

# LEARNING TO ADAPT: ORGANISATIONAL ADAPTATION TO CLIMATE CHANGE IMPACTS

FRANS BERKHOUT<sup>1,\*</sup>, JULIA HERTIN<sup>2</sup> and DAVID M. GANN<sup>3</sup>

<sup>1</sup>*Institute for Environmental Studies, Faculty of Earth and Life Sciences,  
Vrije Universiteit Amsterdam  
E-mail: frans.berkhout@ivm.vu.nl*

<sup>2</sup>*SPRU-Science and Technology Policy Research, University of Sussex*

<sup>3</sup>*Innovation Studies Centre, Tanaka Business School and Civil & Environmental  
Engineering, Imperial College London*

**Abstract.** Analysis of human adaptation to climate change should be based on realistic models of adaptive behaviour at the level of organisations and individuals. The paper sets out a framework for analysing adaptation to the direct and indirect impacts of climate change in business organisations with new evidence presented from empirical research into adaptation in nine case-study companies. It argues that adaptation to climate change has many similarities with processes of organisational learning. The paper suggests that business organisations face a number of obstacles in learning how to adapt to climate change impacts, especially in relation to the weakness and ambiguity of signals about climate change and the uncertainty about benefits flowing from adaptation measures. Organisations rarely adapt 'autonomously', since their adaptive behaviour is influenced by policy and market conditions, and draws on resources external to the organisation. The paper identifies four adaptation strategies that pattern organisational adaptive behaviour.

## 1. Introduction

It is widely recognised that climate change will impose new stresses on both natural and socio-economic systems, and that these systems will tend to adjust to such stresses in a process termed adaptation. An understanding of this process is important because it will allow analysts and decision makers to assess vulnerabilities and potential future damages; explore the more subtle indirect effects of climate change; and provide knowledge for better choices about how to achieve efficient, effective and equitable adaptation.

A substantial academic literature has developed on adaptation and related concepts such as sensitivity, vulnerability, resilience and adaptive capacity (Easterling et al., 1993; Burton, 1996; Downing et al., 1996; Yohe et al., 1996; Glantz, 1998; Tol et al., 1998; Schneider et al., 2000; McCarthy et al., 2001; Adger, 2001). However, progress towards developing theoretical understandings of adaptation has been slow (Kasperson et al., 1995; Kelly and Adger, 2000; Folke et al., 2002). Existing accounts draw on frames, methods and taxonomies borrowed from a range of disciplines including conservation ecology, welfare economics, and hazards and risk research. Although efforts have been made to develop common definitions and

generic prescriptions, especially through the Intergovernmental Panel on Climate Change (IPCC) and in national assessment processes, these have not yet generated a coherent conceptual framework or a clear research agenda (Smit et al., 2000; Parson et al., 2003).

This paper sets out a framework for analysing adaptation to the direct and indirect impacts of climate change on organisations. Organisations, such as business firms, are the primary socio-economic units within which processes of adaptation will take place, even if their vulnerability and adaptive capacity will be profoundly influenced by the market and regulatory contexts within which they operate. Our analysis takes the perspective of the organisation, and views climatic stimuli as one among many drivers for change that the organisation will face. This contrasts with much climate-related literature on adaptation, which takes as its starting point climate stimuli (cf. Burton, 1997; Smit and Pilifosova, 2001; Reilly and Schimmelpfennig, 2000). Our aim is to take a more organisation-centred view of adaptation that looks at processes of adaptation in business firms. We believe that issues of perception, interpretation, problem-solving and decision-making are central to determining whether and how adaptation amongst social agents takes place. The central aim of the research is to explore which factors determine adaptation to climate change on the basis of what we know about the ways in which organisations learn, innovate and change in response to conventional regulatory and market pressures. Our objective is to develop means to anticipate and influence the adaptive strategies of organisations. We also aim to contribute to the debate on the assumptions about agent strategies used in integrated assessments (cf. Schneider et al., 2000).

Drawing on evolutionary theories of economic change and organisational learning literatures, we argue that processes of adaptation involve changes to organisational 'routines' (Nelson and Winter, 1982). Routines represent much of an organisation's on-going activity, which come to be challenged and adjusted in processes of learning. We further argue that many of the characteristic signals and mechanisms that play a role in market-induced organisational learning and change are attenuated with regard to adaptations that may be made in response to climate change stimuli. This has implications for how adaptation processes are likely to unfold, and draws attention to the importance of uncertainty, indirect signals to adapt and processes of co-adaptation (with respect to non-climate drivers of organisational change).

Based on empirical research into processes of adaptation in nine companies in two sectors in the United Kingdom the paper sets out a framework for analysing adaptation to the direct and indirect impacts of climate change on business organisations. It begins by exploring key concepts of learning and innovation in organisations with a view to their applicability in understanding adaptation to climate change impacts. It then describes the methodology of the empirical research. Following this, we use the framing of learning in organisations to analyse how the case study firms perceive, interpret and respond to climate

change. Conclusions and questions for further research are presented in the final section.

## 2. Learning in Organisations

Theories of organisational learning draw on behavioural studies of organisations and have traditionally been concerned with the question of why and how organisations change their behaviour. The work has mainly been concerned with understanding how organisations learn from direct experience, how they learn from others, and how they develop conceptual frameworks for interpreting that experience (Levitt and March, 1988: 319). Learning involves the encoding in organisational routines of lessons learnt from experience and leads to changes in organisational behaviour – a process often referred to as adaptation (cf. Chakravarthy, 1982; Aldrich and Auster, 1986; March, 1991; Staber and Sydow, 2002).<sup>1</sup>

### 2.1. ROUTINES

The notion of routines is at the heart of behavioural studies of organisations (Cyert and March, 1963; Nelson and Winter, 1982). Routines are the means by which organisations carry out activities by matching appropriate procedures to situations they face, whether ordinary or extraordinary. This process of matching generally does not involve rational choices between alternatives, but is rather the enactment of processes that are seen as suitable and legitimate given a recognised set of circumstances. Routines include a wide variety of phenomena: rules, procedures, strategies, technologies, conventions, cultures and beliefs around which organisations are built and through which they operate. At any one moment, the routines enacted by individuals and subunits in an organisation are those that have been selected as being advantageous through a process of experience and learning. These activities, which are geared to the operational functioning of the organisation, have been referred to as operating routines (Zollo and Winter, 2002: 340). Routines are modified or adapted when the organisation experiences novel situations for which appropriate procedures have not yet been developed, when existing routines prove to be unsuccessful, or when alternative routines which promise greater advantages are discovered internally or externally (Gavetti and Levinthal, 2000). In these situations, routines are adapted incrementally in response to feedback about outcomes (Steinbruner, 1974). However, this process of modification requires special effort on the part of the organisation and a specific set of capabilities.

## 2.2. OPERATIONAL AND DYNAMIC CAPABILITIES

Two types of capabilities are commonly referred to: operational capabilities are those that enable a firm to carry out its routine business activities; and dynamic capabilities that enable a firm to change and adapt operational activities (Collis, 1994). Dynamic capabilities involve the ability to integrate, build and reconfigure internal and external competencies and routines (Teece et al., 1997). Zollo and Winter (2002: 340) define a dynamic capability as ‘...a learned and stable pattern of collective activity through which an organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness.’

All organisations are seen as possessing dynamic capabilities, although the appropriate investment of resources in these capabilities may vary depending on the perceived benefits arising from them. Sometimes dynamic capabilities will be costly to maintain. In general, organisations operating in stable environments are assumed to focus on efficiency gains through improvements of operating routines, while in less stable environments greater investments are made in exploration and the discovery of new ways of doing things (March, 1991; Benner and Tushman, 2003). It is important to recognise that learning processes are deemed to apply to both operating routines and to dynamic capabilities.

## 2.3. SIGNALLING AND INTERPRETATION

In studies of organisational learning, change in routines comes about in response to direct organisational experience. However, before change can be initiated, a signal needs to be recognised as evidence of a novel situation, in response to which existing routines are inappropriate or ineffective. One of the main conclusions from research on sense-making in organisations is that interpretations of experience depend on the frames of reference within which that experience is understood (Daft and Weick, 1984). There is generally a resistance to drawing conclusions that challenge these frames of reference, so that organisational myths, beliefs and paradigms are maintained, often in the face of considerable counter-evidence. Evidence derived from experience is more likely to be recognised the more frequent, unambiguous and salient it is to an organisation. Research has identified a range of reasons why evidence from experience may fail to be recognised and interpreted as significant. These include scarcity of evidence, blindness to evidence, and uncertainty in assessing the relevance of evidence (Levitt and March, 1988: 333).

## 2.4. EXPERIMENTATION AND SEARCH

Two different mechanisms are described in the process of initiating an adaptation of organisational routines: trial-and-error experimentation and search (March,

1991; Nelson and Winter, 1982). Trial and error relates to semi-automatic stimulus-response processes and the, mainly tacit, accumulation of experience that occurs incrementally through the enactment of operating routines (Zollo and Winter, 2002: 341). This process has been observed in practice and modelled using the idea of learning curves, but is not much further discussed. Processes of search involve an exploration of alternative ways of responding to novel situations, and are seen as being constitutive of dynamic capabilities. This is a creative process involving internal and external scanning for relevant experience and knowledge that can be applied and recombined in an effort to generate a variety of adaptation options (Nonaka, 1994).

## 2.5. KNOWLEDGE ARTICULATION AND CODIFICATION

Adaptation options are typically exposed to an internal selection process that identifies a sub-set deemed appropriate and legitimate for the organisation. This involves an evaluation process through discussion, and internal or external assessments. A critical aim is to reduce the causal ambiguity that frequently exists between adaptation options and their performance implications (Lippman and Rumelt, 1982). This selection process is succeeded by a higher level cognitive effort in which modified routines and their performance implications are codified in manuals, blueprints, decision-support tools, software, targets and so on. This process of codification is necessary because it enables the transmission of the adapted or new routine, and its justification and replication in new behaviours through the organisation. Codification is resource-intensive because it requires abstraction and working through situations in which new or reconfigured routines should be applied.

## 2.6. FEEDBACK AND ITERATION

Organisational learning can be seen as a cycle which begins with a stimulus leading to the generation of variation through experimentation and search, proceeds with a process of internal selection, articulation and codification, followed by the replication and enactment of new routines across the organisation, finally returning to the beginning of a new cycle of innovation by virtue of a new stimulus. Throughout this process between the initial stimulus and the broad application of new routines there is an assumption that evidence from experience will continue to validate it. In the simplest case, a new product is successfully commercialised. This happens through processes of feedback that continue to show that the adaptation is an effective way of responding to experienced situations, and because it is perceived to be leading to performance benefits. A schematic of an organisational learning cycle is presented in Figure 1.

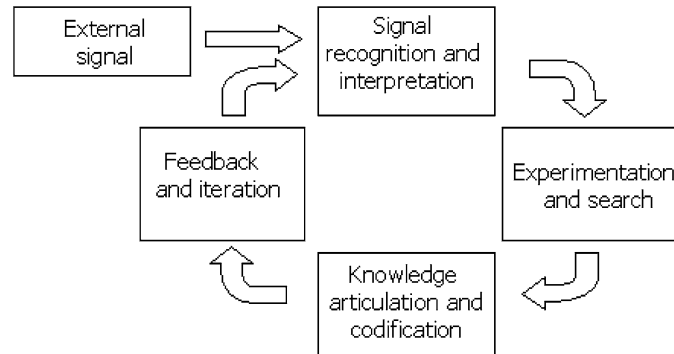


Figure 1. Schematic of learning cycle (adapted from Zollo and Winter, 2002: 345).

### 3. Method

The case study research was designed to explore adaptive behaviour in firms and to interpret the empirical findings using concepts from behavioural approaches in organisational studies. A multiple case studies approach (Eisenhardt, 1989) was used in two sectors—house-building and water utilities in the UK. The behavioural perspective adopted requires the establishment of close working relationships with organisations, enabling the research team to gain detailed insights into the attitudes and working methods of managers, capabilities, operations, culture and institutional settings. The case study design was therefore restricted to nine companies, five housing developers and four water companies.

Within this restricted sample, we aimed to cover different types of companies whose activities spanned a range of geographic locations and markets (see Tables I and II). The case studies included two housing associations (providing housing for low-income and vulnerable social groups), a large national commercial developer, and two more specialised regional developers. In the water sector, the research was undertaken with two larger water and sewerage companies, as well as two smaller companies that supply only water. A choice was made in the research design to include companies expected to demonstrate high degrees of adaptive capacity – this made the phenomenon easier to observe and facilitated better access to the companies. Most of the companies in the sample were regarded as market leaders in their approach to innovation and several had demonstrated substantial interest in environmental issues, as evidenced through, for instance, environmental awards.

Research was carried out over a two-year period, and included iterated rounds of interviews and workshops with representatives of the nine companies. The research process began with an initial orientation interview to collect organisational and business information and to investigate attitudes to climate change and adaptation. This was followed by a workshop that brought managers from the companies together with other specialists and stakeholders to define critical impacts and adaptation issues in the two sectors, and to develop inventories of possible climate impacts

TABLE I  
 Characteristics of housing companies

Company Code	Housing Companies				
	A	B	C	D	E
Business type	Specialist developer	Specialist developer	Developer	Housing Association	Housing Association
Functions of interviewees	- land buyer (2), development manager	- construction director, regeneration director	- head of marketing, strategic land director	- property manager (2), development manager, technical director	- development manager, maintenance service manager
Size (value of sales/no. of units)	Medium (~GBP 110 m turnover)	Medium (~GBP 200 m turnover)	Large (~ GBP 700 m turnover)	Large (~20.000 units)	Medium (~1.500 units)
Scope	South	London	National	London	South
Planning horizon	Up to 3 years	Up to 5 years	Mostly 1 year	Up to 25 years	Up to 30 years
Climate change awareness	Low	Low	None	Medium-low	None
Key climate signal	Direct (flooding)	Indirect (regulator)	None	Indirect (industry bodies)	None
Key perceived climate sensitivity	Flood risk	Flood risk	None	Flood risk	Flood risk
Perceived current significance	Low	Low	Low	Low/Moderate	Low
Adaptation measures (2002)	Modified land-buying guidance	None	None	Planting schemes	None

TABLE II  
 Characteristics of water services companies

Company code	Water Companies			
	F	G	H	I
Business type	Supply and treatment - water resource manager	Supply and treatment - water resource manager	Supply only - water resource manager	Supply only - water resource manager
Function of interviewees	sustainability manager	water resource planner		
Size (value of sales)	Medium (~GBP 250 m)	Large (~GBP 700 m)	Small (~GBP 90 m)	Small (~GBP 70 m)
Scope	West	Midlands	Kent	Avon
Planning horizon	Up to 25 years	Up to 25 years	Up to 25 years	Up to 25 years
Climate change awareness	High	High	High	Medium
Key climate signal	Mostly indirect (regulator)	Mostly indirect (regulator)	Mostly indirect (regulator)	Mostly indirect (regulator)
Key perceived climate sensitivity	Water resources	Water resources	Water resources	Water resources
Perceived current significance	Moderate	Moderate	High (Rejection of water resource plan by regulator)	Low
Adaptation measures (2002)	Modelling of climate impacts on future water resources	In-house scoping study on climate impacts on business	Adjustment of water resource plan in line with EA guidance	None



and responses. Results of this workshop were used to develop a more detailed questionnaire with companies. This included summary tables of possible impacts and responses which were presented to interviewees for comment. This round of in-depth interviews was followed by another workshop with companies to review results and discuss preliminary conclusions. A final workshop, in which project results were fed back to project participants and policymakers, was also held. Insights gained from each of these interactions have been incorporated into our analysis.

In total, twenty-one in-depth second-phase interviews were carried out with employees in the nine organisations representing different functions (technical, financial, marketing, procurement, senior management). The goal was to collect alternative views from different members of the organisation about perceived climate impacts, and about actual or potential organisational responses to climate stimuli. A semi-structured questionnaire, consisting mostly of open questions, was implemented. Interviewees in the house-building sector were provided with written information about projected climatic changes and possible impacts on the sector. Although this imposed a certain framing of the issue, it was deemed necessary because orientation interviews revealed that the majority of interviewees had limited knowledge of climate change impacts on the industry.

The first part of the second-phase questionnaire focused on the firms' current understanding and approach towards climate change, existing and potential sources of information and the perception of its likely impact on their businesses. In the second part, we sought information on the specific mechanisms through which climate change impacts would affect different activities and parts of the organisation. The final part explored how the company (and the various internal actors) might respond to impacts recognised as significant, and the factors that would determine their ability to respond. Here, we used both hypothetical questions ('How would your company address the issue of more frequent instances of combined sewer overflow?') as well as 'mini-cases' of past experiences that had similarities with anticipated adaptation challenges ('How do site managers seek to minimise damage to building materials during wet winters?'). Together with the interviewees, we identified a particular decision in the past that resembled events and choices expected under conditions of future climatic change. For example, to analyse the ability of a housing association to introduce technological innovations, we explored company D's decision to abandon the use of plastic frame windows (employed since 1993 for replacement in old housing stock) which had led to frequent complaints. The aim was to identify internal and external conditions which facilitate or hinder the management of technical or organisational change prompted by the stimulus of a changing climate.

All interviews were written up (summary transcription) and analysed qualitatively. This research method (in-depth analysis of a small number of cases and contextual, exploratory and open questioning, plus reflections gathered in workshop contexts) did not lend itself to more formal and quantitative methods of interview analysis.

#### 4. Climate Change Adaptation as a Learning Process

Changing climatic conditions, whether experienced or anticipated, can be regarded as one signal amongst many to which organisations can choose to respond. We would also expect the processing of these signals and their channelling into new organisational behaviours to follow a similar course. In this section we assess the empirical evidence from interviews and workshop activity with managers from the nine house-building and water services companies, in the light of the organisational learning model.

##### 4.1. CLIMATE SENSITIVITY

The performance of the housing and water companies was found to be strongly-related to climatic conditions. Companies in both sectors build and manage large infrastructures that are exposed to weather and climate. Their ability to deliver their respective products and services is affected by a variety of climatic variables, in particular precipitation and temperature.

Sensitivities to climate change impacts are apparent in respect of a range of organisational functions. For a water services company in the UK the primary operational functions are the provision of reliable supplies of safe water, effluent treatment, maintenance of the sewage network and maintenance of bathing water quality. The sensitivity of most water companies to climate change is defined by the availability of 'headroom', i.e. the averaged margin between the supply and demand of water. But sensitivities affect many of the more specific functions of water companies as well (see Table III). For example, under the high-level 'effluent treatment' function, one key performance objective is to meet regulatory discharge consent standards. In relation to this objective alone, we were able to identify four areas of climate sensitivity: higher temperature affecting treatment processes; altered stream-flow affecting discharges; higher demands for water affecting throughput; and potential flooding of sewage treatment plants.

This illustrates the extent to which organisational climate sensitivity is multi-faceted and determined by the interplay between particular factors and conditions. As these are frequently organisation-, location- and time-specific, detail matters enormously in assessing the climate-sensitivity of a company, or of any other organisation. In our small set of cases, large differences existed between companies in the perceived threat to headroom and the capacity to meet future discharge consent standards under forecast climatic conditions. In addition, those functions and performance objectives that are climate sensitive are themselves subject to other pressures for change. For instance, higher than average population growth in the south-east of England is predicted to place greater stress on available water resources, absent climatic changes. In other words, the sensitivity of companies is a composite of climate and non-climate factors that may be specific in their impacts on the organisation.

TABLE III

Business functions, relevant dimensions of climate change and other drivers for two water company business functions: treatment of effluents and maintenance of bathing water quality

Business functions sensitive to climate change	Relevant dimensions of climate change	Non-climatic drivers of change
<i>Treatment of effluent</i>		
Meeting consent standards	Altered temperature affecting treatment processes	Change in regulatory environment
Sludge disposal	Altered streamflow affecting discharges	
Plant operation	Altered demands affecting throughput Accumulated soil wetness affecting access to land Windstorms and flooding	
<i>Maintaining bathing water quality</i>		
Frequency of 'polluting incidents' and water quality failure	Altered peak rainfall intensity Altered septicity Altered overland flow from farmland	Change in land use

TABLE IV

Selected adaptation options available to UK housing developers

Impact	Adaptation options		
<i>Direct</i>			
Disruption of construction process	Change building techniques (on site)	Move to off-site manufacture	Increase flexibility of construction process
Damage to buildings under warranty/in ownership	Bear cost / increase financial reserve	Improve insurance cover	Sell most vulnerable stock
<i>Indirect</i>			
Attitudes of planners and customers to flood risk	Avoid areas at risk	Take effects on property value into account	Design buildings to accommodate flooding
Changes to building standards	Build to new standards (proactive)	Build to new standards if mandatory (reactive)	
New customer demands	Build to new standards (proactive)	Build to new standards if demand is very strong (reactive)	

This also meant that, from the point of view of the interviewees, 'adaptation to climate change' often appeared to be a somewhat artificial concept, as it relies on a separation between climate and non-climate factors, which they did not make themselves. Instead, certain sensitivities or vulnerabilities tended to be framed in relation to a particular business function (such as the construction of buildings) and the way in which this function might be affected by a range of future trends. As a result, climate sensitivity was not perceived or treated differently from more conventional drivers of technological, market or regulatory change. Managers found it difficult to rank sensitivities to climatic change relative to their sensitivities to more conventional changes, and therefore to place these novel risks into their existing risk assessment frameworks, whether tacit and formal. Through the process of interviews and workshops, interviewees tended to become more persuaded about the seriousness of their climate sensitivity, but also more convinced about the availability of practicable adaptation measures.

#### 4.2. SIGNALLING AND INTERPRETATION

The learning literature suggests that for adaptation to occur, a sensitive organisation needs to receive and understand signals about a change in the condition they face. While most interviewees were aware that the global climate is expected to change, *direct* signals of climate change experienced in businesses activities and performance were rare and tended to be hard to interpret. An interviewee of company F, for example, reported subtle changes in their waste-water business due to what he referred to as 'weather change', but he was unsure whether these could be attributed to climate change. Company A had experienced severe flood damage to one of its new developments in the winter 2000/2001. This was taken as a signal of higher risks of riverine flooding in the future, but little further assessment was done of the causes of this possible trend. Other house builders reported a decreasing number of frost days bringing fewer work stoppages during winter and increasing attention to the risk of skin cancer due to outside working.

Overall, direct signals of climate change were both routine (the continuous monitoring of water resources by water companies) and *ad hoc* (flooding of a site under development by company A). In the housing sector these signals were usually perceived as being specific, rather than being interpreted as indications of a wider phenomenon of climate change. Little or no interpretive work was done to understand better the causes of these signals or impacts. This appeared to be due to the complexity of evidence and the absence of organisational capabilities to make sense of and learn from such data. There was also an expectation that housing companies would 'develop an intuitive understanding' of changes through monitoring market signals such as changing customer expectations and by listening to regulators (interviewee in company C). In the water companies, by contrast, we found significant capacity to recognise and interpret climate-related sensitivities.

These included monitoring and modelling capabilities and were linked to their management of resources and capital-intensive infrastructures in the context of service and performance standards defined by regulators

*Indirect* signalling occurred more frequently, especially in the water sector where companies were required to adjust long-term (25 year) water resource plans to take account of regional climate change scenarios (see Hulme et al., 2002). In one specific case, Company H was required by the national environmental regulator (the Environment Agency, EA) to revise its water resources plan because it failed to show a future supply-demand balance under this analysis. Several housing developers reported more stringent planning restrictions in flood plains by the EA, but they were unsure whether this was due to higher flood risks as a result of climatic change, or due to increased awareness as a result of recent flooding events. Diffuse indirect signalling also arose from the coverage of climate issue in the specialist and general press. In some cases this produced confusion amongst house-builders whose primary association with climate change had been with mitigation issues, especially the energy efficiency of buildings. For many managers, a changing climate had remained a hypothetical notion towards which Government policy was directed, not an everyday reality about which they would need to make independent, commercially-based decisions.

Indirect signals about climate impacts and sensitivity tended to be based on scientific assessments, which were translated into news, best practice guidance or new and revised regulatory standards. In these cases the interpretive work is done by a third expert party, with the signal translated into a form making it tractable for the organisation to absorb into routines. These third parties included trade bodies, industrial research organisations and to some extent government departments. There was some evidence of collaborative research undertaken by sector bodies to develop interpretive capabilities on the basis of shared cost and collective learning. CIRIA, a UK building industry research body, has recently sponsored a number of climate-related seminars and briefings, while UK Water Industries Research (UKWIR) has been active in research relevant to climate adaptation, mainly in relation to decision-support tools (Herrington, 1996; UKWIR, 2002). Several companies actively participated in UKWIR research and had on-going links with climate-related research programs. This 'externalisation' of interpretative work by some companies, while a rational response to novelty and uncertainty, could hold back learning by limiting internal reflection about sensitivities and adaptation options.

We found that the market (customers, competitors and creditors) was the source of few indirect signals to adapt, although the housing companies saw them as major potential future drivers of adaptation. A growing demand for space cooling market in more expensive segments was viewed as an existing trend that could be strengthened with reference to more frequent summer temperature peaks. Water company customers are seen as primarily concerned with the quality and reliability of supply only, with domestic demand for water continuing to grow, another trend that could be amplified by climatic change (especially summer peak demand).

### 4.3. EXPERIMENTATION AND SEARCH

We found that different functions across all case study companies were able to identify adaptation measures appropriate to their climate sensitivity. This perception is in line with the findings of recent technical studies done in the two sectors (Graves and Phillipson, 2000). A water sector study listed 65 adaptation measures available to utilities operating in SE England (Environment Agency, 2003). It is significant that developers could not identify vulnerabilities where adaptation was technically or financially unfeasible. This confidence was not reflected amongst the water companies, which tended to emphasise the limits imposed by regulators and customer expectations on their capacity to adapt.

The wide range of possible responses led us to define the basket of options available to a given set of companies as the *adaptation space*. By ‘available’ we are not concerned with costs and benefits in any given option, but with technical and organisational practicability in principle. The adaptation space includes well-established options, as well as options that are novel and not yet fully explored. Importantly, the adaptation space is not static, but dynamic – growing and mutating as new options are generated, and as existing ones are replaced or become unattractive.

Our research suggested four modes of adaptation (cf Hertin et al., 2002):

- changes to the commercial strategy of the firm (*commercial adaptation*);
- changes to technologies used to provide products or services (*technological adaptation*);
- changes related to financial management systems (*financial adaptation*); and
- changes in data gathering and monitoring trends (*information and monitoring of climate stimuli and search processes for adaptation measures*).

These adaptation modes correspond to the basic functions of the companies we investigated.

Much of the knowledge and know-how needed to adopt adaptation measures already appeared to be held by the specialised communities at work in organisations. For instance, the technical directors of housing companies were able to identify a range of practical measures to prevent storm damage on construction sites. These included physical protection measures as well as changes in building techniques that could include greater use of fabrication off-site. The solutions considered will be related to the specific competencies held by an organisation and to the market segment. For example, interviewees in company B held the view that, as an engineering-led organisation with good relationships with the Environment Agency, it held advantages over its competitors in the development of sites at risk from flooding. While other developers were thought to be moving away from these sites, company B aimed to exploit flood risk as a new source of market advantage in high-value sites.

Responses to climate change stimuli tended to be viewed in ways that minimised challenges to prevailing routines and beliefs – a phenomenon well known

in organisational behaviour. Potential future water supply problems were seen as best addressed through engineering solutions, even though the recent UK water resources strategy has promoted a more mixed and adaptive strategy (Environment Agency, 2001). Similarly, developers argued that their land-buying strategies could be adjusted incrementally to take account for increased flood risk and that this could be achieved through existing appraisal, risk assessment and decision-making procedures. We came across few cases where novel measures were considered in response to revealed climate-related vulnerabilities. This suggests that search for adaptation measures may be limited (at least at the outset). Companies tended to draw upon the repertoire of responses already open to them, rather than invest in research and development to identify new options. In other words, the adaptation space will be an envelope of known measures. The key influence of climate stimuli may therefore be to add a further justification for certain measures over others, rather than to stimulate an active search for alternative measures. It is interesting to note that – although there is a close link between adaptation and mitigation in both sectors, as they develop long-lived infrastructures – the implications for greenhouse gas emissions were not raised as an evaluation criterion to choose between different adaptation options. Isolated cases of linkage between adaptation and mitigation were identified. These included an investment in a sludge incinerator to generate steam and power by Company F in response to regulatory constraints on sludge disposal to land during wet winters.

The adaptation space is not only circumscribed by the limits of what is already known and available. Our research showed the importance of contextual factors, both as an opportunity and as a constraint on adaptation. The range of options available to a firm is strongly influenced by the regulatory and market context, by external resources (regulatory approval, market demand, skills and expertise, competent supply chains) and by interactions with actors outside the organisation. Whether the development of new water resources is part of the adaptation space for a water company depends on policies and decisions made by economic and environmental regulators. The ability of housing developers to build to higher technical standards requires suppliers that can deliver the specified design at a satisfactory price and quality, a market that is willing to accept and pay for it, and building regulations which allow for the use of new technology.

#### 4.4. ARTICULATION AND FEEDBACK

We found only limited evidence of the articulation of climate change adaptation in terms of new routines codified as blueprints, decision-support tools, targets and so on. The clearest evidence was in the use of climate change scenarios in water companies' water resources plans (Arnell, 2002; Arnell and Delaney, 2003). In the housing sector, company D had recently begun to integrate climate considerations into the design of planting schemes for 'green spaces' (including more

drought-resistant and sub-tropical plants). Here, articulation occurred because it provided ancillary benefits at low cost to customers and clients. Company A had recently adopted a new policy of not buying or developing sites 'anywhere near a river' (interview with land buyer). This was the one case in which experiential learning led directly to the modification of a key organisational routine, although this change had not been codified. It served more as a 'rule of thumb'.

We did not find any examples where companies had received significant positive feedback on the implementation of climate adaptation measures. This was mainly because many firms had not yet adopted adaptation measures that could clearly be identified as climate-related. Examples of negative feedback did exist, such as the failure of water companies to succeed in making the case to the national economic regulator for higher water tariffs to take account of higher climate-related investment costs. Positive feedback might come from the market (in terms of measurable economic benefits or reduced risks), from regulators (lower regulatory costs) or in terms of improved reputation. Most companies believed that in the near-term, most of the benefits would be regulatory and reputational. For many organisations, accounting for the economic benefits of specifically 'climate' adaptation is likely to remain elusive, mainly because such adaptations will be embedded in other changes that have also been justified for a variety of reasons.

#### 4.5. ADAPTATION STRATEGY

Through extended interaction with managers, we came to recognise patterns in the assessment of vulnerability and adaptation options in the nine companies. For instance, Company B appeared to see climate impacts as representing new commercial opportunities, possibly in the short-term. Company H, on the other hand, had responded mainly defensively and sought to draw on external resources, such as the environmental regulator. Our case study research identified four factors that appeared to shape patterns of an organisation's approach to adaptation:

*Core competencies:* Companies can be expected to search for and adopt adaptation measures in areas that match their core competencies. Interviewees tended to suggest adaptation measures that the company would be able to design and implement within the framework of the knowledge base of the organisation. Adaptation measures were framed in terms of current business practices and drivers.

*Core business:* If a climate change is seen to have a significant physical impact on the core business, companies tend to engage with the issue on a technical level. For instance, water companies will be inclined to adopt engineering solutions to respond to an imbalance between supply and demand due to climate change. Where only a marginal activity is affected, risk-sharing or risk-shifting options such as insurance or out-sourcing often appeared more appealing. The degree of exposure to climate-related risks therefore influences the mode of adaptation.



*Dynamic capabilities:* Whether a firm is an early or a late adapter will depend on its dynamic capabilities, i.e. the ability to modify and adapt organisational routines and behaviours in response to external drivers of change. This finding emerged particularly strongly in the house-building sector, where the only firm that had started to think about climate impacts was also leading on other industry issues (e.g. partnering and sustainable construction).

*Organisational culture:* Organisational culture appeared to be a key determinant of the way in which a firm responded to new risks posed by climate change. Water companies, with their more conservative business cultures, tended to respond more cautiously to potential climate impacts than commercial property developers who operate in a dynamic and competitive market. In general, we find that adaptation measures reflect and affirm, rather than undermine a company's attitude and approach to risk management.

Taken together, these factors shape what we characterise as an organisation's *adaptation strategy*. Given the limits to experiential learning, the ambiguous link between adaptation and performance, and the indirect nature of feedback, an adapting organisation needs to employ some 'guiding principles' in making choices between alternative approaches to climate adaptation under conditions of high uncertainty. Rather than assuming an optimal set of responses (Mendelsohn, 2000), we believe the organisation will choose from a range of measures based on these principles. Working with case study companies, we identified four alternative adaptation strategies:

1. *Wait and see:* A strategy of deferral, based on scepticism or uncertainty about the possible impacts of climate change and about the benefits of adaptation.
2. *Risk assessment and options appraisal:* A strategy of appraising options in preparation for adaptation of organisational routines.
3. *Bearing and managing risks:* A strategy of handling risks and opportunities arising from climate impacts employing organisational resources and capabilities.
4. *Sharing and shifting risks:* A strategy of seeking to 'externalise' risks associated with climate impacts through insurance and collaboration.

Many of the housing companies we studied fell in the first category, while the water companies were following strategies 2 and 3. In respect of some risks, such as damage due to high-impact events (with perceived changing frequency), companies in both sectors were pursuing a number of options falling into strategy 4. For instance, house-builders had investigated the possibility of reducing the warranty period for new buildings, while water companies were seeking to negotiate exemptions from discharge limits following severe storm events. This identifies an added dimension of complexity in that organisations may deploy a range of strategies across different functions. Shifting risk of flooding (strategy 4) by seeking to limit liability in at-risk properties may be combined with a strategy of managing risk (strategy 3), such as storm damage to construction sites. We therefore postulate that mature adapting

organisations will be those that are able to deploy appropriate adaptation strategies across their different organisational functions.

## 5. Conclusion

This paper began with a review of key concepts from the organisational learning literature. Behaviourist studies argue that organisations enact ‘routines’ – rules, procedures, strategies and so on, that can be repeatedly carried out in response to recognised situations. Organisations match their available routines to the situations they face. Learning takes place, either by virtue of repetition (learning by doing) or - when a novel situation is confronted – through a process of search and planned modification of routines to suit the new situation.

We used this conceptual framework to analyse current and possible future patterns of climate change adaptation in UK house-building and water-services companies. This analysis leads us to conclude that the way in which firms respond to pressures from climate change is in many ways similar to conventional market, technological or regulatory adaptation. However, we can also see that climate change adaptation has certain distinct features. Interpreting climate change signals is challenging for many organisations. Not only is evidence of change ambiguous (the problem of signal to noise), the stimuli are often not experienced directly by the organisation. In addition, interpretation of signals frequently depends on the advice of external specialists who are not able to provide clear and definitive answers. Advice therefore does not usually come in a form that translates easily to the experience and routines of the organisation. Because of the weakness and ambiguity of climate change stimuli, we suggest that trial-and-error experimentation around standard operating routines will not play a significant role in all but extremely climate-sensitive sectors – where more direct climate feedbacks are likely to exist (e.g. agriculture). In most sectors, organisations are likely to engage in search and assessment processes, suggesting also that the process of adaptation will be managed by higher-level functions in the organisation.

Knowledge articulation and codification also pose a challenge because of the causal ambiguity between adaptation options and their performance implications. In the absence of a clear climate signal it is difficult to identify those options that lead unambiguously to greater organisational effectiveness. Feedback mechanisms demonstrating the benefits of an adaptation option or strategy will usually be weak. This is because average climatic conditions change only slowly compared with learning cycles typical in organisations, and because examples of more extreme events will often not be related to climate change with any certainty. Even if such events do remove ambiguity about climate signals and precipitate action, they may not, by themselves, generate sufficient evidence with which to justify and calibrate adaptation measures and strategy. Much feedback

is generated indirectly through appraisal processes, such as risk assessments that deal with hypothetical, rather than measurable performance. The conceptualisation of adaptation as a circular learning process also casts doubt on the usefulness of the common distinction between anticipatory and responsive (or *ex ante* and *ex post*) adaptation. Adaptation by reflexive human agents occurs *both* in response to a signal (e.g. a recent flood event) and in anticipation of the future (e.g. the next flood event).

We have also found that adaptive behaviour is patterned by specific internal resources and external conditions, and is therefore difficult to predict and subject to generalisations. While business organisations will often operate with a wide adaptation space, adaptation measures do not always represent discrete and well-defined options. Most adaptations require chains of adjustment and innovation, and complex management processes drawing on rules of thumb and external resources. When and how organisations adapt will depend not only on costs and benefits, but also on the process of receiving and interpreting climate change signals. Here, the long time-scales and uncertainties inherent to climate change sets it apart from more conventional drivers of change such as competition, technological change or market demand. Many of the pressures to adapt are likely to be indirect, and some of the resources employed in carrying out processes of adaptation are likely to lie outside the boundary of the organisation. Inter-relationships between organisations and numerous other actors are therefore key to understanding how adaptation processes will unfold. As weak feedback processes restrict the opportunities for organisational learning about climate change, we expect it to take longer for appropriate climate-adapted routines and capabilities to be developed.

Further research in this area could aim to explore whether the patterns of adaptive behaviour found in house-building and water companies apply equally to other economic sectors and to public sector organisations. It would also be interesting to assess whether the expected strengthening of climate change signals would remove some of the barriers to organisational adaptation identified in this paper.

### **Acknowledgments**

We are grateful to the Tyndall Centre for Climate Change Research for funding the research upon which this paper is based. We also wish to thank our collaborators from the business partners involved in the ADAPT research project: Gleeson Homes; St George Regeneration; Wilcon Homes; the Peabody Trust; the Chichester and Diocesan Housing Association; Wessex Water; Anglian Water; South East Water; and Bristol Water. This paper benefited from comments of participants at the ARGCC Conference, Columbus OH, 29–30 October 2003. We are grateful to three anonymous reviewers for their perceptive comments and constructive criticism.

### Note

<sup>1</sup>In this paper we take an explicitly behaviourist approach which argues that organisations are satisficing (searching for 'good enough' solutions) rather than optimising (searching for the 'best possible' solutions). Much economics research on climate change makes the assumption that economic agents tend to optimise their welfare, given a set of resources and objectives.

### References

- Burton, I.: 1997, 'Vulnerability and adaptive response in the context of climate and climate change', *Climate Change* **36**(1–2), 185–196.
- Adger, W., Neil, P., Kelly, M., and Huu Ninh, N.: 2001, *Living with environmental change: social vulnerability, adaptation, and resilience in Vietnam*, Routledge, London.
- Aldrich, H. and Auster, E.: 1986, Even dwarfs started small: liabilities of age and size and their strategic implications, in Staw, B. and Cummings, L (ed.), *Research in Organizational Behavior*, Greenwich, CT, pp. 165–198.
- Arnell, N. W.: 2003, 'Effects of IPCC SRES emissions scenarios on river runoff: a global perspective', *Hydrology and Earth System Science* **7**, 619–641.
- Arnell, N. W. and Delaney, E. K.: 2003, *Adapting to climate change: water supply in England and Wales*, ADAPT Project paper, Department of Geography, University of Southampton, Southampton, October.
- Benner, M. J. and Tushman, M. L.: 2003, 'Exploitation, exploration, and process management: the productivity dilemma revisited', *Academy of Management Review* **28**(2), 238–256.
- Chakravarthy, B.: 1982, 'Adaptation: a promising metaphor for strategic management', *Academy of Management Review* **7**(1), 35–44.
- Collis, D. J.: 1994, 'Research note: How valuable are organizational capabilities?', *Strategic Management Journal* **15**, 143–152.
- Cyert, R. M. and March, J. G.: 1963, *A Behavioral Theory of the Firm*, Prentice-Hall, Englewood Cliffs, NJ.
- Daft, R. L. and Weick, K. E.: 1984, 'Toward a model of organizations as interpretation systems', *Academy of Management Review* **9**(2), 284–295.
- Downing, T. E., Olsthoorn, A. A., and Tol, R. S. J.: 1996, *Climate change and extreme events: altered risks, socio-economic impacts and policy responses*, ECU Report No 12/IVM Report No R 96/4, Vrije Universiteit, Amsterdam.
- Easterling, W. E., Crosson, P. R., Rosenberg, N. J., McKenney, M. S., Katz, L. A., and Lemon, K. M.: 1993, 'Agricultural impacts of and responses to climate change in the Missouri-Iowa-Nebraska-Kansas region', *Climate Change* **24**(1–2), 23–62.
- Eisenhardt, K.: 1989, 'Building theory from case study research', *Academy of Management Review* **14**(3), 532–550.
- Environment Agency: 2001, *Water Resources for the Future: A Strategy for England and Wales*, Environment Agency, Bristol.
- Environment Agency: 2003, *Water Resources Planning Guidelines. Supplementary Guidance Note 1: Treatment of Climate Change*, Environment Agency, Bristol.
- Folke, C. et al.: 2002, *Resilience and sustainable development: building adaptive capacity in a world of transformations*. Edita norstedts tryckeri AB, Stockholm.
- Gavetti, D. and Levinthal, D.: 2000, 'Looking forward and look backward: cognitive and experiential search', *Administrative Science Quarterly* **45**, 113–137.

- Glantz, M. H.: 1988, *Societal responses to climate change: forecasting by analogy*, Westview Press, Boulder, CO.
- Graves, H. M. and Philipson, M. C.: 2000, *Potential implications of climate change in the built environment*, FBE Report 2, Foundation for the Built Environment, London.
- Herrington, P.: 1996, *Climate Change and the Demand for Water*, HMSO, London.
- Hertin, J., Berkhout, F., Delaney, K., and Arnell, N.: 2002, *Business and climate change: measuring and enhancing adaptive capacity, Progress report: Preliminary results from the house building and water sector*, SPRU/Tyndall Centre for Climate Change Research, Brighton.
- Hulme, M. et al.: 2002, *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*, Tyndall Centre for Climate Change Research, Norwich.
- Intergovernmental Panel on Climate Change (IPCC): 2001, *Climate change 2001 – The Scientific Basis: Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.
- Kasperson, J., Kasperson, R. E., and Turner, B. L.: 1995, *Regions at risk: comparisons of threatened environments*, United Nations University Press, NY.
- Kelly, P. M. and Adger, W. N.: 2000, 'Theory and practice in assessing vulnerability to climate change and facilitating adaptation', *Climatic Change* **47**(4), 325–352.
- Levitt, B. and March, J. G.: 1988, 'Organizational Learning', *Annual Review of Sociology* **14**, 319–340.
- Lippman, S. and Rummelt, R. P.: 1982, 'Uncertain imitability: an analysis of interfirm differences in efficiency under competition', *Bell Journal of Economics* **13**, 418–438.
- March, J.: 1991, 'Exploration and exploitation in organizational learning', *Organization Science* **2**, 71–87.
- McCarthy, J., Canziani, O., Laery, N., Dokken, D., and White, K.: 2001, *Climate Change 2001: Impacts, Adaptation, and Vulnerability Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.
- Mendelsohn, R.: 2000, 'Efficient adaptation to climate change', *Climatic Change*, **45**(3–4), 583–600.
- Nelson, R. and Winter, S.: 1982, *An evolutionary theory of economic change*, Belknap Press of Harvard University Press, Cambridge, MA.
- Nonaka, I.: 1994, 'A dynamic theory of organizational knowledge creation', *Organization Science* **5**, 14–37.
- Parson, E. A. et al.: 2003, 'Understanding climatic impacts, vulnerabilities, and adaptation in the United States: Building a capacity for assessment', *Climatic Change* **57**(1–2), 9–42.
- Reilly, J. and Schimmelpfennig, D.: 2000, 'Irreversibility, uncertainty and learning: portraits of adaptation to long-term climate change', *Climatic Change* **45**, 253–278.
- Schneider, S. H., Easterling, W. E., and Mearns, L. O.: 2000, 'Adaptation: sensitivity to natural variability, agent assumptions and dynamic climatic changes', *Climatic Change* **45**, 203–221.
- Smit, B., Burton, I., Klein, R. J. T., and Wandel, J.: 2000, 'An anatomy of adaptation to climate change and variability', *Climatic Change* **45**, 223–251.
- Staber, U. and Sydow, J.: 2002, 'Organizational adaptive capacity – a structuration perspective', *Journal of Management Inquiry* **11**(4), 408–424.
- Steinbrunner, J.: 1974, *The cybernetic theory of decision*, Princeton University Press, Princeton, NJ.
- Teece, D., Pisano, G., and Shuen, A.: 1997, 'Dynamic capabilities and strategic management', *Strategic Management Journal* **18**, 509–533.
- Tol, R. S. J., Fankhauser, S., and Smith, J. B.: 1998, 'The scope for adaptation to climate change: what can we learn from the impact literature?', *Global Environmental Change - Human and Policy Dimensions* **8**(2), 109–123.
- UK Water Industry Research: 2002, *Uncertainty and Risk in Supply/Demand Forecasting – Final Report (Volumes A and B)*, Project Report CL-09, UKWIR Ltd., London.

- Yohe, G., Neumann, J. E., Marshall, P. B., and Ameden, H.: 1996, 'The economic cost of greenhouse induced sea level rise for developed property in the United States', *Climatic Change* **32**(4), 387–410.
- Zollo, M. and Winter, S. G.: 2002, 'Deliberate learning and the evolution of dynamic capabilities', *Organization Science* **13** (3), 339–351.

(Received 25 May 2004; accepted in final form 20 July 2005)