business adaptation to climate change

A Systematic Review of the Literature

Network for Business Sustainability

Business. Thinking. Ahead.

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It's time for businesses to go beyond just mitigation. Firms must adapt to climate change impacts.

Firms need to learn from the leaders and build tools for modelling risk and assessing opportunities.

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executive summary

Business adaptation to climate change requires new knowledge, capabilities and collaborations.

SUMMARY

There is no common definition of business adaptation to climate change, despite a growing realization that businesses will need to adapt. Some theories exist but further development is limited by a lack of application and empirical work.

Climate risks and opportunities are often sector-specific, so adaptation strategies must also vary by sector. Managers should work within and across sectors to evaluate the risks and opportunities and develop appropriate strategies for their organization. In addition to developing sector-specific studies, researchers should conduct cross-sectoral studies to discover common concerns and solutions and to promote collaboration among sectors.

Most businesses have yet to undertake substantial adaptation measures, preferring to assume a "wait-and-see" approach. Strategic timing is essential to adaptation, as are ensuring alignment with overall firm policy and commitment within the organization.

BACKGROUND

There is growing consensus among researchers and policy makers that adaptation is a central strategy in dealing with the impacts of climate change. Adaptation is most commonly described as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities," (IPCC).

In 2008, the Network for Business Sustainability commissioned a systematic review to synthesize the current state of research and practice related to business adaptation to climate change. This report presents a sector-by-sector analysis of risks, opportunities, drivers, strategies, and barriers and gaps to adaptation.

FINDINGS

- There is no agreed upon definition of adaptation or what adapting to climate change will entail for businesses.
- Some sectors are leaders in adaptation to climate change: the insurance sector in risk assessment and the agriculture and tourism sector in awareness. The finance sector, although highly vulnerable, is in a position to influence adaptation among all sectors. The water sector is facing more risks than opportunities. Ski and coastal regions are the most at risk tourism regions. Adaptation strategies in the energy sector include technological innovation, building infrastructure, and behavioural and market strategies.
- Some businesses are incorporating climate change into their business models and strategies, but mostly only in terms of mitigation or risk evaluation.
- In general, business is taking a "wait-and-see" approach, with adapters being the exception rather than the rule.

IMPLICATIONS FOR MANAGERS

- Bring the adaptation discussion into the mainstream within the firm and in multi-sectoral platforms. Develop shared definitions.
- Collaborate within your sector to share knowledge and address common risks. Leading organizations can share knowledge with lagging organizations and be perceived as leaders. Collaborate across sectors with academics and other stakeholders to innovate new solutions.
- Establish sectoral and cross-sectoral platforms for sharing knowledge and concerns on the issue. Share information about adaptation strategies and practice with researchers, to advance learnings.
- Develop tools to evaluate risk, opportunities and adaptation strategies.
- Acknowledge that taking a "wait-and-see" approach comes with great risks.
- Increase awareness of risks and vulnerabilities associated with climate change.

IMPLICATIONS FOR RESEARCHERS

- Bolster business adaptation practice with definitions and theories based on solid empirical research.
- Develop industry and sector-specific climate impact scenarios, and refine the organizational learning model and other theoretical models.
- Study vulnerable sectors (e.g. water, agriculture, energy) to discover new opportunities and develop strategies.
- Conduct cross-sectoral studies to discover common concerns that can promote collaboration among sectors.
- Conduct primary research on firms and their adaptation practices. Develop case studies, lessons learned and best practices. Focus on neglected sectors and on drivers, strategies, barriers and gaps.
- Focus on developing tools for risk modeling and opportunity assessment.

METHODS

A systematic review of resources from the public sector, private sector and academia dating from 1997 to early 2009 revealed 201 sources pertinent to business adaptation to climate change. An interpretive narrative synthesis was employed to distil the large volume of varied data into accessible and intelligible frameworks. By analyzing the findings, we identified gaps in the literature and made recommendations of potential further research that could meet the needs of both academic and business practitioners in the field.

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[1] The contents of this report do not necessarily reflect the opinions of Oversight or Advisory Committee members.

introduction

This report discusses how organizations in various sectors are adapting to climate change and provides detailed summaries of risks, opportunities and strategies by sector.

There is a growing consensus among researchers and a number of policy makers that adaptation should be a central strategy in dealing with the impacts of climate change. In 2008-2009 the Network for Business Sustainability commissioned a systematic review to synthesize the current state of research on business adaptation to climate change, in order to identify and advance the theory and practice in this field.

Three major questions were explored:

- Are businesses incorporating climate change into their business models and strategies? If so, how? And do differences exist across business units in terms of risks, opportunities, processes and outcomes?
- Are certain sectors ahead of others? If yes, what drivers account for these differences, and what lessons can the leading industries offer the laggards?
- What tools and processes do businesses use to evaluate the opportunities to be gained from adapting to climate change? Are there any examples of businesses creating a competitive advantage by building adaptive capacity?

Multiple biographic databases and resources were searched – including academic studies, industry reports, think tank research, case studies, and newspaper articles – dating from 1997 to early 2009. We used a standard process for systematic reviews: definition of eligibility criteria; search for eligible titles and abstracts; selection of titles and abstracts that may be eligible; selection of eligible reports from review of full documents; and data extraction and synthesis of the material into a report. The search revealed 201 pertinent sources.
An interpretive narrative synthesis method was employed because we considered it the most appropriate to achieve the overall goals of this systematic review, particularly that of distilling an enormous amount of widely varied data into an accessible and intelligible framework for practitioners seeking to advance best practices and understand new developments in this emerging field of theory and practice.

concepts & definitions

This section includes both direct and indirect definitions of adaptation to climate change and related concepts, such as adaptive capacity, risk and vulnerability.

There is no one agreed upon definition of adaptation or what adapting to climate change will entail for businesses or business strategy. This is not surprising considering that adaptation to climate change by business is a relatively new idea, is being interpreted in a wide variety of ways by a wide variety of actors and is a highly contextual process dependent on sector, region and size of firm among many other factors. This is complicated by the substitution of other concepts for adaptation in the literature, such as risk and opportunity as they relate to climate change. This is also further complicated by the common conflation of adaptation with the process of businesses "adapting" their strategies to government mitigation policies.

Despite this, there are some emerging commonalities of how governments, the private sector and academic researchers understand adaptation as it relates to business. In this section, we have synthesized and organized both direct and indirect definitions of how "adaptation" has been interpreted by these actors. We first discuss direct definitions of adaptation in the literature, followed by inferred or substituted understandings via other concepts. The IPCC definition is accepted as the standard throughout the rest of this report.

DEFINING ADAPTATION – DIRECT AND INDIRECT DEFINITIONS

The earliest origins and dissemination of adaptation as a concept arose from the (IPCC), a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP). The IPCC has released a number of scientific reports on climate change (1st Assessment, 1990 and 1992; 2nd Assessment, 1995; 3rd Assessment, 2001; and 4th Assessment, 2007).[2] Scientific evidence in the 2nd Assessment revealed the inevitability of climate change, even in light of mitigation efforts. In 1995, the concept of "adaptation to climate change" was developed and defined in the first *Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses* report. By 2001, the IPCC defined climate change adaptation as "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, public and private adaptation, and autonomous and planned adaptation." (IPCC, 2001)[3]

[2] For the purposes of this study, adaptation is most explicitly defined in: IPCC TAR, 2001 a. Climate Change 2001: Impacts, Adaptation and Vulnerability. IPCC Third

[3] ibid.

These types are defined as (IPCC, 2001 in OECD, 2006: 17)[4]:

- **Anticipatory Adaptation**: Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
- **Autonomous Adaptation**: Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- **Planned Adaptation**: Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.
- **Private Adaptation**: Adaptation that is initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actor's rational self-interest.
- **Public Adaptation**: Adaptation that is initiated and implemented by governments at any level. Public adaptation is usually directed at collective needs.
- **Reactive Adaptation**: Adaptation that takes place after impacts of climate change have been observed.

The origins and classification of climate change adaptation by the IPCC is an important preface to this systematic review, as most of the definitions discussed below either directly or indirectly make use of some or all of the IPCC definitions.

These categorizations are a useful framework in determining how different actors understand adaptation as it relates to business strategy. While we found that government and international organizations tended to have broad-based definitions that covered the socio-economic dimensions of climate change and collective needs, business definitions adhered to the general IPCC definition but narrowed their focus to risk, opportunities, and rational cost-benefit approaches which can be related to the concept of "private adaptation" above.

This systematic review contains a wide variety of sources concerned with adaptation as it related to business strategy. The sources can be categorized into three major source types: government and international organization publications, private sector and think tank publications (including think tanks, consortiums and business associations), and academic publications (consisting of journal articles, dissertations and academic books). Of the 201 studies reviewed, 21 provided a direct definition of adaptation, while all of the studies gathered referred to it, either directly or indirectly, through related concepts. The following sections provide a synthesis and examples of the direct definitions found in each source type category (see Appendix C, "Findings by Source Type", for details), as well as a synthesis of indirect definitions including risks, opportunities, vulnerability and adaptive capacity.

[4] ibid., see also OECD, 2006 in biography

Box 1
DEFINITIONS OF ADAPTATION FROM GOVERNMENTS

Government of Canada (2007):
Adaptation to climate change is any activity that reduces the negative impacts of climate change and/or takes advantage of new opportunities that may be presented. Adaptation includes activities that are taken before impacts are observed (anticipatory) and after impacts have been felt (reactive). In most circumstances, anticipatory, planned adaptations will incur lower long-term costs and be more effective than reactive adaptations (NRCAN, 2007: 5).

Government of the United Kingdom (2009):
Adaptation is adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Effective measures directed at enhancing our capacity to adapt (building adaptive capacity) and at minimizing adjusting to and taking advantage of the consequences of climatic change (delivering adaptation actions) are required (Government of the UK, 2009: Online).

Government of the United States of America (2006):
Adaptation is defined in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Planned adaptation…refers to strategies adopted by society to manage systems based on an awareness that conditions are about to change or have changed such that action is required to meet management goals. The purpose of adaptation strategies is to reduce the risk of adverse outcomes through activities that increase the resilience of ecological systems to climate change stressors (Environmental Protection Agency, 2006: 1).

Government of Australia (2006):
Adaptation is an adjustment in response that leads to a reduction in risks or a realization of benefits. Risk treatments developed and implemented by an organization in response to climate change can be regarded as one type of adaptation. Because of the long time scales, climate change risk treatments will usually involve strategic planning and the allocation of new resources. They are thus often distinguished from short-term reactive adjustments. Climate change risk treatments can include technological and infrastructure measures, planning, research and education, or a combination of actions (Government of Australia, 2006: 48).

GOVERNMENTS AND INTERNATIONAL ORGANIZATIONS

Literature on climate change adaptation from various governments – such as the Government of Canada (Natural Resources Canada), United Kingdom (UK Climate Impact Program), United States (Environmental Protection Agency) and Australia (Australian Greenhouse Office) – offer definitions of adaptation. Almost uniformly, each of these government sources relies on an exact replication or slight modification of the definition used by the IPCC (2001) (*see Box 1*).

International governmental organizations, such as the European Union and the United Nations in its various branches, also offer definitions of adaptation. These sources too rely on an exact replication or slight modification of the definition used by the IPCC (2001) (*see Box 2*).

Box 2
DEFINITIONS OF ADAPTATION FROM INTERNATIONAL GOVERNMENTAL ORGANIZATIONS

The European Union (2007):
Adaptation aims at reducing the risk and damage from current and future harmful impacts cost effectively or exploiting potential benefits. Adaptation measures can be anticipatory or reactive. Adaptation applies to natural as well as to human systems. Ensuring the sustainability of investments over their entire lifetime taking explicit account of a changing climate is often referred to as "climate proofing" (European Union, 2007: 3).

United Nations Framework Convention on Climate Change (2009):
Adaptation is practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example, flood walls should be built and in numerous cases it is probably advisable to move human settlements out of flood plains and other low-lying areas" (Website of the UNFCCC Secretariat in Livena and Tripak, 2006: 7).

United Nations Development Program (2005):
Adaptation is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed and implemented (UNDP, 2005 in Livena and Tripak, 2006: 8).

Government and international governmental organizations also define concepts related to adaptation. These include **adaptive capacity**, **risk** and **vulnerability**.

Adaptive capacity according to the IPCC, is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of potential opportunities or to cope with the consequences of climate change (IPCC, 2001 in OECD, 2006: 17).

Risk is the probability that a situation will produce harm under specified conditions. It is a combination of two factors: the probability that an adverse event will occur and the consequences of the adverse event. Risk encompasses impacts on human and natural systems, and arises from exposure and hazard. (Australia Greenhouse Office 2003 in Livena and Tripak, 2006: 21). The UNDP identifies climate-related risk as the result of interaction of physically defined hazards with the properties of the exposed systems – i.e. their sensitivity or (social) vulnerability. Risk can also be considered as the combination of an event, its likelihood, and its consequences – i.e. risk equals the probability of climate hazard multiplied by a given system's vulnerability (UNDP, 2005 in Livena and Tripak, 2006: 21). UNEP 2006 presents a six-point typology of climate change risks for business including market risk, operational risks, reputational risks, counterparty risk, political/legal risks and business risks (UNEP, 2006: 16).

The IPCC 2001 defines **vulnerability** as a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. (IPCC, 2001 in Livena and Tripak, 2006: 17). However, vulnerability can also be considered as the underlying exposure to damaging shocks, perturbation or stress, rather than the probability or projected incidence of those shocks themselves (UNDP, 2005 in Livena and Tripak, 2006: 17). The Australian government identifies vulnerability as the extent to which a natural system or human society is unable to cope with the negative impacts of climate change, variability and extremes. It depends on changes in climate as well as the sensitivity and adaptive capacity of the system or society (Australian Greenhouse Office, 2003 in Livena and Tripak, 2006: 18).

PRIVATE SECTOR

Literature being produced by the private sector (including think tanks, consortiums and business associations) is focused more on how adaptation relates to business and business strategy, and tends towards evaluating and coping with climate risks. Some business definitions of adaptation include opportunities as well as successful adaptation in their conception of climate change adaptation. However, the majority of business discourse on climate change adaptation is concerned with risk mitigation. Most business literature refers to the IPCC definition or a slight modification to it, while also relating to what the IPCC terms "private adaptation."

Very few private sector sources to date define adaptation directly in their own terms. The business discourse on adaptation includes a risk management approach and a cost-benefit approach. For example, the Chartered Accountants of Alberta define adaptation as "taking action to minimize and respond to the effects of climate change. Initiatives in these areas largely originate from a risk management perspective" (Desjardins and Schuh, 2007). The International Chamber of Commerce (Commission on Environment and Energy, 2007) states that:

> *"the classic definition of adaptation is policy and operational approaches to reduce climate change risk, vulnerability and damage ... [adaptation includes] infrastructure development, human settlements, water provision and new industrial installations amongst others, many of which will be in use for decades into the future. Climate change should be taken into account as part of ongoing planning, development and investment processes." (Ibid, 2007: 2)*

Sullivan et al. (2008) define adaptation as "actions taken to cope with a changing climate," with the objective of reducing risk and damage, and exploiting potential benefits. In this frame of reference, public policy and corporate adaptation are trade-offs between the costs incurred in taking action in response to climate change and the potential costs associated with climate change (Sullivan et. al., 2008: 6). The Chartered Accountants of Canada (CAC) (2008) define adaptation as:

> *"... taking action to minimize and respond to the effects of climate change ... for companies, adapting to these phenomena will involve identifying their current and potential impacts on business, reducing vulnerability to them and taking advantage of any potential opportunities they present. Some geographical areas and some industries may be impacted more than others by adaptation issues. Companies will increasingly address adaptation as aspects of their business strategy and risk management. Actions taken to minimize and respond to the effects of climate change will ultimately be reflected in financial statements." (CAC, 2008: 6)*

The vast majority of studies by the private sector take an indirect approach to climate adaptation, tending to frame adaptation in terms of vulnerability and adaptive capacity, risk and opportunity. The Pew Centre (2004) frames adaptation to climate change in terms of the availability and accessibility to adjustment opportunities. In managed systems, wealth, availability of technology, appropriate decision-making capabilities, human capital, social capital, risk spreading (e.g. insurance), ability to manage information and the

perceived attribution of the source of stress all contribute significantly to adaptive capacity and the capability of such systems to actively and adequately respond to changing environments (Yohe and Tol, 2002, in Easterling, Hurd, and Smith, 2004: 4). Reactive adaptation is consistent with the concept of resilience defined as the degree to which a system can absorb disturbance and still return to its pre-disturbance steady state (Easterling, Hurd, and Smith 2004: 5). In contrast with reactive adaptation, proactive or anticipatory adaptation is associated with the concept of adaptive reorganization whereby a system survives disturbance by altering existing relationships or establishing new relationships and components (Holling, 1986 in Easterling, Hurd, and Smith 2004: 5). This reorganization could involve the development of new economic, technological and political institutions to avert damages, or it could mean taking advantage of opportunities in anticipation of future climate change (Easterling, Hurd, and Smith 2004: 5).

Table 1 summarizes the indirect aspects of adaptation in the business literature.

Table 1 **INDIRECT ASPECTS OF ADAPTATION IN BUSINESS LITERATURE**[5]

RISKS					
Regulatory Risk	Financial Risk	Physical Risk	Litigation Risk	Reputational Risk	Competitive Risk
OPPORTUNITIES					
Enhancing Corporate Reputation	Gaining and Maintaining Competitive Advantage	Technological Opportunities	New Product Development		

[5] Adapted from the ideas put forward throughout KMPG, Climate Changes your Business, 2008.

SUMMARY OF KEY POINTS

- Adaptation has entered the business discourse, but is still being confused with mitigation.
- 21 of the 201 studies reviewed provided a direct definition of adaptation.
- There is no one agreed upon definition of adaptation or what adapting to climate change will entail for businesses or business strategy. The most commonly used definition is the IPCC (2001) definition and derivatives of it.
- Adaptation is interpreted in a wide variety of ways by a wide variety of actors and is a highly contextual process dependent on variables such as sector, region and size of firm.
- Adaptation as a concept has been largely dominated by the IPCC's work.
- There is a need for mainstreaming the definition of "business adaptation to climate change" across the public, private and academic sectors.

theoretical models

This section includes studies which explicitly develop theoretical models to understand the impact of climate risk on business practice and how businesses may adapt.

Our systematic review yielded 16 studies which engage in a theorization of business adaptation to climate change. These are defined here as studies which explicitly develop theoretical models that attempt to understand the impact of climate risk on business practice, business opportunities created by climate change and when, why and how businesses may adapt. Part one, Business Adaptation in Theory, discusses articles that summarized and theorized existing theoretical approaches to business adaptation. Part two, Impact and Risk Models, discusses theories that primarily focus on understanding how businesses are or may be affected by climate risk. Part three, Drivers of Business Adaptation, discusses a variety of models that are being used to understand the complexities of the decision-making processes by which organizations decide to adapt.

BUSINESS ADAPTATION IN THEORY: METATHEORETICAL ISSUES

Only two studies reviewed (Hertin et al. 2003; Berkhout et al. 2004a)[6] offered metatheoretical analyses of how business adaptation to climate change had been conceptualized within a range of literature on the subject. Both studies contend that academic research into adaptation, both theoretically and empirically, is still at a very early stage. Hertin et al. (2003) suggest that theorizations of adaptive behavior are often oversimplified as a "question of optimal choices between a broad set of clear alternatives made by individuals and firms pursuing their personal interests" (Hertin et al., 2003, p. 280, citing Mendelsohn, et al. 1994 and Mendelsohn 2000).[7] They go on to argue:

> *"In other words, [businesses] will adapt once they have experienced the effects of climate change and will then adapt by precisely the amount that maximizes their overall welfare. This approach to explaining adaptation has been much criticised for making invalid assumptions about the nature of climate impacts (Schneider et al., 2000) and for misunderstanding the complexity of decision making by adapting organisations and actors (Kandlikar and Risbey, 2000)." (Hertin et. al 2003, p. 280)*

Berkhout et al. (2004) also argue that oversimplification has been a major problem thus far in theorizing adaptation. They state:

> *"... progress towards developing theoretical understandings of adaptation has been slow (Kasperson et al., 1995; Kelly and Adger, 2000; Folke et al., 2002)[8]. Existing accounts draw on frames, methods and taxonomies borrowed from a range of disciplines including conservation*

[6] Berkhout, et. al. 2004b also collected during the systematic review is a working paper of the final draft reviewed here. We have excluded it here as it is a less nuanced duplicate of the final draft (Berkhout et. al. 2004a).
[7] Mendelsohn, R., Nordhaus, W. and Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. American Economic Review: 84, 753–771.; Mendelsohn, R. (2000). Efficient adaptation to climate change. Climatic Change: 45(3–4), 583–600.
[8] Kasperson, J., Kasperson, R.E., Turner, B.L., (1995). Regions at risk: comparisons of threatened environments. United Nations University Press, NY.; Folke, C. et al., (2002). Resilience and sustainable development: building adaptive Capacity in a world of Transformations. Edita norstedts tryckeri AB, Stockholm.; Kelly, P.M., Adger, W.N., (2000). Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change: 47 (4), 325-352.

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)[9]. The aim is usually descriptive (for instance, listing the factors that may influence adaptive capacity) or normative (making recommendations about the role of policy in enabling adaptation) rather than analytical. Therefore, it is not yet possible to answer fundamental questions like: What are the attributes of the adaptive capacity of specific communities, organisations and resources? What motivates adaptation processes? What factors determine processes of adaptation?" (p. 3)

Berkhout et al.'s observation that the literature is typically highly descriptive and applies a wide range of taxonomies and methods borrowed from a variety of sources was true of much of the literature reviewed in this study as well, with the exception of the 16 articles discussed in this section. In other words, the conceptual architecture demonstrated in the previous section is generally the full extent of theory deployed by individuals and organizations attempting to make sense of the how and why businesses are adapting.

Since the publication of these two articles (Hertin et. al., 2003 and Berkhout et. al., 2004), there has been a push to develop more analytical and explanatory approaches to business adaptation. These studies are reviewed below.

[9] Smit, B., Burton, I., Klein, R.J.T., Wandel, J., (2000). An anatomy of adaptation to climate change and variability. Climatic Change: 45, 223-251; 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.

IMPACT AND RISK MODELS – HOW WILL CLIMATE CHANGE AFFECT BUSINESS?

Potential Climate Change Scenario Modelling

One method that researchers are using to study the potential impacts of climate change on business is through the application of climate change scenario models derived from scientific/meterological forecasting to behavioral analyses of business decision making and consumer reaction. Seven studies we reviewed employed this type of analysis, all of which were specifically focused on the tourism and recreation sector where it appears that the relationship between the sector and weather can more easily be modelled under current and historical conditions.

Five of the scenario-based studies, which are developed by research teams led by or including Daniel Scott (McBoyle, Mills, and Scott., 2003; Scott and Jones, 2006; Scott and Jones 2007; Scott et. al 2006; Scott et. all 2007) focus on the potential impact of climate change on the Ontario ski industry, golf participation in the Greater Toronto Area (GTA), the ski-based tourism industry in eastern North America, the Quebec ski industry and the Canadian golf industry, respectively. The other two studies focused on the Scottish tourism industry (Yeoman and McMahon, 2006) and the Australian ski industry (Hennessy et. al, 2008). In each study, climate change forecasts projected over particular intervals (typically 30 year periods, e.g. 2020s, 2050s, 2080s) are related to particular climate sensitive variables (season length, golf rounds played, resources needed for snow making, film making on location, etc.) of which relationships to climate change have already been established through historical modelling.

While these scenarios are useful in modelling potential risks or opportunities to business, their contribution to understanding how and why businesses may adapt to them is limited thus far. With the exception of two studies focused on snowmaking as a technical adaptation (Scott et al. 2003; Hennessy et al. 2008), adaptive behavior is only discussed as an area for further research or it is assumed that businesses, supplied with the appropriate information, may shift business practice. Gössling and Hall (2006) have also critiqued this scenario-behavioral based model for being weak on a number of grounds, namely that climate scenarios are constantly shifting thus making projections potentially irrelevant, and that the relationship between weather and tourist flows is often viewed as a determinate relationship.

Vulnerability Approach Modelling

Another method that researchers are using is a vulnerability-based approach. One study reviewed employed this approach (Belliveau et al. 2006). Based on an implicit critique of the limitations of the scenario-based approach described above, the vulnerability approach embeds the potential impacts of climate change within a multi-exposure analysis. This approach includes highly variable political, economic, institutional and biophysical conditions [see diagram here, p. 369]. As opposed to a "top-down" application of potential scenarios, a vulnerability approach stresses "bottom up" qualitative investigations of human decision making in the face of a changing climate, seeking also to capture dynamic adaptation processes.

Belliveau et al.'s (2006) study of multiple exposures in the grape industry in British Columbia's Okanagan Valley employs such a vulnerability approach. They utilize a qualitative interviewing process with open-ended questions designed to inductively draw out the risks and opportunities as perceived by grape growers, and then compare these to climate data and projections, as well as political, institutional and economic data. They find this method allows them to uncover, in particular, risks that are not discussed in scenario based approaches.

Adaptation in relation to vulnerability of farmers is discussed using the concept of "adaptive capacity", which is modelled in terms of short-term (tactical) and long-term (strategic) planned reactive and anticipatory shifts in practice to threats such as colder, wetter seasons, extreme heat, frost, pests and low tourism. These shifts in business practice are part of a "built in" adaptive capacity for farmers who are constantly shifting business practice in relation to the variety of pre-existing risks.

DRIVERS OF BUSINESS ADAPTATION – WHEN, WHY AND HOW DO BUSINESSES ADAPT?

Adaptation as Behavioral Response

Only one study reviewed (Mendelsohn, 2000) theorizes the relationship between climate risk and business adaptation as one governed by the self-interest of business organizations. Mendelsohn develops a formal static economic model which assumes that "private adaptation" will occur in climate sensitive sectors of the economy when the costs of inaction outweigh the costs of adapting and, conversely, when potential economic benefits outweigh the investment costs for taking advantage of them. He develops this primarily through modelling potential opportunities in the agricultural sector due to new crop varieties made possible by variations in temperature (see diagram available here or here, p. 589).

Adaptation as Organizational Learning

A small number of studies (n=3), mainly derived from the Tyndall Center's 2004 ADAPT project (denoted by *), have begun to theorize business adaptation to climate change as an "organizational learning" process (Berkhout et al. 2004a; Arnell and Delaney, 2006*; Pelling et. al 2008). Theories of organizational learning draw on behavioral studies of organizations. They are primarily concerned with "how organizations learn from direct experience, how they learn from others, and how they develop conceptual frameworks for interpreting that experience" (Levitt and March, 1988:13 in Berkhout et al. 2004)[10].

Berkhout et al (2004a) developed a four-stage model (see diagram available here, p. 9) which integrates adaptation as an element in traditional organizational learning by business. Within this model, they note a number of key problems related to adaptation. Stage 1, Signalling and Interpretation, seeks to understand when and why businesses acknowledge climate risk as a threat or opportunity to business practice. They argue that organizations may find it difficult to recognize and interpret climate change stimuli. External pressure and expert advice may be essential in many cases. Stage 2, Experimentation and Search, examines how businesses typically take on a trial-and-error approach to incorporating climate risks into existing routines. They argue that given the ambiguity of climate change stimuli, it is unlikely that most businesses will adapt through a trial and error method. Stage 3, Knowledge Articulation and Codification, involves internal discussions within business concerning adaptation options, the selection of options and their codification within business practice. They argue that businesses may have difficulty in incorporating adaptation options into existing routines and may have to create new routines. Stage 4, Feedback and Iteration, is the end of the learning cycle in which the business assesses the effectiveness of the adaptation option, typically by way of some performance measure. They argue that most adaptation may not provide the performance feedback that is typical of business learning, as the feedback may be largely indirect (i.e. through customers, regulators, creditors). This organizational learning model was developed and tested through a number of empirical case studies in the UK housing and water sectors (Berkhout et al. 2004, 2006; Arnell and Delaney, 2006).

[10] Levitt, B., March, J.G., (1988). Organizational Learning. Annual review of Sociology: 14 319-340.

Pelling et. al. (2008) also developed an organizational learning model that considers the broader social context in which organizations make decisions, and are influenced. They propose an analytical framework for understanding the adaptive capacity of an organization through the lens of "six adaptive pathways" (see diagram available here, p. 873, or here, p. 14). This organizational learning model is tested through three case study examples of a local agricultural business and two government organizations in Wales, UK.

Belief in Climate Risk and Business Adaptation

Bleda and Shackley (2008) developed a theoretical model using a computer simulation of how businesses develop an organizational "belief" in climate change. Their primary assumption is that businesses will first adopt a "belief" in climate change, and then make moves to adapt to it only when they become cognizant of potential or real changes to competitiveness. The model – which can be appropriated by both business and researchers – allows users to plug in different types of variables, specific to business and market type, and provides the ability to see under what circumstances a business may or may not develop an organizational belief in climate change (see diagram here, p. 520).

SUMMARY OF KEY POINTS

- Theorizations of business adaptation to climate change are still in a very early stage.
- Most literature in the area does not go beyond simple definitions or taxonomies borrowed from the IPCC or other sources.
- Potential climate impact scenarios have been utilized by those in the tourism and recreation sector to understand possible changes in demand for services. These are very limited though, and make a number of assumptions regarding climate and tourist behaviour that may be proven false.
- Vulnerability approaches may be a way of overcoming some of these deficiencies.
- The organizational learning model is the most developed attempt thus far to understand how, why and when organizations will adapt – the next step is for field researchers to refine this model through empirical research.
- The major limitation thus far in theorization has been twofold: limited application of already existing cross-disciplinary approaches to the field, and limited empirical work upon which to base new theorizations.

risks & opportunities by sector

This report is structured on a sector-by-sector basis. The insurance sector is the most advanced in evaluating climate change risks.

In this report section we review studies that examine which firms and sectors are adapting to climate change and seek to identify key adaptation drivers and strategies. This literature illustrates which sectors are most at risk and what barriers may be preventing adaptation, as well as any gaps in business practice that are identified in secondary sources. In addition, this report identifies the emerging market opportunities associated with climate change and the sectors or firms that are taking advantage of them. A table analyzing these components is given for each sector.

A few broad cross-sectoral studies (KPMG, 2008; Pricewaterhouse Coopers, 2008) have attempted to synthesize climate risks and impacts for the business community as a whole. While these are useful as an introduction, due to the variability of climate impacts, risks and opportunities across sectors, the authors believe a sector-by-sector analysis is more comprehensive and arguably more useful.

In 2008, KPMG classified four types of risk that companies across all sectors may face as a result of climate change. These are physical risks related to weather and changes in ecosystem productivity, regulatory risks including new legislation, risk to reputation and risk of litigation. Potential risks vary from low to high on a sector-by-sector basis. For example, the agricultural sector is more likely to be exposed to physical risks as a result of climate change. Nonetheless, cross-sectional research on perceived risk to climate change by the Carbon Disclosure Project and PricewaterhouseCoopers in 2008 (Carbon Disclosure Project, 2008b) found that 84 percent of FTSE companies, 79 percent of S&P companies and 89 percent of Global 500 companies surveyed reported risks to their operations from climate change.

Opportunities also vary considerably on a sector-by-sector basis. For instance, the firms operating in high-tech industries may have tremendous opportunities by inventing new technologies for water innovation (water conservation and improved quality), energy innovation (extracting energy from new sources, improving renewable energy technology) transport innovation (reduced fuel use or carbon output) and biotechnological innovation (pharmaceuticals and developing weather-resistant seeds). Conversely, the water sector has seemingly few opportunities beyond water conservation measures and improved infrastructure. The aggregation of data in the global Carbon Disclosure Project study of 2008 finds perceptions of climate change opportunities on par with risks. Notably, 85 percent of FTSE companies, 79 percent of S&P companies and 89 percent of Global 500 companies surveyed reported business opportunities extending from climate change.

The specificity of climate risks and opportunities suggests that adaptation strategies are generally sector-specific and firm-specific. Comprehensive analyses of risks, opportunities, strategies and barriers, are often presented on a sector-by-sector basis, with the exception of only two studies that attempted to amalgamate business risk and only one study that attempted to amalgamate business opportunity. As such, this report

has been structured on a sector-by-sector basis in order to provide a comprehensive overview of the risks, opportunities, adaptation strategies, and barriers to adaptation that businesses face.

The literature provided adaptation information on the following 15 sectors: insurance (35 studies), agriculture (22 studies), tourism and recreation (20 studies), energy (17 studies), water (15 studies), building and construction (16 studies), finance and banking (eight studies), mining (5 studies), forestry (four studies), infrastructure (three studies), food and beverage (three studies), information technology (two studies), transportation (one study), chemicals (one study) and manufacturing (one study).

INSURANCE SECTOR

The 35 studies reviewed on the insurance industry suggest that the sector sits at a crossroads on climate change adaptation. On the one hand, the literature views the insurance industry as a potential victim of heightened risk exposure primarily due to the increased existence and probability of catastrophic weather events. On the other hand, the literature also perceives the insurance industry's unique position to both take advantage of opportunities for new insurance products related to climate change and be a catalyst for promoting adaptation across all sectors.

The literature has generally focused on risk as losses to the industry due to property damage, health insurance losses, life insurance losses and third-party liability claims resulting from climate change (Dlugolecki, 2008; Hecht 2008; Maynard 2008). Another significant risk to the industry is the potential loss of geographic and sector-specific markets because of uninsurable climate risks. Risk modeling has become significantly more complex because of the extreme variability and unpredictability of climate related events as the global climate system changes (Dlugolecki, 2008).

However, some literature emphasizes the potential market opportunities for the sector as a whole to take a leading role in policy and product development. Insurance is uniquely positioned to take on a role in public-private partnerships for mitigating greenhouse gas (GHG) emissions and lessening climate change, and co-coordinating a tripled dividend (adaptation, disaster management and sustainable economic development). As well, opportunities may lie in new product development such as green insurance products, catastrophe bonds and weather derivatives. For example, Swiss Re is developing a $60 million sustainability-based investment and venture capital portfolio to encourage the development of green energy technologies (Deering and Wade, 2002).

Major adaptation initiatives in the insurance sector, to date, have focused around building institutional networks which allow for collaboration to address the common risks to the industry. For example, the two most prominent initiatives globally, which were repeatedly referred to in industry studies, are the ClimateWise consortium and CERES. ClimateWise is an initiative of more than 40 leading companies and organizations in the insurance industry that collaborate to analyze and reduce risks among their client base. CERES is a U.S. network of companies, investors, environmental organizations and public interest groups collaborating to advance climate change solutions in insurance such as developing more sophisticated risk modeling, promoting risk reducing behavior through insurance and developing new insurance products.

Table 2 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the insurance sector.

Table 2 **SUMMARY OF ADAPTATION IN THE INSURANCE SECTOR**[11]

RISK & VULNERABILITIES
• High physical risk to climate change • Climate change is a serious threat to future financial stability • Losses could raise the cost of capital and volatility of insurance markets • Shrinking return periods due to inapplicable historical modeling, incorrect rating of risks, exposure too high, claims-capacity handling too low, credit ratings too generous • Assets may be uninsurable against extreme events • Higher premiums • Potential liquidity problems • Increased volume of claims • Potential litigation from clients and shareholders • Disruptions to business operations become unpredictable and more financially relevant • Claims patterns could differ from pricing data, increasing the risk that pricing is inadequate • Changed risks not modeled (i.e. life insurance and changed exposure to illness) Increased exposure of primary insurers will increase the cost of reinsurance; large losses may decrease the reinsurers ability to meet the cost of losses • Risk modeling will become more complex and the quality of risk management will be increasingly important • Certain risks will become uninsurable • Reduced reliability of historical losses information

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[11] Adapted from: World Business Council for Sustainable Development, 2008; Sussman and Freed, 2008; Llewllyn, 2007; Harris, 2008; Packard and Reinhardt, 2007; Meder, 2007; Deering and Wade, 2002; Lenkus, 2008; Blazey and Govid, 2007; Botzen and van den Bergh, 2008; Dluglolecki and Keykhah, 2002; Dlugolecki, 2008; Lloyd's, 2007.

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OPPORTUNITIES

- New insurance products and markets (e.g. micro-insurance for the developing world)
- Green insurance products (green energy, green auto hybrid car discounts, pay-as-you drive insurance, Insurance discounts on environmentally certified buildings)
- Increased demand for risk management consulting services
- Global weather risk business (catastrophe bonds, weather derivatives)
- Better capitalized insurers benefiting indirectly through weakened competitors

DRIVERS

- Insurance companies are uniquely situated to catalyze all sectors towards climate change adaptation through both education and accurate risk assessment of climate risk
- Insurance companies need to ensure that their models and prices are accurate to avoid catastrophic losses

STRATEGIES

- Develop accurate underwriting tools such as catastrophe models to establish exposure based rates for insurance
- Better risk pricing and better wording of policies
- Support the use of green technologies and sustainable business practices to help reduce GHG emissions
- ClimateWise: general insurance sector and life insurance sector have grouped together to analyze the major risks posed by climate change, and reduce these risks among their client base
- CERES Coalition working to increase disclosure of climate risks by publicly traded companies
- UNEP Financial Initiative
- Participation in the Risk Prediction Initiative (U.S. Insurers)

LEADERS

- Travelers Inc., Munich Re, AIG, Aviva, AXA, Royal and Sun Allianz, Swiss Re, Lloyds, Zurich, Gerling

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BARRIERS TO ADAPTATION

- Cognitive
- Political
- Analytical
- Operational
- Few companies have begun to disclose climate risk, making risk assessment difficult
- Industry has yet to properly price/quantify climate liability
- Some big markets will be uninsurable by 2025
- Limited capacity for property insurance by 2035

GAPS

- Insurance industry must widen its understanding of risk
- Need better access to current scientific information
- Sector must become more proactive
- Need for updated risk-management practices through pricing and capital allocation models
- Pricing and capital markets are deficient and lacking

AGRICULTURE SECTOR

The 22 studies reviewed on the agriculture sector revealed that climate change risk is only one of a wide range of risks the industry is exposed to. Climate change is part of a much broader risk management framework that takes into account a high rate of weather variability. However, while the sector is highly vulnerable to climate change it is also highly adaptive due to extended, historical and regular risk exposure to weather variability (Burton and Lim, 2005; Belliveau et. al., 2006; C-CARIN, 2004; Wall and Smit, 2006). Farmers are adapting to climate change in the short-term, on a season-to-season basis, and the literature reveals that most adaptations to climate change in the sector are reactive and short-term, as opposed to proactive and long-term (Burton and Lim, 2005). Agriculture is highly dependent on eco-zones and as ecosystems change due to long-term climatic change, the crop varieties, pest exposure, growing season and water availability will all likely change in different agricultural zones globally (Granahan et. al., 2006).

The long historical experience of agriculture with climate variability appears to place it in an unprecedented position to adapt to climate change when compared to other sectors. Experience already with crop rotations,

changing planting patterns and modified crop varieties place producers at an advantage to grow new crop varieties as conditions of climate change. However, to do so requires appropriate and timely information which may not always be available under conditions of long-term climate change. The sector, particularly in North America and Europe, is expected to experience increased productivity of crops but only if climatic change is 2°C or less. At temperature changes of two degrees or more, any increased crop yields may be offset by extreme weather events, pest outbreaks or scarcity of water. As well, climate change in North America and Europe will present opportunities for a longer growing season and a wider crop variety only if technology and timing match the changes synchronously.

Adaptation strategies in the sector are highly dependent on government programs, subsidies and technological developments. Government programs for crop insurance, safety net programs, and subsidization of research and development are drivers of adaptation for producers because they mitigate losses against potential crop failure and disaster. As well, the sector's ability to adapt depends on technological development mediated by governments, such as the development and approval of new crop varieties as well as the development of national, regional, and local weather forecasting technologies and knowledge dissemination. Other technological developments for adaptation in the sector include the development of climate resistant crops, new irrigation technologies and conservation tillage. However, some literature reviewed (McLeman and Smit, 2006; Smithers and Blay-Palmer, 2001) noted that substantial barriers existed with both government programs and technological strategies for adaptation. In the case of government programs, disaster subsidies may reduce the incentive to adapt due to protection from losses, and implementing technology can be impaired by high cost, patent rights and inaccessibility for small producers.

Table 3 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the agriculture sector.

Table 3 **SUMMARY OF ADAPTATION IN THE AGRICULTURE SECTOR**[12]

RISK & VULNERABILITIES
• High physical risk • High sensitivity, but high adaptive capacity • Loss of competitive advantage from failure to recognize new growing regions • Interruption of supply due to inappropriately sited crops and over dependence on high-risk regions • Changes in availability and price of commodities • Business interruption • Irrigation problems due to water stress • Decreased production for rain fed crops • Increased risk of crop loss due to weather cycle extremes • Increased concentration of carbon can stimulate crop growth • Disruptions to transportation systems from storms • Livestock could be affected physiologically and through change in feed (animal welfare) • More refrigerated distribution and storage required • Problems with livestock transportation; milk production decline • Limited availability of water and potential interruption of supply • Equipment and expertise are linked to specific crops • Quality issues: overheating of grain, or availability of water for pre-washed products • Access to land during flood or extreme rain conditions • Less frequent frosts will affect quality of certain crops • Pests/disease • Exposure of workforce to increased heat • Could create imbalances in ecosystems, possibly threatening species • Farm buildings affected by weather extremes • USA: National output estimated to peak at 2 to 3°C (4 to 5°F) increase; output falls after 5°C increase. Southern areas more likely to face reduced output of grain production. Changes in yields due to precipitation and temperature extremes, increases in pests and disease, salination of irrigation water, changes in timing of biological events. • Canada: Insect infestations, crop damage from extreme heat, planning problems due to less reliable forecasts, increased soil erosion, increased weed growth and disease outbreaks, decreased herbicide and pesticide efficacy, increased moisture stress and droughts. • Europe: Countries with a warmer climate will be disadvantaged. Water shortage issues could be amplified, especially in southern Portugal, southern Spain and Ukraine. Excess heat will tend to shorten the growing season at low latitudes. • Greatest adverse impacts are likely to be experienced by the economies of central and northern Asia, the western Sahel, coastal tropical regions of South America and some small island states.

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[12] KMPG, 2008; Pew Centre, 2004; NRCAN, 2007; Sussman and Freed, 2008; Granahan et al., 2006; C-CAIRN, 2004; Ross, 2007; Llewllyn, 2007; WBCSD, 2008; Burton and Lim, 2005.

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OPPORTUNITIES

- Climate change could allow for new crop species and varieties to be cultivated in areas where climatic conditions were unsuitable so far
- Increased yields due to extension of the growing season and temperature increases in some regions
- Canada: Increased crop productivity in warmer temperature, possibility of growing new crops, longer growing seasons, accelerated maturation rates and decreased moisture stress.
- Europe: Agricultural sector could benefit from moderate warming (global average temperature increase of less than 2°C) in high-latitude countries. The growing season is lengthened due to the warming in certain regions.

DRIVERS

- The degree of adaptation depends on available technology, market structure and organization
- Appropriate government incentives and programs to adapt, which include R&D for climate resistant crop technologies (e.g. drought and flood resistant seeds), subsidies for adaptation implementation (e.g. technology transfers)

STRATEGIES

- Technological developments (new crop varieties, water management innovations for water conservation and retention)
- Insurance (commercial general liability insurance, crop insurance)
- Change farm production practices (crop diversification, dropping crops, changing planting and sowing times, change land use, irrigation)
- Change farm financial management (crop shares)

LEADERS

- None identified

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BARRIERS TO ADAPTATION

- Weather forecasting needs to be more reliable (technological lag)
- High costs for producers
- Information on risks is not always consistent or reliable
- Genetically modified crops (i.e. weather resistant crops) may compromise organic marketing strategies

GAPS

- There is little or no understanding of what the added stress of climate change will actually do to agriculture
- To make informed decisions farmers require information on short-term seasonal and inter-annual variability for very specific localities
- There is a general sense that long-term climate change is not, and should not be, high on the farming agenda

TOURISM AND RECREATION

The 20 studies reviewed on the tourism and recreation sector revealed that the risks in the sector can be categorized as those risks that are global and those which are regional and sub-sector specific (i.e. sand, sun and ski).

The risks that can affect tourism operations globally are related to a general unpredictability due to changing weather patterns that affect where tourists travel (i.e. islands) when tourists travel (i.e. length of season) and if they will travel (i.e. improved or worsened climate conditions at home). The UNEP study on tourism in 2008 was unique among the studies in identifying those regions of the world most at risk to climate change: namely the Caribbean, Mediterranean, Indian Ocean and small islands, Pacific Ocean and small islands, Australia and New Zealand. Regionally, different tourist attractions are impacted differently from climate change: ski and coastal tropical destinations are the most at risk to changing weather patterns due to their dependence on stable weather conditions and ecological resources for recreation.

Northern latitudes stand to gain from potentially longer and warmer summer seasons, as tourists choose to either remain in country or travel abroad to other northern destinations, also potentially as a reaction to increased climate extremes and loss of attractiveness (i.e. hurricanes, flooding) in traditional southern destinations. However, these opportunities for new tourist ventures may be offset by other climate effects on northern latitudes such as intolerable city heat and forest fires limiting outdoor recreation.

Adaptation strategies in the tourism and recreation sector are typically industry specific (i.e. ski or coastal resort) and involve some combination of technical, managerial, financial or behavioural adaptations.

Technological solutions involve innovation in protecting or recreating the natural resource base of the sector and are so far most evident in the most vulnerable industries, such as the ski industry (snowmaking technology) and coastal resort industry (cyclone building protection). Management and behavioural solutions include education of guests and staff (water conservation and towel usage), ecological protection, evacuation plans (cyclone disaster planning) and offering more indoor activities (substitute to traditional tourist attractions).

Table 4 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the tourism and recreation sector.

Table 4 **SUMMARY OF ADAPTATION IN THE TOURISM AND RECREATION SECTOR**[13]

RISK & VULNERABILITIES
• High level of physical risk and risks remain underestimated • Unpredictability of tourist flows due to changing weather patterns • Reputation risk • Property damage and damaged infrastructure • Stranded assets in former tourist regions • Loss of attractiveness and scenic appeal due to weather damage (vegetation and beach damage from hurricanes in tropical destinations) or destroyed resource base (low-altitude ski resorts) or lost ecological resources (forest fires and reduced camping/hiking/hunting activities) • City tourism is sensitive to extremely hot weather • Distribution of holiday trips during the year could change • Obsolescence of destinations as they become too hot, water scarce or at risk from wild fires and the spread of formerly tropical diseases • At risk hot spots 2050-2100: Caribbean, Mediterranean, Indian Ocean, small island nations, Pacific Ocean and small island nations, Australia and New Zealand • Longer summer, reduced southern tourism • Destruction of ecological resources on which tourism depends (snow for skiing, coral reefs for scuba diving in tropical destinations, water system health for fishing) • Coastal zones: Rising sea levels, coastal retreat and erosion, changing wind patterns, destruction of coastal ecosystems (coral reefs, estuaries), cyclones, heavy flooding • Northern climates: Less snow

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[13] Adapted from Becken, 2005; Bicknell and McManus, 2006; Dawson, 2007; Dubois and Ceron, 2006; Elaser and Burki, 2002; KMPG, 2008; Gossling and Hall, 2006; Hennessy et. al., 2008; McBoyle et al., 2003; Moen & Fredman, 2007; Scott and Jones, 2006; EU, 2006; Scott et. al., 2006; UNEP, 2008.

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OPPORTUNITIES

- Northern latitudes may become more attractive destinations
- Push-pull factors: warmer temperatures in home country increase demand for domestic tourism while colder hospitable weather at home increases outbound tourism
- Improved weather increases opportunities for outdoor recreation in northern regions (e.g. golfing, hiking, camping, fishing)

DRIVERS

- Climate conditions: Generally, cool destinations become more attractive as they get warmer and warm countries become less attractive
- Customers and investors increasingly aware of potential impact on weather-dependent tourist destinations
- Seasonal tourism activities (golf, skiing, coastal tourism) respond to weather changes. For example, golf courses opening earlier as the weather warms in the summer or ski resorts making snow as precipitation declines

STRATEGIES

- Tropical and coastal tourism construction-based measures in coastal zones (weather-resistant building structures, water storage, replanting trees, self-sufficient energy supply, setting back structures in coastal areas)
- Ski tourism, artificial snow making, flexible lift ticket prices, development at higher altitudes, non-snow activities in winter, all-year tourism
- Behaviour based (education, ecological protection, evacuation plan, more indoor activities)
- Diversifying markets
- Research into site location that accounts for climate change risks
- Insurance coverage (e.g. cyclone and hurricane insurance)

LEADERS

- Caribbean resorts: Sandals, Club Med, SuperClubs, TNT vacations and Apple vacations are offering hurricane waivers and guarantees
- Coastal tourist resorts in Fiji: evacuation plans, cyclone proofing buildings, water, food and energy self-sufficiency.
- North American ski resorts: heavily invested in snowmaking technologies. Virtually all ski resorts in Ontario have snowmaking systems that cover 100 perent of ski-able terrain. In Quebec ski-able terrain covered by snowmaking is 50 to 90 percent in Quebec and 62 to 98 percent in the U.S.

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BARRIERS TO ADAPTATION

- Knowledge gaps regarding the vulnerability of tourist destinations across the developing world
- Competing priorities for scarce resources (e.g. beach front property development for short-term economic gain)
- Lack of knowledge implying that risks go unperceived and unacknowledged
- Insufficient financial resources to adapt even when risks are perceived (e.g. small-medium resorts unable to retrofit property and restore ecological zone due to financial constraints)
- Lack of capacity (e.g. qualified staff)
- Lack of government support

GAPS

- Research gaps: lack of regional climate models, imprecise current models, local studies not placed in context and not related to one another

ENERGY: OIL, GAS AND ELECTRICITY

The 17 sources reviewed in the energy sector revealed that all energy producers (coal, oil, gas, electricity) will likely face some risk to infrastructure (e.g. damage to power transmission lines, offshore oil rigs, flooding of power plants). The literature with regard to electricity generation, emphasized the risk of increased consumer demand during peak periods and potential failure of power grids to meet the demand given a warming climate. Conversely, natural gas companies may see a drop in demand for their products given warmer winters. Regulatory interventions by governments enforcing new GHG mitigation policies will see a reduced demand in carbon intensive energy products (oil and coal). As well, power generation, coal fired plants and oil extraction are all water intensive, and may face competition from other groups including agriculture producers and public water suppliers as water levels fall due to climate change.

Despite potential risks, the electrical energy industry stands to gain from increased consumer demand as well as societal shifting towards clean technology. Fossil fuel providers are investing in research and development of renewable energies such as geothermal, hydro, solar, wave, wind, and bio fuels.

These energy markets are expected to grow as societies move towards low-carbon economies.

Adaptation strategies include technological innovation (low-carbon energy), building infrastructure (power grid capacity and transmission capability), and behavioural and market strategies (encouraging energy conservation).

Table 5 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the energy sector.

Table 5 **SUMMARY OF ADAPTATION IN THE ENERGY SECTOR**[14]

RISK & VULNERABILITIES
• Highly exposed to climate risks across all industry activities, from electricity generation, oil and gas extraction, energy distribution and trading • High regulatory risk, physical risks and reputational risks • Reputational risk from being seen as a contributor to climate change • Business interruption and failure to meet contractual obligations due to extreme weather events • Interruption in fuel supply due to extreme weather and related events along the supply chain • Shifting demand patterns in energy demand from winter to summer • Loss in revenue due to climate impacts on customer demand, such as interruption of their businesses, decreased need for heating • Uncertainty over energy output from hydroelectric plants due to potential water shortages • Uncertainty over water supplies for cooling power plants • Summer peak demand could increase beyond maximum capacity • Hydro-electricity: Risk that decreased water volumes could be insufficient to meet peak demand • Electricity: Coal-based electricity, risk that decreased water volume could be insufficient to dilute cooling water effluent • Damage to facilities and infrastructure (power stations, oil rigs) from extreme unpredictable weather (flooding, storm-surges and rising sea levels) • Hot weather may reduce the efficiency of extracting energy particularly gas • Extreme weather events, such as Hurricanes Rita and Katrina, can mean losses in oil refining capacity and consequent oil price rises • As facilities age, and as more demand is put on them, they are more likely to fail under extreme events and incremental climate change

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[14]Adapted from Becken, 2005; Bicknell and McManus, 2006; Dawson, 2007; Dubois and Ceron, 2006; Elaser and Burki, 2002; KMPG, 2008; Gossling and Hall, 2006; Hennessy et. al., 2008; McBoyle et al., 2003; Moen & Fredman, 2007; Scott and Jones, 2006; EU, 2006; Scott et. al., 2006; UNEP, 2008.

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- Reduced energy demand for space heating in winter (e.g. milder winters in the Northern Hemisphere) could result in reduced energy demand
- Change in temperature, affecting efficiency of equipment operation
- Thawing of permafrost, resulting in ground shifts and instability, making exploration and production in northern regions more difficult
- Rising sea levels, threatening electricity generation facilities and refineries in coastal, riparian and estuarine locations
- Increased competition for water resources, leading to potential conflict between users such as power generators (for cooling and hydropower), public water suppliers and the agricultural community
- Ability to generate hydroelectric energy will reduce as temperatures rise in some countries (Canada, UK, USA)
- Supply and demand balance not realized
- Disruptions in supply chain from storm events
- Increased insurance costs
- Considerable business interruption risks in the face of weather-related catastrophes, especially in oil and gas

OPPORTUNITIES

- Growth in clean-tech (renewable energy, bio-fuels)
- Emerging technologies (fuel cells, photovoltaics and biomass)
- Growth in low carbon energy production
- Increased demand for energy-efficient technologies
- Increased energy demand for space cooling in summer
- Reduced costs for oil and gas exploration in the north
- Investing in carbon sequestration technology

DRIVERS

- Regulations
- Limited findings and research in this area

STRATAGIES

- Innovative measures to deal with record power demands due to hotter summers and increased peak demand periods: conservation and demand management strategies, cool building design and better insulation
- Public outreach for energy conservation

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- Move away from wet cooling power plants to dry or hybrid strategies
- Meet peak demand periods through multiple fuels and renewables
- Reimburse businesses willing to curtail daytime usage of electricity, redirect excess power from other parts of its network and purchase additional power from other countries
- Energy conservation programs
- Invest in green R&D: renewable energy portfolio investments
- Move toward decarbonized energy sources (wind, solar and hydroelectric)
- Market and trade low-carbon power
- Oil and gas technology research and development (e.g. advanced vehicles and fuel technology, and hydrogen generation technologies)
- Develop bio-fuel markets
- Invest in increased capacity and improved transmission distribution networks (hydro-electricity)
- Clean coal technology is being developed
- Nuclear technology as an alterative energy source
- Risk management and planning

LEADERS

- British Petroleum, Shell, Texaco, Hydro One Ontario, Entergy, Excelon, Florida Power and Light, and Constellation Energy

BARRIERS TO ADAPTATION

- Limited research and information (existing information on best practices is not readily available, information sharing networks in infant stage)
- Lack of available technology and decision support tools (power generation and transmission technology takes decades to research and implement, significant lag between design and implementation)
- Institutional networks between different levels of government and the energy sector have begun to develop adaptation strategies but are only in the preliminary stages

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GAPS

- None identified

WATER

The 15 studies reviewed on the water sector revealed that adaptation in the sector is critical because changes in the water supply and water quality have the potential to impact all other sectors of the economy which use water as either an input or output (e.g. hydroelectricity, agriculture, mining, forestry, fisheries, food and beverages, manufacturing, transportation and tourism). Moreover, water is a unique resource: it is necessary for all life on earth and as such is highly connected to the social, cultural and material fabric of society. As the climate changes, competition between actors (producers, people and ecosystems) is likely to grow, and water scarcity and competition over access is likely to become a defining issue in the 21st century as climate change reduces the quantity, availability, accessibility and quality of water. The water sector is also different from all other business sectors covered in this study in that it remains largely public or governed through public-private partnerships throughout much of the world.

The water sector will face a variety of risks as the climate changes. Changes in rain patterns and stream flow will impact the quantity and quality of water resources available for use. Warmer temperatures are expected to increase the demand for water while rising sea levels are expected to cause salinization and reduce freshwater supply. Regional variability will decrease freshwater availability in some regions more than others (i.e. droughts in sub-Saharan Africa). Extreme weather is expected to negatively impact the infrastructure of the water sector (e.g. flooding).[15]

Climate change presents few business opportunities for firms in the water sector. Although people tend to drink more water as the weather warms, limited or poorer quality supply will place pressure on suppliers potentially beyond capacity. However, the sector may see economic gains if innovation in water saving and water quality technologies is pursued.[16]

Adaptation strategies in the water sector emphasize the conservation of water, improved supply treatment, extracting water from new sources, and improving existing infrastructure and management capability.

Table 6 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the water sector.

[15]Adapted from the World Business Council for Sustainable Development, 2008.
[16]Adapted from the World Business Council for Sustainable Development, 2008.

Table 6 **SUMMARY OF ADAPTATION IN THE WATER SECTOR**[17]

RISK & VULNERABILITIES
• Reduction in the quantity and the quality of free water resources available • Increased water stress due to changing precipitation patterns and increasing frequency and intensity of floods and droughts • Decreased rainfall, water shortages and shrinking water sources (e.g. Himalayas) • Variable reliability of raw water sources (change in flow, variation in water availability, decreased water availability in some regions) • Water scarcity, which could stymie business operations, particularly those of water-reliant industries • Increased pollutant loading from more intense runoff • Increased treatment costs to maintain the same quality • Salination of freshwater; Salination of groundwater reservoirs due to aquifer penetration by rising sea levels • Greater demand for water as supply shrinks; regions dependant on glacial melt • Potential damage to water supply infrastructure during heavy rains or drought • Flooding of water supply works in riparian locations, leading to supply disruption • Infrastructure upgrade costs and damage from sewer flooding, associated with flash floods • Impact on other supply chains: food and beverage, agriculture, energy, automotive, tourism and manufacturing • Increased water scarcity • Industrial users in water-scarce areas likely to face increasing pressure to conserve water which may threaten a firm's license to operate
OPPORTUNITIES
• Increased demand for water-saving technologies and services • On very hot days, when consumers prefer water to quench their thirst
DRIVERS
• Awareness of water resource managers (e.g. links to the research community, interest of managers in climate change issues) • Concern over climate change threats (threats posed by climate change must be seen as equally important to other pressures) • Desire to maintain reputation • Need to meet increased regulatory requirements

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[17] Firth and Colley, 2006; KPMG, 2008; Llewllyn, 2007; PEW Center, 2008; WBCSD, 2008; Arnell and Delaney, 2006; Levinson et. al., 2008; CBI, 2008; Berkhout et. al., 2004a; Beirbaum, 2008; Easterling et. al., 2004; ICF International, 2007; Subak, 2000; Water UK, 2008.

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STRATEGIES

- Enhance the capacity to adapt through skills training, workshops, research
- Alter infrastructure or management practices to cope with impacts such as increased demand, lower water quality, etc.
- Invest in infrastructure for the containment, storage and transport of water
- New or enhanced reservoirs
- Ground water development
- Import icebergs
- Water metering in demand hot spots
- Conservation of water resources; technology, and promotion and education of water conservation
- Water reuse and recycling
- Use and collection of rain water
- Improve water supply and treatment systems
- Desalinate freshwater sources
- Low Regret Investing: Measures with relatively low costs for which benefits under climate change scenarios are high

LEADERS

- Anglian Water
- UK water sector

BARRIERS TO ADAPTATION

- Long lead time necessary for the implementation of new resource schemes
- Difficulties in exerting control over the demand for water (customers are rarely metered)
- Education strategies may be ineffective in curbing high use

GAPS

- None identified

BUILDING AND CONSTRUCTION

The systematic review found 16 sources that directly examined the impact of climate change on the building and construction sector. Many of the climate change risks to the sector revolve around a changing regulatory environment and new building codes. New materials and methods in building are needed as the life expectancy of buildings is longer and the physical risks of buildings to climate change is significant. Moreover, work within the sector may experience unexpected disruption and delays due to extreme weather events. Additionally, these organizations within the sector may suffer losses in property value as it either becomes undesirable due to increased exposure or uninsurable due to high risk or extreme weather events.

Opportunities in the sector are few. In northern climates, later frosts may increase the days available for construction. Also, in general, opportunities for building retrofitting to meet either energy efficiency regulations or to meet new hazard codes might arise as the climate changes.

Adaptation strategies in the sector include risk avoidance, redesign and technological developments. For example, avoiding construction in high-risk areas (tropical beachfronts) or changing building locations will greatly minimize the risks future properties might face as the climate changes. Redesign measures include taking into account flood risks and building flood-proof foundations, integrating natural defences into site design and changing building materials to deal with warmer weather. As well, technological developments in energy efficiency, new windstorm- resistant roofing and improved supply chain management may protect the sector from some of the risks it will face in a climate changed world.

Table 7 offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation in the building and construction sector.

Table 7 **SUMMARY OF ADAPTATION IN THE BUILDING AND CONSTRUCTION SECTOR**[18]

RISK & VULNERABILITIES
• High regulatory risk, medium physical risk • Litigation risk and reputational risk • Changes in building codes • Disruption of construction due to extreme events (restricting work days) • Disruption in delivery of materials and transportation infrastructure (muddy site) • Damage to building materials • Shortened time due to increased rainfall and wind • Increased regulation by planning authorities for the development of carbon neutral buildings • New regulations regarding flood zones, water savings, energy efficiency • Reluctance of customers to buy properties in areas of risk • Reduced or loss of property values • Refusal of insurers to cover properties at risk or expensive premiums • High temperatures may restrict the amount of time workers can safely engage in some tasks (roofing) • Increased UV exposure to workers may increase the incidences of skin cancer • Infrastructure affected by extreme weather events • Predicted physical risk with respect to commercial real estate include increases in sea level and a rising frequency and intensity of storms, including a lengthening of the hurricane season • Functional obsolescence • Inappropriate materials and design strategies • Modern housing is more vulnerable to flood damage because of the greater use of chipboard floors, dry wall plasterboard, cavity insulation and design features such as lower door thresholds to improve access
OPPORTUNITIES
• Reduced work stoppages caused by frost, thereby extending the portion of the year during which construction is possible • New product markets such as climate proofing materials and building designs • Locally sourced materials become more attractive

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[18] Berkhout et. al., 2004; Hertin et. al. 2003; Pew, 2008; KMPG, 2008; Llewllyn, J., 2007; Hecht, 2008; WBCSD, 2008; EU, 2006; Firth and Colley, 2006.

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DRIVERS

- Legislations and regulatory changes
- Long life span of buildings 20-100 years means that climate change needs to be planned for and taken into account in construction designs today

STRATEGIES

- Avoid construction in high-risk areas
- Design flood-proof buildings
- Work with government to build natural climate defenses (trees, green space)
- Products to pay for post-loss reconstruction upgrades to "green" building standards and commissioning to ensure energy savings
- Catastrophe-resistant building codes
- Redesign pricing
- Form environmental risk committees and working groups
- Retrofit older buildings
- To deal with hotter summers, include several features in building designs such as shading and natural high thermal mass, shading, and natural (open windows) or mechanical (fans) night ventilation.
- Change building materials
- Design buildings for potential future water constraints
- Change building locations
- Technological measures (the development of new roofing technologies against more intensive wind storms; or deeper foundations against increased problems of heave)
- Modular systems, prefabrication, larger drainpipes, flood prevention equipment and improved supply chain management

LEADERS

- None identified

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BARRIERS TO ADAPTATION

- Expect to see some polarization between the larger, more efficient companies, which would most likely choose to upgrade stock and smaller companies without the scale or financial capacity to do so
- Expensive or impossible retrofitting

GAPS

- Companies in the sector have low perceived vulnerability to climate change, despite the exposure and risks the sector will face as the climate changes
- Builders were far more aware of the need to mitigate greenhouse gases than of the impacts that climate change could have on their businesses and sector

FINANCE AND BANKING

The literature review found eight sources on finance and banking that discusses and analyzes the implications of climate change for the sector. The finance and banking sector's broad economic participation makes it exceptionally vulnerable to climate change around the world. The finance and banking sector contains organizations that have world-wide investments, portfolios, assets, debtors and collateral. They also have invested across sectors any of which may be adversely affected as the climate changes. As such, the sector will be exposed to climate change mostly indirectly. For instance, declining values in beach front properties and extreme weather events may increase the default rates on loans in the coastal tourism sector, and climate change may also reduce the collateral backing of such loans, leaving the property lender exposed. As well, poor disclosure regarding climate change risks and carbon footprints make evaluation of investments from a climate risk perspective difficult.

However, the sector is also positioned such that it can impact adaptation in all other sectors if financing includes evaluation of how potential clients respond to the challenge of climate change. Banks and financial institutions can require lenders to undertake climate change risk assessments and undertake carbon offsetting strategies by making these prerequisites for access to financing.

The finance and banking sector can greatly influence adaptation measures by offering financing for adaptation projects in all other sectors, developing microfinance schemes for developing countries, and providing consultancy and risk assessment services to other sectors. As such, there are some opportunities for the sector to find new markets, investments and ventures as the marketplace changes due to climate change.

Some early strategies emerging in this sector are the development of sustainable development funds that invest in clean technology, advancing the sophistication of risk management tools to include climate change impacts, developing special financial instruments that are related to potential weather changed, and encouraging further research on climate change risk and impacts.

Table 8 below offers a detailed summary of the risks, opportunities, drivers, strategies, leaders, barriers, and gaps in climate change adaptation in the finance and banking sector.

Table 8 **SUMMARY OF ADAPTATION IN THE FINANCE AND BANKING SECTOR**[19]

RISK & VULNERABILITIES
• Indirect risks, exposed through investment portfolios • Macroeconomic downturn hurts business volume • Market value of securities could be impacted by climate change • Uneven and unpredictable impacts on global markets and infrastructure rebuilding • Compounding risk across entire portfolio of converging activities (asset management, insurance, reinsurance) • Property damage risks to project finance and real estate finance • Cancelation of real estate insurance exposes property lender • Physical damage to corporate assets • Regulatory and political risks • Macroeconomic disruptions impairs long-term asset appreciation • Hidden carbon liabilities affect market value of securities • Real estate holdings impaired by weather events, increased energy costs • Reduction in competitiveness of GHG-intensive business investments • Potential deterioration in project economics and investment viability due to national financial policy responses to climate change • Uninsured damage to project assets • In retail banking, customer defaults due to climatic extremes • Threat of business failure when companies cannot maintain sufficient financial capacity to deal with climate risks • Impacted by both domestic and global extreme events due to the global nature of the sector

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[19] BInnovest, 2002; Ethical Funds Company, 2008; Aspen Publishers, 2008; Firth and Colley, 2006; Desjardins and Schuh, 2008; Deutsche Bank, 2008; Dlugolecki, 2000; London Climate Change Partnership, 2006; UNEP, 2006.

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OPPORTUNITIES

- Develop new markets and demand for new products related to GHG reductions and/or adaptation to climate change
- Assess credit risks associated with climate change as well as preserve crucially important carbon sinks
- Public/private partnerships in green municipal funds, etc
- Weather derivatives
- Finance climate resilient projects
- Finance clean energy technology development
- Finance infrastructure development arising from adaptation
- Enhanced project returns from sale of credits
- Lending by commercial banks to customers for energy efficiency-related projects
- New markets (e.g. political/regulatory risk transfer)
- Innovative climate-related theme funds (e.g. new energy)
- Consulting and advisory services
- Microfinance opportunities in developing countries

DRIVERS

- Financial risks and losses

STRATEGIES

- Investment community has set up “sustainable” investment funds and increasingly invests in renewable energy
- Ensure that contingency plans include worst-case disasters
- Some fund managers are assessing and responding to the implications of climate change now and in the future by encouraging appropriate research into the implications of climate change and by asking appropriate questions to reveal exposure to climate change and implications for portfolios
- Risk management of potential climate change impacts, development of sophisticated risk management tools
- Specialist financial instruments like catastrophe bonds and weather-related international trading markets
- Using the Equator Principles when investing (a set of procedures for identifying, evaluating and mitigating environmental risks associated with project finance)
- Lending money for renewable energy/energy efficiency, and are paid back through the energy savings carbon audit and assessment of climate risks faced by clients

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LEADERS

- Global banks are better prepared then local ones
- HSBC, TD Bank and the Royal Bank

BARRIERS TO ADAPTATION

- Climate change risks are still not a major concern

GAPS

- Wide variation in preparedness among banks
- The majority of finance executives feel unprepared to cope with the financial risks from current weather conditions

OTHER SECTORS

Data on climate adaptation in several other sectors (mining, forestry and fisheries, information and communication technology (ICT), manufacturing, transport, health and retail) were not comprehensive or sufficient to warrant individual sector-by-sector analysis. Therefore, available information regarding these sectors is consolidated in Table 9 and organized into risks, opportunities, drivers, strategies, leaders, barriers and gaps in climate change adaptation.

Table 9 **SUMMARY TABLE OF BUSINESS ADAPTATION IN VARIOUS SECTORS**[20]

RISK & VULNERABILITIES						
Mining	**Fisheries & Forestry**	**ICT**	**Transport**	**Manufacturing**	**Health**	**Retail**
Regulatory risk Energy and water Intensive sector, already susceptible Vulnerable to water shortages Rainfall and risk of flooding creates risk of overflow of storage reservoirs containing contaminants Economic policies on climate change could decrease demand for thermal coal and steel	Physical risks Risk of extinction of local fish, ecosystem services severely affected Change in sustainable harvests and mixture for all fish populations Change in forest yields, growth, migration of tree species and risk of forest fires Changes in fish stock and supply, changes in timber supply and rent value Changes in availability and price of commodities Business interruption and failure to meet contractual obligations	High users of energy, vulnerable to any damage to infrastructure or energy supply Increased risk of subsidence damage to communications masts and possible increased storm damage to overhead cables disrupting operations and processes Higher indoor temperatures can compromise high technology and precision engineering processes Vulnerable to any disruption in supply chain or manufacturing processes	Regulatory risk Significant contributor to GHGs, higher energy costs Relatively low preparedness Disruption of ground and marine transportation systems as a result of severe weather Supply chain interruptions: Inundation of transport routes, infrastructure and distribution facilities Failure to meet contractual obligations Transport infrastructure is vulnerable to flooding, which can cause severe disruption to services and require frequent repair	Regulatory risks and reputation risks Higher prices in raw materials Unanticipated changes in consumer preferences Disruption in supply chain Increased costs resulting from higher energy demand Disruption of coastal manufacturing facilities, transport networks, production facilities and infrastructure Business interruption, asset damage Failure to meet contractual obligations due to extreme weather events	Huge impact on human health Rise in the number of deaths resulting from heat waves Outbreak and spread of disease especially water borne illnesses New diseases in new regions Increased tropical disease Less water, dehydration risk Increased premature deaths associated with Lyme disease, tick-borne encephalitis, Dengue fever and malaria Changing distribution of some vectors of infectious disease and allergenic pollen species	Weather plays a significant part in affecting consumer preferences Complex distribution systems make this sector vulnerable to the impacts of climate change Distribution in supply chain All premises and transport systems are vulnerable to extreme weather events Damage to infrastructure along the retail product supply chain caused by extreme weather events Changing shape, size and location of markets for goods and services as regional change consumption patterns change

[20] Reinhardt and Packard, 2007; NRCAN, 2007; KPMG, 2008; Firth and Colley, 2006; Llewllyn, J., 2008; WBCSD, 2008; Cogan, 2006; Medelshon, 2000; Stennes, 1998; Carey, 2006; Ford et. al., 2008; Fisher, 2005; Miller et. al., 2008; Milllerd, 2005; Levinson et. al., 2008.

Mining	Fisheries & Forestry	ICT	Transport	Manufacturing	Health	Retail
		Climate change is likely to increase the operators' energy demands: higher temperatures will result in more air conditioning	Port and harbour facilities will need to be able to cope with changing sea levels, wind speeds and storm surges damage Any disruption within the transport sector has impacts for businesses in every other economic sector	Interruption in fuel supply due to extreme weather and related events along the supply chain	Changing impact on malaria regions Reduced productivity through increased incidence of disease and overheating of working environment Higher health insurance costs Higher expectations of companies to provide medicine and health care	Changing customer expectations as consumers avoid products perceived to be causing climate change

OPPORTUNITIES						
Mining	**Fisheries & Forestry**	**ICT**	**Transport**	**Manufacturing**	**Health**	**Retail**
Economic policies on climate change could increase demand for uranium and aluminum		In the position to help offset the effects of climate change as the products and services can contribute to displacement of goods and reduction of travel Development and marketing of innovative products and services which reduce dependence on carbon-intensive processes and lifestyles	Creation of new shipping routes as sea ice patterns change Creation of new markets for automotive Equipment suitable for specific climatic conditions Increased investment in rail networks Port expansion and use of deep water ports	Increased demand for low-water and other sustainable products and services, including energy-efficient products and services Increased demand for cooling equipment systems and services during hot weather Increased demand for resilient products Increased demand of retrofitting equipment components	Opportunities for delivering new products and treatments to meet the challenges of new diseases and health issues In higher latitudes, reduced healthcare costs as winters become milder, development of new medicines Increase in respiratory diseases, “diseases of the developing world”, and tropical diseases Could benefit companies manufacturing related drugs and vaccines	New product and service opportunities as weather changes consumer preferences

STRATEGIES						
Mining	**Fisheries & Forestry**	**ICT**	**Transport**	**Manufacturing**	**Health**	**Retail**
Water conservation and lower GHG emissions Risk modelling	Develop technology to understand the spatial distribution and relative abundance of fish stocks Reduce non-climatic stresses and maintain genetic diversity of fish stocks Increase monitoring capacities Improve research and communication with stakeholders	Companies may opt for home-working, video conferencing, electronic billing and electronic tax filing	Efficiency Lower fuel consumption Technological innovation (e.g. hybrid cars) Reduce fuel emissions Develop more light-weight materials with greater electronic components Truck engine manufacturers will continue to invest in reduced emission engine technology	Develop energy efficient technologies		

BARRIERS TO ADAPTATION						
Mining	**Fisheries & Forestry**	**ICT**	**Transport**	**Manufacturing**	**Health**	**Retail**
				Risks largely unexplored	Largely unresponsive to risks and climate change potentials	

GAPS						
Mining	**Fisheries & Forestry**	**ICT**	**Transport**	**Manufacturing**	**Health**	**Retail**
		Companies in this sector are strongly advised to have well designed and tested business continuity plans	The auto and machinery sector should review climate risks to supply chains and logistics, particularly where extreme events have potential to disrupt			

SUMMARY OF KEY POINTS

- Information on risks, opportunities, adaptation strategies, leaders, laggards and barriers exists sporadically on a sector-by-sector basis. There have been very few cross-sectoral studies. This may be due to various causes such as the sector specific nature of climate change, the relatively recent (since 1999) focus on this field of research and/or proprietary access to sensitive decision-making information.
- Climate change is clearly seen as a risk and an opportunity. The Carbon Disclosure Project (2008) finds that executives see climate change risk and opportunities both in the 80th percentile.
- The **Insurance sector** is arguably the most advanced in evaluating risks and opportunities. Major adaptation initiatives in the insurance sector have focused around building institutional networks that address common industry risks through collaboration. It is likely that the Insurance sector leads in this area due to its vulnerability, but also because of its historical experience in risk management and climate-related risks.
- The **Agricultur sector** is already adapting to climate change on a season-to-season basis. However, it is unclear how agriculture will adapt to climate change in the long term as the risks and opportunities are still uncertain. This sector will rely heavily on government support and intervention for climate change adaptation.
- The **Tourism and Recreation sector** appears to have a general idea of the risks that it will face. However, only firms in regions that are already affected (northern mountains and tropical destinations) are adapting to climate change using technical, managerial, financial or behavioural adaptations. It is unclear how tourism in other areas will be affected by climate change. It appears that stable weather is an important determinant of destination attractiveness.
- The diversity of the **Energy sector** makes the evaluation of risks and opportunities arising from climate change difficult to generalize. Adaptation strategies also vary considerably from firm to firm depending on how climate change is expected to affect the sector.
- The **Water sector** has the fewest opportunities arising from climate change, and for the most part will need to deal with the risks associated with changing weather and water availability and quality. Currently, the sector is adapting with conservation measures.
- In the **Building and Construction sector**, the greatest risk from climate change surrounds a changing regulatory environment and new building codes. Opportunities in the sector from climate change are few. Adaptation strategies in the sector include risk avoidance, redesign and technological developments.
- The **Finance and Banking sector's** broad economic participation makes it exceptionally vulnerable to climate change around the world. The sector has investments, portfolios, assets, debtors and collateral across the world and across sectors, any of which may be adversely affected as the climate changes. The Finance and Banking sector can greatly influence adaptation measures by financing adaptation projects in all other sectors, developing microfinance schemes for developing countries and providing risk assessment services to other sectors.

best practices, case studies and lessons learned

This section features sector-based case studies discovered through the systematic review.

The systematic review uncovered only 39 instances where case studies, lessons learned and best practices in business adaptation to climate change were described or mentioned. In these, case studies and lessons learned often tended towards exemplifying business responses to climate change by way of GHG mitigation and low carbon footprint strategies (e.g. Kolk and Pinkse, 2005; Carbon Disclosure Project, 2008; Bansal and Gao, 2008; Begg et. al., 2005; CBSR, 2007; Cogan, 2006; PEW, 2006; Anglo Gold Ashanti, 2008; Economist, 2006; Economist, 2000). However these findings were excluded from this study as they were outside of the scope of the research questions.

Most literature on lessons learned, best practices and case studies tends to be general, discussing only the potential for adaptation or naming limited examples of business adaptation by sector. This literature tends to feature short example summary cases on potential responses. The scope of primary research on companies and their adaptation practices is exceptionally narrow (Berkout et al. 2004, Pew 2006, Carbon Disclosure Project 2008), making any generalizations regarding lessons learned and best practices difficult to ascertain. The reasons for this knowledge gap may be threefold: 1) most businesses have yet to undertake adaptation measures despite real risks and vulnerabilities to climate change, possibly due to lack of knowledge, inadequate risk modelling and poor information on future climate change variability 2) businesses that have taken on adaptation measures have done so only recently and it is too early to gather empirical findings or literature in this area and 3) the focus of business response remains on GHG mitigation.

In this section, we feature sector-based case studies that were discovered through the systematic review. We synthesize lessons learned and best practices wherever possible given the limited findings. Due to the sporadic and insufficient information in this area, we suggest that future studies and research focus on primary research in business adaptation to uncover potential case studies, lessons learned and best practices.

BEST PRACTICES

Best practices were discussed in only four of the studies gathered during the systematic review. The limited literature reveals that best practices in business adaptation focus on responses to climate risk that either minimize profit loss or turn a climate risk into a profit opportunity. For example, with respect to minimizing profit loss, Dubios and Ceron (2006) note that a “wait and see approach” tends to dominate where short-term financial solutions appear to be more efficient, particularly when knowledge on the concrete impacts of climate change is limited. From the literature in business adaptation to climate change reviewed in this study, it appears that the majority of businesses likely fall into this category, with adapters being the exception rather than the rule.

However, where potential market opportunities from climate adaptation arise, there is some activity in the business community. The insurance industry, prone to suffering heavy losses as a consequence of climate change, appears to be a key leader. It has been quick to identify successful elements of adaptation to weather extremes and changes (i.e. Hurricane Katrina 2005, european heat wave 2003). According to Chemarin and Picard (2008), insurers have to prepare for adverse

climate effects on business and help customers identify potential risks. Insurers have been responsible for building better risk models and providing products and services that mitigate risks to climate change. The insurance industry is increasingly collaborating with other sectors, experts on climate change, NGOs and policy researchers intent on finding solutions to climate change.

CASE STUDIES

Case studies appeared in 30 sources found through the systematic review. In some instances, there was only brief mention of a particular company taking on climate adaptation strategies or potential adaptation measures by business (Pew 2008, UNEP 2008, Pew 2006). While short snapshots of information on companies were made available in several instances on either risks, opportunities or adaptation strategies (CBSR, 2007, PEW Centre 2006, Lehman Brothers or Levinson et. al., 2008), it was not common to find comprehensive cases that included all three. In other instances, detailed cases were made available as learning aids and problem-solving exercises for business faculties and their students (Mikes, 2008, Carbon Disclosure Project 2008, Bansal and Gao, 2008), but these provided little information as an example of best practices or lessons learned. In other instances, generalizations were made in case study research without disclosing the identity of the businesses studied (see Berkhourt et. al., 2004).

The data in this area is sporadic and lacks more comprehensive examples of actual adaptation strategies in specific companies. It is recommended that future research focus on the gathering of primary data from companies to produce specific case studies on business adaptation to climate change.

In the following boxes, we have summarized the available information by sector-based case studies in business adaptation to climate. These are direct extractions from the case literature gathered during the systematic review, simplified and copy edited in places for better readability. The cases were selected based on availability and richness of information.

Box 2
INSURANCE SECTOR CASE STUDIES

Allianz Group[21]
Adaptation to climate change is any activity that reduces the negative impacts

Allianz Group, with business lines in insurance, asset management and banking, has created the first flood catastrophe bond to mitigate the risk of severe, regional floods with a global fund, thereby spreading the risk across clients as a form of climate adaption. Allianz are providing micro-insurance to vulnerable populations most likely to be affected by climate change. As a result Allianz has acquired 100,000 new customers since 2003.

Munich Re[22]
Collaborating among insurers, stakeholders and leading researchs

Munich Re operates across the insurance and reinsurance value chain. Munich Climate Insurance Initiative was founded in 2005 by Germanwatch, International Institute for Applied Systems Analysis, Munich Re, Munich Re Foundation, Potsdam Institute for Climate Impact Research (PIK), the Swiss Federal Institute of Technology, the Tyndall Centre for Climate Change Research and the World Bank. Its aims are to: 1) Develop insurance-related approaches to impacts of climate change, combining resources and expertise of public and private sectors 2) Support pilot projects for insurance-related solutions in partnerships and through existing organizations and programs 3) Advance insurance-related approaches with other organizations, identify success stories and disseminate information on success factors and 4) Promote loss reduction measures for climate-related risks. As well, Munich Re is undertaking geo-risks research, covering all pertinent disciplines like meteorology, seismology, geology, geophysics and geography. The initiative gives advice and provides services for all in-house departments and external users dealing with issues related to natural catastrophes and needing geoscientific knowledge. It has published many reports on the impacts of climate change on the insurance industry.

Swiss Re and BASIX[23]
Refinancing of microfinance networks

In India, a microfinance institution BASIX insured some of its crop lending portfolio against a monsoon deficit during the period July to September 2004, with an Indian insurer, backed by reinsurance into the international risk transfer market with Swiss Re, a reinsurer with expertise in risk transfer. It covered three business units in three districts, with a sum insured of about 15,000 USD for a premium of around 1,600 USD. The pilot was restricted to only three branches in BASIX in the state of Andhra Pradesh and covered only the crop loan portfolio of these branches. Thanks to this weather hedge, BASIX maintained its credit operations in those drought-prone “risky” districts, therefore benefiting the local economy and farmers. The facility improved the quality of the BASIX portfolio, which makes it a more attractive partner for other financial institutions and enables further expansion.

[21] United Nations Framework Convention on Climate Change, 2008. For all case studies, text copied directly from the reference, then simplified and copy edited for readability.
[22] Llewllyn, John, 2007
[23] UNEP, 2006,

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The Travelers Companies Inc[24]
Linking the interests of homeowners, business, and insurance providers

The Travelers Companies Inc. is one of the largest providers of personal and commercial property and casualty insurance products in the United States.

Following the severe 2004 and 2005 Atlantic hurricane seasons, the company determined that a more cohesive and integrated approach to climate risk was needed. Travelers formed a number of new internal working groups and expanded the roles of existing groups to address exposure and risk associated with climate change. Travelers continue to be engaged in initiatives designed to reduce exposures to extreme weather events for itself and its customers. These actions include providing information and price incentives for insured parties to help mitigate personal and commercial losses due to extreme weather events, reassessing its exposure to risk because of changes in climate, and modifying pricing strategies and policy terms and conditions to reflect updated assessments of current and future risks.

Specific actions that Travelers has taken to adapt to climate change include:

- Reassessing coastal underwriting practices: The definition of coastal areas has been expanded to include counties farther inland than previously considered and contractual terms of coverage now include more sharing of responsibility for both households and businesses.
- Updating catastrophe modeling: Travelers joined an effort initiated by the Center for Health and the Global Environment at Harvard Medical School that is drawing together a number of business and academic stakeholders to determine how catastrophe models can better integrate climate change science and estimate potential loss.
- Offering "Risk Control" services: Travelers provides assistance with a range of loss mitigation and adaptation techniques. These include monitoring building code standards and regulations in support of building resiliency, providing assistance in disaster preparedness planning and delivering business continuity training.
- Redesigning pricing: Pricing strategies for commercial and personal customers take into account differences such as building age, construction and loss mitigation efforts, which affect likely losses during extreme weather events due to changes in building codes over time. Travelers has also introduced pricing strategies to encourage environmentally responsible behaviour. This includes providing discounts on car insurance for drivers of hybrid-electric automobiles and enhanced coverage for owners of "green" commercial buildings.
- Engaging in community and government outreach: Broad-based efforts encourage disaster awareness and preparedness among homeowners and commercial customers. These efforts also focus on providing information to governmental organizations about the benefits of long-term loss mitigation strategies, including the adoption and enforcement of more robust building codes and enhanced land-use planning.

[24] Susmann and Freed, 2008: 23-25

Box 3
TOURISM SECTOR CASE STUDIES

Sandals, Club Med, SuperClubs, TNT Vacations, and Apple Vacations[25]
Improving customer confidence in attractiveness of destination

The Caribbean region and Gulf of Mexico are expected to experience increased summer temperature extremes, changes in demand seasonality and potential for increased frequency or strength of hurricanes as a result of climate change. The Caribbean Tourism Organization and individual member states have begun to actively market themselves as four-season destinations in the late 1990s with multi-million dollar advertising campaigns that target the honeymoon market and budget-conscious families. In combination with marketing messages that downplay the region's summer heat are upgraded air-conditioning, discounted room rates and new hurricane interruption policies at many resort companies, including Sandals Resorts, Club Med, SuperClubs, TNT Vacations and Apple Vacations. The hurricane guarantees or waivers differ slightly from company to company, but basically provide a replacement stay of the same duration and equivalent value as the one originally booked. The strategy has proven successful as summer occupancy rates at beach resorts are approaching or equalling winter season in many destinations. The State of Florida allocated US$30 million to "hurricane recovery" marketing following the devastating sequence of four hurricanes in 2004 and developed a weather insurance program for convention organizers, where it pays the premiums for US$200,000 insurance coverage for rescheduling costs associated with hurricane disruption.
(UNEP, 2008: 58)

Fairmont hotels[26]
Implementing a sustainable tourism strategy for today and the future

The Fairmont hotel chain was looking for a way to reduce negative impacts on the environment and increase operational efficiencies while enhancing their guests' hotel experience. The "The Fairmont Green Partnership Program" includes tracking energy used in each room through the use of sub-meters in the Vancouver hotel, allowing guests the opportunity to have their sheets replaced less often, reducing water and energy usage, replacing and fixing leaky steam traps and fixing leaks to reduce steam consumption, installing automated climate control systems in Ottawa's Château Laurier to return room temperature to a pre-set point upon guest check out to save energy. Through their efforts the Fairmont reported an increase in cost savings and a reputation as an environmental leader in the hotel industry, giving the hotel chain a competitive advantage.

[25] UNEP, 2008: 58
[26] CBSR, 2007

Box 4
WATER SECTOR CASE STUDIES

Thames Water[27]
Changing infrastructure

Thames Water, the U.K.'s largest water and sewage company, is adapting operations already by putting new design standards in place to prevent sewer flooding, improving water efficiency and working with stakeholders to determine how to maintain service levels as climate impacts occur.

Anglian Water[28]
Conserving water, changing infrastructure and raising awareness

Anglian Water, part of the Anglian Water Group, provides water and wastewater services to around six million industrial, commercial and domestic customers in the east of England and Hartlepool. It has set climate change priorities to mitigate and adapt to climate change impacts, increase the resilience and reliability of water and wastewater service, keep bills at current affordability, secure and conserve water resources and improve the environment in the region. As one of the largest energy users in the region, the company also recognizes its responsibility to reduce its carbon emissions to limit its contribution to climate change. Anglian Water's climate change strategy assesses the impact of the main climatic changes on its operations and identifies what actions are required to continue to deliver its vital service. Anglian Water has developed an adaptation strategy to prepare for the implications of climate change in the east of England.

Anglian Water has been building adaptive capacity within the company through a program of raising awareness with staff undertaking research to investigate what measures are required to protect critical infrastructure from future flooding events and undertaking a project with the Tyndall Centre to understand the implications of sea level rise for coastal assets. Adaptation actions are now being delivered at a number of sites including Great Yarmouth where the company has utilized its knowledge of rainfall intensity changes over recent years to validate an increase in the design capacity of its proposed sewer improvements in the town over the next two years. Other areas include the development of new lagoons at Rutland Water which will provide new wildlife habitat for the internationally important wildlife that may be displaced when more water is abstracted from the reservoir to meet the demands of growth and the impacts of climate change.

Anglian Water has a carbon reduction strategy to save on energy costs and reduce emissions by 60 percent by 2050, 10 percent of which will occur by 2010. The most visible benefit of Anglian Water's climate change program in the short term is reducing energy costs. The company has already achieved a 15 percent reduction (based on 2006/07 baseline of 748 KWh) towards its target of cutting costs by 20 percent by 2010. Anglian Water has been recognized as an industry leader on energy management which has raised awareness and increased trust among key stakeholders.

[27] UNFcc, 2008
[28] Anglian Water, 2008 pages 1-4

Box 5
ENERGY SECTOR CASE STUDY

Entergy[29]
Adapting to current and future climate change

Entergy Corporation is an integrated energy company engaged primarily in electric power production and retail distribution operations. In 2001, Entergy set a voluntary goal of stabilizing emissions at 2000 levels through 2005, becoming the first electric utility in the country to announce such a target. After meeting that goal, it set a new target in 2006 to reduce greenhouse gas emissions from its operating plants and stabilize those emissions at a level 20 percent below year 2000 levels from 2006-2010.

After suffering $2 billion in losses from Hurricanes Katrina and Rita, Entergy considers itself the prime example of the potential negative physical effects of climate change. While Entergy points out that the 2005 hurricanes cannot be clearly linked to climate change, the New Orleans-based energy company believes the storms can be viewed as a sign of things to come if greenhouse gas emissions are not brought under control. Facing significant infrastructure damages and forced relocations of several offices located in New Orleans, the hurricanes prompted CEO Wayne Leonard and other senior managers to begin preparing for potential future climate impacts and adapting to observed changes in climate.

The company has already taken important steps to adapt to the changing climate, but knows it will likely have to do more in the future. Following Hurricane Katrina, Entergy took immediate action to relocate important business centres, including moving a data centre to Little Rock, Arkansas, creating redundancy in data storage throughout the service area, and moving its transmission centre to Jackson, Mississippi. Entergy made decisions about where to locate these important business centres based in part on information about the climate-related risks in different geographic regions within the service area and in order to locate centres and buildings in different parts of the service area. In addition, Entergy put together a business continuity group specifically to look at broader implications of climate in the context of other serious business threats, including terrorist acts and a potential flu pandemic. The group, which included both in-house experts and consultants in the fields of security and medicine as well as energy, undertook a three-phase analysis.

The first phase was a scoping study identifying climate and related-risk drivers. This study identified likely changes in a number of key climatic and related physical effects over the near term (20 years), medium term (20 to 50 years) and long term (end of the 21st century). Using GIS (geographic information system) techniques, consultants mapped potential changes in climate and physical effects to Entergy's service area and to other areas where Entergy has large-scale investments. The second phase looks at the correlation of each identified risk with Entergy assets or operations, in order to identify candidate threats for response and adaptation. The third phase has not yet begun, and will assess existing risk mitigation plans and seek alternatives to reduce impacts. In the near term, Entergy recognizes that unchecked climate change poses potential long-term risks to the economic viability of Entergy's franchise and asset base, both of which are located in an area that is vulnerable to flooding and hurricanes. The recent intense hurricanes that ravaged the Gulf Coast have put Entergy's business continuity planning to the test and provided valuable lessons on how to manage near term physical risks, restore systems and recover from devastation.

The next steps will require more careful deliberation as they are likely to be more expensive and taken in anticipation of events expected to occur over a longer time horizon.

[29] Susmann and Freed, 2008 page 25-28

Box 6
MINING SECTOR CASE STUDIES

Rio Tinto[30]
Designing to weather, climate and climate change

Mining giant Rio Tinto is a member of the U.S. Climate Action Partnership, a coalition of 27 major corporations and six leading nongovernmental organizations calling on the U.S. Congress to pass legislation establishing mandatory limits on greenhouse gas emissions at the earliest possible date.

Rio Tinto's interest in adaptation was first motivated by an internal climate change risk assessment undertaken in 2002, which prompted the company's management to ask, "If the climate is going to change, what does that mean for our operations?" Rio Tinto was already engaged in climate change policy and emissions abatement work, and an evaluation of potential climate impacts seemed a natural extension. The company's first adaptation study was a desk-top review using the IPCC's Third Assessment Report (TAR), knowledge of Rio Tinto operations and phone interviews with site managers to identify the types of climatic variables that would be important to Rio Tinto's diverse businesses. The study looked at actual impacts of weather events and predicted climate changes described by the TAR. The order of magnitude scoping study concluded that – broadly defined – changes in climate could be important and should be considered more deeply.

Rio Tinto followed with a second study that focused on the implications of climatic changes at a finer spatial detail. For this study, the company asked the Hadley Center for Climate Change in the U.K. to provide a summary of how climate variables might change over the next 25 to 50 years to assist in understanding the geographic regions where Rio Tinto has mining interests, or relies on supporting infrastructure and services, such as electricity supply, water, shipping lanes and roads. Included in this study was an examination of weather insurance and Rio Tinto's actual exposure to weather-related events. As part of this study Rio Tinto also commissioned external engineering consultants to undertake a review of how potential climate change had been incorporated into engineering design standards and what the greatest vulnerabilities were. This study was completed in 2005.

Rio Tinto concluded from these studies that regions in which it operates will experience changed climate regimes. In the near term the changes are minimal, but are expected to increase over the longer term. Consequent impacts to its businesses are likely to occur gradually, allowing time for operations to learn and adapt. The work also indicated that building and engineering codes and standards have been slow to incorporate climate change risks. The studies indicated that, properly applied, current standards would provide adequate protection to weather events and so major upgrades to existing structures would not be required in the short to medium term. Over the longer term, Rio Tinto's exposure to climate risk is likely to vary by location. North American assets, for example, appear less vulnerable than those in the Southern Hemisphere, where increased intensity of cyclones and drier conditions are both predicted.

This work is now being followed with very detailed site assessments for many of Rio Tinto's higher priority sites. The sites have been selected based on their remaining life, prospective developments and expansions, and their location in climate sensitive lparts of the world. The assessments are underpinned by high resolution climate modelling (down to 20 kilometre by 20 kilometre grids), which are able to provide some indication of changes in cyclonic activity and topographic effects.

Rio Tinto's chief climate change concerns are about water: either having too much (floods) or too little (drought). While Rio Tinto does not ascribe any individual weather event to climate change, it believes the more extreme events it experiences could occur more frequently. In addition, Rio Tinto is concerned with reports that climate change will induce deeper and/or more frequent droughts. Partly as a result, it has developed a strong water strategy to respond to various aspects of droughts and floods.

[30] Susmann and Freed, 2008: 25-28

Continued from previous page

Anglo Gold Ashanti[31]
Preparing to mitigate and adapt to climate change

Anglo Gold Ashanti is a global mining company, headquartered in Johannesburg, South Africa. The company has 21 operations and a number of exploration programs in both the established and new gold-producing regions of the world www.angloglod.com). Anglo Gold's climate change strategy began with a carbon footprint analysis and set a stretch target for reducing greenhouse gas emissions on a per ounce basis of 25 to 30 percent (AngloGold 2007: 186). The vulnerabilities of Anglo Gold to climate change include: more frequent and more intense storm events requiring more costly engineering safeguards for tailings facilities, waste rock dumps and other vulnerable structures, reduced water availability which will have an impact on processing capacity at some sites, higher insurance premiums and increased expectations from host governments for corporate involvement in managing the challenges of adaptation to climate change. However, climate change also presents several opportunities including cost savings from energy switching and efficiency projects, enhanced relationships with key stakeholders as the company develops grass-roots adaptation projects, and working with host governments and industry to develop wide-ranging adaptive capacities and technology changes.

Box 7
TECHNOLOGY SECTOR CASE STUDY

Siemens[32]
Developing solutions in infrastructure for climate change adaptation

Siemens, a diversified electronics and electrical engineering company, developed a portable water purification system that does not require electricity or purification chemicals, but is low cost and easily available. This has opened a market opportunity to cater to the needs of disaster risk communities, a market that may grow as climate extremes become more prevalent. They have also formulated state-of-the-art infrastructure for buildings, which can reduce energy consumption up to 30 percent.

[31] Ashanti Gold , 2007
[32] UNFCC, 2008

Box 8
AGRICULTURE CASE STUDY

Meinert Enterprises[33]
Adapting to climate change through changing growing patterns and spreading risks

Meinert Enterprises is a southwestern Saskatchewan agriculture operation concerned with dryland farming. Meinert produces cereals, pulses and forages in a continental climate on approximately 6,000 acres of land. Conditions are semi-arid and challenging due to both annual and seasonal variability and unpredictable frosts. Typically, there are 110 frost-free days, an average of 15 inches of moisture and an abundance of sunlight in the region. Noting that farm decisions must include managing several factors at once, challenges include economic risks related to interest rates, dollar value, energy costs and the need to maintain a consistent cash flow in a highly variable environment related to marketing and income. Uncertainty in these factors is exacerbated with the uncertainty in climate and weather conditions. In recent years, the major concerns pertain to moisture levels. Meinert Enterprises employs several farm practices to lessen the negative effects from moisture deficits including: trapping snow with stubble from the crops (some crops leave more desirable stubble than others); diversifying crops to include those with greater drought resistance, varying maturation lengths and different stubble heights; enhanced early moisture infiltration; and employing crop rotation to improve soil quality. Meinert also employs different strategies for managing farm finances in light of climate/economic risks, including taking part in income stabilization programs, buying crop insurance, relying on help from family and earning off-farm income.

[33] C-CARIN 2004: 5

Box 9
FINANCE AND BANKING CASE STUDY

Toronto-Dominion Bank Financial Group[34]
Improving environmental risk assessments

TD Bank offers personal, commercial and wholesale banking, insurance and wealth management services. With the June 2007 release of its Environmental Management Framework, TD is helping to set the bar in Canada on what banks can and should be doing to mitigate climate risk. The Environmental Framework now includes a statement on climate risk and addresses carbon intensive industries including oil and gas, coal, electricity generation and metals production. Significantly, TD has called for governments to implement a carbon tax to provide incentives for GHG emissions reductions. To begin the process of climate risk mitigation, TD is committed to a carbon audit and an assessment of climate risks faced by their clients. The Environmental Framework indicates that their climate change policy will extend beyond lending to underwriting and equities research. TD's framework also addresses risks associated with loss of biodiversity, which extends to financing, underwriting and advisory services. TD is engaging clients to increase the bank's understanding of the risks involved in conducting operations in high conservation value forests. For clients involved in logging operations, TD is asking for third party sustainable forest management certification. TD categorically states it will not finance operations that significantly degrade critical natural habitats. The protection of high conservation value forests is particularly important. Canada's boreal forest represents a crucial opportunity for protection. To guide implementation of the Environmental Framework, the risk committee of TD's board of directors oversees all environmental policies, including climate. TD also has a high level Environmental Steering committee made up of business directors from across the bank. To build capacity, TD has assigned staff to implement and further evolve its climate-related policies. TD is committed to supporting organizations working on technical issues to better enable conservation assessment and planning.

[34] Credit risk, Biodiversity and Climate Change, 2008

LESSONS LEARNED

The systematic review revealed only five studies[35] that discussed lessons learned in business climate change strategies. Like in the case of best practices, these lessons focused on GHG mitigation, even though the general findings could potentially be applied to adaptation given their broad nature. The Pew Center's 2006 study identified four overarching lessons from a 100-question survey distributed to 27 members of the Business Environmental Leadership Council (BELC). These lessons cut across all elements of climate-related strategies and involve timing, commitment, policy development and business opportunity (PEW, 2006: 6). Ensuring the strategic timing of climate action is critical: while there is danger in pursuing initiatives too early, there is also danger in starting too late and losing competitive advantage and opportunity, given that resources and lead time are required to develop effective climate strategies. Establishing appropriate levels of commitment to climate strategies is an important lesson learned from corporate experience with GHG mitigation. And given that the policy and market impacts of climate change are still very uncertain, it would be unwise for any single company to get too far ahead of the general business community in mitigation and adaptation, and pursue initiatives that may not yield financial or strategic benefits (PEW, 2006: 6). Moreover, it is important that a company should not pursue new climate opportunities independent of its overall competitive strategy.

[35] Hofmann, (2006); Ross, et. al. (2007); Sussman and Freed (2008); Hoover and Roberts (2007); Hunt, (2008)

tools for business

This section identifies tools to help businesses assess risks, evaluate opportunities and implement adaptation options.

The systematic review found 17 sources in which tools for business adaptation were mentioned. These tools allow businesses to assess climate **risks**, to evaluate **opportunities**, to identify and implement **adaptation** options and to **disclose** actions and outcomes. The sources of these tools for business are presented in Tables 10 and 11.

In the area of risk tools, various risk-screening processes, decision-making frameworks and potential impact assessments are available that allow companies to "plug in" their own variables. The literature review identified five types of climate change risk tools. The most widely identified, appearing in nine studies, is risk frameworks. A risk framework is a step-by-step risk management process which allows companies to screen particular risks to their business practice, analyze and evaluate those risks, and finally treat those risks by identifying and implementing adaptation options. Another type of risk tool is a scenario tool, which appeared in five studies. Scenario tools allow businesses to use projections of potential climate change scenarios to assess potential risk to their operations. Decision trees were presented as a risk tool in two studies and are another type of step-by-step risk management process that take the format of yes/no questions which guide the reader to suggestions for action. As well, costing tools were identified in two studies. Costing tools allow businesses the ability to assess what the potential financial impact of climate change may be on various aspects of their business. Finally, one study used a computer simulation tool to identify risks. This tool uses a behavioural software model that attempts to identify the likely points at which companies will form a "belief" in climate change as a priority for organizational adaptation.

With respect to tools for evaluating climate change opportunities, there are very few tools identified in the literature. Only one study identified an existing opportunity tool to give businesses a framework of current and potential opportunities made available by climate change. This tool was a list of current opportunities across sectors that businesses could scan to locate those applicable to their operations and strategies.

In general, there are five types of adaptation tools identified in the literature: adaptation identifiers, step-by-step guides, success measurement, adaptation networks and adaptation option tools. Adaptation identifiers appeared in eight studies. These tools allow businesses to identify adaptation options via a set of questions that businesses can use to make a self-assessment of what category of adaptation options might be suitable for their particularly situation, such as available resources to devote to adaptation, human capital and knowledge within the firm capable of executing adaptation, and available technology.

Step-by-step guides appeared in seven studies and are a comprehensive adaptation tool that typically incorporates some type of risk framework. They allow businesses to identify and choose appropriate adaptation options and suggest a form of monitoring or feedback to self-assess the appropriateness of the adaptation in practice. Tools for measuring adaptation success were found in six studies. These are typically benchmarking tools that provide businesses points for testing the effectiveness of adaptation measures to evaluate its success. The review also identified six adaptation networks which allow businesses to connect to networks concerned with adaptation. Finally, five studies made note of adaptation option tools that allow businesses to pick adaptation options best suited to particular risks they are already facing or likely to face from climate change.

In addition, there was one study that provided a tool to guide managers in disclosing their adaptation activities. This tool was a short guide of possible climate related disclosures that investors may be concerned with and a list of resources that businesses can tap into to disclose those risks.

Table 10 **CLIMATE CHANGE RISK AND OPPORTUNITY TOOLS FOR BUSINESS**

SOURCE	SOURCE TYPE	SECTOR	TOOLS FOR	RISK TOOLS					OPPORTUNITY TOOLS	
				Risk Framework	Decision Tree	Scenarios	Simulation	Costing	Current Opportunity	Future Opportunity
Australian Greenhouse Office (2006)	Government Report	All	Private Sector	◆						
Blenda & Shackley (2008)	Peer-Reviewed Journal	All	Academics/ Private Sector				◆			
UK Climate Impacts Prog. (2009)	Government Report	All	Private Sector	◆		◆		◆		
Sullivan et. al. (2008)	Think Tank	All	Gov/Private Sector	◆						
UNEP (2008)	International Organization	Tourism	Gov/Private Sector							
AXA Insurance (2006)	Industry Rep.	Small Business	Private Sector	◆		◆				
Chartered Accountants of Canada (2009)	Industry Rep.	All	Private Sector							
Eldis (2009)	Website	All	All							
UNDP (2007)	Website	All	All	◆		◆				
Deutsche Bank (2009)	Private Sec	All	Private Sector	◆				◆		
Conference Board of Canada (2008)	Industry Rep	All	All							

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SOURCE	SOURCE TYPE	SECTOR	TOOLS FOR	RISK TOOLS					OPPORTUNITY TOOLS	
				Risk Framework	Decision Tree	Scenarios	Simulation	Costing	Current Opportunity	Future Opportunity
Toled et. al. (2008)	Dissertation	All	All	◆						
Berkhout et. al. (2004)	Think Tank	All	Private Sector	◆		◆				
CBSR (2007)	Think Tank	All	Private Sector	◆		◆				
Freed and Sussman (2006)	Think Tank	Water	Gov/Private Sector							
ICF International (2007)	Think Tank	Water	Gov/Private Sector			◆				
Lash and Wellington (2007)	Non-Peer Rev, Journ.	All	Private Sector			◆			◆	
Pew Center (2008)	Think Tank	Alll	Private Sector	◆						

Table 11 CLIMATE CHANGE ADAPTATION AND DISCLOSURE TOOLS FOR BUSINESS

SOURCE	ADAPTATION TOOLS					DISCLOSURE TOOLS	
	Adaptation Identifiers	Adaptation Options	Success Measurement	Step-by-step Guide	Adaptation Networks	What to Disclose	How to Disclose
Australian Greenhouse Office (2006)							
Blenda & Shackley (2008)							
UK Climate Impacts Prog. (2009)	◆	◆	◆				
Sullivan et. al. (2008)							
UNEP (2008)	◆	◆	◆	◆	◆		
AXA Insurance (2006)							
Chartered Accountants of Canada (2009)					◆	◆	◆
Eldis (2009)					◆		
UNDP (2007)	◆	◆	◆	◆	◆		
Deutsche Bank (2009)							
Conference Board of Canada (2008)							◆
Toled et. al. (2008) (2007)	◆			◆			

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SOURCE	ADAPTATION TOOLS					DISCLOSURE TOOLS	
	Adaptation Identifiers	Adaptation Options	Success Measurement	Step-by-step Guide	Adaptation Networks	What to Disclose	How to Disclose
Berkhout et. al. (2004)	◆	◆	◆	◆			
CBSR (2007)	◆	◆	◆	◆			
Freed and Sussman (2006)	◆			◆			
ICF International (2007)							
Lash and Wellington (2007)							
Pew Center (2008)	◆		◆	◆			

SUMMARY OF KEY POINTS

- Risk tools dominate the literature and, of those, risk frameworks (a step-by-step risk management process) are the most common. There are a few limited scenario-based tools and computer simulation tools, which suggests a need among businesses for more sophisticated risk modelling tools. The overwhelming focus on risk tools is most likely due to the fact that risk management frameworks already exist and can be easily modified to include climate risks.
- Only one opportunity tool was identified in the study. This represents a significant gap in the tools available for business adaptation to climate change. This tool focused on current opportunities and there were no tools for identifying potential opportunities. The very limited availability of opportunity tools might speak to the fact that climate opportunities depend on the idiosyncrasies of individual firms and their strategies, making generalizations around climate opportunities difficult to summarize.
- The few adaptation tools identified mostly tend towards climate change education or collaboration networks available to business to learn and connect with other businesses concerned with adaptation. It is hypothesized that the overwhelming tendency for adaptation tools to focus on networks speaks to a preliminary stage of business climate change adaptation, and the need to first learn "what is out there" before developing any models of climate change adaptation by individual businesses.

recommendations

This report finds three groups of knowledge gaps and associated areas for future work.

THEORY

It is difficult to create common understanding or successful models concerning adaptation for several reasons: 1) climate change is not linear and presents much uncertainty 2) business adaptation is an area as varied as it is diverse 3) basic definitions about perception and use of resources are not consistent across sectors and 4) this area of research is in its infancy. Advances in theory will help address these issues.

At the conceptual level, the lack of a consensus surrounding the meaning of business adaptation to climate change has made risk modelling, opportunity evaluation and adaptation identification difficult in theory and practice. Further discussion on how adaptation can be defined for business is recommended. Moreover, consultation and fieldwork on how the business community understands adaptation may help develop a broad definition that reflects the meaning of climate change to this segment of society.

Theoretically, more interdisciplinary work needs to take place in metatheoretical development and discussion. As the field currently stands, researchers from a wide range of disciplines are developing theory without reference to other methodologies and as such there is limited critical reflection between scholars on business adaptation theory. Thus, it is recommended that further work engage in theoretical development from an interdisciplinary perspective.

Other recommendations:

- Develop more interdisciplinary theories. Increase the amount of critical reflection between scholars on business adaptation theory.
- Amalgamate information on business risks, opportunities and adaptation strategies across sectors towards generalizations.
- Reach consensus on the definition of adaptation, which will make risk modelling, opportunity evaluation and adaptation identification easier both in theory and practice.
- Base new theories on rigorous field work on how businesses understand adaptation.

SECTORAL AND CROSS-SECTORAL ANALYSES

The scope of primary research on companies and their adaptation practices is exceptionally narrow (Berkout et al. 2004a, Pew 2006, Carbon Disclosure Project 2008), making any generalizations regarding lessons learned and best practices difficult to ascertain. There has been no attempt by the academic community to amalgamate information on business risks, opportunities and adaptation strategies across sectors towards universal generalizations. This may be due to the difficulty in creating universalization in an area as varied and diverse as business adaptation or it may be due to the fact that this area of research is in its infancy. We recommend that further investigation into the causes of this knowledge gap be undertaken.

Where sector studies exist, they are the most comprehensive in the Insurance, Tourism, Agriculture, Energy, Construction and Building, and Water sectors. For other sectors, there is no information on the drivers of business adaptation and very limited information on strategies, barriers and industry gaps (see Table 9). As such, it is recommended that the research community engage in further research work and analysis of business adaptation in these sectors.

CASE STUDIES AND BEST PRACTICES

The most significant knowledge gap in the literature is the lack of case studies, lessons learned and best practices. As the field currently stands, there has been no systematic attempt to develop business adaptation case studies across all sectors. The literature tends to feature short summary cases, often from industry reports, on potential adaptation responses businesses could undertake. In general, there is very little information on how businesses actually incorporate climate change adaptation into their operations. It is recommended that future research engage in field work and primary research into the adaptation strategies of actual companies that face risks, opportunities or both from climate change in order to develop case studies as well as to identify lessons learned and best practices. Reasons for the knowledge gap in case research, lessons learned and best practices, were hypothesized to be threefold: 1) businesses are yet to undertake adaptation measures despite real risks and vulnerabilities to climate change possibly due to lack of knowledge, inadequate risk modeling and poor information on future climate change variability 2) businesses that have embraced adaptation measures have done so only recently and it is too early to gather empirical findings or literature in this area and 3) the focus of business remains short-term and on GHG mitigation. It is recommended that future research look into either affirming or refuting these hypotheses.

Other recommendations:

- Make available information on both industry leaders and laggards in adaptation.
- Broaden the scope of primary research to make generalizations on best practices possible.
- Study the drivers of business adaptation, about which we know very little.

TOOLS

Finally, the tools available for business adaptation are limited, most focusing on risk. While advancements have been made by governments, more sophisticated tools need to be developed to address the highly particular concerns of businesses of particular sizes, sectors and geographies. Tools, to date, remain at a high level of generality and it is suggested more research be done into creating specific tools that meet the needs of adapting businesses.

Other recommendations:

- Develop businesses tools for risk assessments, evaluating potential opportunities and developing adaptation strategies at the firm level.
- Develop tools available to evaluate opportunities to be gained from adapting to climate change (there is currently only one such tool).

SUMMARY OF KEY POINTS

Business needs a clearer understanding of what adaptation to climate change means

- The lack of a consensus surrounding the meaning of business adaptation to climate change has made risk modelling, opportunity evaluation and adaptation identification difficult in theory and practice.
- Rigorous field work is needed on how the business community understands adaptation.

Business needs more information on how companies are adapting

- There is very little information on how businesses actually incorporate climate change adaptation into their operations
- There is a lack of case studies, lessons learned and best practices regarding climate change adaptation – both across sectors and at the firm level.
- There is a need to have more consistent information about industry leaders and particularly laggards.
- Interdisciplinary and cross-sectoral research and cooperation on climate change adaptation is needed.
- More information on drivers, strategies, barriers and gaps is needed – particularly in the forestry, fishing, mining, manufacturing, retail, health and ICT sectors.
- There is a need to broaden scope of primary research on companies and their adaptation process, resulting in better and more applicable lessons learned and best practices derived.

Business needs practical tools to help them adapt

- Outside of risk management frameworks, there are few tools that businesses can use for adaptation to climate change.
- There is a need to develop business tools for use in assessing risks, evaluating potential opportunities and developing adaptation strategies at the firm level.

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Total number of studies with direct definitions: 21

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