of NZ	6/5/2006
50.	Innovation & entrepreneurship	Biocommerce Centre, Massey	23/4/2007
51.	Research institution communications	Crop & Food	24/7/2006
52.	Innovation & change processes	Crop & Food	26/5/2006
53.	Energy systems & entrepreneurship	Canterbury Manufacturers Association	15/11/2006
54.	Biotechnology sector policy & strategy	NZBio	9/5/2006
55.	Energy innovation & system management	Electricity Commission	7/12/2006
56.	Energy policy	Energy Efficiency and Conservation Authority	6/12/2006
57.	GM science research – vegetables	Vegfed / Horticulture NZ	20/4/2007
58.	Science innovation & entrepreneurship	Auckland University	7/3/2007
59.	Wind energy innovation research	Canterbury University	9/10/2006
60.	Energy sector policy & innovation	Ministry of Economic Development	7/12/2006

Appendix 2: Research outline sent to interviewees

RONNIE COOPER

Research for PhD, University of Canterbury, Political Science Department
rco28@student.canterbury.ac.nz
03-341-5445 / 021-204-5905

PERCEPTIONS OF BENEFIT FROM RADICAL NEW SCIENCE AND TECHNOLOGIES

INTRODUCING THE PROJECT

Background:

Some new technologies are characterized by considerable uncertainty – both as to their effectiveness and potential unpredicted effects – yet attract significant support from powerful sectors including government, commercial and research institutions. Structures of production and development, and the formal policies and strategic directions of government, are central to the advancement of these technologies. Broader concepts of progress and modernity, and the marketing and presentation of these technologies, also help to shape perceptions of benefit and confidence.

Other kinds of transformational technologies are developed with equally problem-solving orientations, yet have not attracted equivalent levels of political support and resources. Characterized by strong environmental priorities, requiring new infrastructure and systems for their application, and perceived as having limited effectiveness and profitability, they have as yet a low profile both in policy and research arenas and with the public.

International work in science and technology studies (STS), and in risk assessment in relation to radical new technologies, has focused predominantly on issues of risk and perception of risk, on the recognition of uncertainty and unknowns, and on developing processes for communication and dialogue between experts, regulators, and the public and concerned groups. Understandably the discourse thus far has focused around the potential for negative consequences from a new technology – and thus around managing the protests and opposition of concerned groups. The issues arising with risky new technologies can became polarised into adversarial stand-offs with consequent damaging erosions of public trust in science, the institutions and corporations developing new technologies, and regulatory bodies.

The orientation of STS and risk assessment work towards the potentials for negative outcomes, whether from the application of a new technology or from adverse public perceptions, has resulted in an imbalance in attitudes and understanding of science and technology that is potentially risky in itself.

This research project:

My research will explore the other side of the paradigm – the concepts of benefit, value and purposeful improvement underpinning the development of and support for radical new technologies, including:

- Confidence in the efficacy and profitability of the technology
- Confidence in the manageability of risk and uncertainty, and of change processes to new systems and ways of doing things
- Confidence in eventual public acceptance of the new technology
- The appeal or attractiveness of some technological options rather than others.

I will explore these questions through a comparative analysis of two technologies and the New Zealand government policies and regulatory systems, research institutions, funding structures, sector group support, and communications upon which their development depends. Interviews will be undertaken with scientists, with regulators and government agency personnel, and with practitioners and sector representatives. Their views, ideas and experiences will give a basis for evaluating relevant theoretical models drawn from political studies, STS, risk management and communications disciplines.

The technologies selected for study are:

- *Genetic modification – pesticide-resistance, bioactives, biopharming, biocontrols*
- *Energy alternatives – solar (water heating and photovoltaics) and wind power.*

These technologies each involve substantial paradigm shifts from the status quo, and are derived from cutting-edge science and research. They are each influenced by – and in turn affect – a diverse range of social, environmental, ethical, economic, technical, and infrastructural factors. And they have each attracted controversy and resistance.

Questions to be pursued include:

- How each technology is framed, positioned and promoted
- What ideals and principles shape the development of the technology, and help to enhance its appeal to the public, interested sectors and decision-makers?
- What benefits and profits are envisaged from the technology, and to whom?
- What problems is the technology intended to address?
    - What is the position re alternative potential solutions to those problems?
    - What is the response to opposition or resistance to the new technology?
- What roles do official policy and government strategies, science institutions and regulatory agencies play in the development of the technology?
- What obstacles (resourcing, institutional, infrastructure, mindsets) impede acceptance and uptake of the technology?
- What communications and public relations are undertaken to position and promote the technology and its intended benefits? What more could be done?

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