CLIMATE ADAPTATION FUTURES

Edited by Jean Palutikof, Sarah L. Boulter, Andrew J. Ash, Mark Stafford Smith, Martin Parry, Marie Waschka and Daniela Guitart

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Preface

As I write this preface, the media is full of accounts of the record-breaking floods in southern Russia, and the record-breaking heatwave in the eastern USA, made worse for many by the power blackouts caused by earlier severe storms. Climate scientists tell us that they cannot unequivocally state that these extremes are caused by climate change but, nevertheless, this is how it begins – with more frequent and more severe extremes, as well as with a gradual increase in temperature and a shift in rainfall patterns. This book sets out to explore some of the challenges that we will all face over the coming decades as we seek to adapt to changing climatic conditions.

It arises out of an international conference on adaptation held on the Gold Coast, Queensland, in June 2012. I had grown weary of the many conferences I had attended on climate modelling which had a day for impacts and adaptation presentations as justification for the large expenditure incurred by the modellers. So, in a new job, in a new organisation, there was the will and the capacity to hold a large international conference dedicated entirely and exclusively to adaptation – a small window of opportunity before we would be overwhelmed by the day-to-day activities of the National Climate Change Adaptation Research Facility (NCCARF, www.nccarf.edu.au). But of course, a new organisation doesn't have the reputation and standing to pull in the crowds – enter the CSIRO Climate Adaptation Flagship (www.csiro.au/ca). So, a natural alliance was formed to hold the conference, which was a grand success, with over 1000 participants from some 50 countries.

This book emerged from the conference, but it has grown to be much more than a straightforward proceedings. Rather, it is a picture of the state of adaptation science built up over the two years since the conference, opening with an in-depth chapter laying out the five challenges of adaptation, followed by 39 chapters/case studies collected into nine sections, which cover the whole spectrum from adapting ecosystems and agriculture through to communication of adaptation knowledge and the intersection of adaptation with issues of poverty, equity, development and sustainability. Ninety authors contributed to the book from 18 countries.

My co-editors are, with one exception, from NCCARF (Sarah Boulter, Marie Waschka and Daniela Guitart) and the CSIRO Climate Adaptation Flagship (Andrew Ash and Mark Stafford Smith). The exception is Martin Parry, who was the Co-Chair of the Intergovernmental Panel on Climate Change Working Group II Fourth Assessment when I was the Head of the Technical Support Unit. I thank these friends and colleagues for their support and commitment to the completion of this book – without them it could not have happened.

Jean Palutikof, NCCARF, Gold Coast
July 2012

Section 1

Introduction

1 The past, present and future of adaptation: setting the context and naming the challenges

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1.1 The purpose of this book

This book seeks to expose and debate key issues in climate change adaptation, and to report the current state of knowledge on adaptation. Adaptation is often the poor cousin of the climate change challenge – the glamour of international debate in metaphorically smoke-filled rooms is around mitigation, whereas the bottom-up activities of adaptation carried out in community halls and local government offices are often overlooked. Yet as international forums increasingly fail to deliver against mitigation targets, the realisation is dawning that effective adaptation will be essential across all sectors to deal with the unavoidable impacts of climate change.

Many challenges surround the definition and implementation of successful adaptation, which this book seeks to address. To explore these challenges, we have taken a selection of papers from the First International Conference on Climate Change Adaptation 'Climate Adaptation Futures', held on the Gold Coast, Australia, in June 2010. This three-day meeting of over 1000 researchers and practitioners in adaptation was the first of its kind.

What are these challenges? We begin this chapter with a discussion of five principal challenges for adaptation. We then outline the content of this book. We map the chapters of the book onto the five challenges, so that those who wish to explore in greater depth can do so.

1.2 What are the five principal challenges for adaptation today?

1.2.1 Challenge 1: Understanding the balance of actions to adapt and actions to mitigate

We tend to assume that the wisest course of action in confronting climate change involves a mix of two actions: (a) reducing emissions as much as we can afford so as to keep impacts and adaptation costs to the minimum over the long term, (b) adapting to most of the remaining impacts so as to minimise damage to society and the environment. Then, thirdly, we bear the costs of the unavoidable residual damage (which includes impacts that we cannot adapt to or we judge not worth adapting to). Figure 1.1 is a

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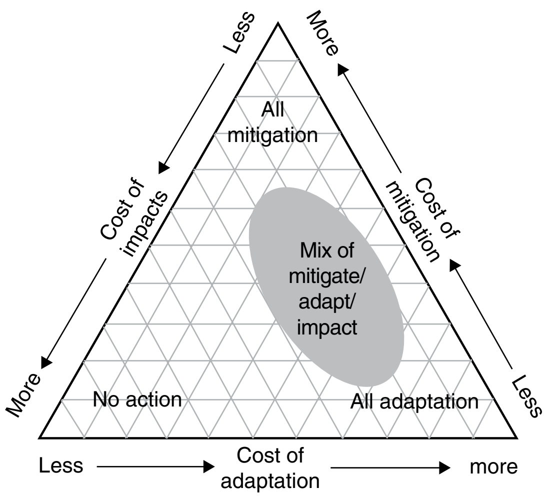

Figure 1.1 Schematic on interconnection between climate change impacts, mitigation and adaptation. With kind permission from Springer Science and Business Media: *Climatic Change*, 96, 2009, 23–27, Closing the loop between mitigation, impacts and adaptation, Parry, M., Figure 1.

schematic of the trade-offs between these three with, in the example shown, the mix being located to the right of the triangle, the predominant actions being roughly equal amounts of mitigation and adaptation, with less being spent on remedial damage. A less optimistic picture (more 'realistic' say those dismayed at the slow progress of international climate policy) would be to locate the mix of actions more to the left of the triangle, with less action on mitigation and adaptation leading to more damage from impacts.

Schemas such as this suggest that we know the relationship between action and outcome, whether it be mitigation or adaptation. In theory we might, but in practice we do not. Even if we did, it is not clear whether an 'optimal' mix of actions exists even in theory (i.e. one where actions along each of the three lines give the most reward). However, this schema is a fair reflection, in outline, of how our current actions are premised: that if we take one line of action we will ultimately reduce costs along another. If this is the case, what task is being left to adaptation given the current effort (and expected outcome) from mitigation?

Adapting for 'overshoot and recover'

It is widely accepted that the threshold for dangerous climate change is a warming of 2 °C above pre-industrial levels. It is increasingly unlikely that emissions of greenhouse gases can be held at a level that will ensure global temperatures remain below this threshold (Rogelj et al. 2011): it would require stabilisation at about 450 ppm CO_2 equivalent (CO_2e) and we are already at 430 CO_2e. Therefore, we need to explore scenarios in which atmospheric concentrations of greenhouse gases, and possibly even global temperatures, overshoot their targets and then recover to stabilise below dangerous levels.

Since the 2007 Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC), partly in response to gaps in the Assessment and also driven by the need to answer urgent questions from policymakers, a number of analyses have been completed of the climate outcomes for varying strategies of emissions reductions (e.g. Hansen et al. 2008; Van Vuuren et al. 2008; Allen et al. 2009a; Meinshausen et al. 2009; Parry et al. 2009b; Schneider 2009; Sanderson et al. 2011; Tomassini et al. 2010).

Figure 1.2 shows the projected global temperature increases using a simple Earth-system model (Lowe et al. 2009). Here we assume that rates of global emissions, which are currently increasing at about 3% per year, are transformed to a 3% annual reduction. The emissions peak or downturn is at varying dates (Parry et al. 2009b):

- immediate action with an emissions downturn in 2015 would lead to a global mean temperature peak at about 2 °C (above pre-industrial) around 2065
- delayed action leading to an emissions downturn in 2025 gives temperature peak at about 2.5 °C around 2080
- a further delay in action with a 2035 downturn points to peak temperatures at about 3 °C around 2100.

Calculations such as these (and there is broad agreement among the estimations referenced above) led to the view voiced at the Copenhagen summit in 2009 that almost immediate action was needed to avoid warming by more than 2 °C (Allen et al. 2009b).

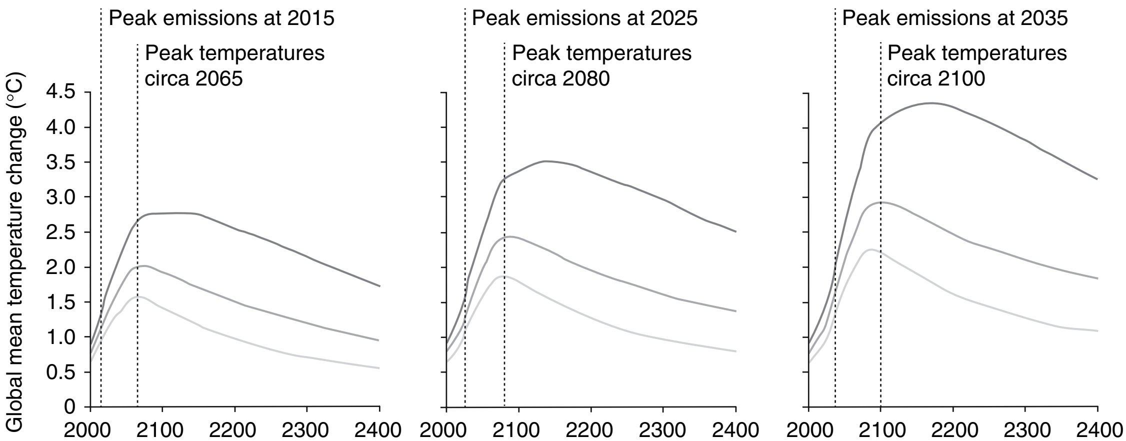

Figure 1.2 Global average surface temperature scenarios of peak emissions at different dates (2015, 2025 and 2035) with 3%-per-year reductions in greenhouse gas emissions. Reprinted by permission from Macmillan Publishers Ltd: *Nature* (Parry et al. 2009b), copyright (2009). For a colour version of this figure please see Plate 1.

It was agreed at the 2011 Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Durban, that action will not be immediate but is planned to be implemented by 2020 – and will still be intended to avoid exceeding 2 °C warming. To achieve this would require more substantial emissions reductions, levels which many find difficult to envisage (Anderson and Bows 2011; New et al. 2011).

The likelihood, from the analysis above and others similar to it, is that we will exceed 2 °C of warming, and realistically we should be planning to adapt to at least 3 °C. We should assume that very substantial adaptation will be needed, in combination with an annual 3% per annum emissions reduction over two centuries (i.e. until 2200). This would bring global temperatures back to about 1.5 °C above pre-industrial levels by 2200 and 1.0 °C by 2300, a state advocated by some as being the highest temperature at which the biosphere could be sustained over the long term (Hansen et al. 2008).

The adaptation 'need' implied by mitigation

As discussed with respect to Figure 1.1, there is a balance to be achieved between adaptation and mitigation. Thus, even if we are successful at limiting warming to just 1.5 °C through mitigation, we will still have to adapt to the impacts we have failed to avoid. This concept is explored further in Figure 1.3.

When the climate outcomes discussed in the previous section are superimposed on the table of impacts from the 2007 Working Group II Fourth Assessment of the IPCC (Parry et al. 2007, Table TS.3), as shown in Figure 1.3, we can explore the impacts avoided (or not) by mitigation, as well as the amounts of adaptation needed to keep residual impacts to an acceptable level. The vertical lines represent projected median temperature outcomes, so that impacts to the right of the lines are as likely as not to be avoided by mitigation, and vice versa for impacts to the left. The area to the left is thus the 'adaptation field', the area of potential impacts that either must be borne or adapted to.

From Figure 1.3, we can see that, even assuming the strongest possible mitigation action (giving an even chance of exceeding 2 °C) the potential impacts are substantial; for example, 1 to 2 billion people are estimated to become short of water. The consequences for delayed or reduced action can also be inferred from Figure 1.3.

There is a substantial range of uncertainty surrounding the temperature outcomes for different courses of mitigative action, shown by the upper horizontal bars in Figure 1.3, and these

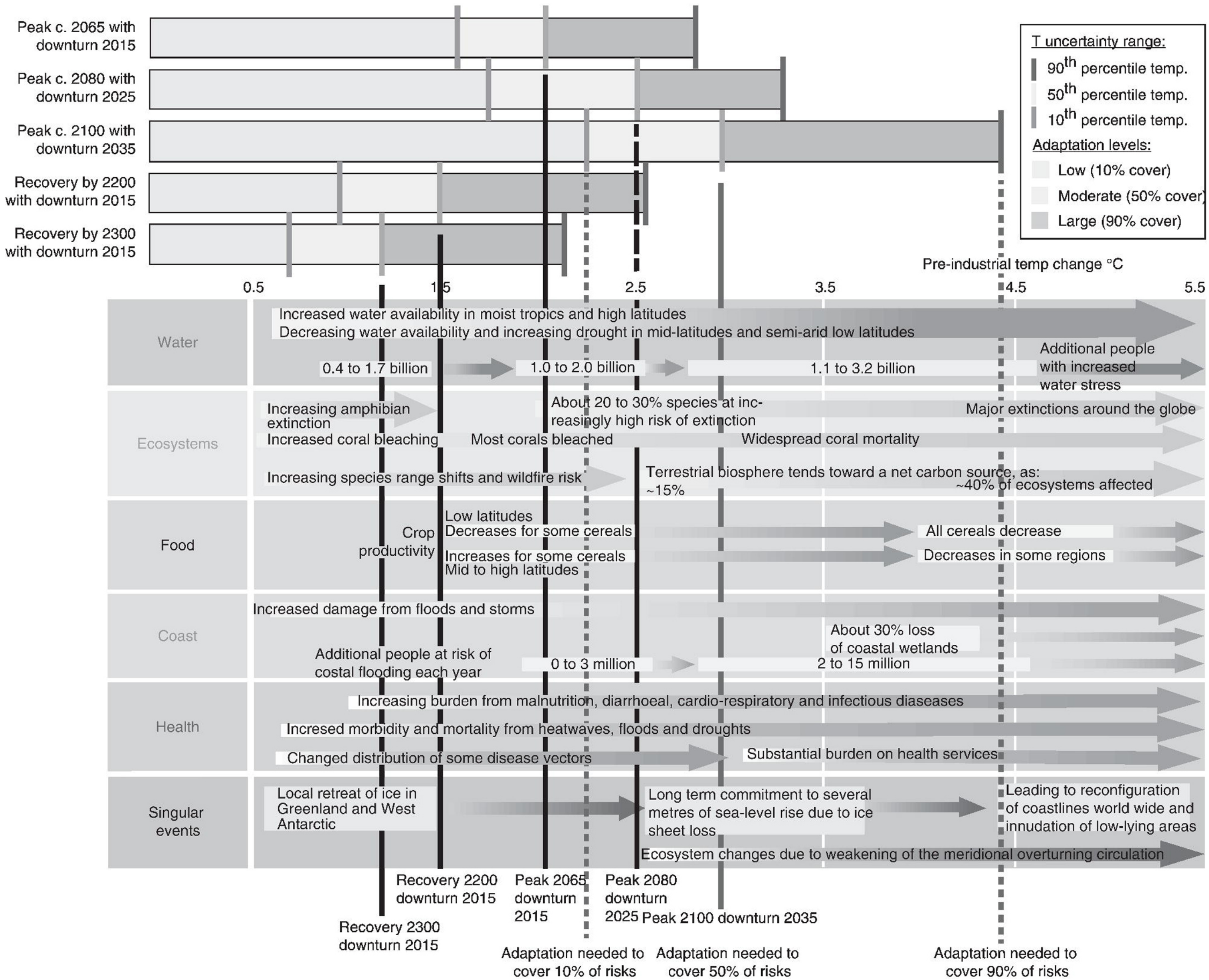

Figure 1.3 Selected global impacts from warming associated with 3% p.a. global emissions reduction, and with global emissions downturns in 2015, 2025 and 2035. Black vertical lines show (a) median projected global temperatures at their peak for different emissions downturn times, and (b) median temperatures at recovery times in 2200 and 2300. Red vertical lines show different adaptation needs for emissions downturn in 2035 and peak temperature c. 2100. Horizontal bars indicate uncertainty range for temperature, and adaptation needs for 10, 50 and 90% coverage of expected climate risk. With kind permission from Springer Science and Business Media: *Climatic Change*, 96, 2009, 23–27, Closing the loop between mitigation, impacts and adaptation, Parry, M., Figure 3. For a colour version of this figure please see Plate 2.

represent a major challenge for adaptation. Since adaptation costs increase steeply, sometimes even quadratically, with climate change there are difficult decisions to be made about the extent of cover to plan for.

In Figure 1.3 we assume that high levels of adaptation are needed to cover 90% of impacts, moderate levels of adaptation would cover 50%, and low levels would cover only 10% of impacts. On this basis, for example, if global emissions did not peak until 2035 and if we wished to cover 90% of expected impacts, then we should be planning to adapt to at least 4 °C of warming.

The challenge left to adaptation by the UNFCCC

What does the analysis so far imply in terms of what has been achieved by the UNFCCC? The accords achieved so far in the UNFCCC process call for all countries to commit to emissions reductions to avoid a global temperature rise of more than 2 °C, and aim to mobilise US$100 billion annually by 2020 for developing countries to fund mitigation and adaptation (UNFCCC 2010).

The pledges put forward by nations so far have, for the most part, been accepted domestically – with one notable exception. The US promise to cut emissions to 14–17% below 2005 levels by 2020 has yet to be approved by the US Senate and for now remains unconfirmed. The outcome of the current pledges, both those officially announced and those under consideration would, if fully implemented, lead to a temperature peak of 3.5 °C (Hohne et al. 2011).

The funding for implementation by developing countries (adaptation and mitigation) agreed to in the UNFCCC Cancún Adaptation Framework is US$100 billion per annum. Assuming that about one half of this US$100 billion is used for adaptation, this is likely only to address the impacts resulting from 1.5 °C of warming (Parry 2009). The food and health sectors, for example, might be able to adapt and thus avoid impacts of up to a 1.5 °C rise by 2030, the water sector up to a 2 °C rise by 2050 and coasts up to a 2.5 °C rise by 2080 (Parry et al. 2009a). But for ecosystems and some singular events, such as Greenland ice melt, most impacts simply cannot be avoided whatever the scale of funding available.

Consequently there is currently a gap of 1.5 °C between the adaptation covered by present funding targets (1.5 °C) and the mitigation pledged within the UNFCCC negotiations (3 °C). If this gap is not closed the unavoided impacts will likely be substantial. This is shown in Figure 1.4.

Moreover the UNFCCC figures for adaptation (to 1.5 °C) could be substantial underestimates. The financial assistance needed by developing nations may be two to three times higher overall and many more times higher for certain sectors (Parry et al. 2009a). The UNFCCC estimates do not, for example, include any costs for ecosystem adaptation, which alone have been valued at US$65–80 billion annually by 2030 for protected areas and almost US$300 billion annually for non-protected areas (Fankhauser 2010). Even the latter figure covers mainly protection of forests and biodiversity in farmed areas and does not include the ecosystem damage in unmanaged areas that is simply unavoidable, such as the loss of warm-water coral reefs.

To conclude, there are currently plans (possibly themselves underestimates) to fund adaptation to 1.5 °C of warming, but the peak of warming from projected emissions, assuming current efforts on mitigation, is likely to be 3 °C or more. Closing this 1.5 °C gap presents a huge challenge to adaptation.

1.2.2 Challenge 2: Adaptation as transformation, adaptation as incremental change

A key challenge for adaptation is knowing when to adapt and how much to adapt. Humans have always adapted to climate variability and change, usually in a reactive, autonomous way, with varying degrees of success (Fagan 2008). However, as we start to gain a better understanding of future climate change in relation to anthropogenic greenhouse gas emissions, we are in a better position to recognise that we need to be more proactive in adaptation planning. Stafford Smith et al. (2011) characterised adaptation decisions according

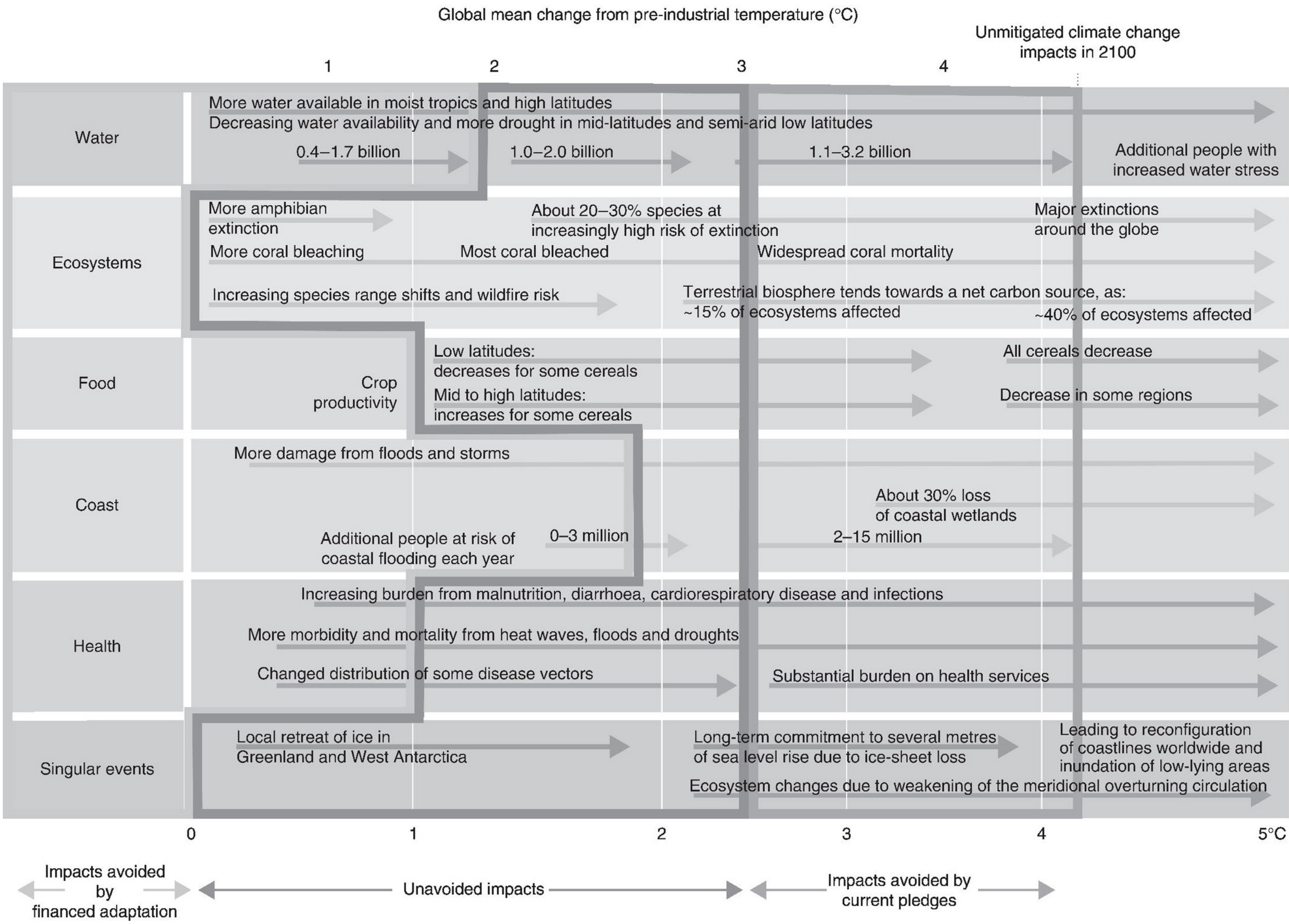

Figure 1.4 Potential impacts currently covered by UNFCCC adaptation targets (blue) and not covered (red). Green shows the impacts avoided by mitigation pledges as part of the UNFCCC process. The global climate impacts are taken from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Reprinted by permission from Macmillan Publishers Ltd: *Nature* (Parry, 2010), copyright (2010). For a colour version of this figure please see Plate 3.

to the lifetime of those decisions. Decisions with a short lead time and a short consequence period, such as in annual planting of crops, can be adjusted regularly, whereas decisions with a short lead time but with a long consequence period, such as building a bridge, really need to consider climate change risks now. Decision lifetime also interacts with confidence in the climate projections e.g. sea-level rise benchmarks for planning decisions in coastal areas can be set on 2030, 2050 and 2080 timeframes to account for the uncertainty in the projections and their interaction with the asset life of the planned infrastructure. Other non-climate drivers such as demographic change or economic change will also interact with decision-making for these longer timescales, reinforcing the need to take account of interdependencies and not make climate adaptation decisions in isolation.

The amount of adaptation required depends on how well greenhouse gas emissions are curbed through mitigation at the global level (see previous section) and at the local level the vulnerability that arises from exposure, sensitivity and the adaptive capacity of individuals, communities and institutions. As indicated in the previous section, greenhouse gas emission targets to limit warming to 2 °C have been widely agreed in principle but in practice the current pledges from various countries suggest that a warming of at least 3.5 °C is more likely (Hohne et al. 2011).

Bringing together these two aspects of decision timelines and the amount of adaptation required leads to thinking about responses in terms of *incremental* or *transformational* adaptation. Incremental adaptation implies essentially business as usual with some manageable changes to deal with climate change which can usually be addressed by adopting an adaptive management approach. In contrast, transformational adaptation requires fundamental changes in systems that are qualitatively and quantitatively different from incremental adaptation. For example, a farmer can adjust incrementally by amending crop planting dates, varieties and management practices but if there is insufficient water in the future to irrigate then a major change in farming system or location may be required.

Adaptation responses that range from incremental to transformational have been classified in different ways: routine – non-routine – complex unbounded (Dovers 2009); coping – more substantial – system transformation (Moser and Ekstrom 2010); preservation – restoration – transformation (Craig 2010); resist – transform – move (Ruhl 2010); incremental – transitional – transformational (Howden et al. 2010). Despite these fairly consistent approaches to thinking on the nature of adaptation responses, definitions of incremental and transformational adaptation, until recently, have proved elusive. Park et al. (2012) have provided definitions:

> Incremental adaptation – 'maintaining the essence and integrity of an incumbent system or process at a given scale'.
>
> Transformational adaptation – 'a discrete process that fundamentally (but not necessarily irreversibly) results in change in the biophysical, social or economic components of a system from one form, function or location (state) to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment'.

Their interpretation is scale dependent: for example, a transformational challenge for an individual farmer may be an incremental challenge at the level of maintaining food production systems nationally. As you move from incremental to transformational adaptation, complexity and risk increase but the benefits are also greater (see Figure 1.5 and Howden et al. 2010).

To date, most attention has focused on incremental adaptation with emphasis on short-term tactical decisions, though increased thinking on transformational adaptation is now going beyond the literature and into policy and on-ground actions (Park et al. 2012). The framing of adaptation by the IPCC may have contributed in part to the focus on incremental adaptation. Firstly, adaptation has been framed as the residual response required after mitigation with, to date, overly optimistic assessments of the likely level of mitigation. The residual impacts are consequently becoming much greater because of this

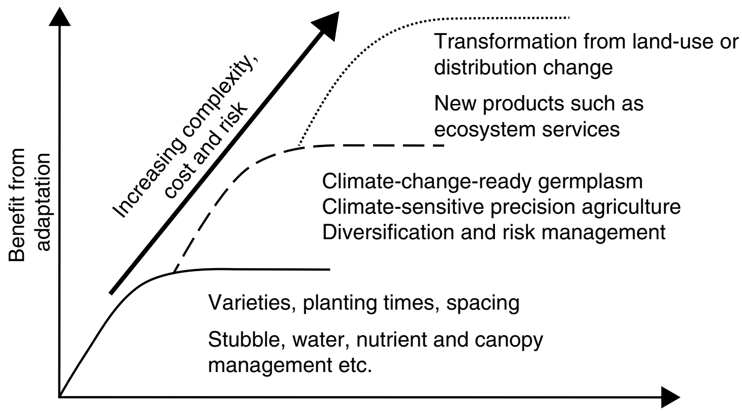

Figure 1.5 Hypothesised relationship between incremental and more transformational adaptations as climate change increases, indicating possible types of adaptations and the likely increasing complexity, cost and risk associated with the more transformative adaptations. From Howden et al. (2010b, Fig. 9.7, p. 109) with permission.

lack of action on mitigation. Additionally, the impacts do not increase linearly with increasing temperature but rather exponentially or abruptly where thresholds are crossed. Coupled with this is the widely used framing of adaptation as the actions needed to fill the vulnerability gap left after intrinsic adaptive capacity has responded to potential impacts derived from exposure and sensitivity. This tends to focus attention on incremental adaptation at the very local level and tends to ignore the cross-scale and systems nature of thinking required for many adaptation responses.

That is not to say that incremental adaptation is not important – proactive and well planned incremental adaptation will be vitally important in dealing with many of the impacts of climate change in the coming two decades. There is much that can be done to modify existing practices, industries, institutional arrangements and policies to adapt to modest amounts of climate change. One area in particular that warrants more attention than it is currently receiving is investment in development of new technologies specifically for climate adaptation. This can take the form of new materials and designs for infrastructure, or breeding new plant cultivars that can both take advantage of rising CO_2 concentrations and be productive under higher temperatures. At the same time, care is needed to ensure that these technologies are not maladaptive or have other unintended and undesirable consequences (Mendelsohn 2011).

Although much incremental adaptation is likely to occur autonomously; it will likely have better outcomes if it is planned proactively. Adopting an adaptive management approach to incremental adaptation provides flexibility and builds adaptive capacity (Tompkins and Adger 2004).

Thinking on transformational adaptation has been strongly influenced by resilience literature and in particular the social-ecological resilience framework (Walker et al. 2004). Social-ecological systems have distinct phases and evolve and transition through adaptive cycles. In the context of climate adaptation Park et al. (2012) have modified the adaptive action-learning cycle to reflect the differences between incremental and transformational adaptation in terms of scale, resources required, and actors involved (Figure 1.6). Important to this conceptual approach are linkages between incremental and transformational adaptation even though the decision types, policy needs and resources required are quite different. Consistent with this thinking, Horrocks and Harvey (2009) proposed 'continuous transformation' characterised by adaptive cycles of incremental and transformational adaptation that are continually evolving along an adaptive pathway.

How well are these concepts of transformational adaptation penetrating actions and/or policies on climate adaptation? Evidence is emerging that some transformational adaptation

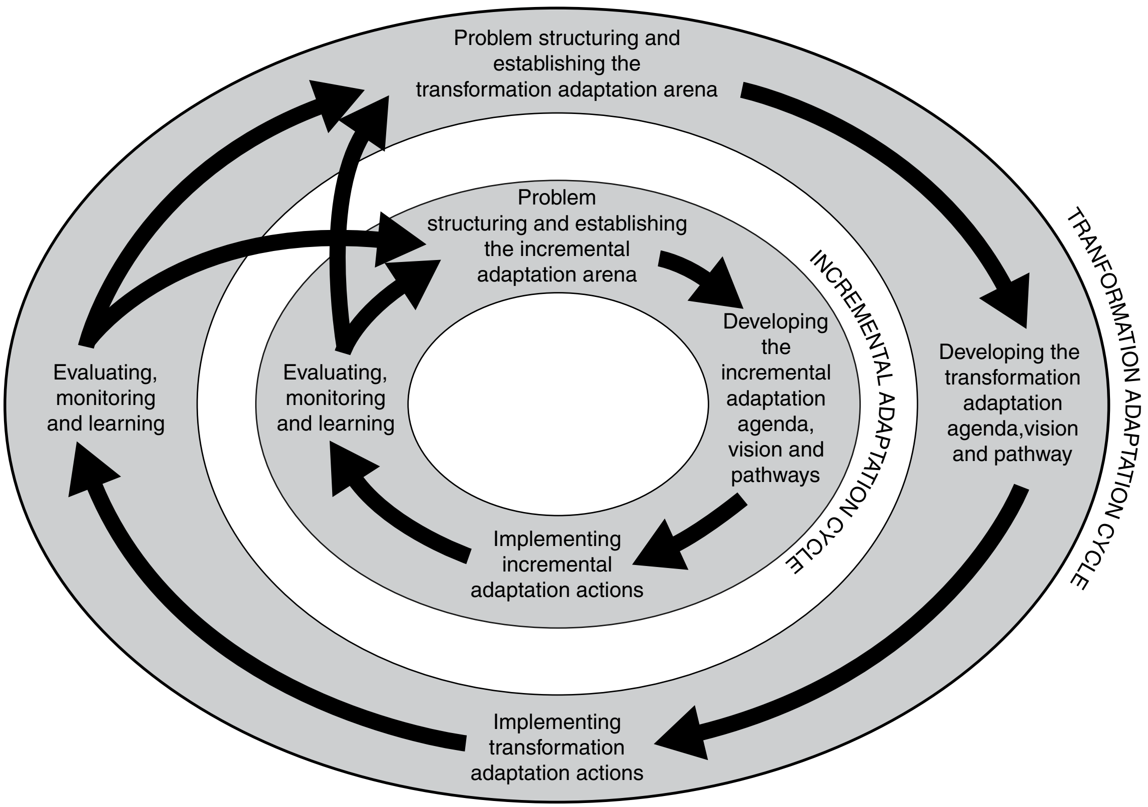

Figure 1.6 The 'Adaptation Action Cycles' framework explored as a basis for analysing the relationships between incremental and transformative adaptation. Park et al. 2012. Reproduced with the permission of Elsevier under the terms of the STM Agreement.

is being practised in terms of on-ground actions; for example, in Australia a large wine company has purchased land in a cooler climate to commence growing varieties currently better suited to a warmer climate (www.brownbrothers.com.au/newsevents/newsdetail.aspx?newsid=53), and some local councils are approaching planning of new residential developments with consideration of significant climate change (SMEC 2010). However, these types of actions are fairly limited, and transformational approaches are likely to be constrained by high-level policies framed in an economic rationalist context that sees adaptation largely driven by market responses with the need for intervention to deal with market failures being rare (Garnaut 2008). Furthermore, there is inadequate thinking on legislative aspects of policy in the context of transformation with current approaches tightly linked to preservation and restoration (Craig 2010; Ruhl 2010).

Both incremental and transformational adaptation will be required as climate change unfolds. It will be common for many industries and communities to be adapting simultaneously across this incremental–transformational continuum even though there will be different needs for information and policies, with scale being a critical driver of these differing needs. Whether it be incremental or transformational adaptation there is an unequivocal need for a proactive and anticipatory approach as it will be more efficient than reacting after significant change has occurred.

1.2.3 Challenge 3: Converting adaptation knowledge into action

The great challenge for adaptation, and indeed for the whole climate change response paradigm, is the conversion of knowledge into action. Despite all the activities of the sceptics, it is still the case that the majority of the general public, and the vast majority of scientists, accept the reality of human-induced climate change (Leviston et al. 2011). However, it is equally true that this acceptance rarely translates into adaptation action, whether by governments, the private sector or the community. This challenge explores why this should be the case, and what remedies are available.

Barriers to adaptation

Knowledge barriers. One of the most obvious reasons why we fail to take action to address climate change may simply be that we may lack, or believe that we lack, sufficient knowledge about future climate, socioeconomic trends and technological developments to allow us to act. As one example, it is common to hear demands for future climate change scenarios at greater spatial and temporal resolutions as a necessary precursor for action. But this implies a fundamental misunderstanding of the nature of scenarios – they are defined by the IPCC as 'plausible … descriptions of how the future may develop' (IPCC 2007). The key word here is 'plausible' – there are a whole host of other, equally likely futures. Thus a scenario, however detailed, cannot and should not be used as a prediction to underpin planning and action.

Scenarios are useful tools to explore our vulnerabilities and sensitivities, and so understand where we need to devote effort in order to enhance resilience. Increasingly sophisticated analyses of multiple simulations of future climate are helping us to develop probabilistic projections of changes (e.g. Jenkins et al. 2011). Even these struggle with some important variables for adaptation such as storminess, and in general speak to the needs of mitigation and impacts, but are insufficient to support adaptation decision-making in terms of the information that they can provide around, for example, thresholds and sensitivities.

Emphasis on the need for information on the future effects of climate change can be a distraction from action. Creating high-resolution climate change scenarios is time consuming and expensive of human and computing resources – it can be seen as taking action, but in fact it makes a limited contribution to our preparedness for climate change.

There are many sectors of human existence where we act in the context of incomplete knowledge and high levels of uncertainty. Defence is a sector that immediately comes to mind. The UK Government's Strategic Defence and Security Review (HM Government 2010) speaks at length of 'growing uncertainty about longer-term risks and threats', but UK Government spending on defence is around £45 billion per year.

Taking all these factors into account, the key is to start from the decision framing rather than from the climate change projections, and to embrace the uncertainty within the decision-making process.

Given that uncertainty is not a barrier to adaptation, then to a great extent we possess the engineering and technological knowledge to adapt. There are gaps, such as around the genetic capacity of plants to acclimatise, which can be bridged through research, but these are not insurmountable. There may also be skills barriers – although the knowledge may exist, it may not be present at the particular place and time required to facilitate adaptation. Training and education programmes, as well as knowledge exchange between developed and developing countries, are the tools which address skills deficits.

Financial barriers. Financial barriers to adaptation exist at all scales, from international through to individual. At the international scale, the UNFCCC has always recognised financing, or lack of it, as a barrier to adaptation in the often highly vulnerable Least-developed Countries (LDCs) (UNFCCC 2007). It has set up the Adaptation Fund, which to date has funded projects to a value of around US$1 billion. This is supported in part by money from the trading of Certified Emissions Reduction credits (2% of their value per annum) (see: www.adaptation-fund.org).

By 2020, the UNFCCC estimates that there will be a need for US$100 billion per annum for adaptation and mitigation activities in the LDCs. One of the actions of the Conference of the Parties in Durban at the end of 2011 (COP17) was to agree the broad design of a Green Climate Fund to address this need, although there was no agreement and little discussion on where the money will be found.

Many arguments support the need for initiatives such as the Green Climate Fund. From a geopolitical perspective, they are an incentive for the LDCs to continue to support actions to reduce greenhouse gas emissions. In the one-country-one-vote forums of the UNFCCC, this continued support is essential for success. From an equity perspective, LDCs are not the author of the problem of global warming, but they are likely to be the most impacted by its effects.

At national, community and individual levels, financial barriers may be perceived to exist. It may be hard to justify allocation of funding to address a problem that won't fully manifest itself for many years, even decades. And such considerations weigh especially heavily, as at present, during economic recession and the global financial crisis. Under these circumstances, financing of actions to address existing adaptation deficits is justifiable, and has the added advantage of building adaptive capacity.

Legislative and regulatory barriers. Legislative and regulatory frameworks can be used to enforce policy change and assist in shifts in social behaviour, and are often used as the 'stick' to persuade other incentive-based forces of change. Legal frameworks already exist for the management of natural resources, biodiversity conservation, planning and development, insurance and emergency management (McDonald 2010), all of which have the potential to contribute, positively or negatively, towards adaptation. Legislation plays a role in allocating agency responsibilities, establishing and empowering institutions and organisations, providing legal authority in decision-making, defining liabilities and defining the process and players of decision-making (Dovers and Hezri 2010; McDonald 2011). It can also provide stability against a background of rapid change and ongoing uncertainty (McDonald 2011). Existing regulatory and governance frameworks will, by necessity, have an important function in adaptation – either in supporting adaptation or as a barrier to be overcome. Existing legislation and regulations that conflict with (counter) adaptation, and those that do not provide the necessary signals to support adaptation, are often seen as key barriers to adaptation.

The law is often perceived as rigid and inflexible. Changes to both statutory and common law take time. Common law relies on precedence and so is tested and shaped as legal challenges arise. Statutory law, on the other hand, is more controllable, but relies on the necessary political and public will, with decisions often based on moral or popular opinion rather than the rational decision-making processes (Inderberg and Eikeland 2009) sometimes depicted in theories of climate change adaptation. The political process is largely influenced by very short funding and governance cycles, far shorter than the planning periods associated with climate change adaptation.

Incremental changes to legislation through amendments to existing statutes will occur in response to emerging adaptation policy, but also in response to extreme events such as floods and droughts. Some authors argue that the unique challenges of adaptation require new legal frameworks and concepts (Inderberg and Eikeland 2009) that allow for greater flexibility (D. Fisher[1], pers. comms. 2010). This is particularly the case for adaptive management pathways, which by their nature invoke a need for flexibility. McDonald (2011) notes that 'environmental degradation caused by creeping or incremental threats may provide more time for legal reform'. However, the very nature of climate change is such that thresholds and shocks may occur, for which existing legal frameworks are inadequate, thus compromising capacity throughout society to adapt.

Failures of communication. Adaptation activities can be seriously undermined by a failure to communicate relevant information in a timely

[1] Douglas Fisher, Professor of Law at Queensland University of Technology, Brisbane, Australia.

and appropriate manner and/or where ineffective communication leads to misunderstanding or misinterpretation of available knowledge (Moser and Ekstrom 2010). Recognising the overarching challenge of communicating complex climate change concepts, failures of communication to support adaptation have included failure to:

- adequately set communication goals
- identify and understand target audiences
- appropriately frame messages and use appropriate language
- make use of 'messengers' most likely to effectively communicate and influence particular audiences
- provide adequate resources (time, funding, expertise) to support communication efforts.

Focusing on developing oversimplified general-purpose 'messages', that are sought as a 'silver bullet' to solve communication challenges, without being developed to address specific communication goals, or targeted at a particular audience, is also unlikely to deliver effective communication outcomes.

There has been a tendency to rely on the 'information deficit model' of science communication, which assumes that audiences are empty vessels that information can be transferred to, from expert sources, in order to meet their knowledge deficit (Nerlich et al. 2010). One key issue associated with this response is that the 'language' or terminology commonly used in climate change adaptation research, such as 'scenarios' and 'uncertainty' is not necessarily transferable to different audiences without the risk of misinterpretation or misunderstanding. This approach is also unlikely to appreciate the importance of engagement with audiences to develop and deliver communication strategies, and the value of co-production and co-generation of communication tools and methods. It is also unlikely to value existing knowledge, experiences, information needs or the capacity of audiences to access and use information to adapt to climate change impacts. Failure to recognise the influence of an individual's values (including cultural values) and beliefs when perceiving risk, and considering and using information when taking action in response to the perceived risk, provides a significant communication barrier (O'Neill and Hulme 2009).

Cognitive and psychological barriers. Even where there is sufficient knowledge, appropriate financial and legislative frameworks, and good communication, adaptation is likely to fail if perceptions of vulnerability, risk and urgency are missing. Human cognition is the basis for all other barriers to adaptation, and it presents arguably one of the most vexatious challenges to address in adapting to climate change. We have learnt from psychological research that when human perceptions of risk, individual opinions and values combine with the inherent uncertainty associated with climate change projections, decision-making is affected. In the political realm, decisions often become moral rather than rational. Cognitive barriers – the lack of ability or willingness to deal with the complexity of climate change along with the other issues requiring attention – reduce the ability of decision-makers to turn an awareness of climate change adaptation pathways into action.

One of the greatest challenges is the long time-lags between identifying future changes and the occurrence of those changes. The ability of individuals to have a clear perception of a risk that is decades into the future, sufficient to undertake adaptation, is limited. Generating a sense of urgency is extremely challenging as a result. In addition, lack of experience of climate-related events can be a barrier to an appropriate response, with a tendency to 'prioritise' risks based on what is most significant to an individual at any given time also reducing the urgency to act (Adger et al. 2007).

Public perceptions of the risk of climate change, when empirically tested, can be at great odds with media reporting of 'beliefs' or attitudes (e.g. Reser et al. 2011). This can lead to unwillingness by decision-makers to act against a perceived public will.

One means of dealing with cognitive barriers is to build adaptive capacity by dealing with existing adaptation deficits (e.g. preparation for extreme events, effective management of water resources, etc.).

Barriers to adaptation and lack of adaptive capacity. All these barriers to adaptation contribute to a lack of adaptive capacity. Where they can be overcome, adaptive capacity increases as does the likelihood that there will be action.

In some cases, there is an existing adaptation deficit (e.g. Burton and May 2004). That is, there is a failure to adapt to current climate conditions, insufficient or misdirected adaptation, or maladaptation. This situation may arise for a number of reasons including a lack of resources to adapt (financial constraints), an inadequate understanding of what is being adapted to (knowledge constraints), or a very rapidly changing set of social, economic or demographic circumstances which renders climate variability a secondary consideration (instability constraints). Where an adaptation deficit exists, developing adaptive capacity to manage future climate change will of course be even more of a challenge. Conversely, addressing the adaptation deficit can build adaptive capacity.

In the next section, we discuss some of the approaches to overcoming these barriers.

Overcoming the barriers to successful adaptation

Market-based and regulatory instruments. Economists such as Stern (2007) and Garnaut (2011) describe climate change, and responses to it, very much in terms of markets. Stern (2007) called climate change the greatest market failure the world has ever seen. Garnaut (2011) talks of 'a strong, flexible economy with smoothly functioning markets' as one of the two main building blocks for successful adaptation, the other being sound information about the impacts.

Both Garnaut and Stern would see well-functioning markets as able to deliver successfully-adapted societies, in which industry, business, communities and individuals are incentivised to adapt. The role of government is to create enabling frameworks for the development and maintenance of these markets, and hence for successful adaptation. Carbon pricing is an integral driver of market success, and provision would be made within these markets for maintenance of healthy ecosystems and biodiversity, and for disadvantaged members of society.

However, in reality, and in the absence of Garnaut's sound information, adaptation action generally takes place in response to extreme events (Berrang-Ford et al. 2011). If the frequency and/or intensity of extremes increases in the future then the pace and magnitude of government and community response will increase. This will not be optimal: responses to extremes are often hurried and poorly-considered and provide short-term solutions which are unsuitable or inadequate to address the long-term threat of climate change (and so are, in fact, maladaptations). It is only in an ideal world, with Garnaut's sound information, that we would be able to plan our adaptation strategies in a well-paced and considered manner.

Under the higher end of global warming that we are beginning to envisage (3–4 °C of warming), there are limits to adaptation that market mechanisms cannot address. Sea-level rise under high rates of warming may simply cause some low-lying small island states to disappear. Increased frequency of inundation of communities by flooding rivers (which is beginning to be observed in some areas of central Queensland for example) may render communities initially uninsurable and eventually uninhabitable. Multi-year, even multi-decade droughts may destroy agricultural communities. These will impact not only on local economies and societies, but on international trading patterns and security. Elsewhere in this book (Chapter 22), human migration as an impact and as an adaptation is explored. It is hard to see the responses to such extremes of climate change as ever representing the successful interplay of market forces.

As described above, there are cases where the market will be unable to drive successful adaptation. In these cases governments have a role: to build adaptive capacity and to ensure that the right actions are taken at the right time, that the necessary regulatory frameworks are in place, that ecosystem services are properly recognised and that vulnerable communities are protected.

Role of engagement and communication. The role of engagement and communication is to ensure that robust and informed adaptation decisions and action can be taken by audiences who have access to, and the capacity to consider and use, information to support and achieve effective adaptation outcomes. Ineffective communication has been identified as a significant barrier to climate change adaptation (Moser and Ekstrom 2010). There is growing recognition that in order to be effective, the communication of information, and engagement with target audiences, to support climate change adaptation needs to be participatory, integrated, iterative, outcomes focused, 'made to measure' (Nerlich et al. 2010; Jäger and Moll 2011) and, needs to take into account the scale at which climate change adaptation activities are being undertaken (individual, local, regional or global).

Pursuing clear communication goals, understanding audiences and what motivates them to take action to adapt to climate change impacts, and then planning and framing communications activities and messages accordingly, will go some way towards overcoming communication challenges (O'Neill and Hulme 2009; Nerlich et al. 2010; Pidgeon and Fischhoff 2011). Reliance on traditional methods of science communication must also be reconsidered, with the use of appropriate communication tools and approaches drawn from a wide spectrum of available options more likely to deliver effective communication outcomes. As noted by Pidgeon and Fischhoff (2011), communication of climate science needs to reflect the long-term integrated nature of climate science itself, and must be 'strategic in its analysis, design, implementation and evaluation'. Effective engagement and communication with audiences, particularly at a local level where adaptation action is happening on the ground, is more likely to ensure that local knowledge and expertise is valued and used, and is more likely to support and motivate the conversion of knowledge into action.

Case studies of successful translation of knowledge into action

Having explored the barriers and enablers of adaptation, it still remains difficult to pinpoint examples of present-day adaptation to address the future risks of climate change. Here we explore two examples: the first is a community-level response to an adaptation deficit which nevertheless will deliver long-term benefits in protection against the effects of climate change; the second is a regional action targeted explicitly at long-term climate change.

The Grantham relocation. Grantham, a small rural community in Queensland, experienced a flash flood in January 2011 which took 12 lives and washed away 120 houses. In response, the local council purchased a parcel of 1000 ha of land above the flood level and, on 23 May 2011, announced its relocation policy. Residents were offered serviced plots of land in exchange for their existing plots, using a ballot system, and the first homes were completed close to the first anniversary of the flood (Lockyer Valley Regional Council 2011). Although settlements in Australia have relocated in the past to avoid flooding, the innovative role of the council and the speed of the action were strong contributors to success. Interestingly, throughout the relocation, climate change has never been mentioned; no doubt a response to the strong scepticism among Australian rural communities. This action contrasts nicely with the more usual role of government, to restore damaged goods to their initial state without taking into account changes that may be necessitated by present or future climate change.

Current *flood defences in the North Sea* owe much to planning in the aftermath of the 1953 storm, when over 2500 lives were lost in the surrounding countries. However, greater certainty that sea-levels will rise in response to global warming, compared to the response of other climate variables (Garnaut's sound information), associated with the very long timescales involved in planning, building and maintaining coastal defences, means that this is an area where adaptation action has taken place in response to a future threat, and in a well-paced and considered manner, rather than as a knee-jerk reaction to an extreme event. In the UK, the Thames Barrier opened in 1984, and in the Netherlands the Eastern Scheldt storm surge barrier (Oosterscheldekering) opened in 1986, so some thirty years after the initial impetus of the 1953 storm. Defence levels included sea-level rise as understood at