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Climate Change:
Business Risks and Opportunities - The Role of Private Sector Adaptation

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Introduction

The aim of this publication is to broaden the understanding of climate risks and adaptation from the perspective of the private sector. Many businesses still tend to underestimate their exposure to climate risks, while business opportunities arising from the need to reduce vulnerability are too often overlooked or unrecognized. This publication provides an overview of the business risks and opportunities that are emerging from climate change and its impacts.

Covering business models undergoing changes in response to the increasingly severe impacts of climate change, this publication illustrates how businesses can reduce climate risks and take advantage of the opportunities that are emerging in climate change adaptation.

Chapter 1 shows why private-sector adaptation is an economic imperative for societies in general, and the implications of this for businesses. Chapter 2 discusses climate risks, describes how businesses are climate-proofing their operations, and assesses the role of businesses in the provision of new technologies, goods and services to address climate risks. Chapter 3 provides an analysis of tools for businesses that are designed to capture risks and opportunities and develop adaptation strategies. Chapter 4 provides examples of adaptation businesses that focus on reducing climate risks with adaptation goods and services. Chapter 5 concludes with an outlook on private-sector adaptation and the factors determining its growth.

Chapter 1. Climate Change Adaptation as a Financial and Economic Imperative

Originating from the need to anticipate climate change impacts and take early actions to prevent losses and damage, climate change adaptation focuses on reducing vulnerability and building resilience to future climate change impacts. Understanding and responding to these impacts well in advance is essential for businesses to plan.

Actual or expected climate change impacts pose both risks and opportunities to businesses. Private adaptation refers to "the process of adjustment by companies to actual or expected climate change and its effects through changes in business strategies, operations, practices, and/or investment decisions". The process of adaptation engages private-sector decision-makers to identify the most appropriate approaches to moderate harm while exploiting beneficial opportunities (IPCC, 2014).

Without early action on adaptation, climate change impacts represent substantial costs: UNEP estimates that the annual cost of adapting to climate change in developing countries could rise to between US$280 and US$500 billion by 2050, with more recent work pointing toward the upper end of the range (UNEP, 2016; UNEP, 2021). It is worth noting that early adaptation is by far the most cost-effective in economic terms. The World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) estimate that the net average benefit of investing in more resilient infrastructure in low- and middle-income countries would be $4.2 trillion, that is, $4 in benefit for each $1 invested (Hallegatte et al., 2019).[1]

Private businesses are catalysts in producing and disseminating adaptation goods and services, and thus have an instrumental role in adaptation in general. The public interest in supporting businesses in climate change adaptation stems from the economic, social and environmental benefits of adaptation that accrue beyond the scope of the individual company. References to adaptation's 'triple dividend' generally refer to its avoidance of future losses, generating positive economic gains through innovation, and delivering additional social and environmental benefits (Tanner et al., 2015). Adaptation can help reduce the risk of supply-chain disruptions and resources being severely affected. For an economy, adaptation means reducing losses in critical economic sectors that are vulnerable to climate change. In this sense, adaptation investment helps vulnerable regions avoid significant economic losses, primarily in agriculture, water supply and the costs of forced migration. From a social standpoint, adapting in a timely fashion reduces the vulnerabilities in health and livelihoods that can go beyond a company's operations and value chain. For instance, it reduces the food security risks from increasingly frequent hazardous weather events. From an environmental standpoint, adaptation may, for instance, prevent further damage to ecosystems, such as freshwater sources (GCA, 2019). Unsurprisingly, this public interest in fostering climate change adaptation is reflected in countless international agreements and forums, where the role of the private sector in climate change adaptation is underscored.

International Agreements and Forums

Climate change adaptation is vital to the Paris Agreement, which adopted adaptation as a key pillar. The Agreement also highlights the need to involve the private sector in the implementation of countries' Nationally Determined Contributions (NDCs). Furthermore, adaptation as an aspect of climate action features prominently in Sustainable Development Goal (SDG) 13. Targets for adaptation for all countries form part of the sub-goals 13.1) strengthening resilience and adaptive capacity; 13.2) integrating climate change measures into national policies, strategies and planning; and 13.3) improving education and capacity building on climate change mitigation, adaptation, impact reduction and early warning. Besides the climate action in SDG 13, climate change adaptation is reflected in or has an impact on nearly all other SDGs. Adaptation is also linked to reducing disaster risks

and introducing resilience measures in the Sendai Framework for Risk Reduction, adopted in 2015. The Framework underscores the need for urgent investment in reducing disaster risks and infrastructure, emphasizing public-private partnerships and the private sector's role in driving investments and cost-effective innovation. Finally, the Addis Ababa Action Agenda, intended to mobilize private-sector resources in implementing the SDGs, highlights the role of the private sector in climate action, including adaptation investments.

Implications for the Private Sector

Along with its increasing prominence in international agreements, climate change adaptation and climate risk management have become the subject of intense interest in the business community. Awareness of climate risks is increasingly visible in business surveys. In the most recent Global Risks Perception Surveys, failure to act on climate change tops the list of risks in terms of impact (World Economic Forum, 2020). Recent years have seen the emergence of standards for organizations, processes, value chains and products to assess and mitigate the risk that climate impacts pose to operations and valuation. Physical risks to business stem from the exposure of businesses, their employees, their supply and distribution chains and customers to climate-related hazards and the increase in median temperatures. At the same time, businesses need to adjust their activities to the risks of the transition to a lower-carbon economy, such as the risk of policy changes and reputational risks. Without early action, various industries are expected to suffer significant impacts from climate-related risks. While impacts affect businesses of all sizes, micro-, small and medium-sized companies (MSMEs) are less well-equipped, often lacking the necessary resources, knowledge and infrastructure to adapt and thereby reduce their vulnerability.

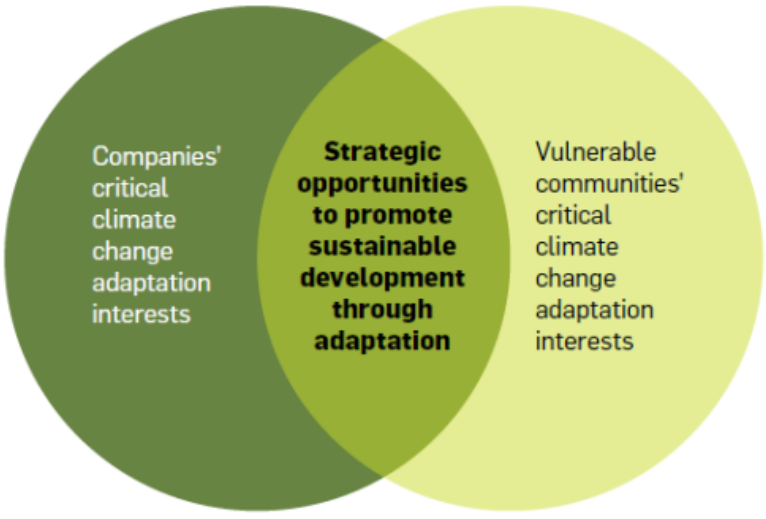
At the same time, climate change adaptation measures represent an opportunity for businesses. The need to reduce the physical risks and the risks associated with the transition to a low-carbon economy has already generated business opportunities and has the potential to incubate new products, services and markets.

Chapter 2. Climate Risks, Opportunities and Adaptation

Over the last decade, private-sector adaptation to the risks posed by climate change has received increasing recognition from both academia and the international climate regime as an important avenue for achieving resilient societies in the face of the increasing severity of climate shocks and long-term climatic changes (Agrawala, et al., 2011, Averchenkova et al., 2016; Frey, et al., 2015; Schaer, et al. 2019). As a key contributor to many countries' economies, the private sector's response will be critical to "climate-proofing" its own operations and ensuring climate-resilient development at large (Trabacchi and Stadelmann, 2016). The different roles of the private sector in relation to adaptation are displayed in Figure 1. This shows, on the one hand, that private companies' climate risks cannot be separated from the risks faced by the communities in which their business operate. On the other hand, through adaptation actions, private companies not only reduce their own climate risks, they also increase the vulnerability of those communities.

This chapter is organized around the two ways in which the private sector can play a role in increasing societies' climate resilience: 1) climate-proofing its own operations, and 2) the development of new technologies and services to address climate risks, thus giving rise to new businesses. While acknowledging the continuum of and fine lines between risks and opportunities, Section 2.1 provides a summary of how the private sector regards and addresses climate change as a risk. It also provides an overview of the determinants and types of climate risks, of how private-sector actors respond to those risks, and of the factors that influence the private-sector's adaptation actions. Section 2.2, on the other hand, focuses on the business opportunities that are emerging from the need to address climate change risks and the creation of businesses dealing in an adaptation good or service.

FIGURE 1. Private-sector adaptation, climate risks and opportunities



Source: UN Global Compact 2012. Business and Climate Change Adaptation: Toward Resilient Companies and Communities

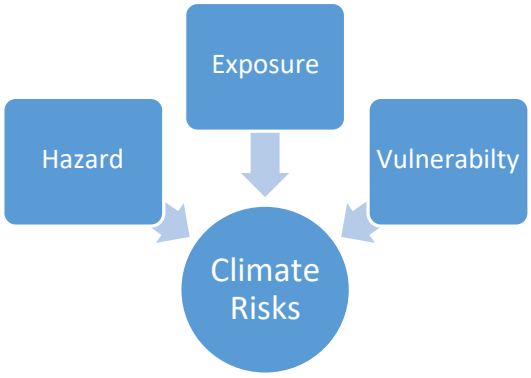
2.1 Changing Business Models as Adaptation

Climate Risks to Businesses

Determinants of Climate Risk

The essential determinants of climate risks to business can be categorized similarly to climate risks in disaster-risk management and other fields, where the risks of climate-change impacts result from the interactions between vulnerability, exposure and hazard (IPCC, 2014).

FIGURE 2. Determinants of Climate Risks



Hazard refers to the possible future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements. While often used synonymously, hazard is a component of risk, not a risk itself. *Exposure* refers to the inventory of elements in an area in which hazard events may occur (IPCC, 2014). If businesses were not located in possibly precarious settings, no climate risks would have to be faced. *Vulnerability* consists in the propensity of exposed elements, including businesses and assets, to suffer adverse effects when impacted by hazard events (IPCC, 2014). It is possible for a business to be exposed, but not vulnerable. For instance, businesses that are located in flood-prone regions can adjust their facilities and behaviour to mitigate potential losses, thus rendering themselves less vulnerable. While individual businesses are impotent in the face of the hazards and limited in their responses to exposure, reducing their vulnerability is the key to and core of adaptation.

Types of Climate Risk

According to the IPCC and Task Force on Climate-related Financial Disclosures (TCFD), climate risks on businesses are commonly divided into two categories, namely physical risks and transition risks (IPCC, 2020, TCFD, 2017). TCFD (2017) defines physical risks as risks "resulting from climate change [that] can be event driven (acute) or longer-term shifts (chronic) in climate patterns",[2] such as damage caused by changes in water availability, sourcing and quality; food security; and extreme temperature changes, which may affect organizations' premises, operations, supply chain, transport needs and employee safety. Similarly, the IPCC (2020) defines physical risks as risks to facilities and infrastructure, impacts on operations, water and raw material availability, and supply-chain disruptions.

Transition risks are defined by TCFD (2017) as risks related to the transition to a lower-carbon economy. These risks could include policy and legal risks, technology risks, market risks or reputational risks. According to the IPCC (2020), transition risks refer, within the lifespan of a business, to the risks associated with the transition to a low-carbon economy, such as stranded assets, lost markets, reduced returns on investment and financial penalties.

To illustrate how physical risks and transition risks are understood by different private sectors under the TCFD framework, Table 1 summarizes five examples of companies across different sectors.[3]

TABLE 1. Climate risks in different economic sectors

Businesses	Sectors	Climate Risks	
		Physical risks	Transition risks
Banco Davivenda, Colombia	Finance	· Risks associated with the mortgage loan portfolio, classifying them by flood and landslide threat levels	· Climate change regulation-related risks that could affect industries that generate the most CO2 emissions
AstraZeneca, UK	Pharmaceuticals	· Business critical sites (operations, R&D hubs, IT centres and other strategic hubs) are exposed to the risks of extreme heat, floods, drought and wild fires caused by increased frequency of extreme weather and climate-related natural disasters	· Increased demand for sustainable low-carbon products and services from health-care providers in some countries (e.g., anaesthetics and respiratory products) · F-Gas Regulations and their impact on respiratory medicines used to treat asthma and chronic obstructive pulmonary disease · Ban and/or restrictions on the sale of petrol and diesel vehicles in some markets · Carbon-pricing and future environmental taxation
CLP Holding, Hong Kong	Energy	· Major HSE (Health, Safety and Environment) incidents · Lower performance of renewables due to limited wind and water resources, and extreme climate events (e.g., cyclone, flooding and landslides) · Major projects delayed / cost overruns	· Major HSE incidents · Gas shortages · Tariff adjustment challenge · Regulatory changes · Customer competition and energy market volatilities · Volume / tariff competition
Fresnillo, Mexico	Mining	· Changes in extreme climate and weather events (rainfall, droughts, heatwaves) affecting operations and neighbouring communities · Increase in temperatures, reduction in precipitation and associated water stress	· Emerging regulations such as carbon taxes and cap and trade systems · Changes to the regulatory framework for renewables
Citi, USA	Finance	· Increased storms · Drought · Fires · Floods	· Carbon price policies · Power generation shifts from fossil fuels to renewable energy

Data sources: TCFD Good Practice Handbook, 2nd Edition, 2021. Based on: Banco Davivenda's 2020 Annual Report, AstraZeneca's Annual Report and Form 20-F Information 2020, CLP Holdings 2020 Annual Report, Fresnillo 2020 Annual Report and Citi Group 2020 Annual Report

Private-Sector Responses to Climate Risks

Businesses that are exposed to hazards should reduce their vulnerability through adaptation. Climate risk management helps private-sector actors identify the potential climate-related risks and to address those risks by modifying their business strategies and models. Effectively integrating climate considerations and proper adaptation actions into business operations can help businesses minimize their vulnerability. To understand the climate risks that businesses face, the existing climate-related disclosure platforms and standards, such as TCDF, the International Integrated Reporting Council (IIRC), the Sustainability Accounting Standards Board (SASB), and the Climate Disclosure Platform (CDP) play a helpful role (Dale, et al., 2021).

Private-sector business models are already undergoing change in response to the need to adapt to physical risks and the risks of the transition (IPCC, 2021; CCSP,2008; DiBella, 2020). For instance, in the agriculture sector, typical adjustments to the business model include changing agronomic practices, switching crop patterns, planting drought- and heat-resilient crops, and investing in on-farm storage and water-efficient irrigation in order to respond to *physical risks*, such as reduced crop yields and quality resulting from higher temperatures, reductions in precipitation, the reduced availability of irrigation water, crops losses due to extreme weather events, or losses from supply-chain and power disruptions. Private-sector adaptation also includes adjustments to business models to avoid the costs resulting from *transition risks*: e.g., for the agriculture sector this would include the risk of the unaffordability of fossil fuel-based fertilizer due to carbon pricing, the reduced demand for meat, mandatory water-conservation practices, changing land-use policies, or a reduction in subsidies to high-emitting agricultural activities. In the tourism sector, business model adjustment involves changing the offer from highly exposed destinations to less exposed or less vulnerable ones (thus reducing the physical risks) or changing programs and product packages to the shifting preferences of the targeted customer groups (thus reducing the transition risks) (SASB, 2019). These examples demonstrate that private-sector business models are subject to change due to physical risks and transition risks.

Table 2 summarizes the typical physical risks for different sectors and lists examples of common solutions. What is striking about the solutions is that many of them constitute business opportunities in themselves (e.g., weather and climate information products, drought-resilient crops).

Data sources: **1**. Adaptation SME Accelerator Project. Adaptation Solutions Taxonomy. July 2020. By Chiara Trabacchi, Jay Koh, Serena Shi, Tara Guelig. Edited by Maria Margarita Cabrera. **2**.UNEP DTU Partnership and UNFCCC (2018). Summary of Country Priorities Technology Needs Assessments 2015-2018. **3**. Chow, J. (2017). Mangrove management for climate change adaptation and sustainable development in coastal zones. Journal of Sustainable Forestry, 139–156. https://publications.iadb.org/publications/english/document/Private-Markets-for-Climate-Resilience-Global-Report.pdf **4**. UNEP FI, BMZ, GIZ, and the Frankfurt School. (2016). Demystifying adaptation finance for the private sector. Geneva: UNEP Finance Initiative. Retrieved from www.unepfi.org/publications/climate-change-publications/demystifying-adaptation-finance-for-private-sector **5**. UNEP 2018. The Adaptation Gap Report 2018. United Nations Environment Programme (UNEP), Nairobi, KenyaPp.. 29-39 **6**. Authors' experience.

TABLE 2. Typical physical risks to different sectors and examples of solutions

Sectors	Examples of physical risks	Examples of solutions
Manufacturing	· Supply chain disruption by weather events, fires, flooding	· Supply chain analytics, including weather analytics · Insurance
Agriculture	· Reduced crop yields and quality resulting from higher temperatures and/or less precipitation · Reduced crop yields in irrigated agriculture due to the reduced availability of irrigation water · Crops losses due to extreme weather events (drought stress, other temperature / humidity impact) · Supply-chain disruptions / power disruptions	· Weather and climate information products · Temperature regulation technologies for livestock · Remote sensing-based drought-monitoring tool · Crop data and analytics · Seed development · Support for certification processes, conservation agriculture practices, good agronomic practices, etc. · Crop diversification and new varieties, such as drought-tolerant crops · High-precision laser land-levelling to reduce run-off · Water-efficient irrigation technologies · Soil-management technologies, farming systems and crop management, water catchment and harvesting, conversion agriculture · Parametric insurance · On-farm storage solutions
Health	· Shifts in geographical range, seasonality and incidence of water-, air- and insect-borne diseases; · Reduced labour productivity due to heat stress, heat strokes · Increased respiratory illness due to heat stress	· Disease surveillance systems and early warning mechanisms · Development of studies of climate change and of the costs of health adaptation · E-Health, e.g., remote diagnostics, health and disease surveillance systems for detecting outbreaks · Rapid diagnostic tests · Long-lasting insecticidal nets, heat-wave protection of elderly and children · New vaccines, pharmaceuticals and products to protect and cure · Capacity training for health professionals to deal with climate change-related impacts · More resilient health-care facilities
Transport	· Damage to road network / rail network / seaports due to extreme weather events · Interruption of transport networks due to extreme weather events · Flooding and inundation of transportation infrastructure due to rising sea levels	· Intelligent transportation systems to, e.g., monitor road conditions, address hazards in real time or move traffic away from areas experiencing a natural disaster · Extreme heat- or cold-resistant paving materials and other innovative and resistant materials · Active motion-dampening systems · Road-network maintenance and upgrade · Refitting infrastructure
Energy infrastructure	· Power disruption from storms, wildfires, extreme temperatures; hydropower shortfalls from drought	· Energy storage, microgrids, advanced hydropower modelling and upstream pumping · Back-up power, distributed renewable energies · Energy efficiency and demand-side management · Energy communities (solar PV)
Buildings	· Damage to infrastructure from extreme weather events (e.g. floods, typhoons) and temperature increases (e.g. gradual and heat waves) · Disruption of supply chains, construction delays · Increase in materials and other costs	· Cooling services, bioclimatic construction · Greening as a way of cooling (green roofs, green facades) · Innovative and resistant materials (heat reflector roofs and walls, biomaterials) · Refitting infrastructure
Water supply and management	· Reduced surface-water availability due to changes in precipitation · Reduced surface-water quality due to, e.g., saltwater intrusions · Increased flooding due to extreme weather events	· Water monitoring and modelling · Hydrological forecasting systems · Water storage and harvesting · Wastewater treatment and grey-water recycling · Desalination of saltwater · Water-saving technologies e.g., smart water meters, leakage reduction, efficient pump motors and pressure-control equipment
Coastal zones	· Damage to assets from more intense and frequent extreme weather events · Flooding due to sea-level rises and storm surges · Reduced domestic, commercial, or industrial water due to saltwater intrusion · Erosion due to rising sea levels	· Early warning systems for extreme coastal weather events · Satellite imagery for monitoring and impact assessment · Sea-level processing software · Geosynthetics (e.g., geotextiles and geomembranes) · Constructed wetlands and artificial reefs · Mangrove management
Finance	· Increase in non-performing loans, loss of value of equity participations · Deterioration of credit-risk ratings	· Insurance mechanisms (risk transfer through insurance) · Financing nature-based solutions · Resilience bonds and other refinancing solutions

In addition to their physical risk exposure, businesses are exposed to transition risks. The table below gives examples of transition risks specific to industries, together with solutions to reduce businesses' vulnerability in this regard. Like Table 2, many of the solutions to be adopted by businesses constitute a product, good or service to be supplied by a business, e.g., energy-efficient appliances to mitigate carbon price risks.

TABLE 3. Typical climate transition risks in different sectors and examples of solutions

Sectors	Examples of transition risk	Examples of solutions
Manufacturing	· Carbon pricing and import taxes for high-emitting imports (e.g., EU's Climate Border Adjustment mechanism) · Reputational risks and changes in demand · Market and technology risks	· Procurement of low-carbon energy from electricity producers (corporate power purchasing agreements) · Low carbon distribution systems (e.g., electric vehicles) · Adoption of technological improvements and supply-chain changes that support the transition to a low-carbon economic system · Procurement of carbon credits/offsets
Agriculture	· Changes in consumer demand · Changes in land-use policies and trade policies · Carbon pricing · Ending of subsidies for high-emitting activities · Price increases (operating costs and costs of agricultural inputs)	· Technology adoption to reduce carbon emissions · Shift to low-carbon energy sources and low-carbon agricultural inputs · End to land-use strategies based on deforestation · Promote sustainable land use · Insurance mechanisms
Buildings	· Changes in building codes · Technology risks · Carbon pricing · Regulatory and compliance costs (e.g. GHG emissions monitoring) · Asset devaluation	· Adoption of technology improvements (energy-efficient appliances and equipment) that support the transition to a low-carbon economic system · Adopt efficient construction practices and sustainable materials · Use energy performance and material labelling systems · Upgrading and refitting infrastructure, namely building integrated renewable energy (e.g., solar PV roofs, solar PV walls)
Transport infrastructure	· Consumer demand shifting to low-carbon transportation · Increase in demand for bike infrastructure and public transport	· Switch to low-carbon transport solutions and soft modes of transportation · Improve modal shift (railroad, sea and inland waterways) · Alternative fuels and electrification of transport · Network/route optimization and vehicle efficiency improvements
Energy	· End to fossil-fuel subsidies · Reduced access to finance / increased financing costs, as financial intermediaries decarbonize portfolios · Demand change and reputational risk · Litigation and legal risk · Stranded assets, loss of markets, reduced returns on investment and financial penalties	· Shift to more capacity (MW) of decentralized, renewable energy and improving energy efficiency · Fossil-fuel removal · Insurance mechanisms
Water supply and management	· Emerging regulatory requirements for water availability, sourcing and quality (e.g., water conservation practices, groundwater protection) · Mandatory disclosure and risk assessments	· Technologies to mitigate water risk and water conservation (e.g., remote sensing of water, leakage reduction, waste-water treatment, desalination of salt water and recycling of greywater) · Energy-efficient motor-pump systems
Finance	· Reputational risks and changes in consumer demand · Stranded assets · Loss of markets (including sustainable finance market)	· Procurement of carbon credits/ offsets · Finance nature-based solutions, including sequestration projects

Data sources: authors' elaboration based on their experience and 1. Cambridge Institute for Sustainability Leadership (CISL) (2019). Transition risk framework: Managing the impacts of the low carbon transition on infrastructure investments UK: the Cambridge Institute for Sustainability Leadership. https://www.cisl.cam.ac.uk/system/files/documents/cisl-climate-wise-transition-risk-framework-report.pdf 2. European Systemic Risk Board. 2021. Climate-related risk and financial stability https://www.esrb.europa.eu/pub/pdf/reports/esrb.climateriskfinancialstability202107~79c10e-ba1a.en.pdf?71a273dc36a85ef05c8bed530466f900 3. Author's experience.

Drivers and Barriers to Private-Sector Adaptation

Many businesses still tend to underestimate their exposure to climate risks, which reflects a narrow view of climate risks and related impacts on supply chains and the broader market. Many private adaptation strategies tend to be reactive and insufficient (Goldstein et al, 2018). This misperception stands in the way of private-sector adaptation.

For businesses, even when climate-related risks are well known, this does not necessarily mean that appropriate responses to address the potential risks will be implemented. There are a number of factors that influence businesses to invest in addressing climate risks. In assessing private actors' interests in climate change adaptation, one barrier to private investment in adaptation measures is the perceived lack of a business case. Businesses need to be sure that adaptation measures that come with an upfront cost are amortised and will thus produce returns with a certain degree of certainty. A potentially enabling factor in addressing climate risks is their adequate pricing. In this regard, the financial sector, including bank supervision authorities and central banks, plays a crucial role. The enabling role of the financial industry in achieving climate targets is also evident and highlighted in a recent IPCC report (2018), which presents the industry itself as subject to both physical risks and transition climate risks, especially in developing countries. If the financial sector fails to adjust its investment strategies to adapt to the changing climate context, it could also act as a barrier to the low-carbon transition (Monasterolo, 2020). Other factors influencing climate change actions in businesses include public policy, prior experience, risk concerns, leadership and commitment, the existence of a division or department in charge of climate change action, and business size (Kang, Yoon and Rhee, 2017).

A recent study on the adaptive capacities of MSMEs in developing countries shows that their capacity to cope with climate risks is influenced by both their inherent characteristics and their enabling environments, for instance, whether information and the ability to take proactive adaptation actions are available, or whether adequate financial services and support prior to and after the damage happens are in place (Schaer et al., 2019). Schaer et al. (2019) summarize research on the inherent factors explaining the limited capacity of MSMEs in developing countries to adapt. MSMEs lack knowledge regarding climate risks and have limited abilities to undertake cost-benefit analysis. Moreover, they lack both the financial resources and the technical competencies to implement adaptation options (Asgary et al., 2012; Terpstra and Ofstedah, 2013; Pathak and Ahmad, 2016; Auzzir, Haigh and Amaratunga, 2018; Chaudhury, 2018; Kato and Charoenrat, 2018).

For small agricultural businesses, research shows that the factors that motivate owners to change their business models include literacy levels, experience, the availability of institutional services and perceptions of climate change risk (Muhammad et al., 2021), as well as the household head's age, education and gender, the farm's and household's sizes, assets, livestock ownership, poverty status and use of extension services (Funk et al., 2020).

Case Study: SMEs adapting to flood risk in Sri Lanka

The capacity of small and medium sized enterprises (SMEs) in Sri Lanka to cope with and adapt to climate related shocks is a major factor in the climate resilience of the local and national economies they are embedded in, especially in developing countries. 80% of businesses affected by the extensive flooding in 2017 are MSMEs.

In 2021, a study was conducted to review the adaptive capacity in Sri Lankan SMEs and its enabling environment for SMEs adapting to flood risk. The study shows that the limitation for Sri Lankan SMEs to adopt suitable proactive adaptation strategies for flood risks include insufficient climate risk information and technical competencies, inadequate financial services and support prior to, and in the aftermath of flooding events.

Source: (Dale et al., 2021)

Besides the above factors, it is well recognized that there are incentives the public sector can provide to foster a business case for long-term private-sector adaptation. However, as considering them would go beyond the scope of this publication, they are not discussed here.

Adaptation as a Business Opportunity

In the previous section, this publication has provided a discussion of climate risks, their impact on businesses and why businesses may or may not address these risks. In this section, a different perspective is taken to explore the provision of adaptation services and goods as a business opportunity.

A survey by Global Compact shows that 86 percent of the 72 companies surveyed thought that responding to climate change risks, or investing in adaptation solutions, poses a business opportunity. The demand for adaptation goods and services represents a growing market, including in developing countries (UN Global Compact et al., 2011).

Climate Services Market

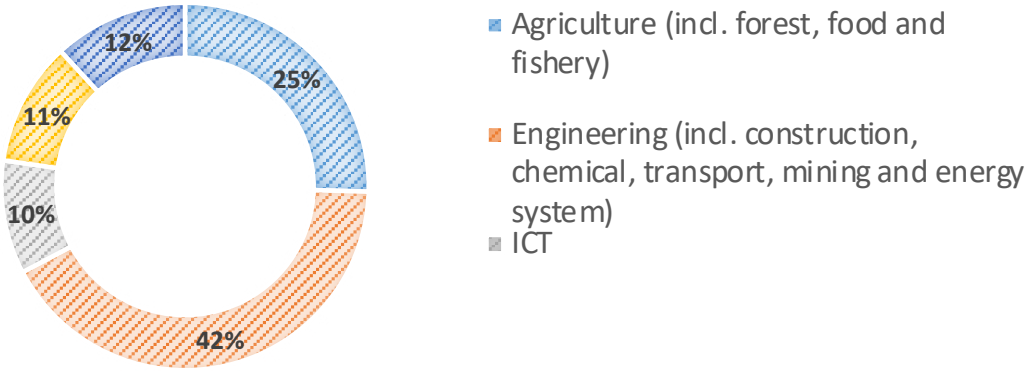
Larosa and Mysiaka (2020) summarised as common features of climate services' business models the following: 1) they are knowledge-intensive and hard to standardize; 2) they are based on close interactions between service providers and clients in producing custom-made products; and 3) they require a systemic understanding of innovation.

There is little research on the size of the global market for climate services. Thus, to gain at least an understanding of the largest segments of climate services, this publication draws on market research on climate services in the European Union (EU), and it categorizes the 102 case studies in the UNFCCC's Adaptation Private Sector Initiative database (PSI).[4] Note that these two sources cover different geographical and topical scopes. EU research on climate services cover the 27 EU member states and the UK, while the database covers examples globally. The PSI database covers both adaptation goods and services, while the EU research scope adheres to a definition of climate services that describes essentially services.[5] Drawing on both these resources sheds light on the most dominant segments of suppliers and buyers of adaptation goods and services.

What adaptation services are available?

According to the 102 PSI cases we analysed, engineering services are the largest adaptation service provider, followed by agriculture services (Figure 3). Unfortunately, three quarters of the cases in the database are adaptation service providers in the Global North. Thus, they may not be reflective of adaptation services in general.

FIGURE 3. Adaptation Service Providers

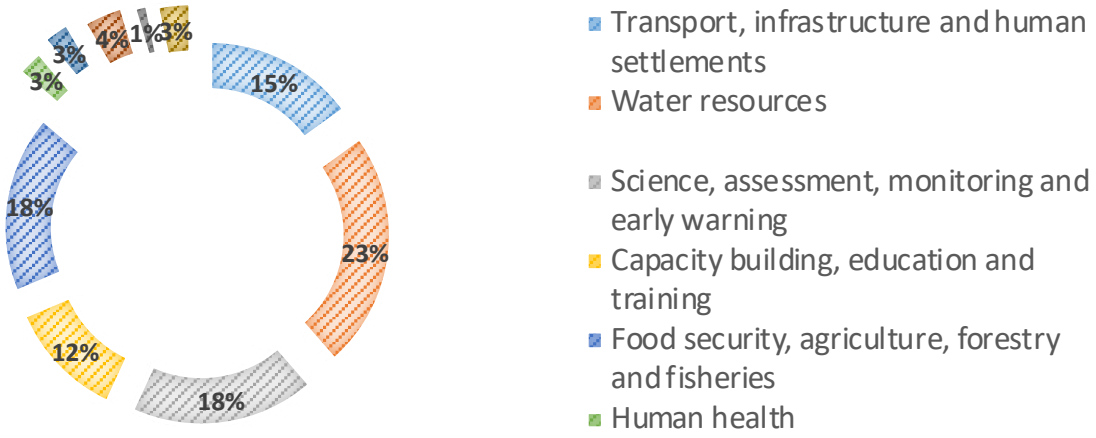


Data source: UNFCCC Private Sector Initiative (PSI): 102 cases

Which sectors seek adaptation services?

Based on the 102 cases registered in the UNFCCC's Private Sector Initiative (PSI), the sectors that sought the most adaptation services were water resource management, monitoring and early warning, agriculture and infrastructure (Figure 4).

FIGURE 4. Customer sectors for adaptation services



Data source: UNFCCC Private Sector Initiative (PSI): 102 cases

As for the demand side, a survey of 248 participants in the 27 EU member states and the UK shows that the largest climate-service markets are in the sectors of renewable energy (48.3 percent of climate service users purchasing climate services for this particular sector), agriculture (44.8 percent) and the built environment (43.7 percent). On average, private customers purchase a larger amount and variety of climate services than public institutions (Lamich, 2018).[6]

While predictions of trends in the future demand for climate services per sector are not available, research in the EU and the UK shows growth in the climate service market has great potential and is expected in agriculture, forestry & timber, health, tourism, energy & energy infrastructures (built environment/utilities) and mining (Lamich, 2018). In respect of adaptation services in particular, a clear demand for services supporting evaluations of the effectiveness of adaptation measures has been identified (Hoa et al., 2019).

Adaptation-Driven Changes to Business Models

Table 5 gives examples of adaptation-driven changes to business models of large companies in three industries, ICT, finance and insurance, made in order to adapt to local climate change impacts. Chapter 4 will provide other examples of adaptation businesses.

TABLE 5. Example of adaptation-driven changes to business models in specific sectors

Adaptation services			Markets		Business models
Sector	Business	Location	Sector	Location	
ICT	Telvent	Spain	Disaster risk management	Bolivia Morocco Mozambique	· offer adaptation service covering the entire value chain: technology, consulting, development and implementation · provide tailored solutions for customers · one business line is the provision of technology and equipment for national meteorological services, especially those of lower-income, climate-vulnerable countries · the market is expected to grow along with concerns about climate change impacts
	Nokia	Finland	Agriculture Health Disaster risk Management	China India Indonesia Kenya Nigeria Philippines	· offer commercial mobile services (with subscription fee) for farmers around the poverty threshold · via SMS, provide highly localized information on weather, market prices, seeds, fertilizers and pesticides in local languages · products have a sustainable financial trajectory, and the firm is gaining business value
Finance	Banco do Brasil	Brazil	Finance	Brazil	· the bank's portfolio of financial products and services (with socio-environmental characteristics) are expanded with the range of climate-resilient products and services
Insurance	Sompo	Japan	Agriculture	Thailand	· offer commercial insurance product protecting rice farmers from drought · internationally designed, locally distributed, at an affordable rate · payments are made based on rainfall data
	Munich Re	Germany	Risk Management	The Caribbean region	· offer climate risk index insurance (Loan Portfolio Cover and Livelihood Protection Policy) to protect the livelihoods of low-income groups · pay-outs triggered when winds reach a certain speed or rainfall exceeds a certain level · SMS-based clients' warning system to minimize losses · New product lines are helping global insurers build new markets and maintain competitive positions
	Swiss Re	Switzerland	Agriculture	Ethiopia	· offer weather-index crop insurance to the most climate-vulnerable farmers · over 13,000 farmers purchased insurance through R4 in 2011. · premium can be made up by contributing time and labour to local climate adaptation and resilience-building projects. · Microinsurance is an emerging business opportunity, with potential for market expansion worldwide

Data sources: United Nations Environment Programme, United Nations Global Compact, 2012. Business and Climate Change Adaptation: Toward Resilient Companies and Communities

Drivers and Barriers to the uptake of Adaptation Goods and Services

A major obstacle to the uptake of adaptation services and goods is the unbalanced benefits of such services across stakeholders (Vaughan and Dessai, 2014). Where the benefits of adaptation accrue predominantly to stakeholders other than the company, the latter's willingness to pay may be limited. Without a legal or regulatory requirements, such adaptation actions regularly go unrealized.

Institutional and policy failures, such as the mispricing of natural resources, are at the root of unrealized adaptation and thus of the lack of uptake of adaptation goods and services. Market failures, such as uncertainties over the amortisation times of investments in adaptation goods and services or the lack of access to finance, are behind the lack of uptake. Technology barriers include the lack of a track record for certain technologies in providing effective adaptation in a given context. There may also be a mismatch between climate solutions and the unformulated needs of potential users. For instance, in studies on climate service in the EU, it was suggested that climate services providers appear to lack understanding of which climate information users exactly need (Bater, 2018; Lamich et. al, 2018, Tart et. al, 2018). Finally, shortcomings in knowledge and technical capacity are a reason why the adaptation goods and service market is still lagging behind its full potential (Trabacchi et al., 2020).

These factors resemble to an extent the barriers identified for market research on climate services in the EU, where barriers were analyzed from different perspectives (Table 6).

TABLE 6. Barriers to the market uptake of climate services

Demand-side barriers to uptake	Supply-side barriers to uptake	Barriers to matching of demand and supply
· underestimated climate risks compared to other risks · inherently short-term business models · lack of risk management in business decision-making · lack of awareness of climate information	· lack of marketing of available climate services · service and products out of range for the user group · Lack of resources for product development and delivery	· inconsistent use of 'language' and conceptions · uncertainty about the eventual relevance of the user's purpose · temporal and/or spatial resolutions do not match other users' data · insufficient guidance and/or embedded consultancy

Data source: (Perrels, 2018)

For private climate-service suppliers to scale up their businesses, one recommendation is to standardize their services (e.g., terms, product categories, product ratings, quality assurance). Suppliers should also consider the user experience in respect of service delivery, visualization and the integration of risk indicators with the user's decision-making variables. Moreover, collaborative service development and delivery models between climate service suppliers and users can be considered. In addition, the enabling environmental plays a great role: for instance, market stimulation by fostering incubation, acceleration and upscaling can contribute considerably to the growth in capacity. This is particularly important for SMEs and start-up businesses trying to identify their market niches. Hoa et al. (2019) also argue that market uptake can benefit from a greater diversity of business models through support of Spin-Offs, Start-Ups or Public-Private Partnerships. SMEs, in particular, can contribute to the uptake of climate services by developing adaptation solutions locally and effectively.

On the demand side, the driving forces include the impact of public-private partnerships and local networks, through which complex climate actions can be interpreted better by customers in the form of participatory approaches, where peers "inspire and incentivise". All these measures help potential customers to increase their understanding of climate risks (Hoa et al., 2019).

Chapter 3. Risk and Management Tools for Businesses

As companies seek to establish and maintain profitable business models, climate-related risks have repercussions for their economic activities and value chains. It has been shown that companies in developing countries, especially MSMEs, operate under difficult circumstances when planning for climate change. This necessitates tools that allow them to screen climate risks and decide which adaptation options and strategies to pursue.

To better understand the climate risks faced by businesses and their adaptation options, several assessment tools were reviewed from the perspective of businesses, assessing depth, user-friendliness and the extent to which they lead to effective adaptation strategies. Ultimately, four tools were identified, which (i) were available publicly and free of charge, (ii) can be used by companies across various economic sectors, (iii) are simple enough to be used by MSMEs in developing countries, and (iv) go far beyond merely disclosing company information relating to climate resilience to guide companies towards more climate-resilient business models.[7]

TABLE 7. Overview of Risk and Management Tools

Tool name	Target size	Target	Method	Methodology elements
GIZ Climate Expert	All sizes	SMEs, companies	4-step methodology spreadsheet	1. Climate change impact assessment 2. Risks and opportunities 3. Adaptation measures & cost-benefit analysis 4. Adaptation strategy
UKCIP Adaptation Wizard	Med-Large	Large companies, institutions	5-step methodology spreadsheet and toolkits	1. Getting started 2. Current climate vulnerability assessment 3. Future climate vulnerability 4. Adaptation options 5. Monitor and review
UKCIP Speed Business Areas Climate Impacts Assessment Tool (BACLIAT)	Med-Large	Companies	4-step methodology spreadsheet	1. Assessing current vulnerability 2. Business areas' climate impacts assessments 3. Changing business practices 4. Potential adaptation measures
Oxfam PREP Business Adapt	All sizes	Value chains of companies	5-step methodology questionnaire	1. Analysing the issues 2. Developing an internal strategy 3. Assessing risks and opportunities 4. Prioritizing actions 5. Tackling actions and evaluating progress

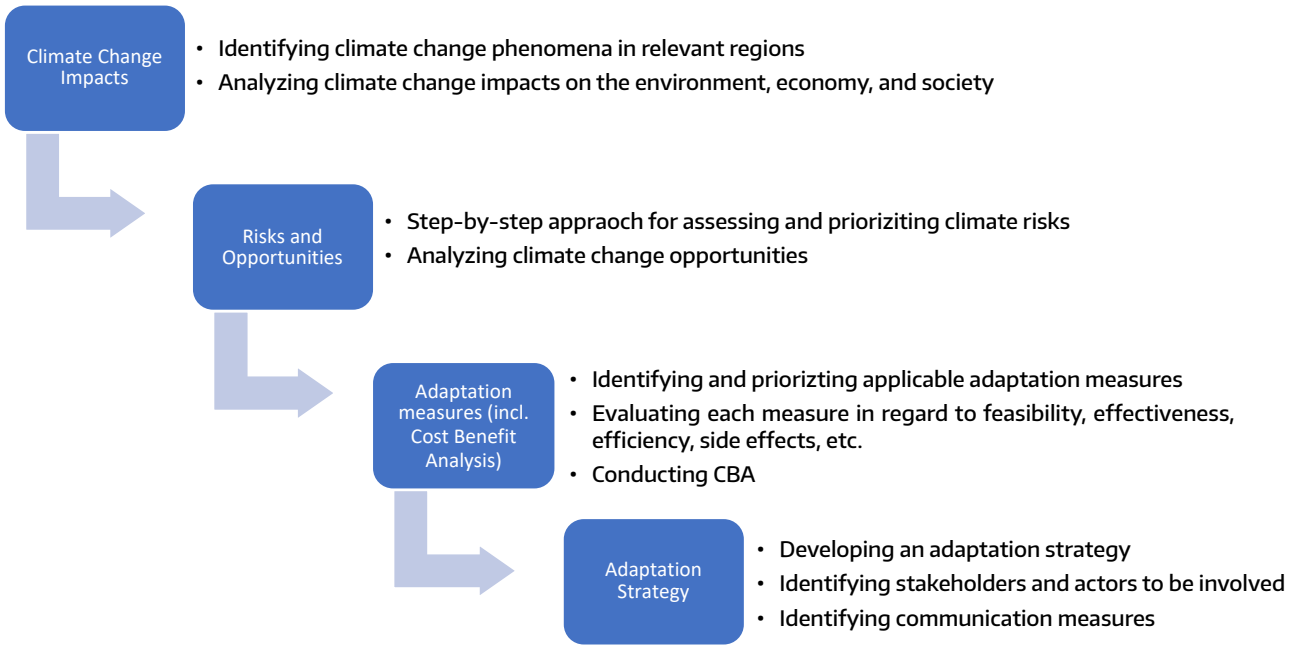
The above table summarizes the four tools and their basic features, which are shown as having certain characteristics in common. A common starting point is an analysis of the context, including an assessment of exposure, hazards and vulnerability. All four can be applied to companies, and all four follow a step-by-step approach, leading the user from assessment and analysis of both business risks and opportunities to the development and prioritization of adaptation strategies. Some follow a value-chain approach, while others focus more on a business and its activities. Physical risks are dominant in the consideration of all four tools. The following chapters contain more in-depth analysis on every tool and its respective strengths.

GIZ Climate Expert

The GIZ Climate Expert tool targets SMEs with the goal of developing complete adaptation strategies. The four-step assessment consists of companies filling out an Excel spreadsheet containing worksheets for every step. This facilitates the process from an initial climate change impact assessment to the formulation of adaptation measures. This assessment tool allows SMEs to identify climate risks and opportunities for various business operations (infrastructure and operations, stakeholders, government and regulation, finance and market) using probability, magnitude and risk as assessment variables. This tool has a high level of practicality for users to assess their internal risks and vulnerability to climate impacts. It also includes a special focus on new business and market opportunities, helping SMEs to envision alternative strategies to plan according to the identified short-, mid- and long-term climate risks. The timeline for weather and climate trends for the company in the spreadsheet is between one and ten years, a short-term perspective compared to the time horizons that are usually discussed in relation to climate change impacts (2025, 2030, and 2050). However, the timeline is aligned with typical business cycles and the investment amortisation cycle of many of the proposed adaptation investments in the case studies that accompany this tool.

One of the main features of the GIZ tool is that companies can specify the risks, costs and benefits of their operations, thereby quantifying the losses in different climate change scenarios and producing cost-benefit analyses (CBA). Completing a risk assessment, risk matrix and cost-benefit analysis leads to the final step in developing an adaptation strategy.[8]

FIGURE 4. GIZ Climate Expert



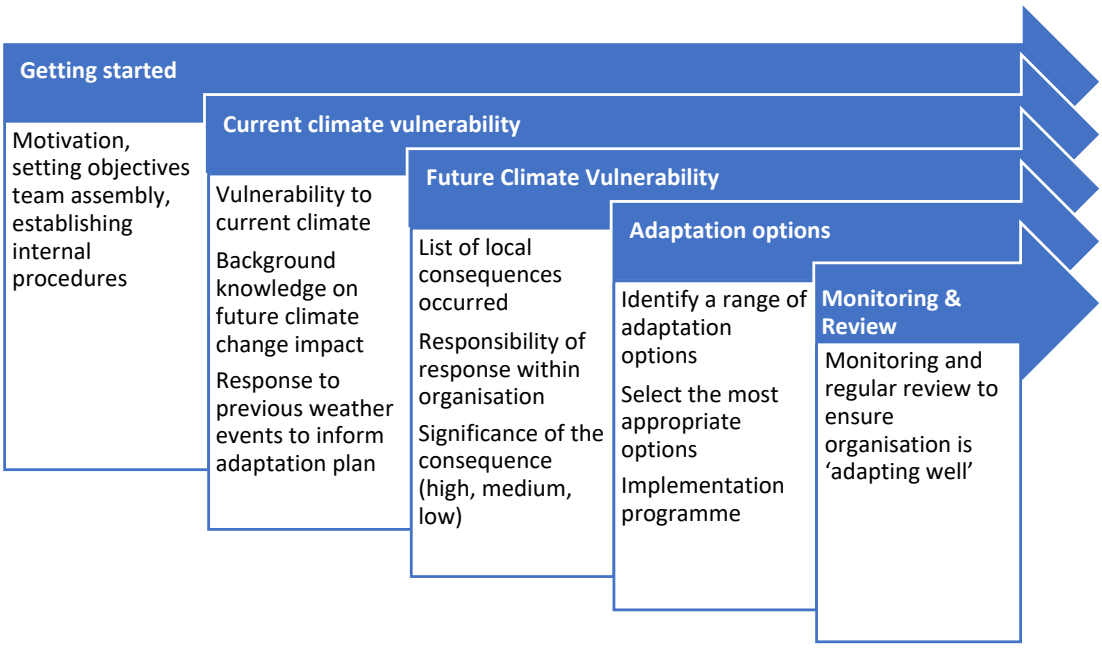
While the CBA is a distinctive strength of the GIZ tool, it should be noted that CBAs of environmental actions have important limitations [9]

The GIZ Climate Expert tool has been used by companies operating in the agriculture sector, such as coffee and rice, as well as in other industries. GIZ also publishes case studies showing how the tool is used in practice on the tool's website, that is, twelve case studies of applications of the tool for various company sizes, from the shipbuilding sector in Bangladesh to Starbucks' value chain. Some case studies are silent on whether the measures were adopted, but the developers documented their experiences in Morocco, Bangladesh, Costa Rica and Rwanda (Frei-Oldenburg *et al.*, 2019).

UKCIP Adaptation Wizard

The UKCIP Adaptation Wizard offers companies a very detailed five-step methodology, each step including resources such as guides and Excel worksheets for users to guide the adaptation process for their own business activities.[10] The tool is targeted at larger companies in the United Kingdom (UK) that seek to identify previous and expected climate risks, allowing them to assess the impacts for each area of responsibility. Moreover, businesses are guided in identifying the indirect impacts and opportunities derived from climate vulnerability with the help of the worksheets and guides. Nevertheless, the tool does not include a cost-benefit analysis as in the previous example, nor practical guidance on costing.[11] It is also not clear how specific business operations will move from risk assessment and adaptation planning to the specific changes that each department in the company needs to make.

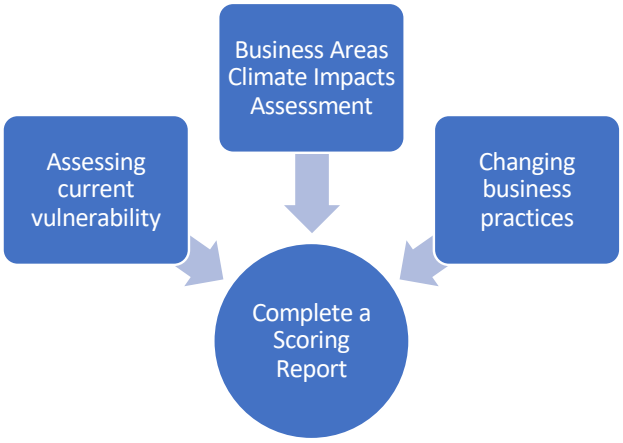
FIGURE 5. UKCIP Adaptation Wizard



If followed in full, the UKCIP Wizard tool is task- and labour-intensive, but it can provide a very detailed and context-specific identification of climate risks. To give an example, one step includes detailed guidance on how to produce profiles of local climate impacts by documenting newsworthy weather events for a particular location that have had an impact on the business. Producing such local climate-impact profiles would involve laborious research. However, the tool's developers believe that completing the Wizard will require little expenditure unless the assessment requires commissioning further research. Once the first step has been taken, three further half-day workshops supported by interim work could finalize an assessment in the developer's estimate.[12]

One strength of this tool is its monitoring and reviewing manual, which takes users from the adaptation strategies to a concrete evaluation process of progress and performance. Another strength is the guidance provided on classical change-management tasks – strategies for effecting change and helping people to adapt to change – that are typically involved at the onset of any new initiative in an organization.[13]

FIGURE 6. UKCIP Speed BACLIAT Business tool



UKCIP Speed BACLIAT (Business) tool

This tool is part of UKCIP's workshop-led approach and its Business Areas Climate Impacts Assessment Tool (BACLIAT) assessment. BACLIAT has been used by trade associations and companies in the UK. Users are invited to finalize the steps in an Excel spreadsheet by themselves or in a day or half-day workshop.

The UKCIP BACLIAT tool focuses on climate impacts that are specific to certain business areas. Users can select their industry type, production activities, resources and other inputs, generating a list of potential climate change impacts based on a database. The climate impacts relate to the company's different business areas. There is also a facility to add one's own assessment of impacts.

The BACLIAT tool is practical in guiding users to specify actions for businesses and assigning responsibility for actions to departments and staff. Moreover, it includes a template for a scoring report to be filled out in the Excel spreadsheet that can be populated with preceding content. However, the UKCIP Speed BACLIAT tool does not include CBA as part of its adaptation assessment, which is a limitation for companies seeking to prioritize cost-effectiveness among adaptation options.

Oxfam PREP Business Adapt Tool

The Oxfam PREP Business Adapt tool uses a five-step methodology that guides companies with a questionnaire to analyse issues that impact on resilience and asks key questions that help business owners identify possible actions. Additional resources such as sectoral modules with questions specific to the value chains of businesses in food, beverages and agriculture, water and energy utilities, and general manufacturing supplement the general questionnaire. Focused on physical risks, the questionnaire probes the business's value chain through questions on both risks and opportunities ("*How will your company take advantage of the market opportunities triggered by a changing climate?*"). Unlike the other tools, this tool does not make use of spreadsheets for businesses to fill out. Instead, it is question-based and refers users to an appendix where they can explore further sources of information and identify key resources to help them navigate the guide. It does not provide case studies of where the application of these steps has been tested; rather, the methodology is preceded by examples from Swiss Re, Lewis, Starbucks and smaller companies and the actions taken to ensure climate resilience.

While it is helpful that concrete entry points are suggested for gathering information and for planning for each step, what are described as "typical corporate processes and documents" do betray a focus on larger companies rather than SMEs (e.g., annual report and regulatory disclosures, sustainability plan, supply-chain risk-management, etc.). Both the suggestions and examples for entry points suggest that, while the steps in themselves are practical enough to apply to companies of all sizes, much of the guidance here applies to larger companies.

Analysis of Risk and Management Tools

An analysis of the risk and management tools shows that there are common features and distinctive strengths. However, it also shows common presumptions. While tools are to varying degrees helpful in systematically assessing climate risks and opportunities and making up strategies, they assume that businesses have at their disposal resources that they are unlikely to have. What businesses in developing countries, especially MSMEs, lack, and what the tools presume decision-makers in these companies to be in possession of are weather and climate information, ranging from downscaled weather information to long-term climate projections, cost data on physical impacts and the cost of adaptation measures, and knowledge and technical capacity on adaptation measures. Listing the assumptions made by the tools should not be misunderstood as a criticism of the tools per se, which are very effective in drawing attention to the need to improve understanding of the climate risks to businesses and their responses. Instead, it will be enough here to show that, where resources are lacking, particularly for MSMEs, businesses are emerg-

TABLE 8. Analysis of Risk and Management Tools

Tools		
GIZ Climate Expert	· Practical but complex, requiring assistance · Time-effective · Guidance on CBA and communication plan	· Presumes weather and climate information or climate change impacts over 5-15 years are known
UKCIP Adaptation Wizard	· Detailed and in-depth guidance on every step and a lot of supplementary material · M&E guidance, change-management guidance	· CBA not included; cost implications known · Assumes information on decision-relevant factors readily available
UKCIP Speed BACLIAT	· Time-effective · Sector-specific impact assessment	· CBA not included; cost implications known
Oxfam PREP Business Adapt	· Sector-specific resources · Focus on value chain	· Presumes information on company-internal and external factors readily available to make decisions

ing and growing to provide just these resources. Before diving into these adaptation businesses in Chapter 4, we will take a more detailed look at the assumptions.

Weather and Climate information

The tools assume that businesses are in possession of very granular weather data and climate projections. While the body of information on the regional impacts of climate change is growing more and more granular, with increasingly downscaled projections becoming available, businesses, and in particular MSMEs in developing countries, might not be aware of their existence or of how to interpret these projections and their implications for their businesses. The analysed adaptation tools tend to use past weather data and impact estimates originating from historic climate risks for companies. Nevertheless, the assessment tools suppose companies have access to climate and weather information, which is actually often difficult to access at such a local level and hard to process for individual businesses' needs in developing countries. For example, the GIZ tool assumes that knowledge on the unavailability of water is prevalent in companies in the long term, which is unlikely to be the case.

Cost data on possible losses and on adaptation measures

All tools assume that the approximate range of the costs of not adapting, i.e., the damage from the impact, is known. But this is unlikely to be the case given the uncertain outcomes and the inaccessibility of weather and climate information that is locally relevant. Moreover, the tools assume that knowledge of the costs of adaptation measures is also largely known. This assumption is perhaps explained by the tools' primary focus on internal and shorter-term responses. The experience of GIZ has found it helpful to encourage SMEs to plan for adaptation by focusing on adaptation measures that come at no or little cost, thus avoiding any implication that adaptation is necessarily costly. Given the relatively short planning horizons of MSMEs, it is reasonable to expect that their focus would be on measures with short amortisation periods (Frei-Oldenburg *et al.*, 2019). However, where this is not the case, information on the costs of adaptation measures and the costs of not adapting is needed.

Knowledge and technical capacity on adaptation options

Depending on companies' capacities, they might find having to use the tools themselves overwhelming. The tools partly acknowledge this. The GIZ tool, while practical, occasionally requires assistance, and GIZ found that SMEs were often reluctant or unable to finance the consultants' work.[14] The developers of the UKCIP Adaptation Wizard consider that it requires little expenditure "unless the need to commission research arises". The Oxfam PREP Business Adapt assumes that information on company-internal and external factors is readily available when making decisions. In some cases, companies will have the knowledge and technical capacity to use the tools, develop adaptation strategies and implement them, especially, as has been discussed, when adaptation strategies consist of low-cost measures. However, in other cases, knowledge and technical capacity regarding their context-specific risks

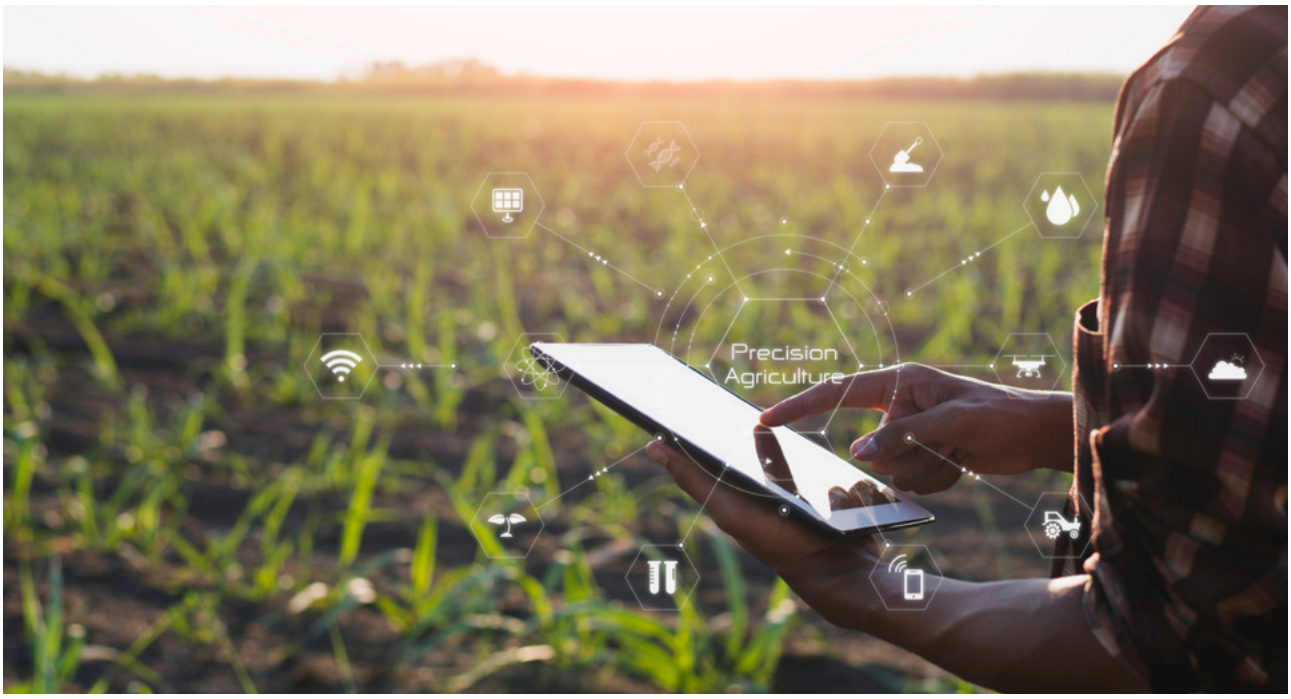
and impacts are required. Adaptation "audits" or other services targeted at companies could fill this gap.

Adaptation beyond a company's scope

Moreover, with one exception the tools neglect the role of cooperation. The Oxfam PREP Business Adapt tool stands out for including questions that probe the potential for engagement with government and stakeholders on climate resilience for every step. Conversely, the GIZ tool does not guide businesses to collaborate with other businesses or stakeholders, nor to seek government assistance to address climate impacts. It assumes no improvements in government systems, or not to the extent that would eliminate the risk sufficiently. Given the current state of public adaptation efforts, it is a reasonable assumption to conclude that the burden of adaptation efforts will fall overwhelmingly on the companies themselves.

And yet there is a limit to a company's ability to address climate change impacts, as is evident from the case studies. The GIZ Climate Expert tool leads users to specific actions and a strategy, but it acknowledges it neglects actions or changes beyond the scope of the company. GIZ recognizes this in some of the case studies.[15] The example of the M/S. Khairul Auto Rice Mill in Khulna, Bangladesh, mentions damage to crop production and harvests, but does not identify an adaptation measure.[16] This may be because no suitable adaptation measures are available to the company (such as insurance) or because there is an acknowledgment that this impact would be beyond the company's ability to address. If not in the tool itself, in a case study the developers encourage the need for public-private dialogues and joint solutions to be able to cope better with climate risks and to find responsible adaptation solutions.[17]

Some of the case studies of use of the GIZ tool stress that some adaptation measures were prioritized over others because they exceeded the company's internal resources. Thus, a next step in which MSMEs in developing countries could benefit from guidance, if not tools, is the implementation of adaptation measures, which, if going beyond internal resources, requires access to finance. In reflecting on their works, GIZ suggested that climate risk assessments and presentations of adaptation strategies could be incorporated into the general risk assessment of loan-appraisal processes in highly vulnerable countries and sectors (Frei-Oldenburg *et al.*, 2019).



Chapter 4. Examples of Adaptation Businesses

In the previous chapter, it has been demonstrated that the risk and management tools for business provide practical guidance to businesses regarding their adaptation needs. However, they are based on a few premises that, though they may be valid for some companies in industrialized countries, are unrealistic for companies in developing countries, especially MSMEs.

This chapter will examine two examples of adaptation businesses that respond to this need and that are particularly relevant for MSMEs, weather and climate information products and index-based insurance. Moreover, as an example of an adaptation good, climate-resilient and low-carbon construction and building materials will be showcased. They are examples of adaptation goods and services that emerged or gained in importance in light of the need to adapt to the impacts of climate change and show how their businesses models are expected to change.

Weather and climate information products

Weather and climate information products are an example of a business model that is gaining in importance due to increasingly severe climate impacts. In their assessment of the potential to unlock adaptation capacities in MSMEs by providing them with relevant weather and climate information (WCI) Hoedjes et al. (2018) illustrate the growth in demand for and delivery of private WCI products. There is vast adaptation potential in using public information – e.g., weather and climate data from meteorological and hydrological services in developing countries – for commercial use by translating it into accessible and user-friendly formats and business- and industry-specific contexts, for example, in the form of "apps", other software and services in general.

A wide range of adaptation solutions can be developed on the basis of actionable, local and timely agrometeorological forecasts: agricultural value chains and weather index-based insurance are two prominent examples that already rely on these products.[18] In the manufacturing sector, supply-chain disruptions could be anticipated, and distribution-chain interruptions in the logistics sector. Weather-induced changes to consumer behaviour are a promising, but largely unexplored opportunity, one in which advance knowledge of WCI can be leveraged by MSMEs to adapt and to generate a profit. Given the variety of user needs among MSMEs in different sectors, different types of applications and services are required to process and present actionable and relevant information. With an eye to MSME needs, Hoedjes et al. (2018: p.143) describe what is typically demanded in the agriculture sector:

> *The type of information that is probably the most relevant for MSMEs in the agricultural sector is a relatively simple short to medium range rainfall forecast that allows farmers to decide when to plant, apply fertilizer and harvest, and where and when to sell produce. Besides accuracy, location specificity is one of the most important aspects of such a forecast. The kind of accurate downscaling algorithms that are required to downscale global model outputs require hydro-meteorological data at a high spatial resolution.*

The potential value of WCI products lies in the extent to which providers of them can access ideally free public WCI cost-effectively, translate them to the user's context, and provide them in an accessible format and medium.

While the potential is vast, there is a need for public investment in national meteorological and hydrological services in developing countries and for WCI services that are more tailored to the needs of MSMEs. Ignitia, a weather-forecasting company specializing in tropical weather, is an example of a pay-for-service model established through collaboration between mobile-phone providers and national meteorological and hydrological services in developing countries.[19] Existing businesses demonstrate that, in addition to investment in modern equipment, what is required is accurate WCI as much as product design and continuous improvement following user feedback. While there is a risk of overestimating willingness to pay, especially by smallholders, practice has demonstrated that smallholder farmers in developing countries have become more prepared to pay for WCI services (Ministry of Food and Agriculture and GIZ, 2014).[20]

WCI is already being used in the agricultural value chains of large agro-industrial companies. Examples include the acquisition of Weather Company by IBM and Climate Corporation by Monsanto (now part of Bayer). But there Hoedjes et al (2018) also describe examples of businesses that provide WCI in developing countries: Ignitia, Earth Networks, aWhere Weather, the Trans-African Hydro-Meterological Observation network (TAHMO), Kukua, Human Networks International (HNI) and MeteoGroup with the Weather Philippines Foundation. While some of these are donor-funded initiatives, more and more are applying a commercial model.

Index-based insurance

Another example of an adaptation service that enables the transfer of physical climate risks and thereby allows preventive planning is index-based insurance (also known as parametric insurance). Whereas traditional insurance products offer a pay-out based on assessed damage, index-based insurance bases its pre-agreed pay-outs on trigger events. There are potential advantages here for both insurer and insured: index-based insurance typically results in faster pay-outs, and the cost of damage assessment is saved. For businesses hit by natural disasters, the speed at which payments are made can have a significant impact. Adverse selection and moral hazard can be avoided, thus reducing underwriting and claim assessment costs.

The insurer assuming the risk agrees to pay the insured an agreed amount upon the occurrence of a specified event, e.g., an earthquake or flooding of specified intensity. Insurer and insured can develop customized risk parameters based on rainfall (or lack thereof) and seek to agree on an authoritative index for that type of event, hence the synonym "index-based insurance". The index can be based on climatic data collected at meteorological stations, for instance, rain, hail, temperature, or wind. Similarly, it could be based on an average outcome measured over a small area such as crop yield, perhaps observed through remote-sensing techniques.[21]

Barriers to the uptake of index-based insurance are numerous. The benefits of insurance, including index-based insurance, to MSMEs are often poorly understood, and its costs are possibly high or perceived to be high. Pre-agreed pay-outs may be too low compared to the damage and losses incurred (or the damage and losses reimbursed with traditional insurance). To the extent that government programs cover the losses of hazardous weather events, MSMEs have no incentive to purchase insurance. Insurance businesses might lack knowledge of MSMEs as a target market or of their product preferences. Due to these drawbacks, index-based insurance as a business in developing countries is still a work in progress.

Nevertheless, the provision of index-based insurance for MSMEs is mushrooming. While weather-linked insurance dates back decades, this business has found new applications and markets, taking into account both the expected intensity and frequency of hazardous weather events and the improvements in data collection that allow insured risks hitherto deemed uninsurable to be calculated. Wide mobile-phone access and new technologies allow the expansion and further cost reductions needed to make business models sustainable without subsidies. Index-based insurance uptake and its value to businesses could still grow. Carter *et al.* (2014) point to the need for product improvement. Reducing basis risk, which is the difference between a weather shock on the business and measured risks at the meteorological station level, is paramount.[22] The more differentiated the microclimate and the fewer the weather stations, the more basis risk can be expected (Clarke, 2011). Product improvements can be anticipated from a feedback loop stemming from impact analyses of ongoing programs and more insights into risk-related behaviour. This also points to the importance of risk layering, i.e., combining insurance with credit, savings and risk-reducing investments to tackle different categories of risk. For this reason, these various financial products should be offered in a coordinated fashion. Beyond MSMEs, there is an increasing motivation for institutions – exposed banks, but also relief institutions such as government agencies or NGOS – to index-insure their at-risk portfolios. Parametric insurance is also an option for re-insurance (Carter *et al.*, 2014).

Climate-resilient and low-carbon construction and building materials

The role of the material manufacturers and distributors in developing and disseminating climate-resilient and low-carbon technologies cannot be overstated. Along with reducing energy demand and decarbonizing the power sector, materials that reduce life-cycle emissions in the built environment are vital to reducing emissions overall (UNEP, 2020). In ensuring climate resilience for the built environment, climate-

resilient materials form part of an integrated approach encompassing whole structures and surroundings.

The construction and building materials industry is bound to undergo a significant transition to climate-resilient and low-carbon technologies, and the businesses that offer these technologies are destined to increase in relevance. An industry report on climate risks for the construction and building materials sector highlights the physical and transition risks the sector faces. Among the responses to these risks, the report identifies business opportunities in product, process and material innovations that reduce greenhouse gas emissions (WBCSD, 2020).

TABLE 9. Summary of climate-related transition and physical risks to building products and material manufacture (WBCSD, 2020)

Climate risk		Building products and materials manufacture
Policy and legal Climate Expert	Pricing of GHG emissions	Diversify towards low-carbon materials and products. Procure competitive low-carbon energy through partnerships with electricity producers (PPAs) and switch to low-carbon distribution methods such as electric vehicles (EVs). Purchase carbon credits/offsets for unabatable emissions and explore options, such as carbon offsetting, to reduce impact of operational emissions.
	Enhanced emissions reporting obligations	Conduct dialogue on how to improve emissions reporting standards, with a focus on Scope 3 emissions calculations and reporting. Undertake more transparent reporting of Scope 1, 2 and 3 emissions across the construction value chain
	Product specification and regulatory changes	Adjust the product mix in response to changes in demand Evolve the product portfolio mix in the longer term to adopt low-carbon alternatives Stay well informed of regulatory developments.
	Climate change litigation	Use existing risk-management procedures to manage exposure to climate change litigation. Company risk registers typically include 'exposure to litigation' as a risk. Monitor developments in climate-related disclosure requirements, including evolving investor and stakeholder expectations regarding climate-related disclosures.
Technology	Substitution of existing products and services with lower emissions options	Incorporate lower emissions options into the product portfolio mix. Assess and communicate the carbon intensity of materials/products using a lifecycle/circular economy approach Increase R&D spending on developing lower emissions materials and products. Increase investment and capital expenditure to develop and deploy technologies that lower operational emissions
	Costs to transition to lower emissions technology	Re-allocate capital based on strategic assessments of low-emissions operations and products, and advocate policies and financing solutions to support and de-risk the development of low-emission technologies.
Market	Increased cost of raw materials, shift in consumer preferences	Diversify product portfolios and hedge the price volatility of key materials. Source raw materials more widely, engage with suppliers and vertically integrate operations. Explore circular economy options.
Reputation	Changing Public perceptions of the sector	Maintain the focus on sustainability reporting, corporate citizenship and environmental responsibility, ensuring this is well documented and transparently communicated. Maintain the strategic focus on minimizing environmental impacts and contributing to climate change mitigation and adaptation efforts. Explore the potential for differentiation in the market based on environmental credentials
Chronic physical risk	Rising sea levels, increasing mean temperatures, changing precipitation patterns	Environmental risk assessments of asset locations, implementation of preventative measures and/or development of alternative risk mitigation strategies. Diversified portfolio/approach to compensate and cover for business interruptions. Comprehensive supplier selection criteria and diversification of supplier mix. Contingency planning in distribution routes.
Acute	Increased severity and frequency of extreme events	Increase the resilience of facilities to extreme weather events by improving defenses and implementing contingency plans. Relocate production sites to less exposed areas where feasible. Build in flexibility and contingency by diversifying the supplier mix. Insurance arrangements.

Climate-resilient construction and building materials include resistant and durable materials that can withstand both the gradual increase in median temperatures and the increased frequency of hazardous weather events, such as wildfires, storms, hurricanes, flooding and heat waves. Low-carbon construction and building materials include recyclable products, materials that foster the conservation of non-renewable resources and any materials that reduce the carbon footprints of the manufacture, processing, installation, transportation, disposal and recycling of building materials. Such materials can reduce emissions intensities in the construction of a structure (embodied carbon) and/or the emissions stemming from the structure over its lifetime (operational carbon).

In combination with corresponding designs, climate-resilient construction and building materials typically result in increased asset lives and reduced repair and maintenance costs, as expensive retrofitting is avoided. This also reduces the risk of buildings and other structures becoming prematurely obsolete. At the same time, climate-resilient building solutions might be more costly at the construction stage than solutions designed for a business-as-usual scenario. For instance, while energy-efficient building insulation or resilient windows can effectively reduce a building's demand for energy for heating or cooling (reducing OPEX), these technologies might be more expensive at the upfront investment phase (CAPEX). Moreover, multiple technologies can have different objectives and at times opposite effects (e.g., stronger structures for disaster resilience or thermal capacity versus lighter structures to reduce resource consumption in construction). There may be a trade-off in technologies that reduce operational carbon but that increase embodied carbon (e.g., fortifying the thermal resistance of the building envelope by using additional insulation) (Shadram et al., 2019). To be considered sustainable, materials need to be chosen through a balanced consideration of their application over their lifetime.

The degree to which climate policies enforce the Paris Agreement's emissions reductions goals will affect the materials sector. To meet the global goal of net zero emissions by 2050, alternatives for the use of cement and steel in buildings will have to be explored, as emissions associated with these "hard-to-abate sectors" are still sizeable (IEA, 2020; OECD 2019). This requires extending the lifetime of buildings, developing new building concepts and designs, possibly incorporating the re-use of steel and concrete structures, and replacing emission-intensive materials in the built environment with materials that contain less carbon. This will require a major change in the business model of companies across the construction and buildings value chain, affecting, for example, raw materials, material manufacturing, construction, developers, property-owners and property-users.

UNEP (2020) suggests adopting concepts around the circular economy by recycling materials through maintaining materials and resources in use as long as possible. Material manufacturers can capture value by moving from a disposal model to a circular model, potentially reducing their supply costs and diversifying their offer through products that contain less carbon and feature other sustainability characteristics. Arup (2017) documents the possibilities of processing agricultural waste that would otherwise go for landfill or incineration and use it as efficient construction material instead. It is estimated that 10 percent of all organic waste could be diverted to construction.

Moreover, UNEP (2020) suggests using biomaterials as an alternative (e.g., wood, wood composite, bamboo, clay, packed earth). While some biomaterials have long been part of the built environment, the drive towards sustainability in the built environment has shed light on innovation in the application and use of biomaterials in various capacities (e.g., cork, leftover grain production or other agricultural residue used for insulation purposes). As a feature of circular economy models, biomaterials have the potential to be up-cycled, thus closing gaps in the product life-cycle. Some biomaterials are decomposable at the end of their life-cycle and can then support the regeneration of natural systems. Some sequester or store carbon while growing, or help to renew soils (UNEP, 2020). A growing demand for biomaterials would be aligned with a wider trend in the construction and buildings sector, namely the increasingly frequent combination of traditional building solutions with nature-based solutions.

Materials for circular solutions and biomaterials form part of what has been referred to as the "green building" materials market, which is forecast to grow at an annual rate of 8.6 percent by 2027 (Global Industry Analysts, Inc 2020), down from 11.7 percent in 2019 (IMARC Services 2019). The long-term market growth of businesses offering climate-resilient and low-carbon construction and building materials will depend

on the advantages of climate-resilient and low-carbon materials in terms of cost, functionality and convenience over established and large-scale incumbent technologies, such as cement and steel. Industry observers (McKinsey, 2021) warn companies in the biomaterials sector against relying solely or unduly on the ability to charge higher prices for green technologies ("green premium") and recommend instead developing a strong understanding of the potential applications of their products, and their relative advantages in terms of their technical performance. The extent to which biomaterials can be presented as having a credible sustainability value based on whole-life carbon and responding to possibly evolving environmental priorities is a key differentiator. Another strength of the use of biomaterials in environmental and financial terms may be their end-of-life applications. In contrast to traditional materials, many biomaterials are biodegradable, or better, can be recycled into other components. For example, sheep-wool insulation can be recycled back into insulation or can be reused as fibre for packaging.

Potent market drivers for these products include policy or regulatory requirements, above all building codes, which can address existing climate risks at both the company and community levels. Introducing major changes to building codes is difficult, as the procedures for their development are often deliberative and thus slow to adapt when it comes to including provisions for climate resilience. Codes may therefore lag years or decades behind accounting for the degrees of hazards experienced as a result of climate change (Global Resiliency Dialogue, 2021). However, building codes are a potent driver of the market transformation that will be required in the construction and buildings sector. A recent mapping shows that building energy codes are mandatory for the building sector in whole or in part in many jurisdictions globally (Global ABC/ IEA/ UNEP, 2019). Down the value chain, building regulations and policies mandating climate-resilient and energy-efficient structures foster the use of sustainable materials (OECD, 2018). There may be policies outside the buildings and constructions realm that have an impact on the functioning of biomaterial markets. For instance, the legal classification of organic waste as hazardous might prevent its re-use as a construction material (Arup, 2017). The use of wood products as a building material may be considered less safe than, say, steel because it is combustible. This is reflected in building regulations in many countries, particularly in taller and larger buildings (Buchanan et al. 2014). Agricultural policies may also affect the availability of and access to biomaterials.

One barrier to the use of carbon-resilient materials is that their benefits are limited unless they form part of a climate-resilient design encompassing the built structure and, importantly, the surroundings. Where neighborhoods lack integrated designs (e.g., flood drains for the whole area, or wind corridors and passive cooling to reduce the urban heat-island effect), severe climate impacts will be felt if a hazard occurs, even when building-level systems, including materials, improve user experience, safety and the market value of the building.

Concerns about costs are also inhibiting the market growth of climate-resilient and low-carbon construction and building materials. Such factors include potentially high CAPEX costs, especially when compared to conventional materials, which are not rapidly amortized or offset through lower operating and maintenance costs. One barrier to uptake in the commercial and residential buildings market is split incentives, i.e., property owners not investing in technologies that benefit mainly the property's occupants. Another barrier to uptake is unfavorable perceptions of climate-resilient and low-carbon technologies. Keena et al. (2020) comment on the use of local biomaterials that are perceived as outdated when compared to modern designs using steel and cement. Finally, the COVID-19 pandemic has affected the construction and materials sector in general and may continue to have an impact overall, including on the uptake of climate-resilient and low-carbon materials in the near future.

To arrive at functioning and scalable markets for climate-resilient and low-carbon construction and buildings materials, an ecosystem of supporting and associated companies and markets is required. It is evident that credible corporate commitments to sustainability and subsequent demands on downstream companies by large real-estate developers, large property owners or commissioners (e.g., cities) and investors are proving instrumental in transforming the construction and building materials sector. Certifications of the sustainability performance of this sector provide valuable market signals and quality assurance to investors, consumers, tenants and policy-makers who are aware of sustainability. For manufacturers offering materials suitable for use in the circular economy, Ramboll

(2021) recommends recording the environmental profile of their products using Environmental Product Declarations (EPDs) and making these EPDs accessible publicly, including in relevant databases. More credible and standardized metrics and reporting requirements in the sector provide assurance to investors seeking sustainability-certified investments that lend themselves to green securitization and thus drive the financing of sustainable materials (UNEP, 2020). Ramboll (2019) recommends that building designers, including architects and engineers, familiarize themselves with the relevant certifications and standards, and add "carbon management" to the services they offer their clients. This would allow monitoring emissions from projects similar to monitoring the construction costs. Specialized insurance products covering against the damage emanating from potential risks are needed, in particular risks to the supply-chain. Ensuring a reliable supply chain of biomaterials may be challenging given the seasonality of many natural materials.

Finally, there is need for tailored finance and insurance solutions to de-risk investments into potential CAPEX-intensive projects that will be needed to market biomaterials at scale. McKinsey (2021) states that public purchase agreements between a consumer brand and a biomaterials business are becoming increasingly common before plants are even constructed. For biomaterials in the construction and building sector this could be an investment possibility and a de-risking approach. Ensuring a sizeable offtaker of large volumes ahead of the investment can make large projects more attractive to financiers.

Arup (2017) made the need for supporting and linked companies and markets evident in a case study of organic waste used as construction materials. Besides a business case for the use of organic agricultural waste in construction materials, Arup (2017) lists business opportunities that arise around access enabling organic waste to be exploited. These businesses range from tools to regulate the waste stream across the value chain to the creation of services, thus allowing whole product-service systems to be offered, rather than just products. It is evident that a large part of the biomaterials value chain would consist partly in different companies (e.g., SMEs, agro-companies, forestry businesses) and partly in new start-ups. "Laboratories" to develop new products and assess applications in different sectors, as well as research institutes and academia to refine and improve materials properties, may also be required.

This is a nascent field, and more innovation is expected around the development of attractive business models for the full integration of climate-resilient and low-carbon alternative materials in buildings and construction. To achieve the potential of these opportunities, pull and push factors are increasingly recognized, such as the capacity of people, the public and the private sector to understand the value proposition of climate-friendly options and how they place the demand for these options in the market.

Chapter 5. Outlook

This publication has sought to highlight the dual reality of climate risks by shedding light on the threats to and opportunities for businesses. It has also shown that businesses are catalysts in the production and delivery of adaptation goods and services. In this regard, this publication forms part of a larger body of research highlighting the role of companies, including MSMEs, as change agents through their provision of adaptation services and goods. In their work to describe this occurrence, Trabacchi et al. describe this development and establish a working definition of "Adaptation SMEs" (Trabacchi et al. 2020, p.23).

> *An Adaptation SME is a company providing technologies, products and/or services that: (i) address systemic barriers to adaptation by strengthening users' ability to understand and respond to physical climate risks and related impacts and/or capture related opportunities, and/or (ii) contribute to preventing or reducing material physical climate risk and/or the adverse associated impacts on assets, economic activities, people or nature.*

It would be too simplistic to expect that, as awareness of the climate risks to businesses grows, markets for adaptation goods and services are bound to grow in a linear manner. Market growth will depend on a number of factors, one of which is public support for businesses to assess and understand climate risks and responses to them better. Another determinant is decarbonization pathways and the consequent impact scenarios. While it is evident that decision-making based solely on historical climates is no longer robust, the extent of climate impacts in the future is still unknown and depends on achieving reductions in global greenhouse gas emissions.

While new technologies allow businesses to identify options that are robust across a range of future scenarios and that allow some flexibility as the future unfolds, there will be times when transformational actions representing a stark change in direction may be needed. Switching to drought-resilient crops is of no use if a location is not fit for farming anymore. More resilient infrastructure may be wasted as cities need to be relocated (Global Commission on Adaptation, 2019). Not all adaptation solutions are "no regret" options, and as the climate crisis unfolds, difficult decisions will have to be made.

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Endnotes

1 Note that these estimates are of economic returns, not financial returns.

2 According to TCFD 2017, acute risks are event-driven, e.g., extreme weather events, including cyclones, hurricanes and floods; chronic risks are longer-term shifts in climate patterns, e.g., higher temperatures, sea-level rises or chronic heat waves.

3 It should be mentioned that, although the aim of this publication is to examine the private sector in developing countries, due to limitations of data (i.e., only large companies are following TCFD's framework in disclosing their adaptation actions), most of the empirical data are based on large companies' adaptation practices.

4 On the UNFCCC PSI database, business sectors covered include (i) Agriculture, Forestry, Food and Fishery, (ii) Engineering, (iii) ICT, and (iv) Business Management (including legal, tourism, real estate and finance services). Locations covered spanned industrialized and developing countries on all continents. Adaptation areas covered included Transport, Infrastructure and human settlements, Water resources, Science, assessment, Monitoring and early warning, Capacity building, Education and training, Food security, Agriculture, Forestry and fisheries, Human health, Tourism, Oceans and coastal areas, Renewable energy, and Terrestrial ecosystems.

5 Note that the market research on climate services in the EU and the UK defines climate services as follows "(…) which covers the transformation of climate-related data – together with other relevant information – into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions, and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management (DRM)" The UNFCCC PSI database has no definition for climate services but it is evident from the content that adaptation services include both services and goods. The UNFCCC PSI database can be visited at: https://unfccc.int/topics/resilience/resources/psi-database (accessed 14 March 2022).

6 Note that users of climate services in this survey responded with an average of four sectors for which they use climate services, rather than just one sector.

7 The authors are aware that, besides these freely available tools, there are a number of tools available for a charge, which were not reviewed. Moreover, there are climate risk disclosure and assessment tools, such as the Taskforce on Climate-related Disclosures (TCFD). While TCFD makes wide-ranging suggestions for what to disclose and can be adopted by the organizations of all industries, it was not reviewed in this chapter as a tool because it guides users in disclosure rather than climate strategies. Likewise, sector-specific adaptation tools are not reviewed here.

8 https://www.climate-expert.org/en/home/

9 CBAs have limitations when applied to climate change, a long-term and multi-dimensional problem (Weitzman, 2009). For instance, quantifying the value of ecosystem services and other non-market goods and services is fraught with uncertainty. Some scholars believe it is misleading. However, others argue that costs and benefits that do not get monetized do not get the attention of policymakers.

10 UKCIP (2013). The UKCIP Adaptation Wizard v 4.0. UKCIP, Oxford. www.ukcip.org.uk/wizard/

11 There is a section on costing, but it does not facilitate the costing of adaptation measures for businesses, let alone businesses outside the UK. There is also a spreadsheet that allows users to explore the costs associated with the impacts of overheating and flooding (costs in relation to health, agriculture, transport, and the built environment). However, its results are indicative only, generating costs for a small number of potential impacts based on two historic UK weather events (winter flooding events of 2000 and the hot summer of 2003). Accessed 13 October 2021 on https://www.ukcip.org.uk/wizard/future-climate-vulnerability/costings/

12 https://www.ukcip.org.uk/wizard/about-the-wizard/

13 https://www.ukcip.org.uk/wizard/getting-started/

14 The suggestion is to cooperate with business associations, NGOs, chambers of commerce, and training institutions focused on businesses, like the Bangladesh BIM Training Institute, which trains enterprises in sustainable supply-chain management, and industrial park managers.

15 https://www.climate-expert.org/fileadmin/user_upload/INCAE_Case_Study__Chiles_de_Nicaragua.pdf

16 https://www.climate-expert.org/fileadmin/user_upload/PSACC_Case_Study_Summary_Ricemill_170620.pdf p. 2

17 Source: Climate_Expert_Case_Study_Rocky_Dockyard_Company_English_Short_Version.pdf (climate-expert.org)

18 E.g., Kilimo Salama is an index-based insurance program for smallholders in Kenya and Tanzania that use weather information IFC, 2015). Tata Consultancy Services' (TCS) Mobile Agro Advisory System (mKRISHI) provides Indian farmers with information on microclimate, local market price and other business-relevant data.

19 www.ignitia.se

20 Hoedjes et al. (2018) cite examples from Niger and Zambia where willingness-to-pay for information services was miscalculated (RMSI, 2013; BASIXm Weather and Risk and MicroEnsure 2013).

21 Insurance Glossary Definition. www.IRMI.com

22 If there is rain at the meteorological station, or more rain than the trigger level, but drought at the location of the farm or business, no indemnities are paid. Similarly, if there is drought at the meteorological station, but rain at the farm or business, indemnities are paid even where no loss was incurred.


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