

UK Climate Risk
Independent
Assessment (CCRA3)

Technical Report
Chapter 6:
Business and
Industry

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This chapter should be cited as:

Surminski, S. (2021) Business and industry. In: *The Third UK Climate Change Risk Assessment Technical Report* [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London

Contents

Key Messages.....	3
6.1 Introduction	10
6.1.1 Scope of the chapter	10
6.1.2 Risk framing in this chapter	11
6.1.3 Terminologies	13
6.1.4 Interdependencies across other chapters.....	14
6.1.5 Evidence base	15
6.1.6 Socio-economic scenarios	17
6.1.7 Net Zero.....	18
6.1.8 Hazard-specific observations.....	19
6.1.9 Spatial aspects	20
6.1.10 Business engagement.....	21
6.1.11 Importance of focus on small and medium-sized enterprises (SMEs).....	21
6.1.12 Natural Capital.....	22
6.1.13 COVID-19 implications.....	24
6.1.14 Inequalities	27
6.2 Risks to business sites from flooding (B1).....	28
6.2.1 Current and future level of risk (B1).....	28
6.2.2 Extent to which current adaptation will manage the risk or opportunity (B1).....	39
6.2.3 Benefits of further adaptation action in the next five years (B1).....	48
6.2.4 Looking ahead (B1)	49
6.3 Risks to business locations and infrastructure from coastal change (B2)	50
6.3.1 Current and future level of risk or opportunity (B2)	50
6.3.2 Extent to which the current adaptation will manage the risk or opportunity (B2).....	58
6.3.3 Benefits of further adaptation action in the next five years (B2).....	64
6.3.4 Looking ahead (B2)	68
6.4 Risks to businesses from water scarcity (B3)	68
6.4.1 Current and future level of risk (B3).....	69
6.4.2 Extent to which the current adaptation will manage the risk or opportunity (B3).....	79
6.4.3 Benefits of further adaptation action in the next five years (B3).....	84
6.4.4 Looking ahead (B3)	87
6.5 Risks to finance, investment and insurance including access to capital for businesses (B4)	87
6.5.1 Current and future level of risk (B4).....	88
6.5.2 Extent to which the current adaptation will manage the risk or opportunity (B4).....	100
6.5.3 Benefits of further adaptation action in the next five years (B4).....	109
6.5.4 Looking ahead (B4)	112

6.6 Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments (B5)	113
6.6.1 Current and future level of risk (B5)	114
6.6.2 Extent to which the current adaptation will manage the risk or opportunity (B5).....	121
6.6.3 Benefits of further adaptation action in the next five years (B5).....	124
6.6.4 Looking ahead (B5)	126
6.7 Risks to business from disruption to supply chains and distribution networks (B6)	126
6.7.1 Current and future level of risk (B6)	127
6.7.2 Extent to which the current adaptation will manage the risk or opportunity (B6).....	134
6.7.3 Benefits of further adaptation action in the next five years (B6).....	138
6.7.4 Looking ahead (B6)	141
6.8 Opportunities for business from changes in demand for goods and services (B7)	141
6.8.1 Current and future level of opportunity (B7)	142
6.8.2 Extent to which the current adaptation will manage the opportunity (B7).....	154
6.8.3 Benefits of further adaptation action in the next five years (B7).....	158
6.8.4 Looking ahead (B7)	159
6.9 References	161
6.10 APPENDIX	188

Key Messages

What are the risks today and in the future?

- None of the current and future risks to business from climate change identified in the second Climate Change Risk Assessment (CCRA2) have decreased in magnitude. This partly reflects an improved ability to assess and report these risks, but it also reflects that business decisions continue to create additional risk by locking in increased exposure and vulnerability.
- Confidence in risk assessments is growing with better quality analysis and more sophisticated analytical approaches emerging, but limitations still exist. For example, it is often unclear if and how risks with low likelihood and high impact indirect risks and interdependencies are being considered by businesses. There is a lack of focus in particular on quantifying indirect losses, despite these potentially having significant implications for different business functions (in particular for B1, B2).
- Business and industry are exposed to threshold effects beyond which there is a step-change in risks, and which may necessitate much greater levels or different types of adaptation. This can be in the context of biophysical, engineering or policy thresholds. For example, increased demand for agricultural products or tourism services are subject to temperature thresholds and are likely to only occur for a specific duration. Another threshold is insurability – once reached this is expected to lead to a significant increase in magnitude of risk. These thresholds are likely to vary by time and place depending on the state of the assets, levels of investment to address climate change risks and/or maintain or improve the state of the assets, and the changing level of risk spatially over time (see B4, B5).
- A further concern are lock-ins that occur when business decisions ‘lock in’ future climate risk that may be irreversible or costly to revert later. There is evidence of lock-in through risk-insensitive behaviour. This can occur through businesses’ decisions on operating models, site locations, infrastructure, supply chains, technologies, policies, or pre-existing adaptation actions, which may increase exposure to long-term risks. Lock-ins are concerning when they result in higher magnitude of risk due to slow adaptation or mal-adaptive response (B1, B2, B3, B6).
- Cross-cutting risks: Physical climate risks and their impact on businesses in the UK are highly interdependent and there are a range of cross-cutting aspects that are relevant to Chapter 6 but covered elsewhere in the CCRA3 Technical Report, which are outlined in Section 6.1.4. These include cross-cutting risks with the natural environment and assets, infrastructure, people and the built environment, and international dimensions of climate risk.
- The focus in this chapter is on domestic (from climate change in the UK) risks. However, a key source of risk for many UK businesses is the result of climate change outside the UK which affects UK businesses through investments, supply chains, distribution networks and other business relationships. Climate change outside the UK may further affect UK

businesses through its impact on production and comparative advantage, and thus trade. While there are some mechanisms to monitor and address these risks - such as interdependencies mapping, supply chain resilience and trade agreements - the extent of these risks relies heavily on the extent of adaptation action outside the UK. Chapter 7 (Challinor and Benton, 2021) explores international risk in more detail – although it is referenced in this chapter where relevant. The urgency scoring in this chapter relates to domestically driven risks only.

What are the opportunities today and in the future?

- The changing climate can bring opportunities to some sectors and localities through shifting demand patterns leading to new markets for goods and services, better growing conditions or an increased need for financial solutions (see in particular B7).
- There are some early indications that some businesses are looking at potential opportunities from climate change, with some examples for goods and for services, but consideration of possible benefits remains largely unexplored (B7).
- Net-zero carbon strategies and the implications of these for adaptation as well as the embedded carbon of some adaptation measures such as air conditioning or flood barriers have not yet been assessed in a systematic way (B1, B2, B5).

Are the risks being managed, taking account of government and other action?

- Evidence of corporate adaptation action remains low. As in CCRA2, this can be viewed as a risk, and limits the ability to indicate the scale of the adaptation shortfall (or adaptation gap) and inform further benefits of adaptation.
- Overall awareness of adaptation as a business issue is low compared to awareness of mitigation and in many instances, businesses confuse mitigation measures for adaptation (see B4).
- Adaptation actions vary across businesses depending on company size, sector, location, past experience, access to information and resources, extent of a public-facing customer base, policy and regulatory frameworks in place, stakeholder and shareholder expectations, risk management processes, competitive advantage and company culture (B1, B2, B3, B4).
- There is little evidence that the growing awareness of climate risks (and their disclosure) has led to changes in investment decisions. This reflects both a timing issue in terms of risk ownership and an expectation that, in the short to medium term, insurance will protect assets. The main exception is in the infrastructure sector, especially in the water industry (see B2, B3, B4).
- There is currently no common method or metric for firms to assess adaptation or resilience efforts of their counterparties, a key barrier for the financial sector in particular. Current

information stems from self-reported surveys or qualitative indicators. Evidence shows a disconnect between understanding and responding to current climate variability as compared to future climate change. Adaptation actions such as business continuity efforts, buying insurance and switching suppliers are immediate steps in response to current risks, but may not be sufficient for future risk levels. While current resilience is important, it can also create a false sense of security and act as a disincentive for considering future risks. In particular, reliance on insurance with respect to current risks can generate a false sense of security and lack of financial incentives, which leads businesses to not take adaptive action in the short to medium term. In addition, insurance is projected to become a larger cost to businesses as extremes increase, which is currently not being factored into a majority of decisions (see in particular B4).

- A key area that might support further adaptation efforts are advances in availability and accessibility of data, and digital innovations. Machine learning might be used to support decision-making by optimising climate forecasting, understanding of historical weather patterns, and supporting climate and disaster risk mapping in real time. Continued focus on this space is needed, particularly in understanding how it can be integrated with or complement existing or planned incentive schemes (B7).

Government and regulatory action

- Business action is influenced by a set of generic (non-sectoral) regulatory actions, including planning regulations (where to build), building codes (how to build) and environmental health and safety (EHS) standards (operations within the building, e.g., overheating in the workplace). These influence current behaviour and guidelines, and standards could be used to incorporate future risk trends. Monitoring compliance, particularly with regards to future risk considerations, is likely to be a challenge for regulators.
- There is growing government and regulatory activity on risk disclosure.
- Regulators in the finance sector have adopted climate change strategies and play an important role in increasing the evidence base by supporting stress testing, scenario analysis and disclosure.
- Further investigation of the role of regulators outside of the finance sector is required to understand how they could create the enabling environment for further adaptation and provide more strategic and systemic analysis to guide integrated and longer-term action. Currently, regulators are mainly focused on aspects such as competition and consumer protection.
- Government has not mainstreamed adaptation into its Industrial Strategy, and in particular climate risk is not a focus of the Government's guidance on best policy principles for developing a local Industrial Strategy. Moving forward, it is imperative that these strategies consider climate risk and adaptation as drivers of economic policy. However, the Green

Finance Strategy does identify climate resilience and an increase in adaptation as strategic objectives, creating an opportunity for further action on adaptation finance.

- Companies cite a lack of information, as well as a lack of support and advice from Government as key barriers to adaptation action. They request help with accessing the right information and understanding what tools and measures can help reduce physical climate risks.
- There is also a role for government in supporting businesses to take advantage of the opportunities of climate change, i.e., addressing the barriers that will allow businesses to realise potential benefits, such as new markets, from climate change (see B7).

Action for government

Table 6.1 Urgency scores for risks and opportunities to business and industry					
Risk number	Risk/Opportunity	Urgency scores			
	Risk/Opportunity	England	Northern Ireland	Scotland	Wales
B1	Risks to businesses from flooding	More action needed (Medium confidence)	More action needed (Medium confidence)	More action needed (Medium confidence)	More action needed (Medium confidence)
B2	Risks to businesses and infrastructure from coastal change	More action needed (Medium confidence)	More action needed (Medium confidence)	More action needed (Medium confidence)	More action needed (Medium confidence)
B3	Risks to businesses from water scarcity	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)
B4	Risks to finance, investment and insurance including access to capital for businesses	Sustain current action (Medium confidence)	Sustain current action (Medium confidence)	Sustain current action (Medium confidence)	Sustain current action (Medium confidence)
B5	Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)
B6	Risks to business from disruption to supply chains and distribution networks	More action needed (Low confidence)	More action needed (Low confidence)	More action needed (Low confidence)	More action needed (Low confidence)
B7	Opportunities for business from changes in demand for goods and services	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)	Further investigation (Low confidence)

How strong is the evidence base?

- The evidence base has increased since the CCRA2, which broadly reflects growing awareness particularly amongst larger corporates, driven by regulatory pressures (particularly in the financial sector) and interest from investors who are demanding greater risk disclosure.
- The Task Force on Climate-related Financial Disclosures (TCFD)'s risk framing (physical risk, transition risk and liability risk) is being adopted by a number of companies in the financial sector and other sectors. However, self-reporting and most published case studies and assessments remain qualitative.
- Physical and transition risks are usually assessed separately by businesses, given the complexity involved in modelling and quantifying each. At present, these are often 'silo-ed' with transition risks dominating current discourse while physical risks are considered as only relevant in the long-term. The possibility of the lock-in¹ of physical risk - through, for example, risk-insensitive site location decisions or real-estate investments - are not typically being considered in risk assessments (see in particular B1, B2, B4, B6).
- For smaller and medium sized businesses, the evidence base remains very limited. We note a discrepancy of available information between small and medium-sized enterprises (SMEs) and larger companies, and listed versus non-listed companies, creating a knowledge gap that requires urgent attention, especially given the importance of SMEs to the UK economy. This applies across all risks identified.
- Overall, the data available for this report is still too limited for a systematic assessment of risks across sectors, company sizes and regions. Data either do not exist or remain outside the public domain, privately held by companies that have undertaken their own physical climate risk and adaptation studies.
- In particular, the evidence base (including for the devolved administrations - DAs) lacks geographically specific information, making a systematic assessment at the regional level based on the literature impossible.
- Results across sectors and risks are difficult to compare as underlying methods, assumptions and assessments vary significantly.
- For businesses operating at a global scale, it is unclear how to combine or compare UK-focused climate information with other national, regional or global risk tools.

¹ Lock-in is defined and expanded upon in Chapter 2

What further analysis is needed to close key knowledge gaps?

- A more systematic and comparable assessment of hazard, exposure and vulnerability to ensure comparability across risks, sectors and regions is needed. This should consider both direct and indirect impacts.
- Better visualization of geographical variations and clusters.
- Joint assessment of physical, transition and litigation risks and their interdependencies across different climate scenarios.
- Quantitative analysis of international interdependencies.
- Cross-sectoral evaluation of private sector adaptation action, including the effectiveness of action taken and the role of risk disclosure as a catalyst for more adaptation.
- Assessment of the effects of Net Zero, including the synergies or trade-offs (including potential mal adaptation) with climate risks and opportunities.
- Considering lessons learned and interdependencies from the COVID-19 pandemic.
- Appraisal of effectiveness of adaptation action and government policy in influencing or creating the enabling environment or incentives for business adaptation.

6.1 Introduction

6.1.1 Scope of the chapter

CCRA3 is concerned with physical climate risks, considering current and future impacts from extreme weather events or changing climatic conditions affecting the UK. This chapter reviews the current and future climate risks and opportunities for business and industry² in the UK. It outlines current and planned adaptation directly undertaken by companies and discusses benefits of further action. The main purpose is to inform government action to support private sector adaptation between 2023-2027.

Climate risks are determined by hazard, exposure, and vulnerability (see Chapter 2: Watkiss and Betts, 2021) for more information about the underpinning CCRA3 methodology). For risks to businesses and industry this requires an understanding of:

- changes and trends in different climatic hazards. This is provided in Chapter 1 (Slingo, 2021), which reviews the latest science on a range of hazards and summarizes how climate change and natural variability are impacting the severity and frequency of these hazards across different parts of the UK.
- factors that determine how these changes impact businesses and industry. This includes location, design and building characteristics that influence current and future exposure levels for different types of assets, employees and customers, and drivers of vulnerability including businesses' processes, behaviour, products/services, demand, relationships, business-size, adaptive capacity, regulatory framework, awareness, and governance, as well as existing adaptation.

The interplay of climate hazards with these factors is investigated in this chapter based on the 3-step CCRA3 methodology:

1. What are the risks and opportunities today and in the future? Are there thresholds, lock-ins or cross-cutting risks?
2. Are the risks being managed, taking account of government and other action? How do we know what adaptation action is happening and what is known about adaptive capacity?
3. Are there benefits from further action over the next five years, over and above what is already planned?

This methodology is applied to seven priority areas identified for CCRA3, based on a business function approach that allows investigations across sectors and business sizes (see Appendix for more details).

² The term 'business and industry' is used to capture the whole of the private sector engaging in commercial activity in the UK, from SMEs to large multinational companies.

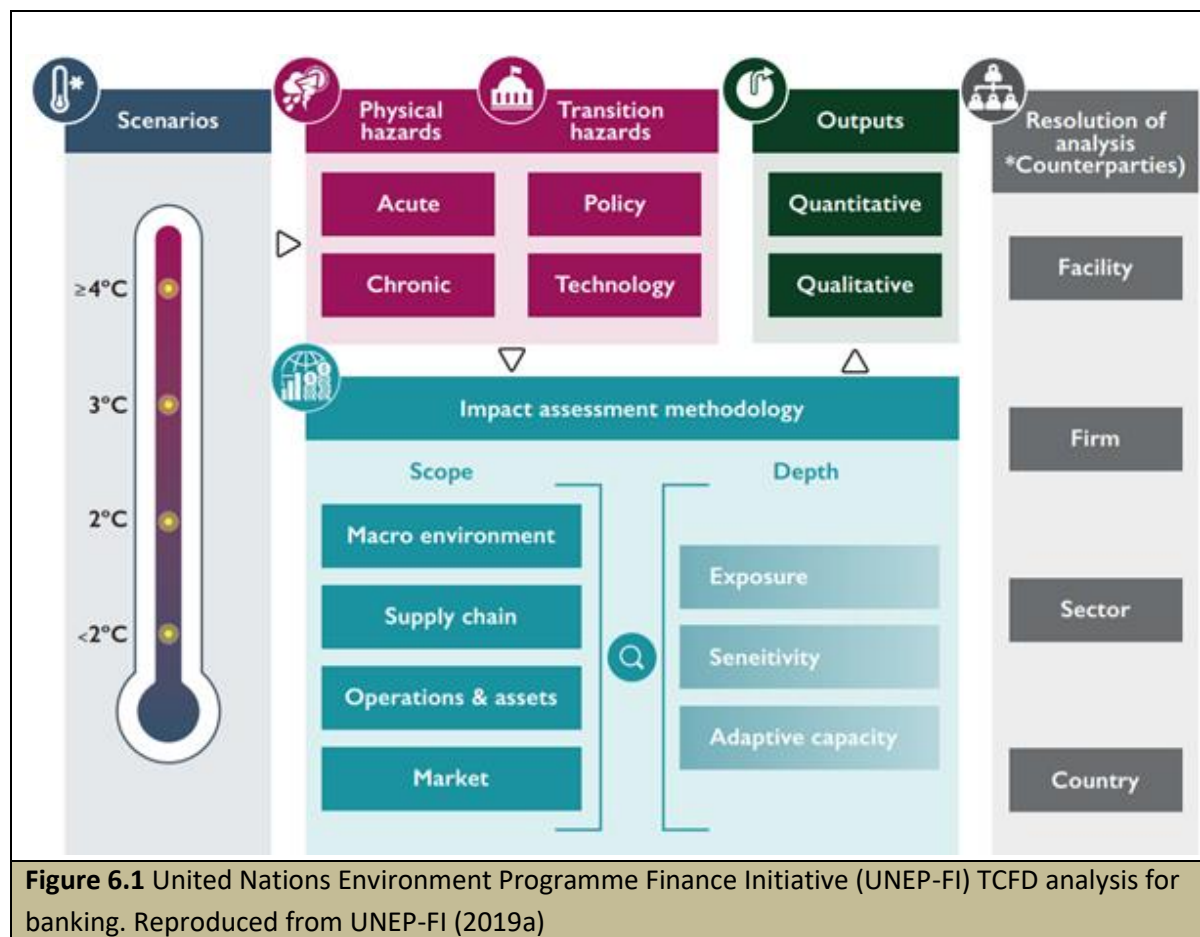
We consider both direct and indirect impacts where evidence is available. For instance, flooding can directly damage infrastructure and subsequently disrupt the supply chain. We then draw overall conclusions by reflecting on the issues across sectors, the role of firm characteristics (e.g., business size, international market connectivity and adaptive capacity) and finally provide an urgency scoring for adaptation responses. CCRA3 also focuses on lock-in and threshold effects faced by businesses. Lock-in effects involve actions or decisions today that ‘lock-in’ the potential for future climate risk and are difficult or costly to reverse or change later (see Chapter 2: Watkiss and Betts, 2021). This can occur through choices about site location, infrastructure, supply chain networks or core business models, which are difficult to reverse and can increase exposure to subsequent risks. For instance, lock-in to site location may expose businesses to future flooding risk. Threshold effects are discussed with respect to biophysical, engineering or policy thresholds, and involve levels or states beyond which there is step-change in risks, and which may necessitate much greater levels or different types of adaptation. For example, increased demand for agricultural products or tourism services, are subject to temperature thresholds and are likely to occur for a specific duration. In business functions such as access to capital, there is a significant increase in the magnitude of risk once thresholds, like limits to affordability or insurability, are reached. Barriers to adaptation, like short-termism in business adaptation planning are also discussed. This is intended to assist in identifying adaptation pathways using the CCRA3 building blocks for early action.

6.1.2 Risk framing in this chapter

Although CCRA3 focuses on physical climate risks, businesses are also exposed to transition risks arising from the shift to a low carbon economy, and to liability risks. These three risks were defined by the Bank of England (PRA, 2015) for insurance companies as follows:

- Physical risks are the first-order risks which arise from weather-related events, such as floods and storms. They comprise impacts directly resulting from such events, such as damage to property, and also those that may arise indirectly through subsequent events, such as disruption of global supply chains or resource scarcity.
- Transition risks are the financial risks which could arise for insurance firms from the transition to a lower-carbon economy. For insurance firms, this risk factor is mainly about the potential repricing of carbon-intensive financial assets, and the speed at which any such repricing might occur. To a lesser extent, insurers may also need to adapt to potential impacts on the liability side resulting from reductions in insurance premiums in carbon-intensive sectors.
- Liability risks are risks that could arise for insurance firms from parties who have suffered loss and damage from climate change, and then seek to recover losses from others who they believe may have been responsible. Where such claims are successful, those parties against whom the claims are made may seek to pass on some or all of the cost to insurance firms under third-party liability contracts such as professional indemnity or directors’ and officers’ insurance.

Framed by the Bank of England in their 2015 report on insurance (PRA, 2015) this has now become a common typology also applied by companies beyond the insurance sector and regulators when assessing, disclosing and reporting climate risk exposure and has led to the development of different assessment methodologies and frameworks including those recommended by the Taskforce on Climate-Related Financial Disclosure (TCFD). See Figure 6.1 for a framework developed for the banking sector.



In this chapter we reflect on information that is emerging from the TCFD process with regards to physical risks, and we also consider current limitations and the need for innovation to further the understanding of climate risks to businesses. However, we do not investigate transition or liability risks. Going forward it will be important to understand the interactions between these different risk types, particularly in the context of net-zero-ambitions or to understand how changes in physical risk trends are driven by changes to emissions and over what time frame. Similarly, it will be important to start including assessments of liability risks and related reputational implications which are expected to be influenced both by how companies manage their own risk and that of others. This includes the question of managing physical risks, although so far, most business experience in assessing climate risk has been in the context of not doing enough to reduce emissions rather than not adapting. However, in the context of creating and enhancing risk levels this is likely to stretch across transition and physical risks. Assessing and monitoring this will be important for corporates

and regulators alike. The integration of different types of risk into a risk assessment is an important consideration for the CCRA process and should be considered for CCRA4.

6.1.3 Terminologies

CCRA3 has an agreed glossary and key terms are set out in Chapter 2: Box 2.1 (Watkiss and Betts, 2021). For this chapter it is important to recognize that companies use a wide range of terms to describe risks, opportunities and their response to climate risks, including, but not limited to ‘business continuity’, ‘business interruption’, or ‘supply chain management’ and ‘due diligence of counterparties’. This was also highlighted in CCRA1 and CCRA2. One term widely used by firms is ‘resilience’, however definition and meaning of this can vary widely³. The IPCC (2014) defines resilience as “the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation” (IPCC, 2014). In a more specific business context, business resilience to climate change is about “preparing for the physical risks associated with climate change while at the same time shifting to a net-zero emissions future. A recent report from the World Business Council on Sustainable Development suggests that a truly resilient business also works to protect nature and achieve resilient communities” (WBCSD, 2019). Organizational resilience is also referred to in the business context. By definition, organizational resilience is “the ability of a system to withstand changes in its environment and still function. It is a capability that involves organizations either being able to endure the environmental changes without having to permanently adapt; or adapting to a new way of working that better suits the new environmental conditions.... it reaches beyond risk management towards a more holistic view of business health and success” (Johnson, 2018).

Different definitions for resilience exist across companies and sectors, as “climate resilience is important for all sectors of the economy, but it will look and feel different across industries and activities. For example, the agri-food sector and water-intensive industries are highly vulnerable to physical climate- and nature-related risks and equity of rural communities. The energy sector’s challenges are in ensuring security, equity and sustainability; the built environment is facing new demand for sustainable and functional structures that can withstand climate-related impacts” (WBCSD, 2019). Implicit in the business definition of resilience is “the requirement for flexibility and adaptability as well as the capacity to absorb market and environmental shocks” (Manning and Soon, 2016). There are also business function-specific terminologies such as: supply chain management, resource security and water and flood risk management (Agrawala *et al.*, 2011; BCI, 2018b). To this end, actions undertaken by businesses to adapt (i.e., to enhance resilience as above) may be part of their standard risk management procedures and may not be explicitly reported (Averchenkova *et al.*, 2016).

³ Chapter 2 states that ‘in CCRA3 we try and avoid the term resilience due to the lack of a commonly applied definition, unless it is used in existing Government policies, or in plans or actions as stated by the private sector or other groups, in which case the specific definition should be included.’ However, the term “resilience” is often used by the private sector instead of adaptation and we therefore include it in this chapter when the primary evidence uses the term ‘resilience’.

6.1.4 Interdependencies across other chapters

It is important to read this chapter in conjunction with other CCRA3 chapters as physical climate risks and their impact on businesses in the UK are highly interdependent, with a range of cross-cutting aspects that are relevant to Chapter 6 but covered elsewhere in the CCRA3 Technical Report (Betts et al., 2021), as summarized in Table 6.2 below.

Table 6.2 Interdependencies between Chapter 6 and other chapters	
Chapter	Interdependencies with Chapter 6
Natural environment and assets (Chapter 3)	<ul style="list-style-type: none"> - Changes in the natural environment impact natural capital, particularly in agriculture and fisheries as business sectors - Eco-system services can help manage risk – loss of nature-based solutions can lead to increased exposure of businesses to physical risk (e.g., loss of natural flood management for business sites) - Interdependencies with natural infrastructure, flood risk management services provided and blue-green infrastructure particularly in the context of coastal areas and marine environment - There are ecosystem-based adaptation opportunities for businesses, but experience and trust are low. - Climatic impacts on the natural environment can have implications for corporate net-zero strategies (reforestation, carbon sinks)
Infrastructure (Chapter 4)	<ul style="list-style-type: none"> - Most business functions depend on reliable infrastructure, with disruptions a key risk for site operations, access to markets, supply chain and distribution networks, employee productivity - Businesses most concerned about disruption of energy, ICT infrastructure, transport and water supply
Health, communities and the built environment (Chapter 5)	<ul style="list-style-type: none"> - Overheating of buildings poses risk to employee productivity - Health and staff well-being are a concern for businesses. - Business responses to climate risks can lead to inequalities – for example low access to capital and insurance for exposed households (e.g. due to risks faced by banking and insurance sectors) - State of built environment and adaptation responses depend on business action, including investment and construction procedures
International dimensions (Chapter 7)	<ul style="list-style-type: none"> - Imported risks through business value chains are likely to have bigger implications than domestic risks for those businesses involved in trade, relying on global supply chain or distribution networks - Risks to agri-businesses from changes in global food production - Global exposure of UK financial sector through international nature of transactions - Also offers opportunities for new services and solutions

6.1.5 Evidence base

Over 366 sources of academic peer-reviewed literature and ‘grey literature’ were consulted for this chapter. As in CCRA2 peer-reviewed academic evidence is still limited for the business sector and accounts for 29% of the overall literature. Moreover, around 76% of the grey-literature comes from the private sector or third parties. For example, consultancies and consortiums conduct their own surveys, for example the annual Business Continuity Institute (BCI) Supply Chain Resilience Index (BCI, 2019a). Increased consideration of climate risk by businesses is illustrated by a rise in advisory reports from accountants, banks and insurers, and more discussion in overarching risk reports such as the Global Risk Report 2019 (World Economic Forum, 2019). Literature in certain industries such as finance and professional services has significantly increased following the TCFD, however the scope is often global rather than country specific (Deloitte, 2018; PwC, 2017; UNEP-FI, 2018; ICAEW and Carbon Trust, 2018). Importantly the accessibility of such grey literature is often difficult where business, consultancies or their advisors may not be able to share client reports.

The evidence base has expanded from CCRA2, partly due to initiatives such as the TCFD, which has increased voluntary business self-disclosure (UNPRI, 2019). In the UK, the Government endorsed the recommendations of TCFD and encouraged all listed companies to implement them. 1,440 organizations have pledged support to TCFD, including eight of the ten largest asset managers and twenty of the largest banks. Many companies in the UK have also committed to implementing the TCFD recommendations, and this increase in climate-related financial disclosures helps to build the evidence base in this area, particularly from the financial sector. Implementing TCFD recommendations will become mandatory from 2023.

The LSE Climate Risk Business Survey 2020 (Mathews and Surminski, 2020) was undertaken specifically for CCRA3 and aims to address current literature gaps. The LSE Business survey ran from 21st November 2019 – 2nd March 2020 and was open to businesses across the UK. The survey was shared with business stakeholders (e.g., business associations, consultancies etc.) participating in the CCRA3 process and circulated with their business contacts and through the author’s network. Business participation was voluntary, and all results were anonymised. Businesses reported their current and future climate risk/opportunities, financial impact and adaptation strategies. They also reported on their climate risk preparedness, reporting, and engagement with internal and external stakeholders. The survey received 225 responses from across the UK and a wide range of sectors (e.g., Agriculture, Manufacturing and Services). Most respondents were small businesses with 0-4 employees and the majority had turnover of £50,000+. The survey contributes to the nascent firm-level evidence in the UK, particularly concerning climate risk perception of SMEs. However, survey results should be treated as indicative as the sample size was limited and non-representative across sectors and countries. Moreover, to increase participation, the survey was open to respondents with different roles in the business (e.g., CEO, CRO), which may have influenced the subjectivity of some responses.

In addition, we also considered business disclosure under the CDP Climate Change Disclosure 2018 survey, which includes responses from 176 companies operating in the UK (CDP, 2018). The survey includes self-reported information about physical risks, resilience opportunities, financial impact and costs of management. Businesses also self-report on time horizon, likelihood, and magnitude of

risks, which were used to inform urgency scoring. Comments on adaptation strategies considered/and or adopted were also analysed. Further information can be found in the Appendix.

We conducted consultations and engagements with the devolved administrations to account for regional evidence. There are some local/regional examples of assessments, such as for the City of Glasgow, that provide information about risk and adaptation levels. This information has been incorporated wherever possible.

Literature review and surveys were also complemented with stakeholder engagement activities, which included: Climate Change Committee (CCC) led stakeholder events, a business roundtable event as part of LCCP/London Climate Week (July 2019), business association roundtable discussions (including Aldersgate Group, ABI, UK Green Building Council, Zurich Insurance, Willis Towers Watson) and individual business discussions. These events provided a bottom-up perspective to supplement the literature surveyed. As part of the evidence collection and stakeholder engagement we also compiled a set of case studies and text boxes to illustrate risks, opportunities and adaptation efforts. A full break-down of the evidence (as of 31st August 2020) is below (Table 6.3). This is more exhaustive when compared to CCRA2, which relied more heavily on business input from larger companies. For example, the gap of focusing on FTSE 100 companies (e.g., CDP data) was addressed using the LSE Climate Risks Business survey from 2020 which predominantly focused on smaller UK businesses. Survey results are illustrative but come with significant health warnings and can't be considered representative due to comparatively low response rates (when considered in the context of the overall number of businesses in the UK). Engagement with trade associations and representative bodies such as CBI should be strengthened further for CCRA4 to ensure wider reach. In addition, most surveys are based on board level perception of climate risk, which may vary from action on the ground. Moreover, self-reporting is influenced by terminologies, timescales and climate models adopted. Thus, information remains fragmented and sector specific, preventing comparisons from being made.

Similar to CCRA2, most of the literature in the evidence base is qualitative. Out of the 366 sources reviewed, only 132 (36%) were quantitative in nature. Table 6.3 provides an overview of the types of evidence consulted.

Despite the increase in evidence from CCRA2 to CCRA3 there are significant limitations:

- There are no clear indicators that show whether vulnerability and exposure to extreme weather is increasing or decreasing, in England and Scotland at least (CCC 2019a).
- Quantitative evidence of the magnitude of impacts is not available on a systematic basis across risks, type of companies, sectors or regions including DAs.
- While the number of assessments is increasing, the variety of climate models, scenarios and projections used makes comparison difficult.
- The evidence is not sufficient in volume and detail to comprehensively test the National Adaptation Programme (NAP)² vision of business resilience (CCC, 2019a), and similar statements provided in the adaptation programmes of the devolved administrations.
- Commercial sensitivity makes business information hard to obtain and verify.

Table 6.3 Summary table of all the evidence consulted	
Type of evidence	Numbers of sources for CCRA3
Academic literature	105
Grey literature	261
Business surveys	15
Reports	44 (Government) 106 (Other)
Guides	17 (Government) 12 (Other)
Tools	12
Online sources (Article, blog, news, press release, podcast, letter etc.)	53
Dataset	2 (ONS, 2018;2016)
Total	366

6.1.6 Socio-economic scenarios

Social and economic trends are highly relevant to the future risks of climate change, and strongly influence future magnitude through changes in exposure and vulnerability (Chapter 2: Watkiss and Betts) as well as adaptation, in terms of the capacity to act. Climate and socio-economic factors can act together as risk multipliers, although for some cases, socio-economic change can reduce vulnerability and thus dampen impacts. The evidence that underpins this chapter does not follow a consistent approach for socio-economic projections: some studies do not include any socio-economic factors, others set out a range of different assumptions which makes comparison difficult. This will require further attention when planning for CCRA4. To achieve a more consistent approach for specific CCRA-related research projects the CCC commissioned a new consistent set of UK socioeconomic projections from Cambridge Econometrics (CE) (CE, 2019). These include projections of population growth, population ageing, and migration (internal and immigration), presented in Chapter 5 (Kovats and Brisley, 2021). The central scenario assumes that the UK population grows at a steady pace, increasing by over 17 million (compared to 2016), to reach a total population of almost 83 million in 2100 (CE, 2019). The central population projection is based on the ONS 'principal projection scenario', which assumes demographic patterns in future such as fertility, mortality and migration trends remain the same as current trends (CE, 2019). Of particular relevance to this chapter, the scenarios also include projections of economic growth. The CE (2019) projections provide central, low and high estimates for total GDP (£ millions, real) and % growth (from the previous year) based on estimates from the Office for Budget Responsibility (OBR). The Central scenario envisages a GDP annual growth rate for the UK of about 1.6% from 2018 to 2028 and an acceleration with GDP expected to grow by 2.2% per annum from 2029 onwards (through to 2100). The figures used for the CE 2019 analysis will require updating in light of the COVID -19 pandemic and the impact on growth.

The increase in economic growth has a major influence on the magnitude of future risk for businesses. There is projected to be a large increase in the value at risk, in terms of assets which

increases the potential exposure to risk, though future economic growth could provide additional resources to address these risks.

It is stressed that the CCRA research project on flooding, which is the most important risk identified in the chapter, does not take this economic growth into account and only considers population growth. The CE analysis also projected gross value added (GVA), employment and labour productivity, all of which are important for the business sector. The GVA projections were based on current value, and future GDP and population, and include values by sector. Labour productivity (derived from employment and GVA) is projected to grow across all sectors

There are also relevant global socio-economic drivers and projections thereof. This adds another dimension of complexity to the consideration of international business risks because it is not just the changes in global physical climate risk that affect the UK, but also the changes in socio-economic trends and the multiplication or dampening of international risk. There are global socio-economic projections available in the IPCC Shared Socio-economic Pathways (SSPs), outlined in Chapter 2 (Watkins and Betts, 2021), which include data at the country level internationally for five alternative pathways. However, CCRA3 does not work with the SSP framing, and it would be extremely difficult to use these in a synthesis exercise such as CCRA3. This is discussed further in Chapter 7 (Challinor and Benton, 2021) in the context of international risks.

6.1.7 Net Zero

During the period that the CCRA3 was undertaken, UK and Scottish Net Zero targets were legislated.⁴ There is not yet a Government analysis of how this target will be achieved, but it could have a major influence on businesses, and the climate risks and opportunities they face. To investigate this, CCRA3 added two questions to consider;

- i) If the Net Zero target is likely to increase or decrease the CCRA3 risk/opportunity and
- ii) If the climate change risk or opportunity could make the Net Zero target easier or harder to achieve? Given the current state of evidence (on Net Zero), these questions were addressed qualitatively throughout CCRA3. The Net Zero target will have important implications for all businesses in the UK and their domestic operations and footprint and will also influence future investment strategies through transition risks (see above). The interplay between physical climate risks and the shift towards a Net Zero carbon economy remains under-investigated. It is clear that in the long-term a successful shift to Net Zero will help limit physical impacts, however there could be trade-offs at least in the short term, where responding to extreme events such as flooding and heat waves could entail energy and resource intensive processes that may also affect the ability of companies to achieve their carbon emission reduction targets.

Overall CCRA3 shows that there is a discrepancy in business awareness and also a lack of joined-up assessments of risk and opportunities arising from physical climate change and transition to Net

⁴ The Welsh Government have committed to legislating a 95% target with an ambition to set a Net Zero target. The Northern Irish Government has also requested the advice of the CCC on an equitable contribution to the UK's target (CCC, 2020a).

Zero. For instance, businesses are predominantly responding to climate risks via Net Zero targets and climate mitigation strategies. This is in line with transition risk response (under the TCFD framework) or industry-wide commitments. For instance, in CDP's Climate Change Disclosure 2018 survey (CDP, 2018), many businesses listed responses such as emissions reduction as part of their strategies to manage physical climate risk. This conflation of preparedness for climate hazards with emissions reductions means physical risks remain neglected in business strategy and underreported. Importantly business decisions taken today will impact both the ability to transition to net zero and the ability to cope with physical risks.

6.1.8 Hazard-specific observations

Chapter 1 (Slingo, 2021) provides an update on the latest scientific understanding of climate hazards based on UKCP18. This offers the first point of information for assessing climate risks for business and industry, summarizing the UK hazard component of the risk equation. There is also a set of hazard-specific observations that indicates where hazards might have broader implications on businesses than through the risks identified in this chapter.

- Flooding is the costliest hazard. In this chapter we consider general flood risk (risk B1) and then assess specific coastal risk (risk B2). Across the different types of flooding, surface water, groundwater and drainage-related risks tend to be less understood by businesses than flooding from rivers or the sea. For CCRA4 we recommend a specific focus on surface water flooding due to the applicability across the country and the impact on areas that have traditionally not deemed to be at flood risk.
- Windstorm risks have been assessed in terms of direct damages and the impact on insurance (risk B4). However, extreme windstorm events can cause significant disruption and cause indirect losses, for example from failure of infrastructure or supply chains.
- Heat impacts on businesses in the UK are recognized in the chapter in the context of labour productivity (risk B5) but there is growing evidence of wider opportunities and risks: high temperatures can also cause irregularities for the cycle of agriculture such as fruit farms, which can damage the quality of the crops or lead to lower yields. For instance, heatwaves and extreme temperatures affect livestock productivity, which significantly impacts agriculture businesses. In Scottish agriculture (Ecosulis, 2019), the biggest impact of extreme weather was in the sheep sector with losses of £45 million during 2017/18. Such business level losses need further investigation in CCRA4. Similarly, the UK Centre for Ecology & Hydrology (UKCEH, 2020) found that increased temperature thresholds impact wheat yields, milk production, parasite outbreaks in livestock and contribute to drought and soil erosion which all affect agricultural business productivity (see also Chapter 3: Berry and Brown, 2021). For instance, for milk production, at the UK level, the estimated economic impact currently ranges from £3 million to £4.5 million per annum. Costs increase to between £8 million to £13 million by the 2050s, and to between £17 million to £57 million in the 2080s. Heat impacts are also likely to have manufacturing and process industry efficiency and quality impacts. For CCRA4 we recommend investigating heat impacts in greater detail, including the impact on building materials and production processes, as well as analysing potential implications for achieving Net Zero.

- Subsidence caused by drying clay soils may increase with hotter, drier summers, and can affect the structural integrity of buildings and underground telecommunications cables and can damage assets and commercial buildings. We notice a lack of specific assessments despite the experience with subsidence in several parts of the UK due to soil composition (Chapter 5: Kovats and Brisley, 2021). For CCRA4 we recommend an assessment of the interplay of subsidence risks with other risk drivers. Long-term hotter and drier temperatures can lead to infrastructure and building damage or the overheating of buildings.

6.1.9 Spatial aspects

Across the UK, current hazards vary geographically and are projected to change differently by location with future climate risks, with regional and local hot-spots emerging for example along the coast or in drought-prone areas. For this chapter, this implies that the exposure of businesses and their different functions depends on locations and geographies. This can be direct – locations of sites for example, or indirect – impacts on transportation, markets and demand. A visualization of this across different hazards through maps is still missing. While far from exact, it would allow an initial regional assessment to see which hazards are expected to be of concern. Currently hazard maps are available, and these can be supplemented with information about location of business sites, water usage, number of employees in offices, agricultural activities and flow of supply chains and distribution networks to gain a better overview of spatial distributions of risks. Importantly, asset-level information is often not available or not in the public domain. For this chapter we capture evidence across different scales from local to national, while international aspects are captured in Chapter 7 (Challinor and Benton, 2021).

A challenge for many businesses is the variety of tools and instruments and their different spatial scope. Some recent initiatives and assessments such as TCFD imply a global perspective and reliance on international models as well as the UK's own climate models. New computing capacity and improved access to data can help address the challenges, however, the utilization of any risk data in day-to-day business processes remains difficult for many companies, particularly smaller-sized companies. Furthermore, one problem for many practitioners in the business and industry communities is that climate data can be too complicated, preventing them from using or integrating it into their own business models and tools. Importantly, new data and computational power can only help in building adaptive capacity if deemed usable and relevant by businesses. Our stakeholder engagement reveals that the lack of sector-specific scenarios and region-specific risk assessments pose an information gap for companies. For example, engagement with insurance brokers and catastrophe modellers reveals that there are significant gaps in knowledge and understanding about current and future risks, particularly when considering the interplay between hazards and vulnerabilities. The confidence in industry assessments of climate change impacts remains low despite the wealth of expertise in general risk analytics. Furthermore, companies that are attempting to assess climate impacts are confronted with a very wide range of tools and approaches. Initially considering different warming scenarios up to 3°C, companies more recently have started including 4°C scenarios in these assessments. One example is the methodology applied by Mercer (2019) in their sequel to the 2015 flagship report on investment risk from climate change,

classifying physical implications of different warming scenarios as follows +2°C=meaningful physical damages; +3°C=highly disruptive physical damages; +4°C=severe physical damages (Mercer, 2019).

6.1.10 Business engagement

Business engagement in CCRA-related discussions has increased since CCRA2, which appears to be in line with growing climate awareness, recent public discourse and regulatory change in the finance sector. Business discussions also reveal significant concern about possible reputational issues arising from inaction or failure to withstand climate risks. Overall business involvement in climate risk assessments is fairly limited (Howarth *et al.*, 2017) and tools and methods developed in the private sector tend to be disconnected from those used by the public sector, including for CCRA purposes. This requires further discussion for CCRA4 to see how the growing knowledge in the private sector including commercially sensitive information about risks and risk trends could be better utilized. The current push for increased transparency and climate risk disclosure is expected to lead to better understanding of risks for listed companies and should provide more insights into corporate exposures. For CCRA3 we have explored this through stakeholder workshops and discussions with trade bodies and individual companies. Of particular interest is the engagement of those companies who themselves conduct risk assessments and own tools that could be of use for CCRA.

Business engagement is also occurring at the trade association level. There are examples in sectors like real estate (Royal Institution of Chartered Surveyors - RICS), industry (Confederation of British Industry - CBI), insurance (Association of British Insurers - ABI), accountancy (Institute of Chartered Accountants in England and Wales - ICAEW) and agriculture (National Farmers' Union of England and Wales - NFU).

One of the biggest challenges of a country-wide risk assessment is the balance between aggregated national level information and sectoral specificity. CCRA2 and CCRA3 do not investigate risks according to business sectors in an effort to avoid sectoral silos. However, for companies, the main interest is likely to be in issues relating to their peers, customers and suppliers, hence a better understanding of risks by sector might be needed. This will require further investigation for CCRA4.

6.1.11 Importance of focus on small and medium-sized enterprises (SMEs)

CCRA1 and CCRA2 have highlighted the low adaptive capacity across SMEs. The CCRA3 analysis confirms this and identifies particular challenges for smaller companies across most sectors and risks. Across regions and risks there is a key urgency in supporting SMEs. SMEs appear less proactive than larger corporates in terms of addressing risks, due to a narrower range of skills available to them, limited information and low levels of understanding of operational risk posed by climate hazards.

The evidence base is often much weaker compared to larger corporates as there are fewer studies on SMEs and less information is being reported or disclosed by those companies. Power *et al.* (2020) study on behavioural changes as part of CCRA3 also notes that the adaptation decision-making processes of SMEs seem more similar to that of individuals, as opposed to large corporations which tend to be driven by corporate governance processes and shareholder reporting. Overall SMEs seem

less likely to have business continuity plans in place than larger businesses, and the evidence points to deficits in adaptation action by SMEs and lack of government support aimed at SMEs.

Key observations related to SMEs:

- In relation to risk B1, there is little evidence of planning or implementation of flood adaptation being done by SMEs. In Power *et al.* (2020)'s study on behavioural changes, less than 20% of SMEs surveyed had taken any permanent protective measures against flooding.
- Regarding risk B3, there is evidence that businesses are investing in ecosystem services, but it would be useful to have a national survey of SMEs to see how widespread these actions are.
- For risk B4, access to capital and insurance is expected to pose a greater problem for SMEs.
- In 2020 the Welsh Government surveyed 243 SMEs regarding risk B5, higher working temperatures and infrastructure disruption, and found that most businesses don't see climate risk as a pressing issue, are unclear on the risks, and few are taking action.
- In addition, although there are increasing climate advisory, consulting and accounting services (risk B7), SMEs lack the resources to utilise these services. At the same time there are significant opportunities for innovation and entrepreneurial activities that SMEs can drive in response to climate risks, but as highlighted in risk B7, there are many barriers that appear to prevent SMEs from gaining advantages from anticipating changing markets. This includes as upfront cost barriers to entering new markets and inertia of the industry.
- Adaptation requires agility and the ability to react to gradual and sudden changes. There are some examples of SMEs realizing opportunities in the face of adversity – for example instance in Section 6.3, the SME community-level engagement example of a furniture store being rebuilt on stilts in Mytholmroyd to strengthen its flood resilience is an example of a business success story that could be mirrored elsewhere.

There is therefore urgency across all parts of the UK to support SMEs in accessing information, funds and skills to address the climate resilience challenge.

6.1.12 Natural Capital

There are many direct links between business and industry and natural capital (the elements of nature that directly or indirectly produce value for people) including ecosystems, species, freshwater, land, minerals, the atmosphere and oceans, as well as natural processes and functions. Dependency on natural capital can impact several business functions and create risks to supply chains, resources, liabilities, customer base and reputation. Overall, for adaptation and climate resilience there are two features particularly relevant for this chapter:

- how do climate impacts on natural capital translate into business risks?

- how is the natural environment mitigating climate risks for businesses through ecosystem services and are businesses actively supporting this risk mitigation function through investment?

The impact of climate change on natural capital is outlined in Chapter 3 (Berry and Brown, 2021) and by the CCRA3 threshold research project. This creates risks for businesses, as most prominently seen in the agricultural, forestry and food sector who are directly linked to natural capital, but other sectors are also at risk, particularly due to supply chain risk (national and international) or in relation to water availability and quality. The TCFD (WBCSD, 2020) maps the repercussions of hazards (e.g. droughts and heat stress, flooding and water scarcity) on ecosystem services (e.g. crop productivity) causing business impacts (e.g. sales, operations and supply chain) and financial impacts (increased Capex, procurement costs and lost revenues). This means businesses reliant on natural assets are particularly vulnerable to climate risk.

However, despite the intrinsic connections between natural capital and agricultural businesses, most agribusinesses view climate change impacts as a low priority compared to aspects like soil health, pest control and economic sustainability (RSA, 2019). This highlights the need to link long-term climate risk exposure with natural capital degradation. As mentioned in Section 6.21 and expanded further in Chapter 3 (Berry and Brown, 2021), the UK Centre for Ecology & Hydrology (UKCEH, 2020) is working on this link and highlights that increased temperature thresholds impact wheat yields, milk production, and parasite outbreaks in livestock - which all affect agricultural business productivity. Impact on natural capital can also be positive, such as short-term increases in crop productivity which can lead to opportunities in the agricultural, food and forestry sector. However, threshold effects may mean land-use and land-use change in some cases will detrimentally affect long-term business profitability.

Even though every business depends on natural goods and services, only very few assess or account for the value of their usage (Natural Capital Committee 2018 and 2020), and the plethora of different approaches reduces transparency and give rise to concerns over greenwashing. The Natural Capital Committee has recently recommended the use of a corporate accounting template to report business use of natural capital and corporate accounting standards as a formal audit requirement (NCC 2020). This would also have implications for the understanding of physical climate risks: companies need to know what natural capital they are consuming as that will help them begin to understand how they are vulnerable to climate impacts which threaten that natural capital.

In addition, businesses also do not have the necessary government guidelines or incentives for utilizing natural capital investments for climate adaptation, such as provision of environmental schemes, land-use planning or diversification. For instance, there is limited progress on adaptation initiatives under the Environmental Land Management Scheme (ELMS) trials (RSA, 2019) and investment in natural capital to support adaptation is still an emergent area for the finance sector, with the pace of translating natural capital's potential into policy and business models remaining slow (Surminski and Szoenyi, 2019). For example, ocean climate change solutions are often hindered by fragmented governance arrangements and integrating the ocean into the global financial architecture is long overdue (Berglof and Thiele, 2019). This is in part due to the disconnect between the members of society who are responsible for, and thus bearing the cost of, land management, and society at large that benefits from land management. This disconnect can lead to

sub-optimal investments in restoration and sustainable land management. Furthermore, short-term financial gains are often favoured over judicious land management practices, leading to the over-exploitation of natural resources (Blignaut, 2019).

A narrow view of climate risk has meant low uptake of solutions based on eco-system services by businesses as documented by the CDP results (Goldstein *et al.*, 2019), although this is not surprising as many benefits are non-market and thus there is a difference between the private and public perspectives of these benefits. This is in line with the LSE Survey results (Mathews and Surminski, 2020), which found that 'hard' engineering and employee-oriented solutions were more frequently adopted by businesses as compared to ecosystem-based approaches. The potential for these adaptation approaches needs to be further explored, alongside their commercial viability.

For instance, the NFU has outlined some strategies such as investment in farm reservoirs and funding for business weather forecasting capabilities which required further government support (NFU, 2018). Solutions are wide ranging from further precision in agriculture technology (Farming UK, 2019), development of regional seedbanks, supporting wild plant and animal diversity (Landworkers' Alliance, 2019) and innovative irrigation techniques (Schroders, 2018). In addition, natural flood management (NFM) (using the natural features of the land to store and slow down the flow of water) is being piloted across the UK and could be a low-cost flood risk management option for smaller communities (Wentworth and Ermgassen, 2020). A 2019 study that interviewed land managers and practitioners of flood risk management in the UK highlighted that barriers to the uptake and implementation of NFM include economic constraints for land managers, the current lack of scientific evidence to support NFM and current lack of governance over long-term responsibility for NFM, which hinders future monitoring and maintenance (Wells *et al.*, 2019). Making this work at a commercial level, under commercial financing terms, is still a key challenge for these ecosystem service focused investments.

Enhanced business awareness may increase uptake, since ecosystem-based measures, like area-based payments, often have private co-benefits (e.g., improved soil health, pollinator habitats and water quality) which farmers prioritise (RSA, 2019).

Natural capital plays a key role in achieving net zero ambitions and businesses are relying on carbon offsetting as part of their Net Zero strategies. Offsetting commitments can positively contribute to natural capital and promote ecosystem-based adaptation solutions, although most focus to date has been on energy efficiency and fuel switching. Whilst large UK aviation and energy businesses are increasingly partaking in such schemes (Financial Times, 2019), these initiatives often occur outside of the UK. Moreover, the larger benefits and additionality of these schemes have been contested in the literature (SEI, 2015). However, as we move towards Net Zero offsetting approaches that sequester CO₂, (which tend to be nature based) will become more important as activities that simply reduce CO₂ emissions i.e., fuel switching must happen anyway.

6.1.13 COVID-19 implications

The COVID-19 pandemic has implications across all sectors and business types and impacts government policy as well as the adaptive capacity of companies. As the pandemic is still ongoing,

evidence of these implications is limited and still emerging, and at this point the evidence is largely anecdotal, as demonstrated below. Business engagement in the CCRA3 process has been hampered due to COVID-19, with several of the collaborations with trade bodies and associations cut short, postponed or moved to a different format during the writing stage of CCRA3. There is also anecdotal evidence that COVID-19 restrictions could hamper the speed of implementing some corporate responses, both in context of adaptation and mitigation for climate change, as engineering solutions in particular can't be executed "from home" but require significant work force located at the site (stakeholder discussions).

Overall, the pandemic appears to have increased awareness of how vulnerable societies and economies can be in the face of global phenomena, and how without foresight and planning we are left ill-prepared. (Howarth *et al.*, 2020). As such, the pandemic has strengthened the case for an economic recovery that puts emissions reduction, and indeed climate resilience, at its heart. At the same time there are growing concerns about a diversion of resources to deal with the COVID-19 crisis response and the aftermath. Amidst general concerns about diversion of resources to the pandemic response the implications for publicly funded adaptation action are as of today unclear but reduced budgets at national and local levels and reallocation of staff to respond to the pandemic could have implications for adaptation efforts.

The pandemic is also highlighting the need for a broader and more holistic approach to risk management and resilience, with growing calls for more efforts in recognizing and addressing compound and systemic risks beyond just the public health impacts of COVID-19. The Coronavirus crisis has shone a light on supply chain resilience (Financial Times, 2020a; WEF, 2020). Anecdotally and in line with previous shocks, in the current state the food supply system seems to have held up well, but the continued impact of the pandemic remains unknown. In addition, the COVID-19 pandemic has highlighted the vulnerability of extended global supply chains, built on lean manufacturing principles in general, and added to the uncertainty created by EU exit and the 2008 financial crisis. For instance, as per a recent survey by the Food, Farming and Countryside Commission (FFCC), during the COVID-19 lockdown (FFCC, 2020), farmers demonstrated less confidence in the future of food, farming and the countryside compared to other respondents. Impacts on manufacturing industries and engineering industries due to the breakdown of the global supply chain appear more significant to the UK than food supply. Stakeholder discussions revealed that even after 12 months of pandemic-related disruption there are still supply chain issues affecting the white goods market due to key component manufacture that is centralised in Asia that has still not yet returned to full production or has been reassigned to higher profit COVID-19 response products.

In general, the inability for supply chains to respond to shocks and changes in demand has been noted in the COVID-19 crisis response (WEF, 2020), and the exposure of a number of vulnerabilities in the UK food system brought on by the pandemic provides the opportunity to study how food supply chains function in crisis conditions. Rather than return to business as usual following the pandemic, companies may seek to decrease the length of supply chains while updating processes to be smarter and more agile and therefore more resilient to future shocks. All of this is likely to provide greater resilience to future climate related pressures. This is asserted by the findings of FFCC (2020), which found that 91% of respondents expressed a need for diverse and local sources of food

production. The need for shorter and diverse food supply chains with more local suppliers was also asserted. In addition, HSBC (2020) found there is some evidence that companies with long-term, sustainability strategies are weathering the consequences of current COVID-19-related supply-chain disruptions better than those who do not have such strategies in place. However, while the short-term shock of COVID-19 requires a rapid and agile response, the much longer-term impacts of climate change call for major strategic responses to supply chain disruption.

Regarding COVID-19's effect on risks to finance, investment and insurance (Risk B4), the pandemic highlights a gap in expectations of customers and insurers, which as stakeholders highlight, must be avoided in the case of climate change. There is also the difficulty in distinguishing between business interruption and contingent business interruption. Thus, contingent business interruption calls for more emphasis on business interdependencies. These business interruption risks are just as important as costs of insurance increasing or becoming available. Whilst the impacts of climate change are much more unevenly distributed than COVID-19 risks and policy response significantly different, the 2019 England CCC progress report highlighted that many businesses do not have continuity plans in place for extreme weather, possibly solely relying on insurance. Another implication of the pandemic is that climate stress-testing to encourage more scenario-based financial analysis is intermittently paused due to COVID-19 (IMF, 2020), with the Bank of England announcing the launch of its CBES exercise for June 2021 (Bank of England, 2020).

COVID-19 has spurred opportunities such as new ways of working, with remote and flexible options to maintain employee productivity during the pandemic (ILO, 2019, Day *et al.*, 2018). These behavioural changes have been tested and employed by various businesses from the onset of the pandemic, but it is unclear if the shift to remote working due to COVID-19 will be a long-term trend (Creative Carbon Scotland, 2018).

Current studies on the impact of working from home on overall productivity could offer interesting findings for coping strategies in the face of climate risks. Similarly, there are likely to be relevant lessons learned from the health and social care sectors regarding vulnerability of staff and their ability to perform their duties during the pandemic. However, the COVID-19 interventions have come at a significant cost to the economy and to welfare, suggesting that “climate change requires a more carefully planned and calibrated, inclusive, less disruptive and more sustained response” (Howarth *et al.*, 2020). There could be an opportunity if COVID-19-responses and economic stimulus would be used to strengthen resilience and support adaptation. This concept of ‘building back better’ and a green and resilient recovery are gaining traction with new research showing the broad benefits that such an approach to recovery could have, including for businesses and innovation (Vivid Economics, 2020).

Changes in demand for goods and services must be viewed in tandem with sectoral change, technological advances and the institutional and labour-market changes. Opportunities also depend on the macroeconomy. For instance, recession, employment loss and health risks post-COVID-19 limit opportunity realisation. This is especially true for the climate advisory sector, as demand for services may fall in cash-strapped sectors and amongst SMEs unless further support is provided. In Scotland, COVID-19 has had a significant adverse impact on heritage businesses (Historic Environment Scotland, 2019). This is likely to affect funds available for adaptation in the future,

exacerbating the resilience deficit. In addition, many businesses operate out of heritage assets such as traditional buildings and/or rely on heritage-driven tourism. Opportunities for business from changes in demand for goods and services (Risk B7) in the heritage sector may have longer implications due to the pandemic. At present, some bodies like the COVID-19 Historic Environment Resilience Forum (CHERF) are facilitating rebuilding, recovery and resilience opportunities. Impacts are significant given the decline in tourism post-COVID-19.

6.1.14 Inequalities

The evidence consulted for this chapter suggests that SMEs have low business awareness of risk and capacity to respond to it. Most businesses that assess physical risk and quantify financial impact use in-house expertise and consultants. However, SMEs tend to have limited capacity and resources to do this. SMEs may also be more vulnerable to climate hazards due to centralised operations, limited financial capital and low investment in resilience measures such as insurance uptake. To this end, stakeholder discussions in the insurance industry have suggested extending schemes such as Flood Re to small businesses. These vulnerabilities mean SMEs are likely to exit the market when faced with frequent climate disasters. Whilst there is some evidence that SMEs (NDF, 2020), are more resilient and likely to adopt adaptation solutions, this requires further investigation.

Employment productivity disruptions from heatwaves (Risk B5) are most likely to affect low-skilled and low-waged workers in industries like agriculture or tourism as well as those working in the construction and manufacturing industries (ILO, 2019). Exposure to heatwaves also puts employees already in ill-health at greater risk. Infrastructure disruptions (Risk B2 and B5) are also likely to affect employees who often live furthest away from their workplaces, such as in the services sector. Business level repercussions such as water scarcity (Risk B3) or food security risks (Risk B6) also disproportionately affect the poor.

Physical risks are going to create sector and location-based winners and losers. Whilst there are some opportunities from climate risks (Risk B7), these are concentrated in sectors such as tourism or agriculture. Moreover, evidence is mixed. Whilst the tourism sector is expected to face greater demand from warmer temperatures, research projects suggest that many hotel businesses will face high flood risk exposure (Surminski, *et al.*, 2020; Roezer and Surminski, 2020). The manufacturing sector is expected to face high losses due to supply chain risks (Risk B6) and location-specific risks, with relocation being a less viable option (Risk B1 and B2). Wealthier businesses have more agency and capacity to take adaptative actions generally. As a specific example, for Risk B2, the Department for Environment, Food and Rural Affairs (Defra) (2018) find that wealthier businesses have more agency and capacity to take adaptative actions against coastal erosion, by for example, attempting to secure planning permission or enforce private defences. Regional discrepancies are seen in the agricultural sector, with productivity expected to increase in the North and West and declining in the East and South East (Ritchie *et al.*, 2019).

6.2 Risks to business sites from flooding (B1)

Current and future risks to business sites from flooding are significant, with high magnitude impacts across the UK. Costs for businesses arise from damage to sites as well as from business interruption and indirect losses such as lost production time and associated costs impacting the profitability of firms. Adaptive action such as enhanced flood protection, planning and preparedness through business continuity management is encouraging but given the scale and the wider implications for the economy and society at large, more action is needed. Thresholds including availability of insurance and costs of capital could increase magnitude even further unless risk levels are reduced through corporate, as well as community-level, adaptation action.

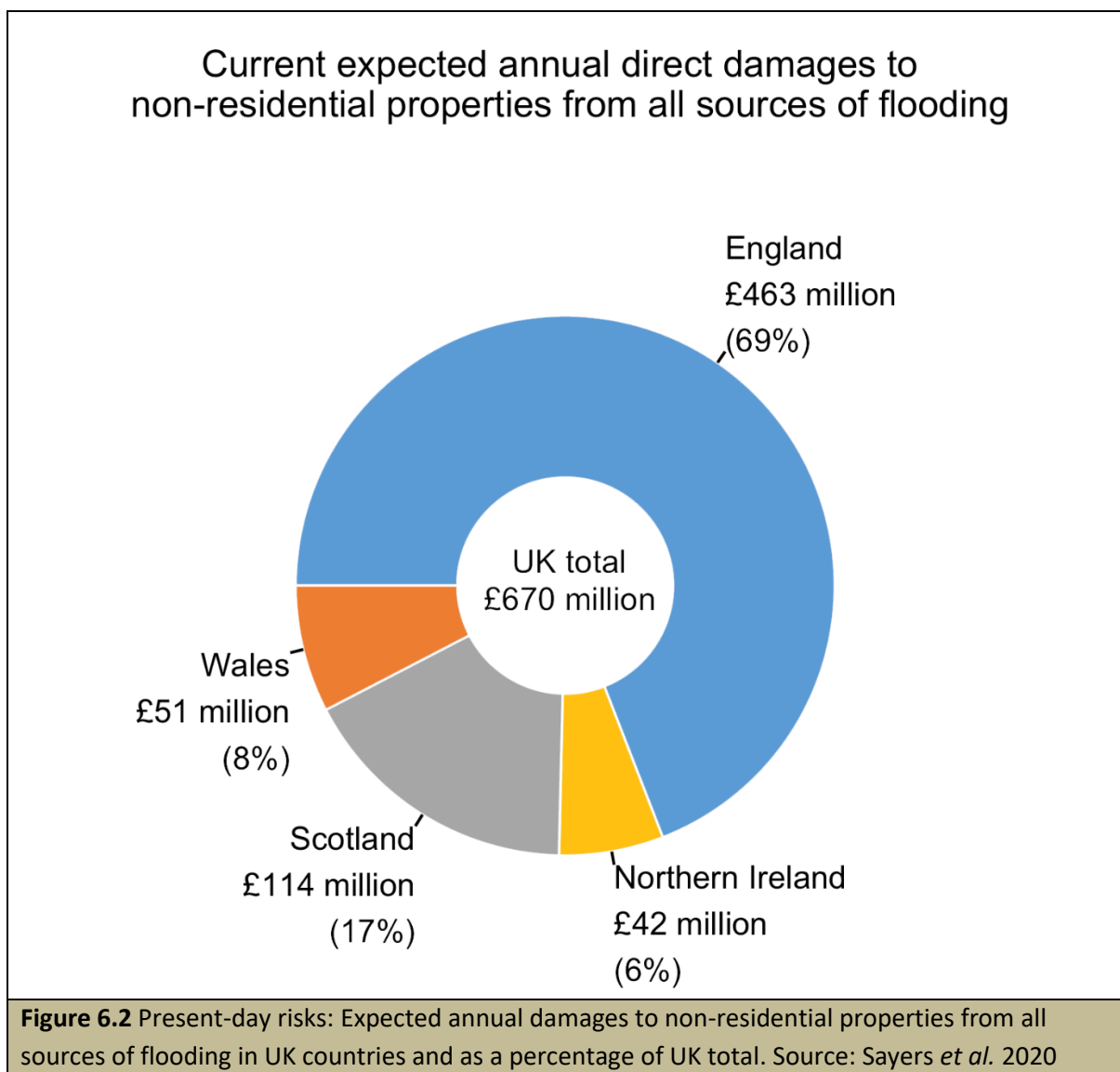
6.2.1 Current and future level of risk (B1)

6.2.1.1 Current risk (B1)

6.2.1.1.1 Current risk - UK-wide

Sayers *et al.* (2020) provides bespoke projections of flood risk to support CCRA3. The projections estimate expected average annual direct damages for non-residential properties from all sources of flooding across the UK; these are outlined in Figure 6.2 to give a sense of the magnitude of impacts on businesses from flooding at present, demonstrating risk with no additional action on adaptation ('Reduced Whole System' adaptation). The total present day expected annual direct damages to non-residential properties from all sources of flooding in the UK is £670 million.

For indirect damages to businesses due to loss of infrastructure Koks *et al.* (2019) use geospatial information on the location of electricity infrastructure assets and local industrial areas and employ a multiregional supply-use model of the UK economy that traces the impacts of floods of different return intervals across 37 subnational regions of the UK. The results show up to a 300% increase in total economic losses when power outages are included, compared to analysis that just includes the economic impacts of business interruption due to flooded business premises. This increase indicates that risk studies that do not include failure of critical infrastructures may be underestimating the total losses – see also Chapter 4 (Jaroszweski, Wood and Chapman, 2021).



6.2.1.1.2 Current risk - England

Sayers *et al.* (2020) report that the expected direct annual damages for non-residential properties in England at present is £463m, comprising 69% of total UK damages, seen in Figure 6.3. The Environment Agency’s National Flood Risk Assessment (NaFRA) takes into account the likelihood of flooding and potential consequences including for businesses. The maps below show the variation in risk to the economy across River Basin Districts (RBD) in England for river and sea flooding.

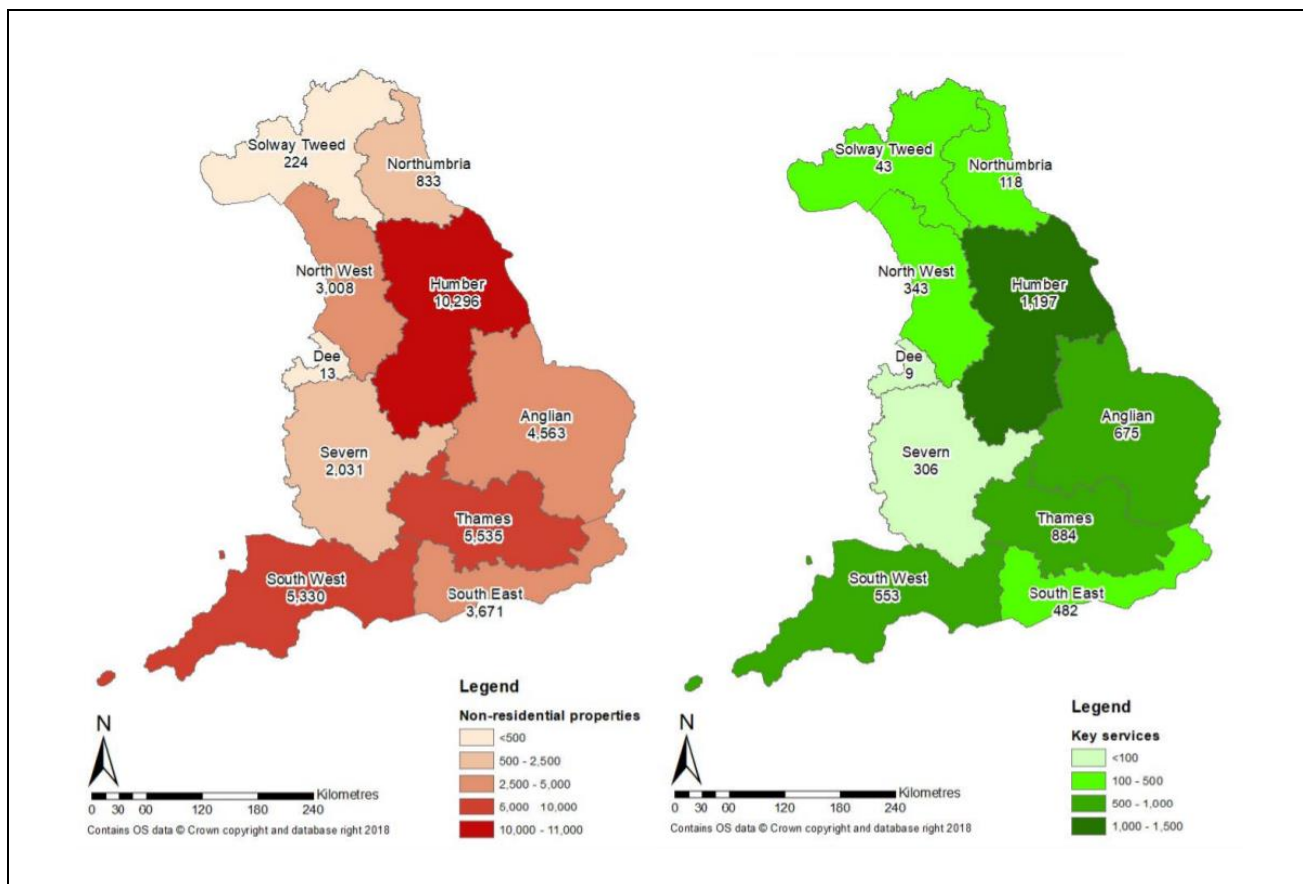


Figure 6.3 NaFRA assessment of risk to the economy in regions of England. Reproduced from: Environment Agency (2018a), Preliminary Flood Risk Assessment for England, pg. 25 and 26. (a) Number of non-residential properties at high risk of river and sea flooding. (b) Number of key services at high risk of river and sea flooding.

Some evidence is also available by sector; for example, CCC (2018) reported that there are nearly 190,000 ha of Grade 1 and Grade 2 coastal agricultural land at high risk of coastal flooding (1:200 or greater risk) which represents nearly 9% of such land in England.

Box 6.1 presents case study data from the 2015/16 winter floods that impacted several areas across the UK. However, as these estimates quantify exposure but not annual impact, they cannot be used as part of the assessment of current magnitude.

Box 6.1 Evidence Arising from the 2015/16 Floods

The winter floods of 2015/16 caused significant damages to businesses and industry in the UK (Marsh *et al.*, 2016). Throughout the winter, flooding impacted communities across northern and western Britain, including some of the UK's major urban centres. Nearly 5,000 businesses across Northumberland, Cumbria, Lancashire, Yorkshire and Greater Manchester were affected by the storms, including the United Biscuits factory and Brunton Park football stadium in Carlisle and the Jorvik Viking Centre in York, a Historic England site. Storm Desmond caused large scale flooding to an area in northern England, particularly Cumbria, which witnessed similar scenes in 2005 and 2009. The flood protection wall in Keswick,

constructed following the 2009 flooding, was overtopped on the 5th of December, inundating 730 residential and business properties.

The Association of British Insurers (ABI; 2016) published a figure in January 2016 showing that between December 3, 2015 and January 3, 2016, the insurance response to bad weather and flooding in the UK included £24 million in total spent on emergency payments to households and businesses. This included emergency payments for immediate needs such as food, clothing and salaries; 3,000 families helped into alternative accommodation; £50,000 was the average cost of a domestic property flood claim and more than 8,300 loss adjuster visits were made since December 3, 2015 (high magnitude).

Table 1 shows the estimated economic costs of the 2015 to 2016 winter floods, from the Environment Agency (Environment Agency, 2018b) using ABI claims information. It is estimated that non-residential, direct business property damages from the floods is £513 million (with a range of £410 million to £616 million).

Box 6.1 Table 1 Estimating the economic costs of the 2015 to 2016 winter floods. Reproduced from Environment Agency (2018)

Flood event	Residential properties					Non-residential, business properties				
	Estimated property numbers damaged by flooding	Best estimate of economic damages (£ million)	Percentage of total economic damages	Average financial cost per property	Average economic cost per property	Estimated property damage by flooding	Best estimate of economic damages (£ million)	Percentage of total economic damages	Average financial cost per property	Average economic cost per property
2015 to 2016 (winter)	16,000	£350	22%	£46,000 £35,000 £24,000	£24,000 £18,000 £12,000	5,000	£513	32%	£153,000	£99,000
2013 to 2014 (winter)	10,500	£320	25%	£44,000	£23,000	3,100	£270	21%	£127,000	£82,000
2007 (summer)	48,000	£1,500	38%	£31,000	£19,000	7,000	£900	23%	£113,000	£75,000

Best estimate of non-residential property damages (£513 million) = ABI non-residential insurance cost + adjustments for underinsurance – economic adjustments.

Where:

- ABI value of residential property claims (£7,540 million) = ABI public data and personal correspondence
- adjustment for underinsurance (£794 million) = £754 million/0.95
- adjustment for economic estimate (£513 million) = $[(£794 \text{ million} \times 0.45 \times 0.5) + (£794 \text{ million} \times 0.55)]/1.2$
- economic adjustments = VAT 20%, inventory items 45% of insured damages, remaining value 50%
- an average insurance penetration rate for business properties of 95% is assumed

Box 6.1 Table 2 provides a summary of the estimates of economic costs according to different impact categories, including impacts on businesses.

Box 6.1 Table 2 Estimates of the economic costs of the 2015 to 2016 winter floods by impact category with uncertainty rating and estimate range. Reproduced from Environment Agency (2018b)				
Impact category	Best estimate (£ million)	Low (£ million)	High (£ million)	Uncertainty rating
Residential properties	£350	£308	£392	Medium to low
businesses	£513	£410	£616	Medium to low
Temporary accommodation	£37	£31	£43	Medium to low
Vehicles, boats, caravans	£36	£31	£41	Medium to low
Local authorities (excluding roads)	£73	£55	£92	Medium to high
Emergency services	£3	£3	£3	Medium to low
Flood management asset and service	£71	£63	£78	Low
Utilities – energy	£83	£75	£91	Low
Utilities - water	£21	£16	£26	Medium to high
Transport - rail	£121	£103	£139	Low
Transport - roads	£220	£166	£275	Medium to high
Agriculture	£7	£6	£8	Medium to low
Health	£43	£32	£54	High
Education	£4	£3	£5	High
Other (wildlife, heritage and tourism)	£19	£13	£25	High
Total	£1.6 billion	£1.3 billion	£1.9 billion	

It is notable that in the 2015 to 2016 floods business property damages were significantly larger than household property damages (a pattern not normally seen in previous estimates of flood damage) – resulting in damage to premises, equipment and fittings, loss of stock, and disruption of business. In the overall scale of costs, the 2015 to 2016 floods at £1.6 billion are similar to the £1.3 billion of the 2013 to 2014 winter floods. The 2007 floods remain, by some margin, the largest economically with costs of £3.9 billion (all in 2015 prices). (Environment Agency 2018b).

6.2.1.1.3 Current risk - Northern Ireland

Sayers *et al.* (2020) report that the expected direct annual damages for non-residential properties in Northern Ireland at present is £42m, comprising of 6% of total UK damages. The Northern Ireland Flood Risk Assessment (NIFRA) (2018) assessed the areas to be at the greatest flood risk in Northern Ireland and the economic impact of such floods (Table 6.4). Note that the percentage changes reported by Sayers *et al.* (2020) may not represent percentage changes relative to the data in Table

6.4 due to methodological differences. The Sayers et al. (2020) changes use a consistent approach across all UK countries.

Table 6.4 Economic impact of floods. Reproduced from: Northern Ireland Flood Risk Assessment NIFRA. (2018). p.32				
	Fluvial	Coastal	Pluvial	Totals
Total Property Damages (Millions)	£10.69	£3.45	£41.83	£55.97
Residential Property Damages (Millions)	£4.32	£0.79	£17.31	£22.42
Intangibles (Millions)*	£0.27	£0.01	£0.40	£0.68
Non-Residential Property Damages (Millions)	£6.10	£2.65	£24.12	£32.87
People at Risk	3359	173	5035	8567
Count Residential	1344	69	2013	3426
Count Non-Residential	321	81	546	948
Count Key Infrastructure	37	7	85	129
Count IPPC	2	1	4	7
Count Cultural Heritage	30	8	83	121
Count Environment	1	0	1	2

*intangible damages take into account the stress or inconvenience of moving elsewhere whilst a home is repaired after a flood event. For the NIFRA 2018, a constant £200 economic impact per residential property has been assumed.

Some case study information is also available for the North West Flooding event in August 2017 in Northern Ireland (DFI, TEO and DCSDC, 2018), where 60-70mm of rain, equivalent to 63% of the average August rainfall, fell in the space of 8-9 hours causing many watercourses to rise, in some areas, to unprecedented levels in a very short period of time. The severe flooding had a profound, and in many cases lasting, impact on businesses, but no quantification of the business impacts has been made. Impacts to agricultural land were also very significant due to large amounts of debris being washed onto the land. 220 farm businesses were impacted, and fences were washed away in many locations. Issues were raised in relation to businesses being unable to claim for hardship payments similar to those provided to homeowners. In terms of lessons learned, a review of emergency plans and business continuity plans has been recommended, as well as clarification of roles, responsibilities and hierarchy of command before, during and after floods (DFI, TEO and DCSDC, 2018).

6.2.1.1.4 Current risk - Scotland

Sayers *et al.* (2020) report that the expected direct annual damages for non-residential properties in Scotland at present is £114m, comprising of 17% of total UK damages.

SEPA (the Scottish Environment Protection Agency) have developed a data visualisation tool which enables viewers to view statistics from the 2018 National Flood Risk Assessment (SEPA), identify the location of areas with the highest levels of risk (Potentially Vulnerable Areas), locate where flooding has previously been reported and view actions aimed at reducing the impact of flooding. It shows

that around 30,000 buildings of businesses and industry were at flood risk with medium likelihood and around 10,000 buildings of businesses and industry faced flood risk with high likelihood. Importantly the number of properties at risks gives a sense of the scale of risk, but it cannot be used to quantify current magnitude as the number of businesses actually flooded per year is not collected by this means (SEPA 2018).

In Scotland, in early December 2015, severe flooding affected the south of the country with Hawick and Dumfries both badly affected. Late December saw further periods of heavy rainfall that brought more flooding to the South of Scotland, badly affecting Peebles and Newton Stewart. Severe flooding also affected the North-East of Scotland in late December 2015 and early January 2016. Some flooding was experienced in Aberdeen city, but most flooding and associated disruption was experienced across Aberdeenshire, in small towns, villages and the open countryside (CREW, 2020). In North East Scotland specifically, the impact of the winter 2015/16 flooding on business was explored in a 2020 CREW report looking at case studies in Ballater and Garioch. In Garioch, it was primarily residential areas that were flooded in January 2016. In contrast, the impacts of the flooding on businesses operating in and around Ballater were more widespread and more severe. As widely reported in the local press (e.g., Press & Journal, January 6th 2016), numerous shops and other commercial premises in the centre of Ballater were inundated by flood waters, agricultural land and forestry were under water and subsequently littered with debris that had to be cleared up and the damage to the main road network disrupted transportation for many weeks after water levels had subsided (CREW, 2020).

6.2.1.1.5 Current risk - Wales

Sayers *et al.* (2020) report that the expected direct annual damages for non-residential properties in Wales at present is £51m, comprising 8% of total UK damages.

Wales produces River Basin Management Plans, and the following risk data comes from the preliminary flood risk assessments which were published by Natural Resources Wales in December 2018: businesses come under a category of non-residential property along with public buildings such as schools and hospitals. This assessment shows the current number of non-residential properties at risk from river, sea, surface flooding for Dee (870 non-residential properties), Severn (4795 non-residential properties) and Western Wales (5180 non-residential properties). The above numbers don't account for risks to infrastructure sites, which local businesses rely on (341 infrastructure sites at Dee, 1658 infrastructure sites at Severn, and 1658 infrastructure sites at Western Wales).

6.2.1.2 Future risk (B1)

6.2.1.2.1 Future risk - UK-wide

Sayers *et al.* (2020) estimate increases in expected annual damages for non-residential properties across the UK at risk from all sources of flooding, for the 2050s and 2080s in scenarios of global

warming reaching 2°C and 4°C in 2100⁵ (Figure 6.4). For conciseness these are referred to as the 2°C warming scenario and 4°C warming scenario below.

These estimates assume that the future economy is the same as today and thus are potential underestimates of future damage⁶. The analysis suggests that, without further action, flood risk could significantly increase for many of those business premises by the middle of the century. In the 2°C warming scenario, the expected annual damages for non-residential properties in the UK overall are projected to increase by 27% by 2050 and 40% by 2080. In the 4°C warming scenario, the projected increase is 44% by 2050 and 75% by 2080. This is calculated using the Reduced Whole System model showing risk in the absence of adaptation (there is no difference in risk between the two population scenarios). Note that these projections are single estimates representing one regional climate outcome consistent with the stated warming pathway, so do not represent the implications of uncertainties in regional climate responses, which may be substantial (Chapter 1: Slingo, 2021). Uncertainties in projected changes in exceedance of a flood-related threshold for pathways to 2°C and 4°C warming are presented by Arnell *et al.* (2021).

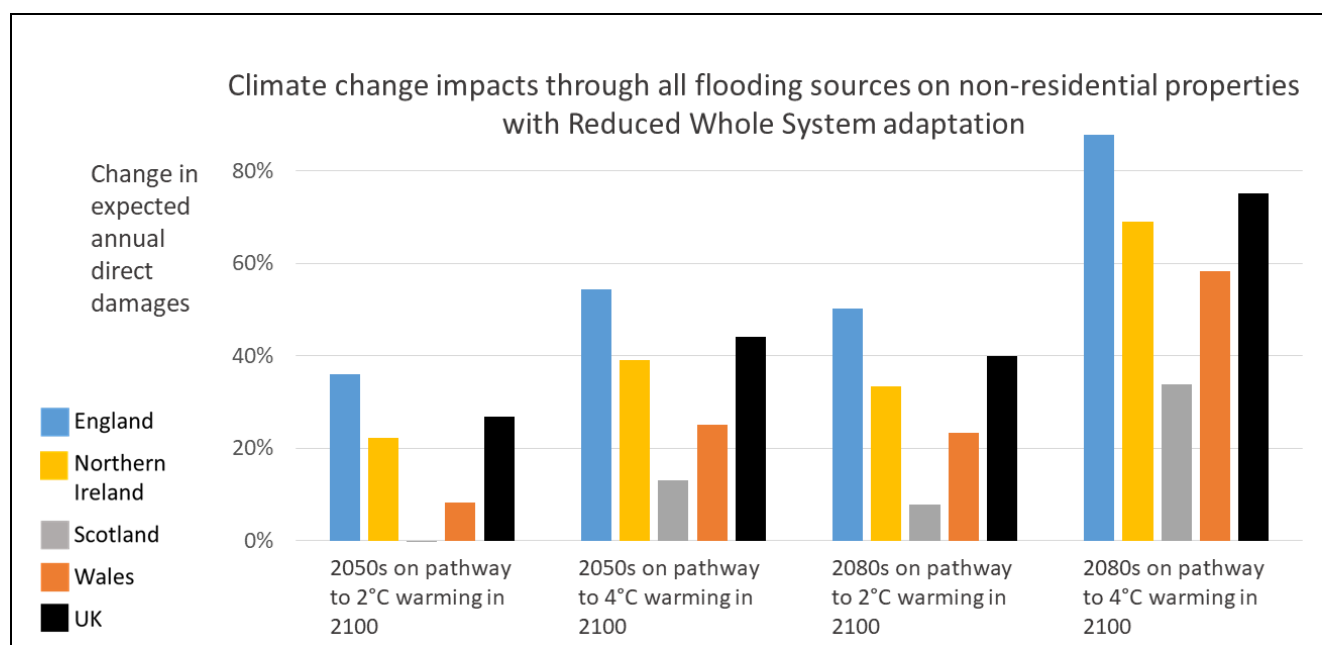


Figure 6.4 Percentage change in expected annual direct damages to non-residential properties from all sources of flooding for scenarios of global warming reaching 2°C and 4°C in 2100. Source: Sayers *et al.* (2020)

6.2.1.2.2 Future risk - England

Sayers *et al.* (2020) report that with Reduced Whole System adaptation (i.e. no additional adaptation), the expected annual damages for non-residential properties in England are projected to

⁵ Using subsets of UKCP18 probabilistic projections reaching global warming of $2.0 \pm 0.1^\circ$ and $4.0 \pm 0.1^\circ$ in the 2090s, relative to 1850-1900, and sea level rise rates within the range consistent with these rates of warming.

⁶ Economic growth, and the increase in the value at risk, has a major influence on future total damage costs from flooding (Rojas *et al.*, 2013).

increase by 36% by 2050 and 50% by 2080 in the 2°C warming scenario and increase by 54% by 2050 and 88% by 2080 in the 4°C warming scenario (Figure 6.4).

6.2.1.2.3 Future risk - Northern Ireland

Sayers *et al.* (2020) report that with no additional adaptation, the expected annual damages for non-residential properties in Northern Ireland are projected to increase by 22% by 2050 and 33% by 2080 in the 2°C warming scenario and increase by 39% by 2050 and 69% by 2080 in the 4°C warming scenario (Figure 6.4).

6.2.1.2.4 Future risk - Scotland

Sayers *et al.* (2020) report that with no additional adaptation, the expected annual damages for non-residential properties in Scotland are not projected to increase by 2050 and are projected to increase by 8% by 2080 in the 2°C warming scenario and increase by 13% by 2050 and 34% by 2080 in the 4°C warming scenario (Figure 6.4).

6.2.1.2.5 Future risk - Wales

Sayers *et al.* (2020) report that with no additional adaptation, the expected annual damages for non-residential properties in Wales are projected to increase by 8% by 2050 and 23% by 2080 in the 2°C warming scenario and increase by 25% by 2050 and 58% by 2080 in the 4°C warming scenario (Figure 6.4).

6.2.1.3 Lock-in and thresholds (B1)

6.2.1.3.1 Are there lock-in risks?

Business investment decisions taken now— notably around buildings and infrastructure assets – face potential risks if future climate change is not considered. As highlighted in Chapter 5 (Kovats and Brisley, 2021), this is a particular risk if development continues to occur on floodplains and where flood risk management measures are currently or will become insufficient to manage risks. A new study (Roezer and Surminski, 2021) uses a new detailed dataset combining information from Ordnance Survey (OS) and the Office for National Statistics (ONS) to analyse the location of new developments built between 2008 and 2018 in England and Wales in regard to their flood risk. The analysis looks into temporal, spatial as well as sectoral trends and indicates both a sectoral and spatial concentration in a few key areas with implications for the long-term flood resilience in those areas. The initial results (Roezer and Surminski, 2021) focus on impacts on residential properties but a follow-up analysis of at-risk business premises is expected to be available for CCRA4.

In the case where businesses are investing in their own flood protection, there is also a risk of possible lock-in if companies do not consider future flood trends, rendering their efforts inadequate and requiring costly upgrades. Similarly, there could be an over-reliance on hard engineering solutions, which can skew adaptation efforts away from more holistic approaches such as ecosystem services, which tend to have a longer run-up time than immediate heavy engineering solutions. Lack

of awareness, experience and trust in this 'green infrastructure' or 'nature-based-solutions' is a challenge (Surminski and Szoenyi, 2019). However, it is also important to note that ecosystem services may not be as effective for extreme events but can help alleviate the more regular types of flooding (Dadson *et al.*, 2017).

Non-reporting or non-assessment of indirect risks and their implications for business performance, productivity and asset values means that risk levels are underestimated and that there is a lack of urgency for action.

6.2.1.3.2 Are there potential thresholds? (B1)

There are thresholds associated with design and engineering for flood protection infrastructure (see also Chapter 4: Jaroszweski, Wood and Chapman, 2021), and business decision thresholds in terms of acceptable risk or investment criteria (see also Chapter 5: Kovats and Brisley, 2021). Thresholds are likely to vary by time and place depending on the state of the assets, levels of investment to address climate change risks and/or maintain or improve assets, and the spatial changes of risks. As per Power *et al.* (2020), businesses surveyed in their study identified flood risk thresholds determined by property values, cost of insurance, cost of capital, and flood protection schemes not being maintained, failing or not performing as expected. Anticipated asset life threshold must also be considered, as the asset life of a retail premises is much shorter than that of a car manufacturing plant or a pharmaceutical manufacturing complex. For this replaceability of assets can also play a role: for example, offices or a call centre operation could be closed down and restored in a new location immediately if planning is in place, as might banking infrastructure with multiple locations. In contrast, a chemical manufacturing plant cannot be simply replicated in multiple locations and any relocation decisions are likely to be lengthier and more complex than in the servicing sectors.

6.2.1.4 Cross-cutting risks and inter-dependencies (B1)

Even if business premises are not directly exposed to flood risk, the operations can still be negatively impacted by risk cascading through value chains, supply networks and infrastructure dependencies. WSP Global *et al.* (2020) identified a number of cross-cutting risks and interdependencies related to flooding of non-residential properties. The most significant of these pathways are through dependency on infrastructure (see also Chapter 4: Jaroszweski, 2021): flooding of power infrastructure, water and sewage infrastructure, and transport hubs can lead to productivity losses. This also includes the significant environmental threat associated with industrial assets being flooded and this leading to further impacts on natural capital or third parties. Examples are the release of toxic chemicals to water courses, urban areas, long term ground contamination, and loss of productive agricultural land. This is also further explored for supply chains and distribution networks in Risk B6.

6.2.1.5 Implications of Net Zero (B1)

Most flood defences have high-embodied carbon, which could be a factor for a Net Zero transition unless a shift to carbon-free building materials is achieved. For public flood defences, the Environment Agency has developed a Carbon Planning Tool for England to assess carbon over the whole life of built assets (Chapter 5: Kovats and Brisley, 2021). The private sector is unlikely to contribute to large scale flood management (unless part of public private partnerships, see below), but there could still be some implications from localised flood management investments. This might influence the type of protection (from hard to soft, or grey to green).

At the same time, the Net Zero transition provides an opportunity for the retrofit of properties – and design of new commercial properties - to improve flood resilience in combination with enhancing energy efficiency. For a discussion of the role of building regulations, see Chapter 5 (Kovats and Brisley, 2021). Realising any Net-Zero opportunities will require increasing awareness amongst business and industry throughout the supply chain as well as upskilling within the sector.

6.2.1.5 Magnitude scores (B1)

Table 6.5 Magnitude scores for risks to business sites from flooding following different global mean temperature increase projections					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	High (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Northern Ireland	High (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Scotland	High (high confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Wales	High (high confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)

Given the expected annual impacts identified by Sayers *et al.* 2020 – (in the £hundreds of millions for England and £tens of millions for the devolved administrations) the magnitude of this risk is high.

This is also supported by other evidence. However, the results from Sayers *et al.* (2020) must be caveated as damages to non-residential properties have relatively high uncertainty due to difficulties in categorising property types. For example, approximately a third of the EAD in NaFRA2018 for England is attributed to "non-classified" properties. This uncertainty is accounted for in the confidence of the findings. It is also important to note that the Sayers estimates do not include future economic growth; they assume that business sites and functions are the same as today.

6.2.2 Extent to which current adaptation will manage the risk or opportunity (B1)

6.2.2.1 Effects of current adaptation policy and commitments on current and future risks (B1)

6.2.2.1.1 UK wide

Across all parts of the UK there are investments and policies in place aimed at reducing flood risk that also protect businesses and infrastructure. These are also set out in detail in Chapter 5 (Kovats and Brisley, 2021. Risk H3). Level of implementation, selection of target areas as well as performance and maintenance of these interventions remains difficult to assess consistently across the whole of the UK. A dedicated project to assess future flood risk across the UK to support CCRA3, Sayers *et al.* 2020, considered the impact of a scenario reflecting the current level of policy ambition to manage flooding across the UK and reported that the expected annual damages for non-residential properties in the UK overall are projected to increase by around 10% by 2050 and 17% by 2080 given the current level of adaptation, with a 2°C warming scenario. With the 4°C warming scenario, this increase is 23% by 2050 and 42% by 2080.

Across the UK the changes are summarised as below (Sayers *et al.* 2020):

- **England:** the expected annual damages for non-residential properties are projected to increase by 17% by 2050 and 25% by 2080 in the 2°C warming scenario, and by 31% by 2050 and by 51% by 2080 in the 4°C warming scenario.
- **Northern Ireland:** expected annual damages for non-residential properties are expected to increase by 18% by 2050 and 28% by 2080 in the 2°C warming scenario and by 33% by 2050 and 55% by 2080 under a 4°C scenario.
- **Scotland:** there is a decrease in expected annual damages of -15% by 2050 and -11% by 2080 in the 2°C warming scenario and by -6% by 2050, but an increase by 8% in the 4°C warming scenario.
- **Wales:** there is a decrease by -7% in 2050 and increase by 2% in 2080 in expected annual damages for non-residential properties, in the 2°C warming scenario and an increase of 3% by 2050 and 23% by 2080 in a 4°C scenario.

These values are calculated using the Current Level of Adaptation scenario showing risk with planned level of adaptation efforts at the time Sayers report was completed, taking account of information in the National Flood and Coastal Erosion Risk Management Strategy for England (Environment Agency, 2020b) and the Flood and coastal erosion risk management Policy Statement (HM Government, 2020). It is important to note that even with this adaptation in place, there are

still significant levels of residual damages (albeit lower than without these measures as in 6.6), and a significant increase in flood damages relative to current conditions.

Power *et al.* (2020) found that the most common behaviours that SMEs take to prepare for a flood event were having stores of sandbags ready (24%) and moving items to higher floors (24%). Automated voice messaging systems, text alerts and government websites were shown to be the most commonly used sources of information about flooding events by small to medium sized businesses. Less than 20% of SMEs surveyed had taken any permanent protective measures (Figure 6.5).

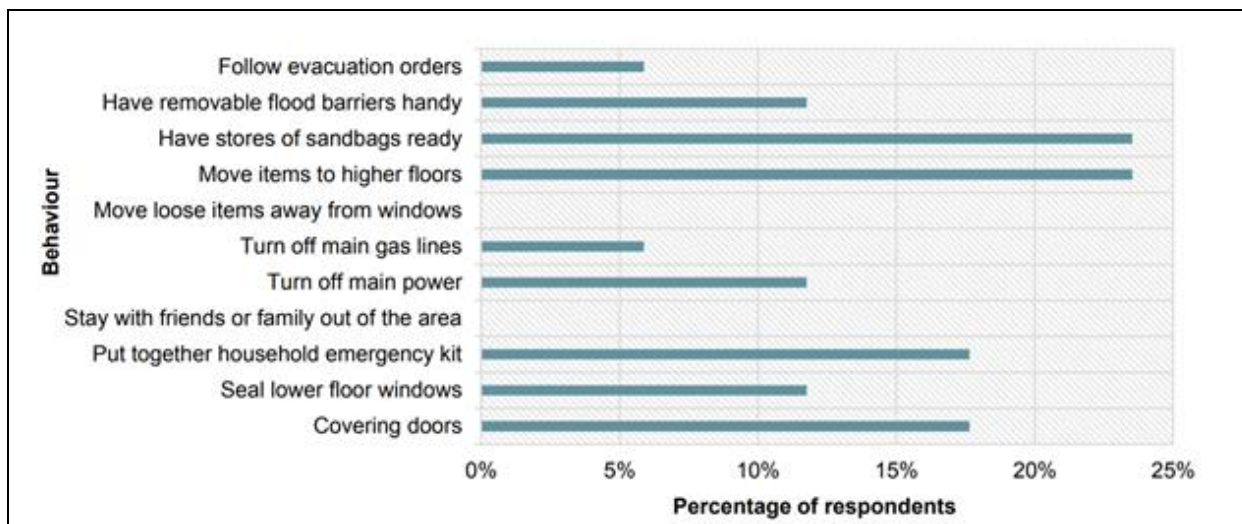


Figure 6.5 Behaviours most likely to be taken by small to medium sized businesses to prepare for a flood event, according to the survey respondents (n = 17). Reproduced from Power *et al.* (2020)

In the LSE Climate Risk Business Survey (2020) companies reported a set of adaptation measures that they have implemented in response to flood risk – as summarized in Table 6.6.

Respondents also identified which information sources on flood risk have helped them develop their risk management strategies, with in-house expertise and consultants, industry or sector-wide reports and Government guidance featuring as the top three sources. (LSE Climate Risk Business Survey 2020 – Matthews and Surminski, 2020).

An example of sectoral activities aimed at facilitating business-level adaptation to flood risk is the property flood resilience (PFR) Bonfield (2016) action plan (resulting from the PFR Roundtable of businesses) which set out how businesses can protect themselves from flood damages. The report (Defra, 2016) made recommendations to make flood resilient measures part of ‘normal’ business practice. Actions included developing a ‘health check’ for small businesses (e.g., assessing whether adequate insurance cover is in place) and providing case studies of successful flood resilient measures and associated costs/benefits. To date there is a lack of evidence that the voluntary code of practice has led to an increase in the uptake of Property Flood Resilience by businesses, as further investigation will only be possible once the Code of Practice has been fully adopted and applied by companies. There have also been initiatives by the Business in the Community Initiative and AVIVA to create guidance around flood preparedness for businesses (BITC and Aviva, 2020).

Table 6.6 Business responses to flood risk (Source: LSE Climate Risk Business Survey 2020 – Matthews and Surminski, 2020)	
Adaptation strategies	Number of companies who have implemented these in response to flood risk
Investing in ecosystem-services / green solutions to reduce risks, e.g. natural water storage/drainage, green roofs, tree planting	23
Investing in 'hard' engineering solutions e.g. upgrades to flood protection, new water saving devices, heat reduction in offices	30
Developing and implementing enhanced business continuity plans that consider current and future risks including regular reviews and tests	25
Using early-warning systems to increase preparedness	10
Engaging with staff to increase awareness, preparedness and identify solutions	26
Adopting adaptation standards (e.g. ISO)	11
Working with suppliers e.g. requiring evidence of climate resilience measures, collaboration to strengthen supply chains	13
Changing type of products or services	14
Adjusting production processes	4
Buying more insurance	5
Avoiding high risk locations, materials, suppliers or investments	6
Engaging with government and/or regulators to receive information and guidance	23
Don't know	3
None	8
Other	1

Although efforts to promote PFR have had some success, it is not used sufficiently in refurbishment/post-flood reinstatement. Based on uptake in properties supported under the grant in aid investment, PFR is used by just 6% of high-risk households, 39% of flooded households and 15% of flooded businesses (Harries, 2013; Bhattacharya-Mis *et al.* 2014). It should be noted that properties have been supported via targeted PFR repair schemes that have been deployed on a handful of occasions since 2013/2014 after a flood event to enable households and businesses to build back better. As these schemes are delivered through Local Authorities, Government does not have accurate figures on the numbers of properties supported.

6.2.2.1.2 England

The recent government announcements and policies on flood risk management are summarised in Chapter 5, Risk H3 (Kovats and Brisley, 2021). The policy direction suggests a greater focus on a portfolio of measures to improve resilience and greater recognition of future flood risk levels (Surminski, Merhyar, Golnaraghi, 2020). In addition to spending on flood defences, the new

government flood risk and coastal erosion policy statement for England (Environment Agency, 2020b) and the flood and coastal erosion risk management Policy Statement (HM Government, 2020) committed to increasing the uptake of property level flood resilience in homes and businesses, as well as other approaches to adaptation such as nature-based solutions, flood resilient design and sustainable drainage systems (see Chapter 5. Risk H3: Kovats and Brisley, 2021).

As reported in the CCRA2 Evidence Report, the CCC has identified evidence of more systematic planning for a range of climate change risks including flood risk for large businesses, but there is little evidence of planning or implementation of flood adaptation by SMEs. Much of the support and advice services available in the past in England no longer exist (CCC, 2019a). While information and advice is available, for example via Regional Flood and Coastal Committees, the uptake of these resources remains unclear. However, some Local Enterprise Partnerships (LEP) facilitate Central Government provided grants and loans for projects or businesses that enable economic growth and job creation by reducing the risk of flooding to land or operations. These have also emerged as investors in Financial Risk Management (FRM) projects that support these outcomes, such as in the East Coast towns of Ipswich, Great Yarmouth and Lowestoft (over £20m of grants and loans).

A public-private partnership funding approach to reduce flood risk is also promoted by the UK Government and requires the private sector to contribute to flood protection and risk management investments. One example is the Bacton to Walcott Coastal Management Sandscaping Project (see also Chapter 3, Risk N17: Berry and Brown, 2021), where the majority of funding originated from the private sector. Through this project, the height and width of the beaches have been increased and access to beaches improved (North Norfolk District Council, 2019). Similarly, the Canvey Island Multi-agency Partnership (MAP) was formed to raise flood risk awareness and increase resilience of Canvey Island's communities and businesses to flooding (Environment Agency et al, 2015). This was a partnership between Anglian Water, Castle Point Borough Council, the Environment Agency and Essex County Council (including Essex Highways).

Other examples are the Willerby and Derringham Flood Alleviation Scheme and River Aire Flood Alleviation Scheme and other examples where the private sector has contributed, e.g., Nestlé and the Lower Dove Flood Alleviation Scheme (Alexander *et al.* 2016), and collaboration between Hull City Council and local water company.⁷ However, this has also created challenges – with some stakeholders arguing that these schemes incentivise local council to grant planning permissions in high-risk areas in order to secure private sector funding for flood risk management (CCRA3 stakeholder discussions). Moreover, the partnership funding approach does not provide any obligation for the private sectors to contribute, and it is up to the Lead Local Flood Authority (LLFA) to present a business case for a voluntary contribution, which in some cases is the main challenge in attracting private funding contributions. This is particularly the case for coastal flooding where FRM infrastructure costs and the density of business assets are higher, meaning partnership funding gaps are typically greater (Surminski, Mehryar and Golnaraghi, 2020).

⁷ <https://www.hullccnews.co.uk/24/06/2019/hull-leads-the-way-in-how-to-tackle-threat-of-flooding/>

Defra is also funding three Pathfinder projects in Yorkshire, the South West and South Midlands between 2018 and 2021 to engage more businesses in flood resilience both from a precautionary point of view as an investment opportunity.

Examples of business-level adaptation include firm flood investment in Cumbria following Storm Desmond in 2015. As per Cumbria LEP (2020), a Cumbrian manufacturing firm invested £2.6m (benefiting from Cumbria Local Enterprise Partnership) to protect its premises from flooding. The new flood protection measures are designed to offer protection from a '1 in 1000' flood event and consist of a flood wall around the firm's production buildings.

Multi-sectoral collaboration is still relatively low in England but there are pilot projects at the local level that aim towards more integration of local businesses in local flood risk planning and decision making. One example is the engagement of the Zurich Flood Resilience Alliance in Lowestoft, Suffolk, where the local government is working with Alliance partners to increase understanding of risk and resilience across different segments of society, including businesses.

6.2.2.1.3 Northern Ireland

Recent assessments and policy announcements on managing flood risk in Northern Ireland are set out in Chapter 5 Risk H3 (Kovats and Brisley 2021).

The second Northern Ireland Climate Change Adaptation Programme (NICCAP2) includes references to flooding as being one of the major risks to businesses in Northern Ireland, and highlights that unlike the rest of the UK, SMEs make up the vast majority (99.9%) of the total number of businesses in Northern Ireland. The programme mentions the role of Invest Northern Ireland (the regional economic development agency for Northern Ireland) in providing guidance to businesses on adaptation. It also provides property support across a range of business parks in Northern Ireland in determining design features of these developments. It also seeks early engagement with statutory bodies over its plans in order to reduce the risk of flooding. Despite this, Invest Northern Ireland accepts that in the future some of its business parks may fall victim to incidents of flooding and with that there will be implications for it as the landlord and for its tenants (NICCAP2).

Invest Northern Ireland also offers a free service, nibusinessinfo.co.uk, which is described as the official online channel for business advice and guidance in Northern Ireland. The service encourages businesses to assess their potential risk of flooding and provides a link to the River Agency's flood map. There is also a guide for sustainable drainage systems and suggestions for good practice.

6.2.2.1.3 Scotland

Flood risk management policy in Scotland is summarised in Chapter 5, Risk H3 (Kovats and Brisley, 2021).

The Scottish Government is investing £420 million over ten years (2017 to 2027), with 42 Flood Protection Schemes or engineering works scheduled to begin between 2016 and 2021 to improve protection for 10,000 properties, though no estimate is given of the number of businesses

protected. Specifically in relation to businesses, Scotland's second Scottish Climate Change Adaptation Programme (SCCAP2) contains actions related to support business resilience to flooding, including guidance provided by Adaptation Scotland, flood forecasting and warning services, updated flood maps and the development of a property flood resilience action plan.

Other initiatives include a Property Flood Resilience Delivery Group (PFRDG) where members will work with multi-sector specialists and key stakeholders to identify and deliver actions that need to be taken to engage the public and the construction and insurance industries with PFR; and a living with flooding action plan which recommends actions for a range of stakeholders, including businesses, to take to help promote property flood resilience in Scotland.

The Scottish Flood Forum is funded by the Scottish Government (£193,000 in 2020-21) to provide recovery and resilience support to businesses including post flooding support, advice on property level protection and on business continuity. SEPA's Floodline business page can help businesses to identify if they are at risk of flooding and prepare accordingly. However, if and how this is applied by businesses when considering site location decisions remains unclear.

The Scottish Government is also preparing a policy document: 'Water Resilient Places – A Policy Framework for Surface Water Management and Blue-Green Infrastructure' that they plan to launch in early 2021 (not yet published at the time of writing). It aims to improve how to manage surface water flooding by complementing and supporting existing policy and organisational responsibilities as set out in the Flood Risk Management (Scotland) Act 2009. The policy objectives aim to make surface water management relevant to all sectors and make it a core consideration in designing for climate adaptation, sustainable place-making and 'delivering great blue-green places to live'.

6.2.2.1.4 Wales

Flood and coastal erosion risk management policy in Wales is covered in detail in Risk H3 (Chapter 5: Kovats and Brisley, 2021). Overall, £144 million has been invested in managing flood risk over five years (2016 to 2021). Natural Resources Wales and local authorities are managing risks to businesses as part of their overall strategic response to managing flood risks to communities. Risks to businesses have been identified across Wales and this was recognised in Prosperity for All: A Climate Conscious Wales, Welsh Government's national adaptation plan. This includes actions to:

- Do more to understand the risks to business from infrastructure disruption and higher working temperatures; and
- Provide support to businesses to help them adapt to the future risks from climate change.

The plan commits to increase research and understanding of the risk to business, while also updating guidance and the provision of 1-2-1 support to businesses wishing to work on adaptation. A Climate Change Adaptation Tool exists in Wales to support businesses in the tourism sector from risks including flood. Welsh Government's climate adaptation plan, Prosperity for All: A Climate Conscious Wales commits to renewing the tool, expanding further into businesses around the historic environment and using it as a blueprint to support tools for other sectors.

The Wales Flood and Coastal Erosion Risk Management Strategy (Welsh FCERM, 2020) sets the overall policy framework for Local Flood Management Strategies delivered through Natural Resources Wales (NRW) and local authorities, by recognising coastal impacts on habitats and species from flooding and erosion and highlights efforts to introduce interventions which use natural systems to reduce negative impacts. The strategy tends to refer to businesses alongside households and communities as a collective, but there are some important points in the strategy from a business perspective including a case study of the Pontarddulais Flood Alleviation Scheme which is protecting 22 businesses; a commitment from NRW to provide more detailed information on the numbers of businesses at risk; and a £150 million Coastal Risk Management Programme aimed at protecting vulnerable businesses within coastal communities around Wales (Welsh FCERM, 2020).

Delivery of FCERM is supported through Shoreline Management Plans, as well as the 'Communities at Risk' Register that provides a consistent way of considering and ranking flood risk from all sources based on the FRAW. In addition, Area Statements for local collaboration planning, stakeholder engagement and action on Sustainable Management of Natural Resources (SMNR), including flood risk management have been developed, but levels of business involvement are unclear. The Welsh Government Consultation on the post-EU Welsh land management scheme focuses on climate mitigation, whereas adaptation and climate risk is only referenced in relation to meeting carbon targets and in the context of flood risk. Post-EU Welsh land management scheme changes to farm payments will potentially focus on supporting farmers for flood risk management (Welsh Government, 2019a).

6.2.2.2 Effects of non-government adaptation (B1)

Evidence on actions by non-government actors are included in the sections on the extent of adaptation underway above, as private-sector investment in flood risk mitigation is part of government strategies. These include action to prevent flood damage by installing flood resistance and resilience measures. Resilience measures are fitted inside a property to reduce damage once flooding has occurred (e.g., internal design such as raising electrical sockets), and resistance measures aim to prevent floodwater from entering a building. Other adaptation measures are also possible such as retrofitting, through climate-smart operation and maintenance procedures, and by increasing preparedness and resilience (flood alerts, flood emergency response plans, insurance). There are various barriers to private-sector adaptation (see below) which suggest that government intervention continues to be needed.

6.2.2.3 Adaptation shortfall (B1)

The term 'Adaptation Shortfall' is used across CCRA3 to describe the difference between actual and possible adaptation, capturing the existing 'adaptation gap' in the UK. The extent to which the interventions summarised above will help to control flood risk to businesses remains unclear, largely due to a lack of evidence from across the UK on business' readiness for flooding, especially within SMEs. However, it is important to recognise that investments in large-scale flood protections will take time to materialise and will never completely remove flood risk. Therefore, it should be kept in mind that flood protection is never absolute and may even create a false sense of security, as it tends to stop other complementary risk reduction and adaptation activities from going ahead.

Considering the concept of residual risk, including the potential failure or breach of flood defences, it is important to continue with holistic resilience efforts, including property-level protection measures and nature-based solutions. This portfolio approach is recognised across all of the national flood and coastal erosion risk management policies in the UK.

Although the evidence above shows that much activity is underway, our view is that given the rising risks from climate change additional measures to support business adaptation and an enhancement of existing plans and actions is required.

There is a lack of national, climate change scenario-driven future flood risk maps, though progress is being made with some regional level analysis such as through the new National Flood Risk Assessments for England and Wales emerging. There is a lack of evidence to show the rate of uptake of Property Flood Resilience (PFR) installations and other resilience measures by businesses. Earlier feedback from flood protection manufacturers suggests overall uptake of property-level resilience measures by businesses is relatively low, in England at least (CCC, 2015), though there has potentially been support through PFR repair schemes after major flood events (CCC, 2019a). Wragg, McEwan and Harries. (2015) suggest that business adaptation to flood risk is a neglected area and that an information 'hub' for businesses will enable sign-posting to advisory sources, 'science communication', and support for those suffering the trauma of damage to their premises and livelihoods. At the moment, guidance and advice are provided separately by each UK nation (and advice and support services have closed in England). There is no single plan or information source to guide people, communities and businesses during their recovery from flooding. Whilst there are many organisations that are managing different parts of the system, further integration of plans could streamline this advice and make it easier to access.

Our engagement with insurance industry stakeholders as part of the UKCCRA3 stakeholder discussions highlight that price signals remain inadequate in signalling risk to businesses. This means businesses underinvest in flood resilience measures. In particular, where there is lack of previous flood history, and provision of relatively inexpensive flood insurance cover, there are few incentives for businesses to change risk-taking behaviour. The need to further reform the planning system was also raised in stakeholder discussions in the insurance sector. For instance, it was suggested that the National Planning Policy Framework (NPPF) and planning guidance on the Design Flood (planning standards) need to include the flood profiles to be modelled to 1 in 500 risks of climate change. Moreover, it was suggested that the 'safe for its design life' definition be rewritten in accordance with this modelling. The government policy statement commits to review the current approach to flood resilient design to consider how to ensure quality, safe housing.

6.2.2.4 What are the barriers preventing adaptation? (B1)

There are a number of barriers and constraints to private sector adaptation action, which make it difficult for businesses to plan and implement adaptation actions. As noted in CCRA2 and analysed in Cimato and Mullan (2010) and Frontier *et al.*, (2013), adaptation to changing flood risks requires a mix of action from businesses and government. The stakeholder discussions that were held during the CCRA3 process (see section 6.15) highlight that there can be confusion about risk ownership and

roles and responsibilities between public and private sector, with companies expecting government action and vice versa. This applies to all risks in this chapter. Importantly, the uptake of any measures is dependent on motivation of businesses and available incentives to make businesses realise the positive benefits of undertaking properly level measures if their business is at risk of flooding. A survey of the UK's 122 largest businesses shows that more than half of the UK's biggest companies have done little or no work to adapt to climate change, although two-thirds recognise that climate change poses a short- to medium-term risk to their business. Small and medium-sized enterprises, which account for more than 60% of employees in the UK, are likely to be less prepared to deal with climate change effects than larger companies. (Chartered IIA, 2020).

There are other barriers that can hamper action, even when it is clear that action is needed. They include:

- Uncertainty, which translates through to the market failure of imperfect information (or in cases asymmetric information or moral hazard).
- An expectation that insurance or government support will carry the costs. Recent investments in flood protection schemes, while reducing risks from one type of flooding for a specific location, could also create a false sense of security. Protection does not replace the need to adapt, particularly with regards to indirect risks from flooding.
- Adaptation actions have a public goods or non-market dimension that the private sector is unlikely to invest in as they do not present immediate returns.
- The available capacity and resources to adapt are often an issue, especially for private sector investment decisions, as the internal rate of return on adaptation will be low compared to other areas.
- Terminologies can also pose issues – with many businesses not familiar with ‘adaptation’ and instead using other terms, including ‘resilience’ (see Section 6.13).
- Lock-in can arise due to site location decisions that disregard future risk trends.

These aspects underline the role for government to intervene as a regulator, by creating the regulatory framework which is conducive to adaptation and resilience, and as a funder of important adaptation public goods such as flood defence, which require large capital investment, as well as to act (similarly) to help address the potential risks of indirect effects (flooding of infrastructure and transport disruption).

6.2.2.5 Adaptation scores (B1)

Table 6.7 Adaptation scores for risks to business sites from flooding			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)

6.2.3 Benefits of further adaptation action in the next five years (B1)

Given our assessment above, our view is that there will be significant benefits from further action in the next five years from low-regret actions to improve the evidence base and provide further awareness raising, advice and support to businesses to improve their resilience to flooding. Quantifying risks and impacts is difficult, particularly for individual business sectors, where data is often commercially sensitive. However, Sayers *et al.* (2020) report that if further adaptation measures are taken, in addition to what is currently planned then the UK-wide expected annual damages for non-residential properties could decrease by up to 21% increase by 2080. Results are calculated under the Enhanced Whole System model.

Businesses could also make use of the flood forecasting and warning services provided by the Environment Agency, Natural Resources Wales and SEPA, in conjunction with the Met Office, to plan for and respond to flooding in their areas. In terms of government support, stakeholder engagement indicates that investing in 3D interactive models for commercial properties would be beneficial for data collection. Whilst this will require significant government investment, insurance companies alone are unlikely to bear the upfront costs. It is likely that improving the uptake of property flood protection by businesses will have significant benefits in the next five years, though further data are required to understand this and the current level of uptake specifically in the context of SMEs.

6.2.3.1 Indicative costs and benefits of additional adaptation (B1)

The overall benefits of further investment in flood management for commercial property through the reduction in expected annual damages are estimated by Sayers *et al.* (2020). This study does not estimate the costs of these measures, and thus does not undertake a cost-benefit analysis, but the literature in general reports high benefit to cost ratios from such investment (Rojas *et al.*, 2013; Ward *et al.*, 2017).

There are some low regret activities where Government can act to enhance adaptation in the private sector. The uptake of adaptation measures by businesses is relatively low, with small businesses particularly at risk: only a quarter of businesses with fewer than 10 employees have continuity plans for extreme weather (in GOS and Foresight, 2017). This despite the fact that such plans are a cost-effective adaptation measure: around four-fifths of businesses with continuity plans in place report that the benefits of having a plan exceed the costs of producing one. There is, therefore, a role for raising awareness on climate risks (flood alerts) and providing relevant information and response planning. There is now a reasonable evidence base on the costs and benefits of property resilience and resistance measures for households (Environment Agency, 2015; Wood Plc 2019). These found that a number of flood resilience and resistance measures could be considered no-regret adaptation measures (i.e., a benefit to cost ratio of greater than one in cases where there is a greater than 1% chance of Annual Exceedance Probability, AEP). In general, this literature reports that all measures are more expensive if retrofitted rather than installed in new builds. For resistance measures, the difference between costs of retrofitting vs. incorporating into new builds are more modest. However, the applicability of each of these measures depends on the type of flooding (recurrence and depth), as this alters the relative cost-effectiveness (and benefit to

cost ratio). While there is less data on the costs and benefits of similar measures for commercial properties, it is likely that similar findings of low-regret adaptation opportunities apply. There is also some wider literature on the benefits of blue and green infrastructure in alleviating direct and indirect damages from flooding to industry and infrastructure, using the city of Newcastle as a case study (Blue-Green Cities Project, 2016). This assessed the benefits of sustainable urban drainage on water flow, sediment dynamics and flood risk in fluvial systems. Given the residual damage costs even with current flood management policy (Sayers et al., 2020) this is clearly an area where there are benefits of future action, and in many cases these benefits are projected to outweigh the costs.

6.2.3.2 Overall urgency scores (B1)

Table 6.8 Urgency scores: Risks to business sites from flooding				
Country	England	Northern Ireland	Scotland	Wales
Urgency Score	More action needed	More action needed	More action needed	More action needed
Confidence	Medium	Medium	Medium	Medium

Given the magnitude of current and future flood risks across all parts of the UK, and the assessment that the risk will only be partially managed in future, more action is needed both with regards to corporate adaptation and implementation of public policy to support businesses to adapt. Lock-ins are a particular concern as there is evidence that current business decisions are leading to increased exposure.

6.2.4 Looking ahead (B1)

Our view based on the assessment above is that businesses across the UK and across sectors are focusing on current rather than future location risks. There are gaps in understanding suitability of location-focused flood resilience measures. It is therefore important that planned and ongoing research and pathfinder schemes collaborate with business and consider business needs and requirements. Public – private partnership approaches can help improve preparedness and resilience in businesses. Furthermore, we see evidence that partnership approaches between businesses can help provide localised adaptation and can complement some of the national schemes. However, it is unlikely that private sector adaptation alone will suffice (see barriers section). Therefore, it is important to direct some tangible measures including financial incentives towards business flood risk management, particularly for SMEs across the UK.

6.3 Risks to business locations and infrastructure from coastal change (B2)

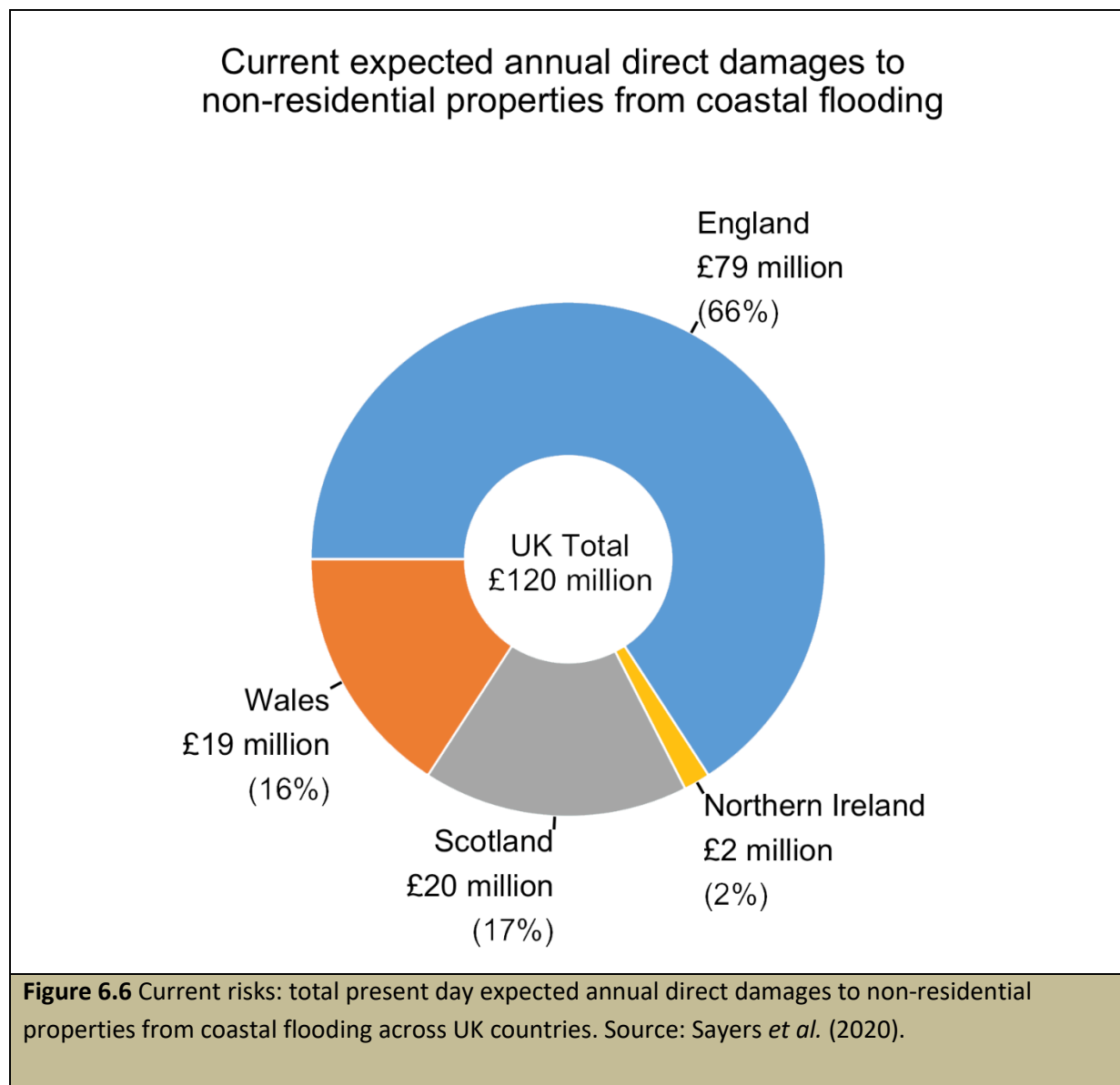
For most of the UK, a considerable amount of industrial and commercial activity occurs along the coast, while significant infrastructure is also located in coastal areas (the risks to infrastructure are outlined in Chapter 4: Jaroszweski, Wood and Chapman, 2021). The type and level of risk to businesses and business-related infrastructure along the coast depends on the geomorphology of the coastline, the coastal processes; nature of the hazard; past human interventions in the coast; and the coastal protection policy currently implemented. All of these are affected by sea level rise, the uncertainties associated with it, and the amplifying impact it has on the risks of coastal flooding due to extreme high tides, storm surges and/or fluvial flooding in tidal rivers and estuaries, as well as erosion. Coastal change across the UK therefore is posing a high risk to businesses now and is expected to remain a high risk in the future. However, there is a significant diversity of levels of information about climate risks and adaptations for the four UK nations which makes a comparison of adaptation difficult. For England, Scotland and Wales, evidence is growing on the changing risks and adaptations being used in the form of risk assessments and shoreline management plans, though we found a lack of similar information for Northern Ireland. UK wide, cascading risks for businesses arising from the failure of critical infrastructures after flood damage are increasingly recognised but there is no centralised evidence base that can be easily accessed. Thresholds associated with risk from coastal change include design and engineering thresholds for coastal flood protection infrastructure and business decision thresholds for levels of acceptable risk or investment criteria. Across all parts of the UK more action is needed to respond to the rising levels of risk.

6.3.1 Current and future level of risk or opportunity (B2)

6.3.1.1 Current risk (or opportunity) (B2)

6.3.1.1.1 Current risk - UK-wide (B2)

The current impact to coastal business locations is mainly driven by coastal flooding and extreme weather events such as the major storms of 2013/14 affecting southern England and floods in 2015-16 in northern England and southern Scotland. Sayers *et al.* (2020) provides estimates of expected annual damages for non-residential properties from coastal flooding by UK country; these are outlined below to give a sense of the magnitude of the risk to businesses from flooding at present, demonstrating risk in the absence of adaptation. The total present day expected annual direct damages to non-residential properties from coastal flooding in the UK is £120 million. A breakdown by region can be found in Figure 6.6.



In comparison, the current risk data for impacts on businesses from coastal erosion is quite limited but growing. For example, Masselink *et al.* (2020) state that “a large proportion of the coastline of the UK and Ireland is currently suffering from erosion (17% in the UK; 19.9% in Ireland)” (Masselink *et al.*, 2020: 158). However, there is significant regional disparity in the quality and depth of understanding of coastal risks for businesses across the UK.

6.3.1.1.2 Current risk - England and Wales

The CCC’s Coastal Change Report highlights that there is a total of 144,985 non-residential properties within Flood Zone 3 in England, which represents the present day 1:200 (0.5%) year risk from coastal flooding. For coastal erosion the CCRA2 Evidence Report and the CCC’s report on coastal adaptation (CCC 2018) reported that around a third of the English coastline is already experiencing impacts of erosion, with Masselink *et al.*, 2020 reporting that “of the 3,700 km

coastline of England (and Wales), 28% is experiencing erosion greater than 10 cm per year, which can be exacerbated by heavy or prolonged rainfall, coastal storms or sea-level rise.” (Masselink *et al.*, 2020)

6.3.1.1.3 Current risk - Northern Ireland

Northern Ireland faces major and increasing risks from coastal erosion and coastal flooding, however due to a lack of baseline evidence on coastal structure and processes it is difficult to assess this (see also The Irish News, 2018). There is a lack of both historical coastal change data and risk information for coastal businesses and infrastructure in Northern Ireland, limiting the potential for effective preparatory decision making: Rates of coastal change, the effects of storms, the seasonal behaviour of the coast, interactions between beaches and dunes, and the possible impact of coastal structures are not known (Cooper and Jackson, 2018).

6.3.1.1.4 Current risk - Scotland

Dynamic Coast, Scotland’s National Coastal Change Assessment (NCCA), has mapped the physical susceptibility of the coast and identifies that soft coastline (i.e., coasts with the potential to erode) makes up 19% (3802 km) of the coast (Hansom *et al.*, 2017). The NCCA estimates that between a half and a third of all coastal buildings, roads, rail and water network lie in these sections subject to erosion (In Scotland, 78% of the coast is considered ‘hard or mixed’, and is unlikely to erode at perceptible rates, 19% is ‘soft/erodible’, whilst 3% has artificial protection. Since the 1970s, 77% of the soft/erodible coast in Scotland has remained stable, 11% has accreted seawards and 12% has eroded landwards” (Masselink *et al.*, 2020). Where coastal changes occur, the NCCA identifies: (i) nationally average erosion rates around the Scottish coastline have doubled since the 1970s to 1.0 metre per year and (ii) accretion rates have almost doubled to 1.5 metres per year (Masselink *et al.*, 2020).

6.3.1.2 Future risk (B2)

6.3.1.2.1 UK-wide

The impacts from coastal flooding and erosion on business assets such as industrial plants (such as chemical processing plants) and factories (such as food processing facilities, pharmaceutical manufacturing), roads, railways, train stations, power stations, landfill sites and farmland, are expected to increase across the UK, as highlighted by recent climate change projections, including potential Low likelihood, high impact scenarios (High ++ or extreme sea level rise scenarios) suggesting that sea levels could rise by more than 1 metre by 2100. Further details are given in Chapter 1 (Slingo, 2021) and in the coastal context, in Chapter 5 (Kovats and Brisley, 2021). These include potential scenarios of very high future sea level rise, that would lead to significantly larger impacts than those used below in association with 4°C global warming by the late 21st Century.

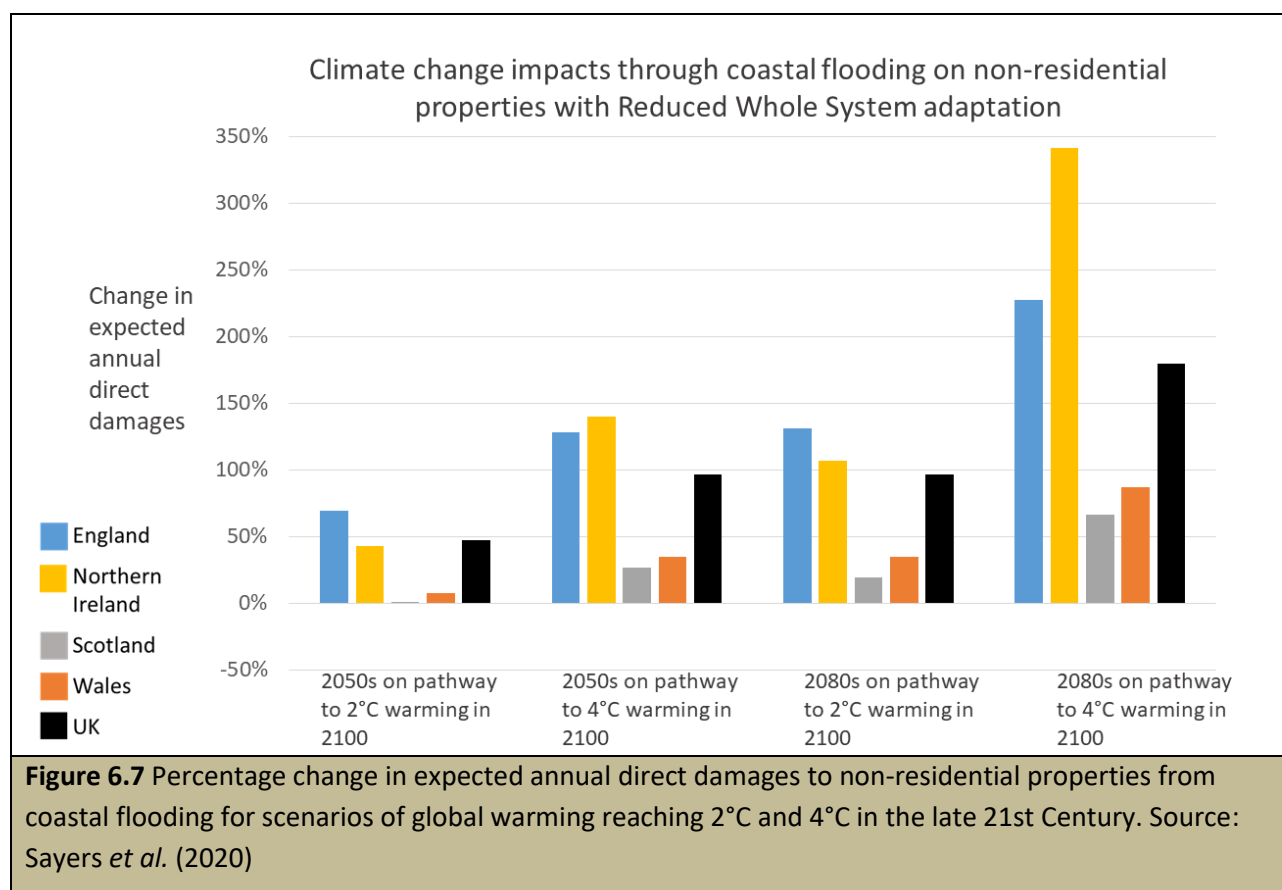
Sayers *et al.* (2020) estimates the following increases in expected annual damages for non-residential properties across the UK that will be at risk from coastal flooding in the 2050s and 2080s,

for scenarios of sea level rise associated 2°C and 4°C global warming by the late 21st Century⁸ (Figure 6.7). For conciseness these are referred to here as 2°C and 4°C warming scenarios, although it should be noted that a wider range of sea level rise rates could also result from these rates of warming.

Sayers *et al.* (2020) report that with the 2°C warming scenario, the expected annual damages for UK-wide non-residential properties from coastal flooding is projected to increase by 47% by 2050 and 97% by 2080 on the basis of no additional adaptation. With the 4°C warming scenario, the increase is projected to be 97% by 2050 and 179% by 2080. These do not assume future economic growth, and thus are potential underestimates of future value at risk and damages.

Based on the Sayers *et al.* (2020) estimate of a 179% increase in damages by 2080 in the 4°C warming scenario, annual costs could increase from £120M to £336 Million for 2080.

This is calculated using the Reduced Whole System model showing risk in the absence of adaptation. A regional breakdown can be found in Figure 6.7.



Recent figures from Mandel *et al.* (2020) calculate the overall direct and total impact induced by an extreme (95th percentile) UK coastal flood event (yearly damages) measured in basis points (0.01%) of World Gross Domestic Product (GDP). Losses are calculated for the financial and private sectors following a shock for two scenarios for socioeconomic and climate dynamics: First, a scenario with

⁸ Using subsets of UKCP18 sea level rise projections within the range consistent with scenarios of global warming of 2.0 ± 0.1° and 4.0 ± 0.1°C in the 2090s, relative to 1850-1900.

rapid and emission intensive economic growth, i.e., combining SSP 5 and RCP 8.5 and a second scenario with low-carbon and sustainable economic growth, i.e. combining SSP 1 and RCP 2.6. (Mandel *et al.*, 2020). Whilst the average financial propagation of shocks amplifies risks by a factor of 2 for most countries, for the UK, the amplification ratio can reach a factor of 10 in a high-impact scenario without adaptation. The UK is therefore listed under the ten most impacted countries, in their study, due to coastal flood risks and its role as a global financial hub (Risk B4).

Ballinger and Dodds (2017) suggested that businesses operating in a coastal environment and facing a change in the coastal management designation from protected to unprotected are likely to experience significant challenges including: loss of value of capital assets located in that coastal area, inability to access financing to relocate out of the blighted coastal area, and potentially complete business failure. Infrastructure providers in the same context potentially face complete loss of coastal access roads, and high costs of decommissioning existing coastal infrastructure to remove any potential for harm from degraded assets.

Heritage businesses which rely on access to seaside resorts are also expected to be impacted: As well as the impact of coastal change on these assets and local businesses they support, there is also potential for maladaptation arising from clean-up operations and flood protection measures. Impacts on the historic environment are also expected to cause economic difficulties in Scotland, where the heritage sector generates £4.2bn for Scotland's economy, with many businesses in these areas strongly connected to the cultural heritage of the places (Historic Scotland, 2020).

Cascading risks from the failure of critical infrastructures after flood damage are increasingly recognised. Chapter 4 (Jaroszowski, Wood and Chapman, 2021) provides a deeper look at this, including the impact of cascading failures and the example of the consequences Storm Desmond had on Lancaster due to the flooding of substations. Within the seafood industry, alongside the known risks of changes in storms and waves, and changes in ocean temperature, emerging risks come from ocean acidification and de-oxygenation of the seas which are explored further in Chapter 3.

Sectoral impacts include the marine leisure industry (MCCIP 2014). Coastal marinas are multi-faceted profit centres that are potentially highly vulnerable to climate change impacts (e.g., storms, sea-level rise and flood risk affecting asset values and occupancy). This could be an issue for older sites if they become unleaseable due to adverse weather events. Rising insurance costs could mean that getting cover for both site and boat owners becomes more difficult (MCCIP 2014).

The port industry (Asariotis *et al.*, 2017) is also at risk from extreme events. Damages could arise from impacts on port infrastructure/cargo from incremental and/or catastrophic inundation and wave regime changes; higher port construction/maintenance costs; potential modulation of tides causing sedimentation/dredging in port/navigation channels and operational timetable changes; effects on key transit points; increased risks for coastal road/railway links; relocation of people/businesses; and insurance issues (Asariotis *et al.*, 2017). For ports, incremental sea level rise is also a significant issue. Many of the UK's ports and jetties will require costly improvements to accommodate a 1m sea level rise (see Chapter 4: Jaroszowski, Wood and Chapman, 2021). With increased high tides and without adaptation, it could become more challenging to moor and load/unload ships, due to inability to secure the ship due to mooring and fender heights. Further

issues might arise from the inability of loading cranes to service ships as they will be higher and from the inability of loading arms (oil, chemical, gas, grain products) to attach to ships at high tide (Becker *et al.*, 2018).

Gibson *et al.* (2020) project impacts of extreme events in the coastal community of Torbay 20, 50 and 100 years ahead, showing significant local differences in the risk to the tourism and hotel industries and the resulting economic impacts.

Within the seafood sector, the main current and future risks are perceived to be alteration of ocean ecosystems; changing catch potential; regional shifts in stock distribution and increased severity of storms and flooding (Garret *et al.*, 2015), with impacts on port infrastructures (Garret *et al.*, 2017; Garret *et al.*, 2018). This can also lead to a loss of product refrigeration due to interrupted / disrupted electricity supply leading to product spoilage/damage, but the scale has not yet been assessed for the UK. The potential implications of these changes are damaging impacts on the national economy through declining fisheries and more localised impacts on employment, which are explored further in Chapter 3 (Berry and Brown, 2021).

6.3.1.3 Lock-in and thresholds (B2)

6.3.1.3.1 Are there lock-in risks?

Business investment decisions have a high potential for lock-in for this risk, because of the location of investment and the rising risks of coastal flooding and coastal erosion. Business investment decisions with long lifetimes taken in the next decade or two– notably in the context of buildings and infrastructure assets – face potential risks if future climate change is not considered or if businesses do not have access to available information including on coastal erosion from local authorities. Lock-in risks related to coastal change include:

- Defra (2018) find that there is a risk for maladaptation where private defences undertaken by business owners may not always offer expected benefits. There is also a concern around how private defences align with the wider Shoreline Management Plans. The report suggests that is fundamental to ensure localised actions do not exacerbate wider risk.
- Attitudes towards the coastal protection and perceptions of longevity of that policy option, mean that businesses may plan for future development based on current protection levels if there is not sufficient community and business engagement in the long-term plans for a specific area, yet these may change.
- Current coastal management policy can lead to the decommissioning of areas, which may be both an opportunity and sizeable loss for coastal business. In our view the business community struggles to appreciate the opportunities involved in re-shaping places and the benefits this might bring to local economy including for tourism. This points towards an engagement challenge and signals that the negative impact on the local economy from coastal change could

also be turned around with some positive imagination of what the place could become with the intelligent application of those policies.

- Furthermore, local economic choices to defend and maintain can ‘blight’ the coastline, and not only lock communities into economic choices that may not be very climate resilient, but also damage economic interests of other communities down the coast (e.g., stopping sediment supply to beaches etc).

6.3.1.3.2 Are there potential thresholds?

A study by Haasnot *et al.*, (2013) investigated the role of thresholds for coastal adaptation, considering thresholds under different sea level trajectories and policy responses. Thresholds included coastal erosion on erodible or soft coastlines and engineering protection standards that would be exceeded beyond a particular risk level. For businesses there can be decision thresholds in terms of acceptable risk levels being exceeded, insurance not being available or experienced damage exceeding a particular magnitude. Businesses may choose to avoid investing in some coastal infrastructure at risk from flooding (Jones *et al.*, 2019), potentially limiting development options for existing businesses and the infrastructure they rely on. Across the UK policy responses and protection investments will influence how soon these thresholds will be met. Coastal management is a devolved issue, whereby decisions about development and rollback options are taken locally. Access to resources for development in coastal areas varies around the UK. This variation in access to funding could become a major threshold for adaptation. In England there are plans to increase council funding through retention of business rates, implying that local tax revenues could become important funding stream for flood and coastal risk management. The impact of moving to the business rates retention scheme could leave many councils in the North out of pocket – with knock-on effects for their ability to fund flood management activities (Hunter, 2019). According to CCC (2018) the application of adaptation pathways focused on the management approach (which can be aligned to SMP policy type) and use of monitoring key thresholds to trigger future management decisions, has benefits over sticking to rigid setting of policy type within defined time-bound epochs as is the case with SMPs. But given local capability, resourcing and funding for coastal management is limited, this may not be practical or feasible.

6.3.1.4 Cross-cutting risks and inter-dependencies (B2)

There are interdependencies in terms of adequacy and performance of infrastructure in coastal locations (see Chapter 4: Jaroszewski, Wood and Chapman, 2021), including a growing recognition of the risk to ports from weather-related disruption (Masselink *et al.*, 2020). For instance, there has been extensive reporting under the Climate Change Adaptation Reporting: second round reports (ARP2) where six harbour authorities and two lighthouse authorities submitted reports. As per the report submitted by the Associated British Ports (ABP), the majority of potential climate impacts are currently considered to be of low risk with a small number of medium-term risks. Key risks identified were related to engineering and vessel traffic service (VTS) functions and the projected impacts associated with sea level rise and flooding, temperature increases and storminess. There are resulting actions proposed which are incorporated in the bodies’ Marine Safety Management

System. ABP's 21 ports around the coast of Britain are estimated to contribute some £5.6 bn to the UK economy every year. To this end, climate risks for ports and their associated hinterland industries and critical infrastructure (e.g., access roads and rail) pose a threat to the UK economy given their contribution to food, fuel, chemicals and electricity generation. Moreover, significant impacts to port infrastructure and associated business impacts could affect a small number of coastal industries that employ large sections of the local workforce (ABP, 2016).

6.3.1.5 Implications of Net Zero (B2)

The same issues apply as for the previous Risk B1. Flood defences have high embodied carbon. This could be a factor for a Net Zero transition and might influence the type of protection (from hard to soft, or grey to green). At the same time, the Net Zero transition provides an opportunity for the retrofit of properties – and design of new commercial properties - to improve flood resilience in combination with enhancing energy efficiency. This requires increasing awareness amongst business and industry as well as upskilling within the sector.

6.3.1.6 Magnitude scores (B2)

Table 6.9 Magnitude scores for risks to business locations and infrastructure from coastal change from erosion, flooding and extreme weather events					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Medium (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Northern Ireland	Medium (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Scotland	High (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)
Wales	High (High confidence)	High (Medium confidence)	High (Medium confidence)	High (Low confidence)	High (Low confidence)

Note: The magnitude scoring is based primarily on the analysis by Sayers *et al.* 2020 and is ‘medium’ for England and Northern Ireland now, with annual economic damages in the £tens of millions today, rising to £hundreds of millions for England in the future. For Wales and Scotland the current magnitude is already high, with £tens of millions damage today, and expected to increase further in the absence of additional adaptation (see Table 2, Chapter 2 (Watkiss and Betts, 2021) for details of the magnitude scoring)

6.3.2 Extent to which the current adaptation will manage the risk or opportunity (B2)

6.3.2.1 Effects of current adaptation policy and commitments on current and future risks (B2)

6.3.2.1.1 UK-wide

Since CCRA1 and CCRA2, there have been notable policy changes in relation to managing coastal change: There is growing recognition of trade-offs inherent in meeting coastal management objectives of coastal residents, businesses and nature (e.g. the National Flood and Coastal Erosion Risk Management Strategy for England (Environment Agency, 2020b), the Flood and Coastal Erosion Risk Management Policy Statement (HM Government, 2020); and the Wales Flood and Coastal Erosion Risk Management Strategy (2020-21). Furthermore, we note an increasing focus on the language of resilience in policy documents and implication of a need for coastal businesses to ‘live with’ flooding (e.g., CCC, 2018).

Historically, coastal protection in the UK has typically included: hard engineered protection (e.g., groynes, rock armour, beach nourishment, seawalls, offshore breakwaters etc.); land reclamation and re-engineering (often in estuaries and around ports); soft protection (e.g. dune nourishment, use of wetlands as a coastal buffer); and allowing natural processes of erosion and accretion to occur. Coastal management policy became more formalised through the Shoreline Management Plans of the 1990s. SMPs are non-statutory policy documents that are implemented in England, Wales and Scotland and which inform wider strategic planning.

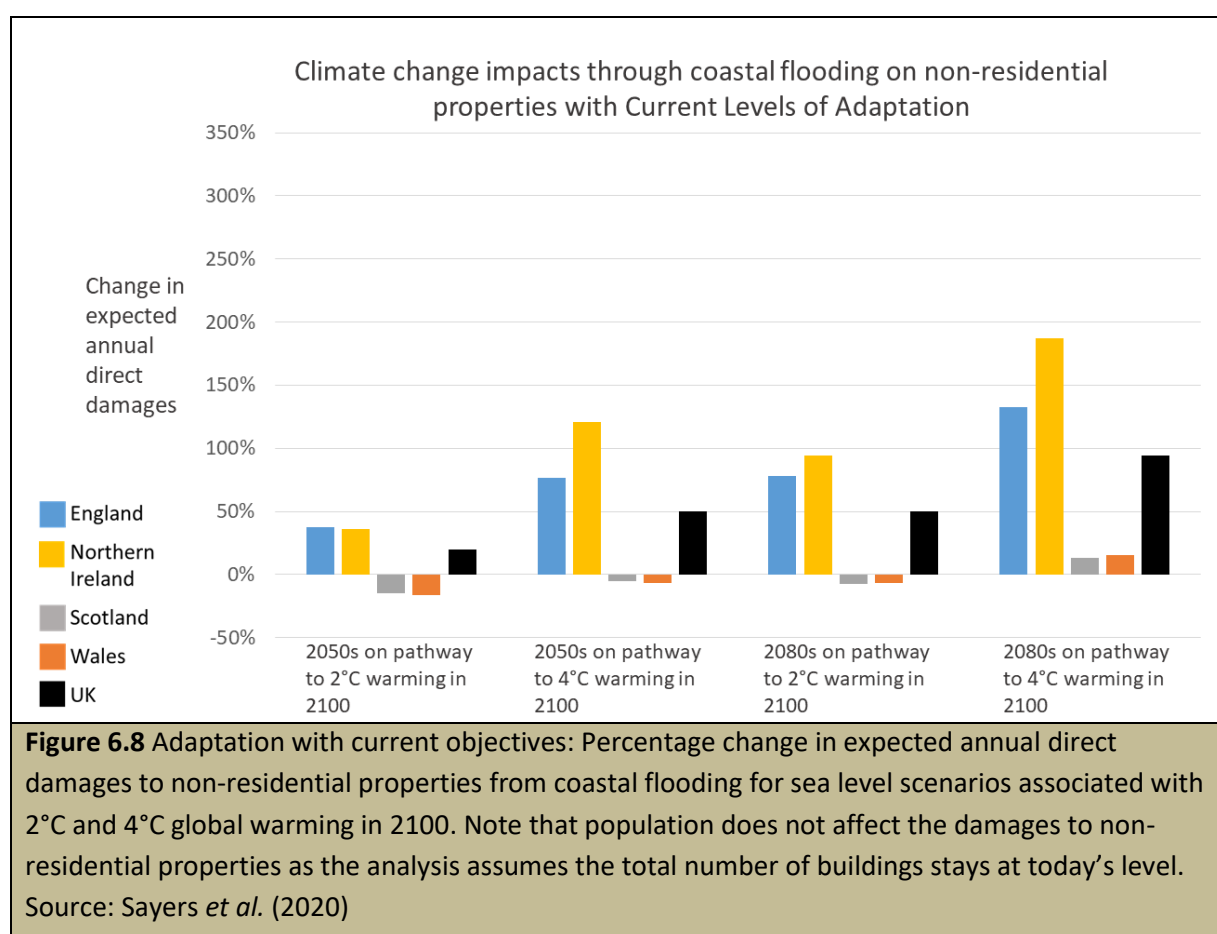
Sayers *et al.* (2020) report that under a scenario of a continued level of current adaptation ambition, the expected annual damages for non-residential properties due to coastal flooding are to increase by 20% by 2050 and 50% by 2080 in the 2°C warming scenario, and by 50% by 2050 and 94% by 2080 in the 4°C warming scenario. These results are UK-wide; regional breakdowns can be seen in Figure 6.8. It should be noted however that the Sayers report did not cover coastal erosion and was concluded before the publication of the National Flood and Coastal Erosion Risk Management Strategy (Environment Agency, 2020b) and the Flood and Coastal Erosion Risk Management Strategy Policy Statement (HM Government, 2020).

Some businesses have undertaken adaptation by

- investing in ‘hard’ engineering solutions e.g., upgrades to flood protection, new water saving devices, heat reduction in offices (Alshebani *et al.*, 2014)

- developing and implementing enhanced business continuity plans that consider current and future risks including regular reviews and tests (Day *et al.* 2018)
- investing in ecosystem-services / green solutions to reduce risks, e.g., natural water storage/drainage, green roofs, tree planting (Lupton, 2018)

Risk B1 in this chapter, and Chapter 5, Risks H3 and H4 (Kovats and Brisley, 2021) set out general policies across the UK to reduce the risks from coastal flooding and erosion, so those are not repeated here. Policies that are specific to coastal flooding/erosion and businesses only are summarised below.



6.3.2.1.2 England

In England (as well as in Wales – see below), two rounds of risk-based Shoreline Management Plans (SMPs) have been developed over the last 25 years, covering all coastal areas in England. It should be noted that these have not been developed in a consistent way across England, and the datasets that underpin these SMPs are not consistent in content nor universally available (Ballinger and Dodds, 2017). The first SMPs were completed in 1997; the second round (SMP2) completed in the late 2000s. SMP2s engaged with the public, including businesses and organisations with an interest in this part of the coast to ensure that the SMP dealt with their concerns. An SMP-Refresh (SMP-R) is currently underway, and the Government committed to review national policy for SMPs in its recent

Policy Statement (HM Government, 2020). The SMP-R identifies some key issues relevant for the business community:

- Lack of consistency in technical information available for SMPs, meaning that key sources of information needed for decision making by businesses may not be available.
- Lack of impact, clarity and usability of SMPs, meaning that the content of the SMPs may not be useable by businesses that are planning developments in the coastal zone.

The Government also committed in its Policy Statement to review the current mechanisms that coastal erosion risk management authorities can use to manage the coast and also to explore the availability and role of financial products or services that can help businesses to achieve a managed transition of property and infrastructure away from areas at very high risk of coastal erosion (HM Government, 2020). The National Planning Policy Framework (NPPF) recommends that Local Planning Authorities identify Coastal Change Management Areas (CCMAs) within Local Plans for areas “likely to be affected by coastal change (physical change to the shoreline through erosion, coastal landslip, permanent inundation or coastal accretion)”. The main barriers to CCMA development appear to relate to organisational arrangement, specifically ineffective integration across sectors within the local planning authority. Defra (2018) note a lack of support from councillors of local council policies with respect to adaptation, while CCC (2018) noted that 18% (17 out of 94) of active coastal Local Plans that could refer to an up-to-date SMP do not.

A number of research projects delivered under the Environment Agency’s 2013 framework for Coastal Research, Development and Dissemination have improved understanding of coastal flood and erosion risk and are developing tools to support coastal management (for example the guide to morphological modelling developed in the iCOASST project).

Natural England have developed good practice for managing protected wildlife sites on the coast. The Environment Agency will continue to explore how to value natural capital assets on the coast and use that understanding to help make choices about the best coastal management approaches to take, including possible natural flood and coastal management (see Risk N17 in Chapter 3: Berry and Brown, 2021).

NAP2 (England) acknowledges the risks businesses face from extreme weather but does not set out specific plans to address these risks for businesses alone. Instead, the actions related to flood and coastal erosion risk management in general.

6.3.2.1.3 Northern Ireland

In Northern Ireland, no Shoreline Management Plans have been developed to date. Ad-hoc measures are in place to protect the coastline against flooding and erosion. All reports identify the urgent need for accessible coastal data (processes, beach profiles, wave data etc.) to underpin decision making in Northern Ireland, e.g., see Cooper and Jackson (2018).

The second Northern Ireland Climate Change Adaptation Programme (NICCAP2) draws on the detailed 2018 Baseline Study and Gap Analysis of Coastal Erosion Risk Management NI (Amey

Consulting, 2018) which identifies lack of coastline erosion data and monitoring as a priority to inform future coastal management policy.

6.3.2.1.4 Scotland

To date SMPs have been produced for only short sections of the Scottish coast, though not all areas of the coast are at risk from coastal flooding and erosion. SMPs are in place in six of Scotland's 25 coastal local authorities (Angus, Dumfries & Galloway, East Lothian, Fife, North and South Ayrshire, and Scottish Borders). Dumfries and Galloway is currently updating its SMP.

For the last five years Scotland has focussed on developing a database of coastal change for future coastal planning, through its Dynamic Coast programmes. Dynamic Coast 2, which will conclude in 2021, will give the Scottish Government an up-to date assessment of coastal changes and ability to adapt to future sea level rise providing a robust evidence base for strategic coastal planning.

The second Scottish Climate Change Adaptation Programme 2019-2024 (SCCAP2) (Scottish Government, 2019) builds on the significantly improved data on coastal change generated through Dynamic Coast. Some of the general activities related to adaptation for businesses to coastal change include: improving prospects for marine fisheries and aquaculture, creating resilient harbours, future-proofing coastal buildings and learning to manage flood damage in historic buildings, managing the relocation of some waterfront buildings, and re-establishing coastal processes and habitats to improve coastal resilience.

6.3.2.1.5 Wales

In 2017, the Welsh Government established a Flood and Coastal Erosion Committee to manage issues related to coastal change. The Welsh Government's climate adaptation plan, Prosperity for All: A Climate Conscious Wales (Welsh Government, 2019b) explains how communities, businesses and infrastructure can adapt to the impacts of climate change. For example, it identifies actions to build defences to guard against flooding and coastal erosion; grow more woodland to reduce erosion and protect soil and slow down floods; and create 25,000 more energy efficient homes by 2021. In addition, as described in Section 6.4, the Wales Flood and Coastal Erosion Risk Management Strategy (2020-21) recognises coastal impacts on habitats and species from flooding and erosion and highlights efforts to introduce interventions which use natural systems to reduce negative impacts, with data available via the River Basin Preliminary Flood Risk Reports.

Round six of the Coastal Community Fund will have around £3.7 million available to fund projects that address the unique economic challenges of coastal areas in Wales. Grants between £50,000 and £300,000 are available for a wide range of organisations and businesses which benefit coastal communities in Wales. Applicants for funding are expected to consider the Welsh Government's National Marine Plan. Additionally, the 2-year Coastal Communities Adapting Together (CCAT) project looks at the regional implications of climate change, focussing on the coastal communities of Milford Haven and Pembroke Dock in Wales (as well as communities in Ireland). As part of the project, local people are encouraged to observe, interpret and record data about their community and coastal environment, and to take an active role in adapting their communities and businesses.

Natural Resources Wales is working with other agencies on Shoreline Management Plans which focus among other things on planning for sea level rise and climate change for the next 100 years (see section on England above for a discussion on SMPs that also relates to Wales).

The Wales National Marine Plan has only broad aims for increasing understanding climate risk and climate resilience for the marine environment. However, it does focus on the marine economy and businesses, location, supply chain, aquaculture, renewables fisheries, and marine freight businesses.

Businesses located in Fairbourne in Wales are experiencing the economic and social effects of planned 'decommissioning' coastal protection within the next 40 years. While no actual impacts are being experienced yet, the loss of 'protected' designation means that (i) people in Fairbourne can no longer get mortgages for new premises as Fairbourne is below sea level and will flood without protection; (ii) equity cannot be released from existing businesses to allow a relocation away from Fairbourne (Coastal Partnership East, 2019). A case study on Fairbourne is set out in Chapter 5 (Kovats and Brisley, 2021).

6.3.2.2 Effects of non-government adaptation (B2)

For some sectors there is evidence of action being taken, for example in the fisheries sector, vessel owners are already enhancing operational safety, but may need to keep a watching brief on how climate change is affecting fisheries (see Chapter 3, risks N14 – N16: Berry and Brown, 2021). The trade agreement concluded with the EU in 2020 provides for the transfer of 25% of fishing rights from EU vessels in UK waters to the UK fishing fleet (European Commission, 2020), which should lead to an expansion of the fleet. Longer term, the vulnerability of entire fleets should be assessed. Onshore, port authorities in the UK are investing in actions to build port resilience but should improve risk management. The vulnerability of freight ferries also needs to be assessed. More evidence is needed to identify the rates at which different sectors are autonomously engaging with adaptation action, and the types of actions that are being undertaken. However, overall there remain gaps in understanding across the UK about the business impacts of coastal change, what actions businesses are taking to prepare for climate change, trends in vulnerability and exposure to coastal flooding and coastal erosion, the resilience of infrastructure services including ports and airports, telecoms, digital and ICT, infrastructure interdependencies (see Chapter 4: Jaroszowski, Wood and Chapman, 2021), and opportunities that could be found from innovative forms of adaptation (such as portable beach homes – see below).

6.3.2.3 Is there an adaptation shortfall? (B2)

Although some action is underway, our view is that it will only partially manage the risks to businesses from coastal change according to the evidence available, which is also reflected in the assessments of coastal adaptation shortfall in Chapters 3 (Berry and Brown, 2021), Chapter 4 (Jaroszowski, Wood and Chapman, 2021) and Chapter 5 (Kovats and Brisley, 2021). A continuation of current levels of ambition as set out in the Sayers *et al.* (2020) analysis suggests that expected annual damages to businesses from coastal flooding will not stay at today's level on the basis of current actions, or even in an enhanced adaptation scenario. It should be noted however that the

Sayers report did not cover coastal erosion and was concluded before the publication of the National Flood and Coastal Erosion Risk Management Strategy (Environment Agency, 2020b) and the Flood and Coastal Erosion Risk Management Strategy Policy Statement (HM Government, 2020).

Mandel *et al.* (2020) find that adaptation policy is vital due to large upfront investments for coastal protection and the uncertainties associated with future sea-level rise. In particular, our view is that further investigation and investment is required for long-term engagement with coastal communities, including their businesses.

6.3.2.4 What are the barriers preventing adaptation? (B2)

The barriers for adapting to coastal flooding are fairly similar to the barriers outlined for B1 discussed above, and for the coastal flooding and erosion risks described in Chapter 3 (Berry and Brown, 2021), Chapter 4 (Jaroszewski, Wood and Chapman, 2021) and Chapter 5 (Kovats and Brisley, 2021).

Barriers include short time frames of business planning; uncertainty in potential sea level rise at a given location over a given timescale; unclear responsibilities or lack of risk ownership; overreliance and trust in protection levels; and lack of confidence about ecosystem services. There is also a lack of research findings to inform businesses on the costs and benefits associated with business opportunities from innovative business adaptation in at-risk locations.

As is the case with other types of flooding, financial resources will not be available in the future to defend the entire coast of the UK, and so priorities as well as guiding principles are needed to allocate resources for coastal protection (Boston, Panda and Surminski, 2021). The National Trust Shifting Shores report (National Trust, 2015) recognises that the protection of coastal areas is 'increasingly less plausible' and supports adaptation strategies that move structures and assets out of risk zones and allow natural coastal dynamics and processes to take place. Flood protection may be appropriate in some cases, but this creates lock-in to protecting properties long-term. This can have threshold effects, additional carbon costs and could discourage more appropriate adaptive actions such as avoidance of flood risk in other areas. Our view on SMPs is that they have been welcome and vital in addressing key issues, like designating areas of No Active Intervention (NAI): where there is no planned investment in coastal defences or operations, regardless of whether or not an artificial defence has existed previously. However, from the evidence collated, there are several criticisms of the SMPs, including: a lack of clarity of how businesses, communities and development planners should use the shoreline management plans and lack of accessibility to the underpinning data and methods used. For North Norfolk, an SMP designation has arguably led to the emergence of coastal blight with house prices and investor confidence plummeting in several rural villages, such as Happisburgh, with 1400 households, and less than 50 small and medium sized enterprises (POST 2009). The risk of blight and the need for innovative financial solutions were highlighted by a parliamentary investigation of the Environment, Food and Rural Affairs Committee into 'Coastal flooding and erosion, and adaptation to climate change' (House of Commons, 2019).

Evidence is starting to emerge that the application of a coastal management policy of 'managed realignment' or 'no active intervention' with no implementation strategy creates significant negative

economic consequences for coastal stakeholders relating to loss of tourism income, assets and residential properties (Phillips *et al.*, 2018, Buser, 2020). A process of transition is occurring in the village of Fairbourne in Wales, whereby a new policy designation (in SMP2) recommends maintaining protection till 2025; managed realignment to 2055; and then no active intervention up to 2105 (Buser, 2020) – see Chapter 5 (Kovats and Brisley, 2021) for a case study on Fairbourne.

Some coastal communities, businesses and infrastructure may need to change in structure, focus, organisation, and location to become viable under future climates. CCC (2018) recommended that information on future coastal change needs to be communicated (unambiguously but with an appropriate recognition of uncertainties) to communities. The need for a ‘National Conversation’ about acceptable levels of risk and how future locations should change was the focus of a UK national conference on adaptation held in October 2020 (UK Climate Risk, 2020).

Policy transitions may also be required, from current strategic options to alternative options. This may create business opportunities in areas which find themselves able to access funding for development (after the policy change), and effective economic stagnation and loss in those areas which cannot access funding for development. The SMP-R should identify opportunities for coastal areas by considering the role of partnership funding and the policy designation within the SMPs (these can be ‘Hold The Line, No Active Intervention, Managed Realignment, or Advance the Line’). Further research is needed to clarify the implications of a transition from one policy option to another.

6.3.2.5 Adaptation scores (B2)

Table 6.10 Adaptation scores for risks to business locations and infrastructure from coastal change from erosion, flooding and extreme weather events			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)

6.3.3 Benefits of further adaptation action in the next five years (B2)

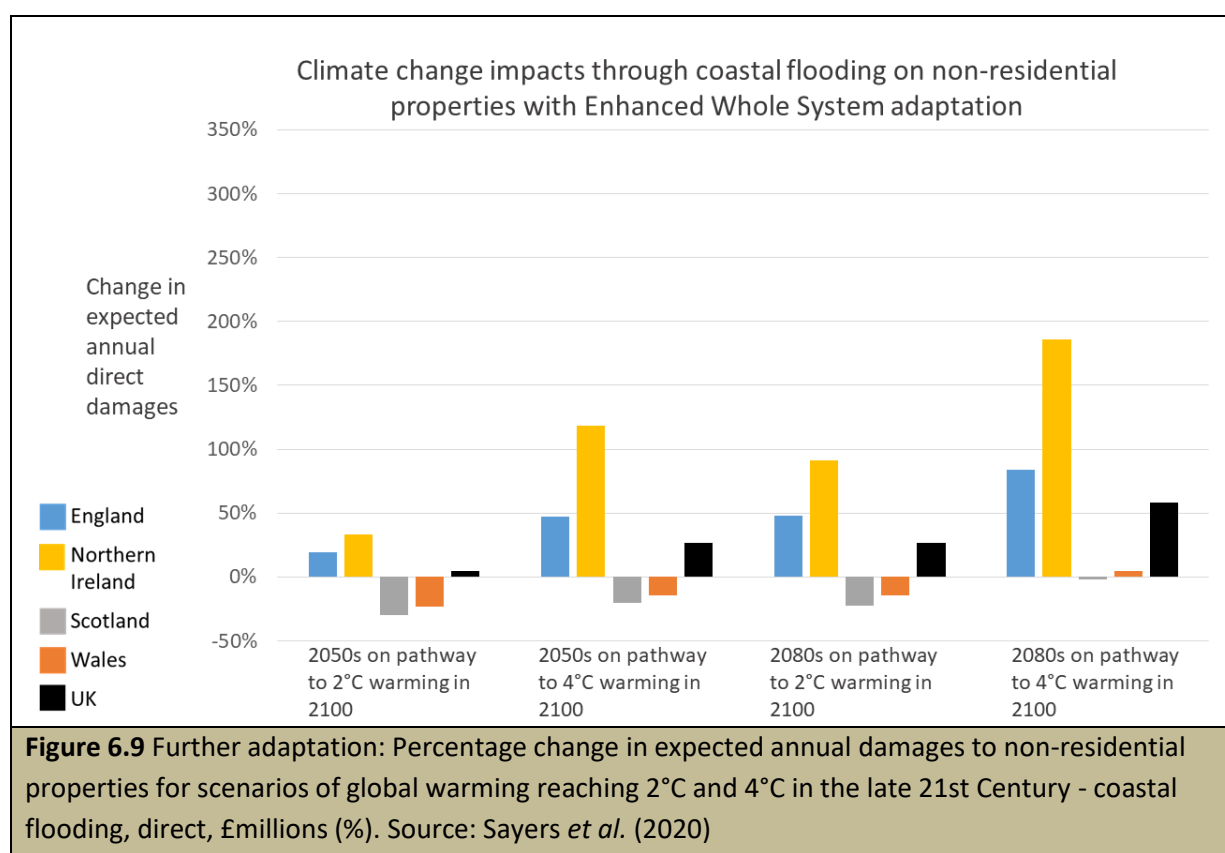
6.3.3.1 Additional planned adaptation that would address the adaptation shortfall? (B2)

Adaptation actions in the next five years have the potential to enable business opportunities to be created from climate change impacts on the coast, and possibly to avoid further losses.

Opportunities exist for coastal businesses from the re-designation of management policy in coastal areas (e.g., from defended to undefended). Depending on the designation, the opportunity exists for businesses to bid for coastal partnership funding to redevelop the coastal area. There is also the

potential for business opportunities to emerge from habitat creation, or new approaches to construction to enable communities to ‘live with rising seas’. Coastal properties could also be purchased and repurposed to generate income, e.g., wind farms, temporary holiday lets (Coastal Partnership East, 2019) Overall there is a lack of research and evidence in this area. There is also a business opportunity for new designs/building structures, such as portable beach homes which can be lifted out of harm’s way, providing low impact low risk solutions for future sea-side tourism.

Sayers *et al.* (2020) report that if further adaptation measures are taken, in addition to what is currently planned (see Figure 6.8), then the UK-wide expected annual damages for non-residential properties will increase by 5% in 2050 and increase by 27% by 2080 compared to present day levels of expected damage in the 2°C warming scenario and increase by 27% by 2050 and 58% by 2080 in the 4°C warming scenario. It should be noted however that the Sayers report did not cover coastal erosion and was concluded before the publication of the National Flood and Coastal Erosion Risk Management Strategy (Environment Agency, 2020b) and the Flood and Coastal Erosion Risk Management Strategy Policy Statement (HM Government, 2020). Results are calculated under the Enhanced Whole System model, with results by country for both the 2°C and 4°C warming scenarios presented in Figure 6.9. As can be seen, additional adaptation would significantly decrease expected annual damages to non-residential properties in Scotland and Wales. It is important to note that adaptation solutions do not apply across the board and are context specific. For example, increased coastal protection may work in one community in response to sea level rise, but relocation may be more feasible for a different community.



Some other potential benefits of further adaptation in the next five years include increased transparency about protection levels and limits to avoid false sense of security; public engagement in developing future visions for coastal communities; or investments in community resilience.

According to the CCC coastal change report (CCC, 2018), one of the main factors that could aid implementation of more proactive, and cost-effective relocation of coastal properties and assets at risk (i.e., 'move the risk'), is a change in government policy, associated funding prioritisation and outcome measures. It should be noted that this report was published before the publication of the National Flood and Coastal Erosion Risk Management Strategy (Environment Agency, 2020b) and the Flood and Coastal Erosion Risk Management Strategy Policy Statement (HM Government, 2020). These changes could facilitate the ability to plan and implement the management approaches identified for each of the coastal areas around the UK, particularly those at high risk. More active business engagement with existing resources available for coastal development in 'at risk' areas would likely increase adaptation, for example through FCERM partnership funding and Grant-in-Aid support. New guidance was released on the Grant-in-Aid scheme in 2020 to help businesses identify what resources are available for adaptation and what additional funds would need to be secured.

Transparency around planned coastal designation changes (from defended to undefended) could support more active adaptation. Providing clearer communication and more transparency should help businesses to avoid a false sense of security and to allow them to plan for future climate risks. Given that the Shoreline Management Plans are non-statutory policy documents, they can only inform wider strategic planning. The Plans also do not consider the full scale of future climate change risks (e.g., high++ scenarios) and do not set out the more radical adaptation responses that could manage those risks.

The CO-designing the Assessment of Climate CHange costs (COACCH) research report (COACCH, 2019a) notes that the costs of adaptation vary significantly with the level of future climate change, the level of acceptable risk protection and the framework of analysis (protection versus economic efficiency). Recognising and working with uncertainty as part of integrated and sustainable policies requires an iterative and flexible approach that positions coastal change adaptation within a broader integrated coastal-zone management policy framework. For example, new coastal development visions should be fully aligned with climate futures. The COACCH Report, which also includes an analysis of adaptation in the UK, reinforces the message that the most appropriate response to sea-level rise for coastal areas is a combination of adaptation to deal with the inevitable rise and mitigation to limit the long-term rise to a manageable level (COACCH, 2019a)

Climate change forms part of a range of risks and uncertainties most industries routinely face. For example, seafood sector adaptations could include much closer science-industry collaboration and engaged research in the short term; and a move towards a more robust and strategic fisheries knowledge base in the medium term (Garrett *et al.*, 2015). More work is needed to identify business opportunities in high-risk coastal areas, including better understanding of funding resources, clearer communication and a realistic appraisal of the risks and opportunities for businesses at the coast.

More research is required to understand the costs and benefits of different adaptation responses to loss of coastal locations for businesses and infrastructure. Further analysis is required on how risk

will change in the future and how this should inform decisions on a national outcome and strategy for flood risk alleviation. The National Infrastructure Commission (NIC) proposed the adoption or exploration of national minimum standards of resilience (NIC, 2018) though as yet this has not been adopted by government.

Defra (2018) indicate that local businesses (potentially with assets at risk) are often an important source of partnership funding for larger schemes. This must be capitalised during stakeholder engagement. Moreover, critical business infrastructure like transport or ports, as well as industry critical business infrastructure such as industrial plants (i.e. chemical and petrochemical plants, oil refineries, gas processing plants) and factories (i.e., food processing facilities, pharmaceutical manufacturing), which are typically located on the coast or on tidal rivers / estuaries out of necessity for process feedstock import and finished product export can be given a level of protected status when it comes to government flood risk management, as suggested by ABP (2016). The Institute of Mechanical Engineers suggests that this infrastructure is vital to national economic prosperity and growth as well as local economies and communities (IMechE 2019).

Our view is that for some sectors and some parts of the UK, guidance on appropriate adaptation in the short term has been identified (e.g., fisheries in England and Scotland), however in other parts of the UK, more investigation is needed to identify pathways of action, for example in Northern Ireland. Since CCRA2, the policy environment has changed, creating new opportunities for businesses and creating more adaptation guidance and support in all four of the UK countries. In the longer term, actions relating to the institutional arrangements for adaptation could be considered. For example, governance of fisheries (of both regulated and non-regulated species) could be adapted in the short, medium and long term as there will likely be a need for flexible institutional arrangements to respond to climate change.

The finance sector can encourage adaptation by policyholders through incentivisation; Governments and insurers can play a key role by providing further financial incentives for adaptation; for instance, they can set policy premiums at a level that more closely reflects the risk to which individual properties are exposed. However, some elements of coastal change such as erosion are excluded from insurance. If adaptation measures are not implemented, the insurance that currently exists will become more expensive and less available. At present, flood insurance for businesses is being driven by private insurance companies, with low government scope or obligation to pay compensation (Sayers *et al.*, 2020). This issue merits further investigations given lack of consideration in current flooding evidence reports (Sayers *et al.*, 2020).

6.3.3.2 Indicative costs and benefits of additional adaptation (B2)

The overall benefits of further investment in coastal flood management for commercial property – and the reduction in expected annual damages – are shown in Figure 6.8 and 6.9 The Sayers *et al.* (2020) study does not estimate the costs of these measures, and thus does not undertake a cost-benefit analysis. In general terms, the literature reports that coastal adaptation is an extremely cost-effective response, significantly reducing residual damage costs to very low levels (Hinkel *et al.*, 2014), however, in rural areas, such measures often have benefit-cost ratios lower than one. A new approach to investigating the wider dividends of adaptation and resilience interventions is

demonstrated by Roezer *et al.*, 2021 for the case of Felixstowe on the East Coast of England, where increased coastal protection from the new flood defences stimulated new investments in the property sector including the creation of new jobs and a boost to local businesses through increase in visitors, of which the local authority attributed around 50% to the new flood protection scheme. The assessment and retrospective evaluation of additional resilience dividends by the Coastal Partnership East (CPE), a group of local authorities, as part of the monitoring and valuation stage was done to support the business case for similar projects and future interventions. (Roezer *et al.*, 2021).

6.3.3.3 Overall urgency scores (B2)

Table 6.11 Urgency scores for risks to business locations and infrastructure from coastal change from erosion, flooding and extreme weather events				
Country	England	Northern Ireland	Scotland	Wales
Urgency Score	More action needed	More action needed	More action needed	More action needed
Confidence	Medium	Medium	Medium	Medium

Note: The evidence synthesized shows that current adaptation efforts will only partially manage the risk in future. There are benefits to action in the next five years, in particular, regarding additional support for critical business sites and infrastructure in coastal locations, as well as the role the finance sector can play in encouraging adaptation efforts by businesses. Further investigation of the opportunities to businesses from coastal adaptation would also be beneficial.

6.3.4 Looking ahead (B2)

There are a range of areas that require urgent attention to help manage coastal change across the UK: Data on exposure to erosion and storm damage remains patchy for much of the UK coast, there is no centralised evidence base that can be easily accessed (along the lines of the Environment Agency's flood risk maps). In addition, data access is not uniform across the UK, clear differences exist between England, Wales, Scotland and Northern Ireland. New evidence, such as Sayers *et al.* (2020) is informative but does not include coastal erosion risks or cost-benefit analyses. Going forward, coastal flooding and coastal erosion should be assessed jointly and with a specific focus on direct and indirect implications for businesses. For CCRA4, a more complete, detailed assessment of coastal risk and vulnerability across all four nations would be a useful starting point.

6.4 Risks to businesses from water scarcity (B3)

The risks that water scarcity pose to businesses in the UK are scored as 'further investigation' due to significant gaps in analysis. Given the importance of water for a wide range of sectors and business

functions any disruption to supply and accessibility can cause significant disruption. Water is used by businesses for cooling and heating, washing products, dissolving chemicals, suppressing dust and also as a direct input to products. Water is also being used by people working in businesses for drinking, washing and sanitary purposes, similar to domestic users. Water-intense manufacturing sub-sectors such as chemicals and chemical products, basic metals, paper and paper products, beverages and food products are more vulnerable to water scarcity. In terms of highest overall use, the manufacturing sector is the biggest abstractor, being responsible for between approximately 45% and 55% of direct abstractions. Other relatively large abstractors include mining and quarrying, as well as arts, entertainment and recreation, and other goods and services. The degree to which businesses will change their water requirements due to socioeconomic circumstances is highly uncertain but potentially a significant driver of risk. If not well managed, risk of water shortage is projected to become material in investment and employment for water-intense sectors. Risks to public water supply in general are covered in Chapter 4 (Jaroszweski, Wood and Chapman, 2021), and international water risks to businesses are covered in Chapter 7 (Challinor and Benton, 2021).

6.4.1 Current and future level of risk (B3)

According to UNEP's CEO Water Mandate, water scarcity becomes a concern for businesses if they are unable "to access adequate water supplies or services to effectively manage a company's operations". This can be caused by drought or long-term water scarcity (i.e., insufficient and/or unreliable access to water); flooding (causing damage to infrastructure and/or disruptions in supply); or pollution, to the extent that such water is rendered unfit for operational use. This is most often a problem for companies with water-intensive operations in water-scarce regions. In addition, there are regulatory risks when policymakers and/or water managers change laws, regulations or management practices in ways that alter companies' access to water, increase the costs of operation, or otherwise make corporate water use and management more challenging. Businesses are also exposed to reputational risks if business water use are deemed to be inefficient or harmful to watersheds, ecosystems, and/or communities (UNEP, 2010). Without sufficient water, production in many businesses would have to be reduced or stopped (CCC, 2015). Businesses obtain water either directly through the public water supply system, or through direct abstraction from natural sources such as rivers and groundwater supplies. Water-intense manufacturing sub-sectors such as chemicals and chemical products, basic metals, paper and paper products, beverages and food products are more vulnerable to water scarcity (CCC, 2014).

Across CCRA3 water use by different sectors is covered in different sections of this report: Chapter 3 (Berry and Brown, 2021) reports on water demand and use from the natural environment, agriculture and forestry; Chapter 4 (Jaroszweski, Wood and Chapman, 2021) by critical infrastructure sectors, including assessing the risks to public water supply and water for direct abstraction by infrastructure providers; and Chapter 5 (Kovats and Brisley, 2021) looks at the risks from water supply interruptions on households. This section focusses on risks to businesses that are not covered in Chapters 3 (Berry and Brown, 2021), Chapter 4 (Jaroszweski, Wood and Chapman, 2021) and Chapter 5 (Kovats and Brisley, 2021). Specifically, this section considers how water scarcity risk may affect different site locations for any type of business.

6.4.1.1 Current risk (B3)

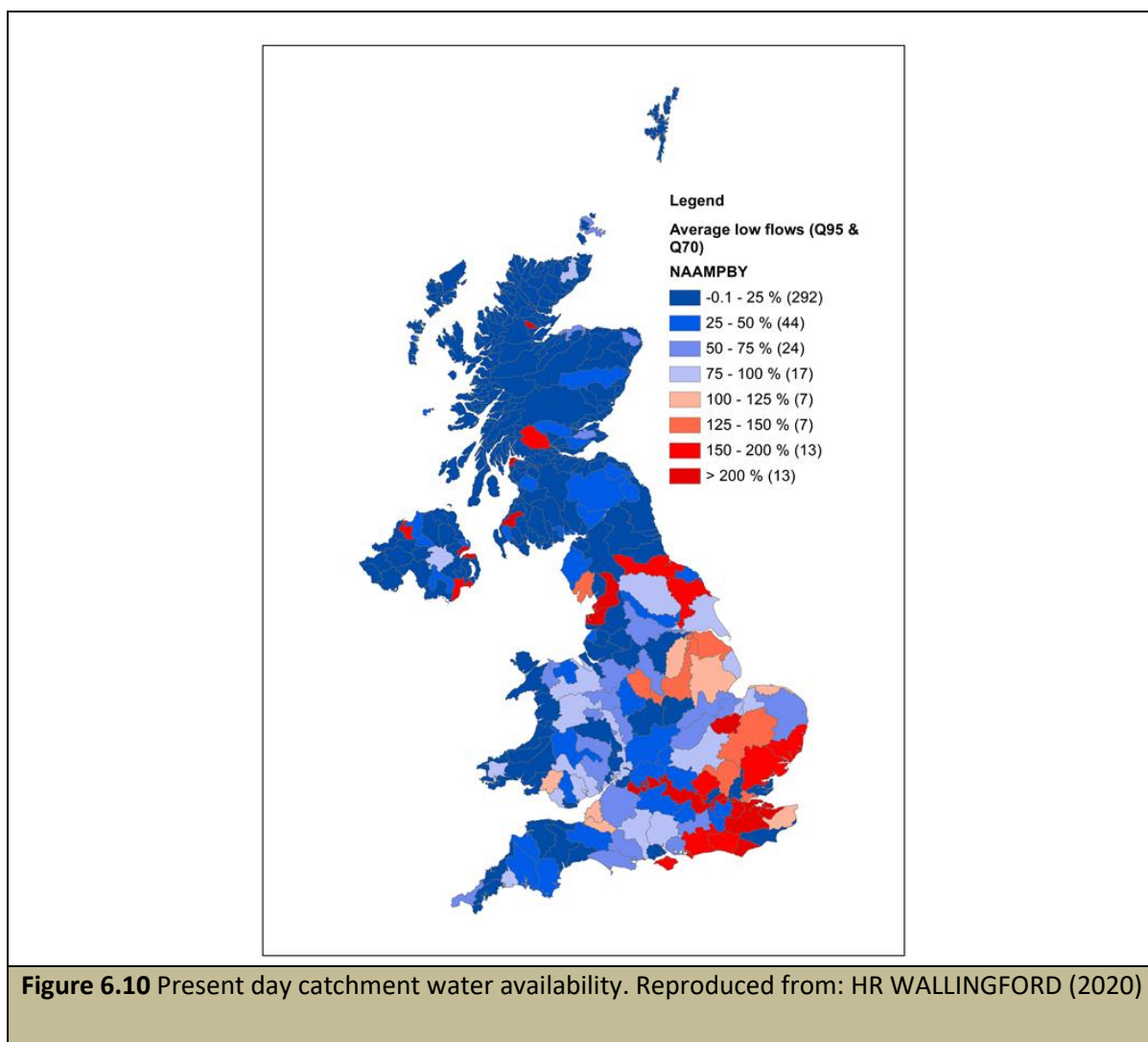
6.4.1.1.1 Current risk - UK-wide

HR Wallingford's recent report (HR WALLINGFORD 2020) offers insights into current and future water scarcity risks for businesses by analysing risks for the public water supply, and by projecting changes in catchment water availability that may impact businesses that rely on their own abstraction licenses rather than the public water supply. An important aspect is non-household water demand, which, as shown in Table 6.12, currently accounts for around 20% of demand in each UK country, lower than household demand and water leakage (HR WALLINGFORD, 2020).

Table 6.12 Main components of baseline (~2019/20) supply-demand balance, deployable output and demand in the four countries of the UK. Source: HR WALLINGFORD (2020).									
Country	Supply-demand balance (MI/d)	Deployable output (MI/d)	Water Available for Use	Demand MI/d (% of total demand)					Target Headroom
				Household	Non-household	Leakage	Other	Total demand	
England	400	16,250	15,150	7,790 (56%)	2,830 (20%)	2,940 (21%)	320 (2%)	13,880	870
Wales	80	1,060	1,010	460 (55%)	180 (21%)	170 (20%)	20 (2%)	840	90
Scotland	300	2,260	2,340	830 (44%)	410 (22%)	590 (31%)	60 (3%)	1,890	150
Northern Ireland	170	840	770	290 (51%)	110 (19%)	160 (28%)	20 (4%)	570	30

Figures in Table 6.12 are rounded to the nearest 10 MI/d (million litres per day) and are informed by the latest water company resource plans. Factors such as target headroom, sustainability and other reductions in deployable output are not recorded in this table, so deployable output minus demand does not equal the supply-demand balance. 'Other' demand includes more ad-hoc water demand, such as that required for firefighting.

For the public water supply, the study finds that all four countries in the UK currently maintain a supply-demand balance surplus. However, at a water resource zone scale, some deficits already exist in water companies' draft baseline plans available at the time of the study. For abstraction, the study finds that the majority of UK catchments are not currently using 100% of the available resource of water at average low flow conditions, i.e., there is a surplus of water available for human uses, though there could be deficits for individual water bodies within a catchment. There are 40 catchments where abstraction demand is already in excess of the available resource in average low flow conditions. These catchments are mostly located in the east and south of the UK, although there are a small number of catchments in Scotland, Northern Ireland and the north-west of England. For businesses specifically, we assess that this evidence suggests a low magnitude risk (medium confidence) for the present day. This is discussed further in Chapter 5 (Kovats and Brisley, 2021).



However, stress on the system during heat waves and accidental disruption to supply has an impact on some sectors, especially water intense industries such as those producing chemical products, paper products and food and drink (Scottish Government, 2019). Moreover, as stated by HR Wallingford (2020) changes in product design in one sector do drive up water demand in another, and this can lead to increase water demand or a shift in the location of demand. An example is a shift from plastic packaging to paper-based packaging, which may see a decrease in water demand in the chemicals manufacturing sector and an increase in demand in the paper manufacturing sector.

6.4.1.1.2 Current risk - England (B3)

In England, around 1 billion litres of water a day are used by industry, power generation, and farming (Environment Agency, 2020a). At present, there is a national surplus of around 400MI/day in the public water supply in England (HR WALLINGFORD, 2020) with no immediate restrictions for business users. As per MOSL (2020) business water usage is highly concentrated: just 200,000 businesses use 90% of the supplied water to businesses in England. Businesses also account for around 9% of direct abstractions from freshwater sources in England (CCC 2019a), with overall abstraction levels currently higher than in 2013, despite an 8% drop from 2014 to 2017 (CCC 2019a).

These changes could be the result of adjustments in production levels or other trends rather than improvements in water efficiency. It is not known how many abstraction licences held by businesses have been adjusted as part of abstraction reform to date. Vivid Economics *et al.* (2013) in a study for Defra estimated that in England £165m in revenue, and £96m in profit was lost by firms and sites in the second quarter of 2012 during the drought early in the year.

6.4.1.1.3 Current risk - Scotland (B3)

At present there is a slight deficit of around 20 Ml/day in the public water supply in Scotland (HR WALLINGFORD, 2020). There has been a sustained decrease in the annual average volume of non-domestic water used per day between 2008/09 (466 Ml/d) and 2016/17 (394 Ml/d) (CCC, 2019b) though as for England it cannot currently be determined what is driving this drop. Data is not currently available on direct abstractions by businesses in Scotland. Business impacts from drought conditions have been reported for the drinks sectors, with whisky producers in Scotland losing output due to drought conditions in 2019, with one distillery reporting the loss of one production month (The Drinks Business, 2019).

6.4.1.1.4 Current risk - Wales and Northern Ireland (B3)

Wales and Northern Ireland both have surpluses in the public water supply of 80 and 170 ml/day respectively, but water abstraction levels for business use remain unclear.

6.4.1.2 Future risk (B3)

6.4.1.2.1 Future risk - UK-wide

The future risks to businesses specifically from water scarcity are potentially very large but also unquantifiable. A Water UK report (Water UK, 2016) states that “*water restrictions could have a range of consequences on businesses and public sector bodies connected to the public water supply, and on sectors wholly or partially reliant on private abstraction sources.*” These risks are not just about loss of production, but also health and safety risks to employees if water supplies at site premises are cut off, and this is a risk for all businesses not just intensive water users (Environment Agency, 2016). Power *et al.* (2020) report that in a severe drought situation, where private supplies became unavailable or were restricted, the majority of abstracting firms would attempt to switch to Private Water Supplies where and for as long as such supplies were available. The authors also found that if private back-up supplies were to be unavailable, most firms did not have a contingency plan in place to allow them to continue to produce with a reduced private water supply, which would imply a fall in production at such locations and for the period when private water was unavailable. Estimates of the economic costs for a number of hypothetical drought scenarios differing in duration, severity and in decade of occurrence ranged from £261m in a one-year severe drought in 2010s to £43,488m in a three-year extreme drought in 2050s. (Power *et al.* 2020)

The National Infrastructure Commission (NIC) compared the short-term emergency costs of providing water during a drought, weighted by their probability of occurrence in the 2020 to 2050 period, with the whole-life costs of building long-term resilience to an equivalent event. The results

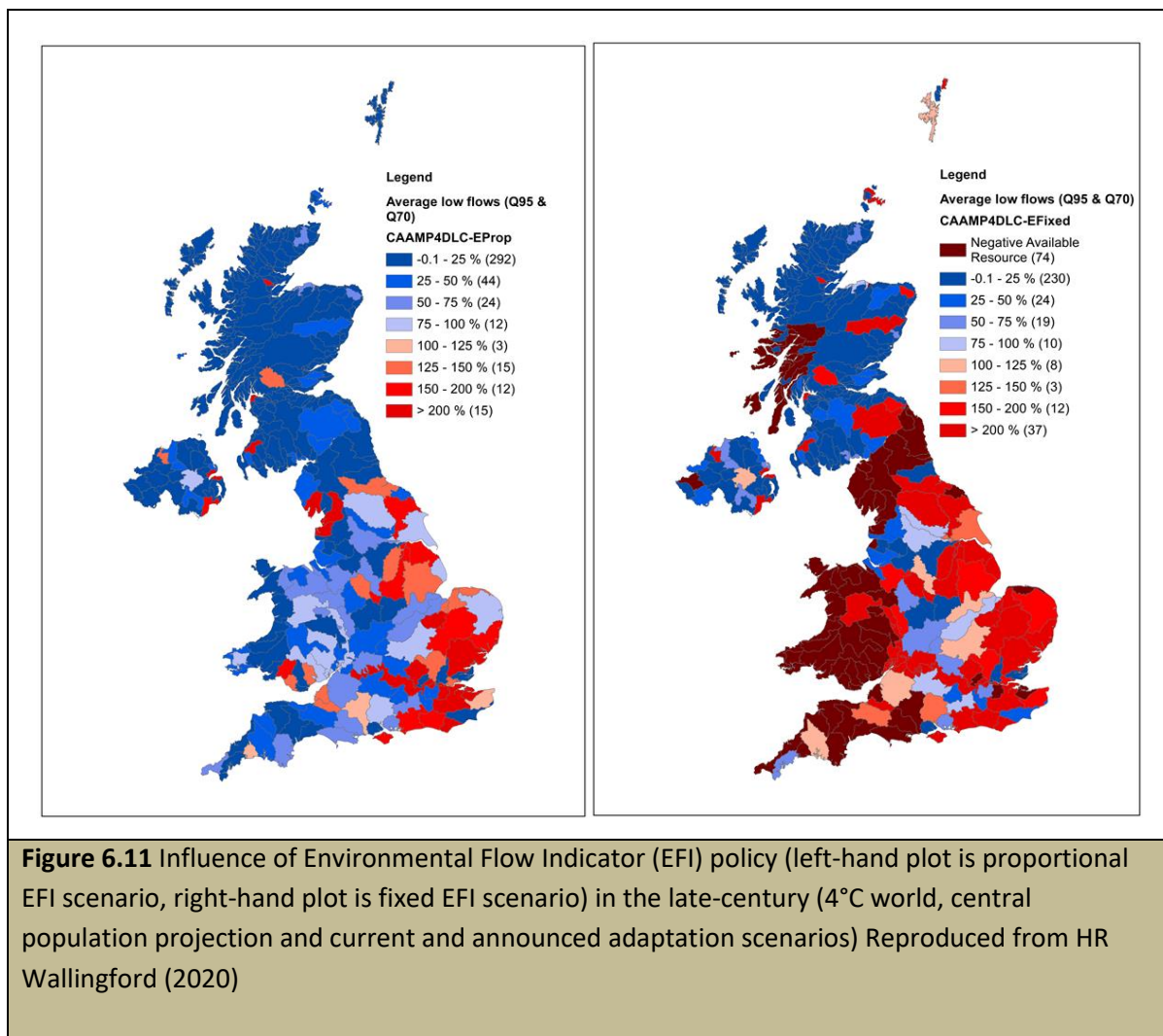
show that at a national level, the cost of responding to a drought emergency are higher than those of building long-term resilience to the same event (NIC 2018).

HR Wallingford (2020) project changes in water resources on pathways to global warming of approximately 2°C and 4°C in the late 21st Century⁹. These warming pathways were termed “2°C world” and “4°C world” respectively in that study, and that naming convention is used here.

The results for all sectors from HR Wallingford (2020) suggest projected changes in river flows at times of low flows (Q95) across the UK are of the order of 0-20% reduction by the mid-century in a 2°C world, everywhere except the western highlands in Scotland (where flows increase). In a 4°C world, this reduction increases (up to 30% flow reduction) in some areas, such as the Severn and Tweed river basins. Projected changes in river flows at Q95 across the UK are of the order of 0-50% reduction by the late century with approximately 4°C global warming. Projected changes in river flow will influence the naturally available resource at Q95 that is available for both large and small abstractors (i.e., those with and without abstraction licences).

When the demands of abstractors are taken into account, catchments at risk of negative available resource i.e., not being able to meet the fixed volume environmental flow requirement before any other abstraction from people, tend to be along the west coast of Great Britain, where the reductions in low flows tend to be greatest. The HR Wallingford study finds that the most significant factor for all the sectors results is the policy for managing environmental flows, while the difference between the 2°C and 4°C worlds for these results is small. It models a scenario where the policy is to keep the environmental flows fixed at the same absolute volume that they are today. Under this scenario, many catchments across England, Wales, some in Scotland and one in Northern Ireland are unable to meet their environmental flow requirements without the addition of discharges to the river network. In the mid-century (4°C world, central population projection and current and announced adaptation scenarios) 22 catchments across the UK, are projected to have negative resource availability i.e. the current absolute volume of environmental flow could not be met. In the late-century (4°C world, central population projection and current and announced adaptation scenarios) 74 catchments across the UK, including some in the south west and far north of England, are projected to have negative resource availability i.e., the current absolute volume of environmental flow could not be met. This is shown in Figure 6.11.

⁹ The HR Wallingford (2020) method defined the 2°C and 4°C pathways as the global warming levels (GWLs) reached late century (2070-2099) at the 50th percentiles of the UKCP18 probabilistic projections with the RCP2.6 and RCP8.5: 1.8°C and 4.2°C respectively. The former is near the centre of the lower CCRA3 scenario, and the latter is on the upper bound of the CCRA3 higher scenario (see Chapter 2: Watkiss and Betts, 2021). Late-century regional climate states were taken from the UKCP18 perturbed-parameter ensemble (PPE) of global 60km projections at those GWLs. Mid-century climate states were taken from the 60km PPE at the GWLs reached with RCP2.6 and RCP85 50th percentiles in 2040-2069. See HR Wallingford (2020) for details.



6.4.1.2.2 Future risk - England (B3)

For England the Environment Agency has estimated the water usage by 2050 in different sectors and regions. For industry the greatest increase is expected in the West and South-East. The EA’s modelling assumes that around 700 million litres per day of water that comes from unsustainable abstractions will need to be replaced by other means between 2025 and 2050. (Environment Agency 2020a). Vivid Economics *et al.* (2013) estimated the impact that an extended drought scenario would have on key sectors based on recent drought experiences. By assuming that management actions taken during the 2011/12 drought would have been applied for the extended period, the study estimated that cumulative “first round” turnover losses would have amounted to just under £2.9 billion over the two-year period, equivalent to 6% of the total turnover under business as usual; and cumulative first round profit losses amount to just under £1.46 billion over the two year period, equivalent to 7 per cent of the total profit under business as usual. (Vivid Economics *et al.* 2013).

HR WALLINGFORD (2020) project that England’s Supply-Demand Balance in the mid-century could be between 40 MI/d and -2,700 MI/d based on their analysis of public water supplies and depending on the extent of climate change and population growth and assuming no additional adaptation to

today. The Supply-Demand Balance for a central population projection is between -1,100 to -1,330 MI/d for 2°C and 4°C worlds respectively. In the late-century England's Supply-Demand Balance could be between 40 MI/d and -5,230 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for medium population projections is between -1,660 MI/d and -3,180 MI/d for 2°C and 4°C worlds respectively. The study finds that if the assumed policy is to keep the environmental flows fixed at the same absolute volume that they are today, many of the catchments across England are unable to meet their environmental flow requirements without the addition of discharges to the river network (HR WALLINGFORD 2020).

6.4.1.1.3 Future risk - Northern Ireland (B3)

The results for public water supplies from HR Wallingford (2020) project that Northern Ireland's Supply-Demand Balance in the mid-century could be between 170 MI/d and 10 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 120 and 100 MI/d for 2°C and 4°C worlds respectively.

In the late-century Northern Ireland's Supply-Demand Balance could be between 162 MI/d and -47 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 120 MI/d and 80 MI/d for 2°C and 4°C worlds respectively. Where the policy is to keep the environmental flows fixed at the same absolute volume that they are today, one of the catchments in Northern Ireland is unable to meet its environmental flow requirements without the addition of discharges to the river network (HR WALLINGFORD 2020).

6.4.1.2.4 Future risk - Scotland (B3)

The results for public water supply from HR Wallingford (2020) project that Scotland's Supply-Demand Balance in the mid-century could be between 450 MI/d and 0 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 290 and 260 MI/d for 2°C and 4°C worlds respectively.

In the late-century Scotland's Supply-Demand Balance could be between 440 MI/d and -170 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 280 MI/d and 190 MI/d for 2°C and 4°C worlds respectively.

Where the assumed policy is to keep the environmental flows fixed at the same absolute volume that they are today, some of the catchments in Scotland are unable to meet their environmental flow requirements without the addition of discharges to the river network (HR WALLINGFORD 2020).

6.4.1.2.5 Future risk - Wales (B3)

The results for public water supply from HR Wallingford (2020) project that Wales' Supply-Demand Balance in the mid-century could be between 110 MI/d and -60 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 60 and 40 MI/d for 2°C and 4°C worlds respectively.

In the late-century Wales' Supply-Demand Balance could be between 110 MI/d and -130 MI/d depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for the central population projection is between 60 MI/d and -10 MI/d for 2°C and 4°C worlds respectively.

The results for all sectors from HR Wallingford (2020) suggest projected changes in river flows at Q95 (low flows) across the UK are of the order of 0-20% reduction by the mid-century in a 2°C world everywhere. In a 4°C world, this reduction increases (up to 30% flow reduction) in some areas, such as in Wales, impacting the naturally available resource at Q95 for both large and small abstractors (i.e. those with and without abstraction licences). Catchments at risk of negative available resource i.e. not being able to meet the fixed volume environmental flow requirement tend to be along the west coast of Great Britain, where the reductions in low flows tend to be greatest. In the late-century (4°C world, central population projection and current and announced adaptation scenarios) 74 catchments across the UK, many in Wales, are projected to have negative resource availability i.e. the current absolute volume of environmental flow could not be met.

6.4.1.3 Lock-in and thresholds (B3)

6.4.1.3.1 Are there lock-in risks? (B3)

There is limited evidence about the extent of lock-in in terms of water dependency. Choice of business processes in terms of reliance on highly water-intensive production processes may lock-in a business and pose risks especially for those with direct abstraction licences, because of the emerging deficits, and thus the likelihood of higher water charges or potential disruptions. WRAP (2011) published an analysis of freshwater availability and use in England and Wales, which suggested that, using the Standard Industrial Classification (SIC) 2007, the manufacturing sector was the biggest abstractor in 2006, being responsible for between approximately 45% and 55% of direct abstractions. At a regional level, over 65% of these abstractions were in the north-west of England or in Wales. Other relatively large abstractors included mining and quarrying, as well as arts, entertainment and recreation, and other goods and services. Certain manufacturing sub-sectors accounted for more abstractions than others. These included the manufacturing of chemicals and chemical products, basic metals, paper and paper products, beverages, food products and coke and refined petroleum products. An example is the British brewing sector: valued at over £20 billion, this highly water-intensive industry had to invest significantly in water efficiency programmes, such as lowering the water use ratio needed to make beer from 10:1 to around 4:1 (Raconteur, 2018).

6.4.1.3.2 Are there potential thresholds? (B3)

At the national scale, there do appear to be thresholds as the UK, and England in particular, is projected to move into a supply-demand balance deficit by the 2050s, and the timing of this, and the subsequent increase in the deficit, will vary between 2°C and 4°C worlds. These would have implications for business water use.

There are also potential thresholds associated with levels of extreme events, though it is difficult to predict when particular thresholds may be crossed, that would lead to a sudden increase in risk to businesses from increased water scarcity. Water drought frameworks and drought plans can provide these thresholds as drought levels are somewhat predictable and would trigger restrictions and possible risks to businesses (those deemed non-essential use). In terms of extremes, current water company plans have typically focused on a 1 in 100-year event, taking account of climate change (although some companies have started applying a 1 in 200 chance of occurrence, as required by the latest water resources planning guidelines). The National Framework asks regional groups to plan for 1 in 500. Other recent analysis (Water UK, 2016) has looked at high climate futures, which include scenarios of drier summers, wetter winters and higher variability. But no single threshold has been identified to date. There also may be policy thresholds, as HR WALLINGFORD (2020) highlight. Thresholds for drought response are currently managed within companies. Each water company has its criteria for deciding that it's reached a certain drought level. The different UK environmental regulators also have different drought levels. And at those levels, different responses are put in place, which eventually include restrictions on non-essential use. In the future, whilst the thresholds may not change the frequency with which they are breached will.

6.4.1.4 Cross-cutting risks and inter-dependencies (B3)

The coincidence of hot weather with drought can potentially exacerbate risks and severe water scarcity could have impacts on people, who would then perhaps not be able to work, and potential for reduced demand for products and services. Further analysis of these interdependencies would be required to assess risk levels.

Some businesses have considered where water scarcity will affect wider supply chains and not just site locations. Marks & Spencer's (M&S) completed a top level assessment which confirmed that more than 90% of its water use as a business is within its supply chains. This is likely to be fairly common for most companies with agricultural supply chains and suggests that influencing and engaging suppliers and other stakeholders in collective action in water risk hotspot areas where a business sources and operates will be the key route to addressing overall water risk for most retail businesses. Moreover, HR Wallingford (2020) suggest that in a scenario where which self-sufficiency, sustainability and increased demand for 'home-grown' products is valued, in the absence of other adaptations, there could be increased water demand across a variety of industries. There are also cases of opportunities for business arising from climate change risks. An example of this is seen in the Viticulture sector in the UK (see opportunity B7) where in 2018 some producers became concerned about drought and started using irrigation for their plants (CREW, 2020).

6.4.1.5 Implications of Net Zero (B3)

Rising temperatures will increase water demand, and water supply and use involves energy use and carbon emissions, although in the long term this energy is expected to be zero carbon. The water industry was the first industrial sector in the UK and one of the first major sectors to commit to a carbon zero future by 2030, as established in the Net Zero 2030 route map that was published in 2020. The goal forms part of the industry's Public Interest Commitment (PIC) released in 2019 (See Chapter 5: Kovats and Brisley, 2021). More efficient water use can deliver energy and carbon savings for businesses as well as for the water sector. Indeed, for many companies their Net Zero commitment could be a greater incentive to reduce water use than saving water per se. There may be some businesses that might implement water re-use systems to increase efficiency, and this would be more energy intensive (Chhipi-Shrestha *et al.*, 2018). However, this is a relatively small proportion of the businesses.

At the same time, some low carbon technologies are also potentially water intensive (Chapter 4: Jaroszweski, 2021), including hydrogen generation and carbon capture and storage; and this could create additional competition for water.

6.4.1.5 Magnitude scores (B3)

Table 6.13 Magnitude scores for risks to businesses from water scarcity					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Low (Medium confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	High (Low confidence)
Northern Ireland	Low (Medium confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	High (Low confidence)
Scotland	Low (Medium confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	High (Low confidence)
Wales	Low (Medium confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	High (Low confidence)

The magnitude scoring follows the evidence above and our expert judgement. Currently magnitude is low across the UK. For the public water supply, the HR Wallingford study (2020) finds that all four countries in the UK currently maintain a supply-demand balance surplus, though there may be some more acute problems at the Water Resource Zone level. Similarly, for abstraction, the study finds that the majority of UK catchments are not currently using 100% of the available resource of water at average low flow conditions, though there are some where abstraction demand is already in excess of the available resource and there may be issues for individual water bodies within catchments. For business specifically, our expert judgement of this and the available evidence is that the annual economic impact is currently estimated to be less than £10million of damage in England and less than £1 million of damage or foregone opportunities in Wales, Northern Ireland and Scotland. These risk levels could change to medium and high if not managed. The degree to which businesses will change their water requirements due to socioeconomic circumstances is highly uncertain but potentially a significant driver of risk. If not well managed, risk of water shortage is projected to become material in investment and employment for water-intense sectors.

6.4.2 Extent to which the current adaptation will manage the risk or opportunity (B3)

6.4.2.1 Effects of current adaptation policy and commitments on current and future risks (B3)

6.4.2.1.1 UK-wide

Chapter 4 (Jaroszweski, Wood and Chapman, 2021) sets out the current government-led adaptation plans in place for public water supply, and the plans in place and the adaptation deficit in terms of the supply-demand balance deficit. Chapter 5 (Kovats and Brisley, 2021) considers this risk in relation to household demand. The policy framework includes the requirement for water companies to produce a Water Resources Management Plan (WRMP), which cover a 25-year planning period, and investment plans over the period (note that the HR WALLINGFORD projections above used the draft water company baseline plans available at the time of the study for its current and announced adaptation scenario).

6.4.2.1.2 England

The 25 Year Environment Plan (25 YEP) (HM Government, 2018) sets out the goal of boosting the long-term resilience of homes, businesses and infrastructure to climate change. This includes a goal to reduce the risk of drought and it sets a target of ensuring interruptions to water supplies are minimised during prolonged dry weather and drought. It is also noted that the 25YEP has a goal of making sure that all policies, programmes and investment decisions take into account the possible extent of climate change this century, which would apply to water investment decisions. However, there is very little specific information in the 25YEP on exactly what these targets involve (what is the metric of resilience, and what level to minimise to?), and what actions will be taken to achieve them. There is also a resilience objective recommended by the National Infrastructure Commission (NIC, 2018), which is for increasing the current levels of resilience (for droughts). The new national framework for water asks companies to increase resilience by planning for a 1 in 500-year drought

rather than 1 in 100. The Commission estimated that this would require additional capacity of 4,000MI/day by 2050, considering a medium emissions scenario. Greater levels of adaptation might be required under a more severe climate scenario. Defra's Environment Bill at the time of writing proposes a water demand target that would include business use of public water supplies as well as household use and leakage (Defra consultation, 2019).

The business retail market accounts for nearly a third of all water delivered to customers in England (Water Services Regulation Authority - Ofwat and Environment Agency, 2020). This 30% of public water supply consumed outside of the home is called 'non-household use' (NHH). NHH is not as well understood as domestic use in England and reducing NHH consumption had largely been left to the new retail market rather than addressed through any government or regulatory interventions. This failure of the market to sufficiently drive water efficiency was recognised in a recent Ofwat-Environment Agency joint letter, which outlines steps industry must take to improve levels of water efficiency. These steps include increased collaboration between wholesale and retailers through Water Resource Management Plans (WRMPs), improving meter reading and data quality of water consumption data, and increased coordination during unplanned events and incidents (Ofwat and Environment Agency, 2020). In March 2020 the Environment Agency published the national framework for water resources which sets out the strategic direction for long term regional water resources planning in England. Five regional water resources groups, comprised of water companies serving each area, will be producing coordinated cross-sector plans to manage demand and increase supply, and to realise opportunities stemming from collaborative working.

6.4.2.1.3 Northern Ireland

The Water Resource and Supply Resilience Plan published by NI Water runs several assessments of water scarcity risks. Although the report shows that for most of Northern Ireland there is expected to be sufficient water over the next 25 years, it indicates possible shortages at the end of that period unless demand management and other adaptation action is implemented. It suggests that without adaptation action there is "increased likelihood of water use restrictions being applied with impacts on households and business" (Northern Ireland Water, 2020). Resource Efficiency capital grants are provided to Invest Northern Ireland client companies to invest in resource efficient technologies. Grants of up to £40k are available to help with the purchase of new equipment that will reduce the consumption of water, waste and raw materials. The rate of support is based on company size (a maximum of 10% of total eligible project costs for large businesses, 20% for medium and 30% for small and micro) (Invest Northern Ireland, 2020).

6.4.2.1.4 Scotland

In Scotland, SEPA's Water Scarcity Plan (SEPA, 2015) includes a hierarchy of action in response to dry weather and encourage business contingency planning. Again though, it is not yet known how this is translating into action on the ground. Scottish Water also undertook an update of its strategic Climate Change Risk Assessment (CCRA) for assets, to refine the understanding of future climate-related risks and to identify knowledge gaps for further research. The Second Scottish Climate Change Adaptation Programme 2019-2024 (Scottish Government, 2019) includes several measures for water scarcity management and examples from the Scottish Whiskey sector.

6.4.2.1.5 Wales

In addition to the broad actions to support businesses set out in ‘Prosperity for All: A Climate Conscious Wales (2019)’ (see risk B1), the plan sets out current policy relating to water supply as a whole. It states that mitigating the effects of climate change on water resources in Wales is deeply embedded in the development of Welsh Government policy, the regulation of the industry and planning and investing for the future. The Water Strategy for Wales (Welsh Government, 2015) sets out Welsh Government’s vision and approach to ensuring a resilient, and affordable water supply and environment over the next 25 years. The strategy, which recognises the challenges that climate change brings, sets Water for Nature, People and Business as one of its 6 key themes.

Water Resource Management Plans in Wales are produced by water companies, and factor in climate risk to water demand, supply, output, river flows and account for population growth. They cover a twenty-five-year period and are required to take into account climate change projections, population growth and new developments. It is important to note that they currently utilise UKCP09 data (Dwr Cymru Welsh Water, 2019).

6.4.2.2 Effects of non-governmental adaptation (B3)

In general, businesses can take measures to reduce the risks of water scarcity by taking measures to improve water efficiency and having contingency plans in place to deal with water scarcity. Businesses will take action when the (private) benefits of doing so outweigh the costs. However, in our view there are a number of barriers stemming from high uncertainty on climate risks and adaptation costs and benefits, market prices and externalities, inertia and procrastination, and policy failures which prevent the private sector from taking the appropriate level of adaptation. The Government can therefore play a key role in providing a regulatory framework which incentivises the uptake of water efficiency measures (e.g. mandatory efficiency labelling of water using products here as well as metering) thus creating the right incentives for water companies to provide and for businesses to adopt measures to reduce water demand.

In terms of end-user responses by businesses, the level of adaptation overall is unknown (for all four UK countries) – but there are promising signs of progress. There are some plans in place to reduce water use by businesses through the implementation of abstraction reform, the water retail market and company initiatives and targets.

There is also some information on water efficiency, which is a potentially low or no-regret adaptation response. Following a letter from Ofwat and the Environment Agency (2020) to water retailers and wholesalers in England and Wales, the Retailer Wholesaler Group has developed an action plan setting out how they will work together and with regulators to deliver greater water efficiency to businesses (MOSL, 2020).

For example, the textile industry currently has a large water-to-dye ratio footprint. Some businesses are experimenting in reducing this from 30 to 1 to 10 to 1 to make the water usage more efficient. Some businesses are also exploring near-waterless dyeing (Guardian, 2013). Additionally, in their 2018 European Report, CDP stated that 92% of businesses reporting on water had some sort of

target or goals in place within their operations, up from 61% the year before. Members of the Food and Drink Federation (FDF) have committed to contribute to an industry-wide target: to reduce water use outside of that embedded in products by 20% by 2020 relative to a 2007 baseline. Reporting members of the FDF had gone beyond this and reduced their water use by 39% in 2017 relative to the 2007 baseline. Data suggest that this was due to improvements in efficiency as water intensity had decreased from 2.5m³ per tonne of product in 2007 to 1.5m³ in 2017. Some further examples of actions underway are included in Box 6.2.

Box 6.2 Examples of business actions to reduce water use

M&S (WWF and M&S, 2017)

- Water stewardship is embedded into M&S's Food Sustainability scorecard programme and Clothing and Home Eco Factory and dye house standards. For example, The Foods Sustainability Scorecard programme has helped reduce water usage for direct suppliers by 8.5million m³ (2014/15 vs 2013/14). It also encourages suppliers to embed the water stewardship approach within their supply chains.
- Suppliers have been supported with face-to-face training and webinars on addressing water risks.
- All produce growers are working towards agricultural sustainability standards which cover good water management.
- Water Stewardship Framework developed to trial with food producers.
- M&S is involved in collective action initiatives and water stewardship programmes in Kenya, South Africa, Spain and Peru.
- There is a long-term strategy partnership with WWF which includes work on fresh water.
- All key supply chains in food and clothing and home have been mapped and analysed using the WWF Water Risk Tool.
- Water risk in commodities is being addressed by working with certification schemes (e.g., Better Cotton Initiative) and through direct projects with growers.
- As a business, M&S is on track to meet targets to reduce direct water use in stores and offices by 35% by 2020.
- M&S has comprehensive measurement systems in place and targets to reduce water use across their estate/stores. During 2015/16, their UK and ROI store, office and warehouse water use was down by 31% at 46 litres per 100 sq. ft (2006/07: 67 litres per sq. ft).

Supermarkets (NERC, 2018):

- The UK 2012 drought led to a crop of blemished and smaller British fruit and vegetables – but Sainsbury's supermarket decided to relax their cosmetic quality standards and accept the uglier produce to help British farmers minimise financial losses. This was an informal arrangement organised ad hoc; however, a similarly formalised approach – enabling flexibility in cosmetic appearance of produce with changing weather conditions – may be welcomed by UK food producers.

- Some progress has been made in this area with some supermarkets rolling out wonky vegetable lines for some produce in 2016. This raises the question whether this could be more widely applied when there is drought to ease the financial pressure on producers.

Source: WWF and M&S, 2017; NERC, 2018

The CDP (CDP 2018) carried out a global assessment, including for the UK, of companies' exposure to water stress across their value chain and evaluated their water management processes and targets. The assessment found that despite almost a doubling of the number of companies setting targets to reduce water withdrawals over four years, there was an almost 50% rise in the number reporting higher water withdrawals. It is not clear how these high-level findings apply to use of water in the UK, but they do suggest a high level of risk to global supply chains from water scarcity (CDP 2018).

The LSE Climate Risk Business Survey (2020) found evidence of businesses investing in ecosystem services such as natural water storage to prepare for drought conditions, new water saving devices, and business continuity plans for water scarcity situations. The sample size is small, however, and it would be useful to see a national survey of businesses, particularly SMEs, to understand how widespread these actions are. The motivation for businesses to minimise their water use is attributed to a set of drivers (Zero Waste Scotland, 2020): The need to cut costs associated with water use, treatment and disposal; rising costs for water supply and disposal; more stringent legislative requirements associated with waste and water management; increasing consumer pressure resulting from environmental concerns; and the requirement to cut greenhouse gas (GHG) emissions (in particular, carbon dioxide) to improve the image of the organisation and help mitigate climate change. However, there is no overarching plan or target for any of the four UK countries at present.

6.4.2.3 Adaptation shortfall (B3)

As set out above and below, there are promising signs of action by individual businesses and there are various Government programmes looking at improving water efficiency and reducing abstraction demand, but it is not clear, due to a lack of evidence, how this activity matches the scale of risk from climate change and whether there is or will be an adaptation deficit in the future (i.e. whether the policies and actions as planned could bring risk down to a low magnitude by the end of the century). Additionally, it is hard to determine the effects at the business level where businesses affected are reliant on public water supply over which they do not have control. Better data on trends in business water use (taking into account production) is needed as is an analysis of adaptation measures taken by SMEs and water intense manufacturing companies to understand the scale of risks. As explained in Chapter 4 there are also further steps that water companies can take to help close the adaptation shortfall (Chapter 4: Jaroszewski, Wood and Chapman, 2021).

6.4.2.4 What are the barriers preventing adaptation to the risk? (B3)

There is limited evidence of sufficient adaptation levels. According to Waterwise (2018) the barriers to water efficiency adaptation for businesses include lack of awareness by businesses of risks and of

available water efficiency services; insufficiently strong financial motivations for seeking water savings amongst both businesses and water retailers; poor quality data on consumption; and a regulatory framework that has focussed wholesaler resources onto reducing household water use rather than business or non-household (NHH) use (Waterwise 2018). However, more data on production and consumption trends is required to understand the scale of the issue (MOSL, 2020). There is a lack of incentives amongst water retailers to provide customers this information. Moreover, firm-level data is hard to disaggregate given the reporting is done by SPID (supply point identifier), regardless of the scale of the business. Ofwat and Environment Agency (2020) also note lack of complete, accurate and timely meter reads, which can undermine retailers’ and customers’ ability to measure and manage water efficiency.

Also of note is that in England there are regulatory performance commitments with rewards and penalties on water companies to reduce domestic water use but nothing on business water use which has the effect of focusing their efforts on the former even when the latter may be feasible (Ofwat and Environment Agency, 2020). Direct abstraction of water by businesses has fallen in recent years, but progress in reducing consumption of the public water supply has stalled. It is not possible to tell whether businesses are becoming more water efficient without additional data on production trends.

Adaptation in some sectors may also have unintended consequences or pose risks of maladaptation. For instance, HR Wallingford (2020) find that adaptation in agriculture and other sectors may not lead to reduced water use. This is because new technologies or increases in fruit and vegetable production may require more water than is currently required. This impact will likely be greater the more the population grows.

6.4.2.5 Adaptation scores (B3)

Table 6.14 Adaptation scores for risks to businesses from water scarcity			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)

6.4.3 Benefits of further adaptation action in the next five years (B3)

6.4.3.1 Additional planned adaptation that would address the adaptation shortfall? (B3)

Watkiss *et al.* (2019) found that there are high benefits (although also high potential costs) of further action to reduce the risk of water scarcity. The costs and benefits do not just fall under the category of businesses but are part of a larger picture of action to reduce demand and increase supply across business, infrastructure, and households, with an aim of protecting and enhancing the natural environment.

Currently, there is a lack of incentives for water companies to help reduce commercial water use, and reduction efforts have been left to the retail market, unlike in the domestic sector. Further understanding of sectoral usage is required for this (Ofwat and Environment Agency, 2020). Water UK (2016) has estimated that a 'twin track' approach of demand management coupled with appropriate development of new resources and potential transfers is the most suitable strategy for providing drought resilience in the future. They estimated that total costs per annum for all potential future scenarios to maintain resilience at existing levels in England and Wales are between £50 million and £500 million per annum in demand management and new water resource options. If resilience to 'severe drought' is adopted, this increases to between £60 million and £600 million and for resilience to extreme drought (beyond the 1 in 100-year event) to between £80 million and £800 million per annum. In England a number of the policy measures that Defra consulted on in 2019 to reduce personal water use, for example, could also help increase business water efficiency and reduce water and energy use. Prime among these is water efficiency labelling of water using products linked to minimum standards for new build and retrofits which would realise significant benefits both for domestic and business water users (Defra, 2019).

One idea MOSL (2020) are looking at is to map out their data on business water users and overlay that data set with maps of current or future water stress areas the Environment Agency hold. This would help identify where efforts to reduce business use could be prioritised and what types of businesses/sectors could be targeted. Ideally this can be used to inform next round of water resource plans so a further adaptation action for the next 5 years. High consumption businesses can be incentivized monetarily, for instance through cheaper rates for businesses if they don't consume in the summer when peak demand is hard to manage.

Some of the key business benefits of handling water stewardship effectively include (WWF and M&S, 2017) reduced water related business risk, increased drought preparedness, reduced carbon emissions from supply and heating of water, continuity of supply from sourcing locations for retail businesses, cost savings associated with water efficiency, strong engagement with the local community, and reputational benefits.

WWF suggests there will be significant benefits to the UK from taking the following further actions (WWF, 2015): the UK government should share the evidence base, for example the Environment Agency's water and agriculture monitoring, widely with business and explore opportunities to help businesses identify key hotspots (e.g., showing impacts related to product type). To ensure there is a strong framework for the sustainable management of water WWF suggests more efforts to bring non-compliant farmers in England into compliance and ensuring basic legislation is sufficient to support further achievement of good health, as defined by the Water Framework Directive. Other suggestions focus on reforming abstraction licensing to ensure environmental needs are met as a function of every licence and that abstraction charges encourage efficient use; and continuing investment in the Catchment Based Approach including by exploring ways to encourage private sector support and funding (WWF 2015).

Stakeholder discussions as part of the UKCCRA3 stakeholder engagement indicate that a consistent methodology for measuring & reporting water use for products (water foot printing) is to be encouraged. There would be benefits to looking at whole life cycle approach to measuring water usage and make sure embedded water is fully taken into account in such reporting. The long-term

trends and pinch point analysis would provide useful tools for industry and Government to show where to focus efforts for either improved water efficiency of business or increased resilience of supply. The retail market could help to create incentives for businesses to become more water efficient but has so far only had a limited impact. The opening of the retail market for water offers multiple benefits for businesses but the potential effect on water efficiency is uncertain.

The CEO Water Mandate's Corporate Water Disclosure Guidelines offer a common approach to disclosure. They put forward metrics that can begin to harmonize practice and also provide guidance for defining what to report. These Guidelines have the potential to drive convergence and harmonization with respect to how companies report their water management practices while helping to minimize reporting burdens, thus allowing companies to allocate more time and resources to actively manage water. The list of endorsing companies as well as reports on their progress can be found online and are updated regularly (CEO Water Mandate, 2014).

6.4.3.2 Indicative costs and benefits of additional adaptation (B3)

As highlighted above, there are studies which have considered the overall costs and benefits of national level action to reduce the risk of water scarcity. There are also a complementary set of demand side measures that can be introduced by businesses, many of which are no-regret and low-regret. As a general rule of thumb, reductions of 30% in water bills are usually achievable at little or no cost for sites that have not previously tried to save water, and as much as 50%, or more, if projects with capital investment payback periods of up to two years are included (WRAP, 2005). There are detailed cost-effectiveness assessments of measures for industrial sites, with indications of costs and payback periods. However, as highlighted above, there remain important barriers to address to encourage the uptake of such measures, which includes a role for government to raise awareness and create appropriate incentives. There is a strong case for Governments to consider adopting consistent national minimum levels of resilience, recognizing that there are significant issues to address, including inter-regional and inter-generational fairness. The investment needed to increase resilience appears relatively modest compared with the cost of drought. A twin-track approach that includes supply enhancement, with associated transfers, as well as demand management, is the most appropriate strategic mix for the future. There is a case for a national level adaptive plan that supports ongoing water company plans and balances risks against opportunities to defer costs. See also Chapter 4 (Jaroszweski, Wood and Chapman, 2021) and Chapter 5 (Kovats and Brisley, 2021).

6.4.3.3 Overall urgency score (B3)

The current magnitude is low, with the potential for it to increase to medium or high in the longer term across the UK. It is assessed that the risk will only be partially managed in future. The growing risk of severe drought and limited understanding of trends of supply to and demand from businesses and effectiveness of policies and adaptation intervention, means that there would be benefits to further investigation in the next five years. The urgency scoring for water-related risks in Chapter 4 (Jaroszweski, Wood and Chapman, 2021) and Chapter 5 (Kovats and Brisley, 2021) is also relevant here.

Table 6.15 Urgency scores for risks to businesses from water scarcity				
Country	England	Northern Ireland	Scotland	Wales
Urgency score	Further investigation	Further investigation	Further investigation	Further investigation
Confidence	Low	Low	Low	Low

6.4.4 Looking ahead (B3)

It is critical to have better evidence for CCRA4. At present, the lack of sectoral usage and business level data means any analysis is high-level and has low confidence. With the new evidence through the CCRA-research project on future water availability (HR WALLINGFORD 2020) it should be assessed where supply-demand deficits in catchments across the UK exist, particularly where there are water-intense industries such as chemical, food/agriculture, and paper. Delivery of the Retailer Wholesalers Group action plan and outputs of the work MOSL are doing on business consumption data would provide further evidence for CCRA4. A systematic approach must be taken to connect business water scarcity with public water supply and infrastructure (Chapter 4: Jaroszewski, Wood and Chapman, 2021) and household water supply (Chapter 5: Kovats and Brisley, 2021) given the overarching regulation governing them. Similarly, water scarcity outside of the UK (Chapter 7: Challinor and Benton, 2021) is projected to critically impact supply chains but lies beyond the scope of this section. The extent of interconnectivity can be better captured in CCRA4.

6.5 Risks to finance, investment and insurance including access to capital for businesses (B4)

The current risk to finance, investment and insurance from physical climate impacts is medium across the UK and expected to increase. There is also a risk that access to capital for businesses will be negatively impacted by climate change through decline in availability and affordability of insurance, a reduction in the value of assets and investments, and increased credit risks and rising costs of capital for firms exposed to physical climate risks.

The exposure of the UK finance sector through international channels is currently medium, but going forward there could be further impacts on business models, products and flows of capital, leading to a higher risk to the stability of the financial system unless the risks are better managed and reduced. This is particularly important given the UK's strong role as a centre for the international financial sector. There is crossover with international risks to the UK finance sector, which are covered in Risk ID7 in Chapter 7 (Challinor and Benton 2021). The adaptation actions advocated in the CCRA2 Evidence Report like stress testing and scenario analysis, inclusion of liability risk and uptake of

green bonds to support adaptation have all been incorporated in government and private sector response to varying degrees. Whether or not this improved understanding is being translated into action remains unclear. The biggest change from CCRA2 is the shift in awareness, understanding, and reporting of risks, including recent Government announcements of making the Taskforce on Climate-Related Financial Disclosures (TCFD) reporting compulsory, indicating a shift in the regulatory approach, which in turn has implications on the behaviour of firms. However, despite a growing number of UK companies engaging in risk disclosure of climate risks, only a very small number of companies do this strategically or demonstrate how the newly gained understanding of physical risks is used in their financial and operational decision making. Internalizing climate risks and pricing it into insurance, lending or investment decisions will have implications for those relying on access to capital and insurance. Currently there is limited evidence of physical climate risks being a driver in pricing, but this could change suddenly in the wake of more frequent and more severe extreme events. Overall direct action to address risks is limited, which poses a challenge: Current lack of investment in physical risk reduction as well as underestimating physical damages and limited understanding of thresholds and interdependencies, particularly in the context of indirect impacts from physical risks, can create lock-in situations for the finance sector and those who depend on it. Another issue is the prevailing focus on averages rather than extreme outliers, which can generate a false sense of security across the sector. Regulators are now suggesting that companies conduct stress-testing for different scenarios. Initially this was limited to scenarios of 3°C global, but more recently this also includes scenarios of 4°C global warming, which no longer are dismissed as unrealistic.

6.5.1 Current and future level of risk (B4)

Building on CCRA2, Surminski *et al.* (2018) warned that “access to capital may become material if credit becomes more expensive or limited for companies that are considered to be taking insufficient adaptation action. Similarly, availability and affordability of insurance cover can be affected by rising risk levels, which in turn would also have implications for business’ access to capital.” CCRA2 also noted potential risks for access to capital through primary channels (exposure of assets to climate hazards and increasing exposure of the insurance industry) and secondary channels (regulatory change in response to future climate, development of new tools to manage risks, changes in credit ratings and changes in market expectations and investor behaviour). Here we revisit these risks and consider the new evidence base for risk and adaptation action. Importantly, risks for some also present opportunities for others. One can broadly distinguish between risks and opportunities to financial services arising from sudden and slow-onset physical risks, such as increased losses for insurers but increasing insurance needs, reduced value of real-estate assets but increased infrastructure investment needs and mortgage defaults but growing capital needs for resilience. Some of these longer-term opportunities are covered in B7.

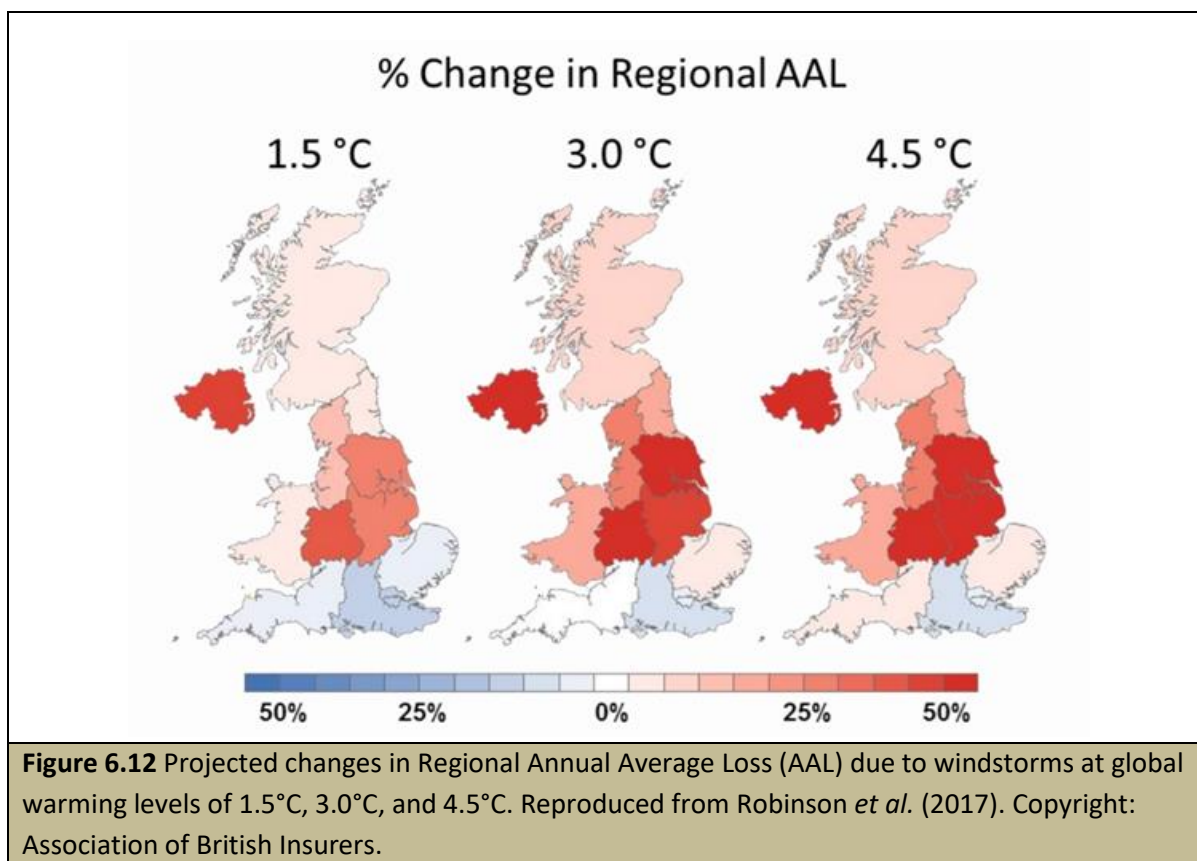
6.5.1.1 UK –wide current and future risk (B4)

Note: it has not been possible to split the evidence by UK country for this risk.

A detailed analysis of climate hazards is provided in Chapter 1 (Slingo, 2021). Here we are looking at evidence of the implications for the financial system across the main hazards of floods, windstorms, subsidence and global risks, before exploring how these hazards may impact different parts of the financial system (6.5.1.2-6.5.1.5).

Flooding. In terms of domestic risks, flooding is the most significant risk for the financial system (Bank of England, 2018) with financial impacts on insurance, mortgages and investment (see below). See sections B1 and B2 for flood specific assessments.

Windstorms. The impact of UK windstorms is less clear. It is recognized that storms are having a significant impact on businesses through damage and disruption to business infrastructure, which can lead to an immediate financial shock to the business, requiring investment and access to capital. This is seen in the damage to Gatwick Airport's North Terminal due to multiple storms, which led to £250,000 in direct costs (Acclimatise, 2018). In Wales, £100,000 was spent by the Welsh government for the clean-up of the Holyhead marina, where 80 boats were destroyed by storm Emma in 2018. Further major investments are expected for the reconstruction of the site (Welsh Government, 2018). Initial ABI estimates for windstorm damage pay-outs from the 2020 storms Ciara and Dennis are £149 million, with 61,000 domestic property claims, totalling £77 million, 9,000 commercial property claims at £61 million, and 3,500 motor claims at £11 million (Insurance Journal, 2020). However, there are some future trend studies (UNEP-FI, 2019, CISL, 2019) that indicate a reduction to windstorm losses in the UK under future climate scenarios. Figure 6.12 illustrates that windstorm loss projections are region specific, with areas of increasing loss particularly in the North of England and Northern Ireland and decreasing loss in the South of England (Robinson *et al.*, 2017). This paper looked at different RCPs and projected the changes in frequency and intensity of windstorms, looking at the average annual loss (AAL), i.e. annual insured loss aggregated over an entire year, the 1.0% exceedance probability (100-year) loss, and the 0.5% exceedance probability (200-year) loss. The results indicated a change in the overall AAL of 11%, 23%, and 25% for global warming levels of 1.5°C in the 2050s, 3.0°C in the 2070s, and 4.5°C in the 2090s, respectively. The analysis also indicated a possible increase of up to 30% in the 100-year return level loss and up to 40% in the 200-year return period loss with 4.5°C warming in the 2090s, though the distribution of these changes are not equal across the country.



Subsidence. With regards to impacts of drier weather insurers have seen a rise in subsidence claims due to hotter and drier weather (Financial Times, 2018). Chapter 4 (Jaroszewski, Wood and Chapman, 2021) assessed the current and potential future subsidence risks. The Association for British Insurers (ABI) reported after the 2018 heatwave that over 10,000 UK households made claims totalling £64 million in only 3 months (July, August, September) (ABI, 2018). These were the highest reported figures since the 2003 and 2006 heatwaves. Subsidence has impacts on building stock and financial implications via insurance/non-insurance and mortgage defaults. Shrinkage and swelling of clay soils is the most common foundation-related cause of damage to low-rise buildings in the UK, and subsidence can be attributed to changes in temperature, humidity, solar radiation and wind speed (Sanders and Phillipson, 2003). In the UKCIP02 projections with a range of emissions scenarios, soil moisture is projected fall by between 20 and 40% in South East England by the end of the century, increasing the incidence of subsidence (Sanders and Phillipson, 2003). This will impact both existing building stock as well as construction of new buildings. Sanders and Phillipson (2003) claim the insurance industry may be expected to have a significant role in the improvements in build quality by refusing to insure substandard properties, if subsidence rates increase. BGS have applied the latest UK Climate Projections (UKCP18) scenarios for rainfall and temperature changes in the UK for the next century, with maps produced for the south-east of England. This shows areas with varying vulnerability to shrink–swell and thus subsidence in the future due to climate change. The maps show that areas with clay soils that shrink and swell with changes in moisture are projected to become increasingly susceptible in the coming century and beyond (BGS Research, 2020).

Global risks. In global terms, the UK is one of the most exposed countries due to its high financial leverage and high centrality in the global financial network (Mandel et al, 2020). The UK is also one

of the leading insurance markets globally, underwriting risks all over the world and across sectors with complex supply chains. The UK is currently the leading exporter of financial services across the world. In 2018, The UK's financial services trade surplus of \$82.7bn (equivalent to £61.9bn) was nearly the same as the combined surpluses of the next two leading countries (the US and Switzerland) (TheCityUK, 2019). This presents both greater risks and opportunities for the UK financial market. The interconnectedness of markets is increasing – for example, the effect of the Thailand floods in 2011 to the manufacturing sector cost USD\$2.2 billion in insurance claims for Lloyds of London (Lloyds, 2012). In 2019, direct economic losses and damage from natural disasters were \$232 billion, with 409 total natural disaster events (Aon, 2019).

6.5.1.2 Risks arising from availability and affordability of insurance (B4)

Rising physical risk levels are already threatening insurability as well as affordability of existing cover: higher claims costs will require a higher premium, which may jeopardize affordability, largely due to the financial dynamics of disasters. Mandel et al (2020), highlight that the size of insurance buffer is critical to ensure that the insurance risk is not being passed on to the financial sector. One issue of increased climate risk is the resilience of the long-term business model of the insurance sector and the potential inability to set premiums high enough to account for the risk and loss in revenue (Surminski, 2020). In the case of floods, premiums might indeed be expected to rise on average, as markets continue to fluctuate in response to climate change (Westcott et.al., 2020). This is partially due to the nature of floods; as a concentrated and correlated risk, floods require insurers to hold a lot of liquidity, which in turn requires that they charge a higher premium (Financial Times, 2020b). Past modelling cannot always be used for predictions and focusing on averages can lead to distorted risk assessments (Swiss Re, 2020), however since CCRA2 there has been significant development predicting future losses, including new models, platforms and assessments such as the OASIS initiative; see also the Natural Hazards Partnership (NHP) (Hemingway and Gunawan, 2018). An example of insurer-led assessment of risk and pricing implications is the framework presented by Institute and Faculty of Actuaries (2019), using the example of Aviva's UK flood assessment and insurance stress test experience.

A recent study models future insurance affordability to floods across Europe, including for the UK (Tesselaar *et al.*, 2020). This finds the effects of climate change will vary across the Member States, because they use different flood insurance models, but projects high levels of unaffordability across the continent. The increase in flood risk under climate change may cause substantially higher risk-based insurance premiums, which makes it less attractive to purchase flood insurance, and this exacerbates inequality problems with the affordability of insurance for low-income households. This study finds rising unaffordability and declining demand for flood insurance especially towards 2080. This happens under all climate scenarios, but it is especially high under a 4°C scenario (Tesselaar *et al.*, 2020). The higher the projected climate warming, the more extensive the implications for the sector. Simply put, AXA CEO comments, "A +4°C world is not insurable" (AXA, 2017). As reported in Aviva's recent climate disclosure report: "The physical effects of climate change will result in more risks and perils becoming either uninsurable or unaffordable." (Aviva, 2019). Only a small proportion of natural disaster events are currently insured – termed the 'protection gap', this disparity presents a significant business opportunity for insurers. In 2019, worldwide economic damage from flooding was \$82 billion, with only \$13 billion of that being insured (Financial Times, 2020b). One opportunity

with high growth potential is that of insurance-linked securities (ILS). Also known as catastrophe bonds, ILS enables insurers to transfer large and complex risks, such as catastrophic risks arising from natural disasters, to capital markets rather than through reinsurers. The capital that is backing ILS stands at around \$90 billion globally, and research by Ernst & Young (EY) estimates that this market could grow to a value of \$224 billion by 2021 – 28% of reinsurance capital as a whole (Green Finance Initiative, 2018).

With regards to current risks in the UK there is no evidence in a shift of overall insurability, but there is evidence of localized issues, for example after the 2019 floods, which triggered the Blanc review on the availability of flood insurance (Defra 2020). Recent business surveys including the LSE Climate Risk Business Survey (2020) indicate that some businesses are experiencing increased costs of insurance for physical climate risks, but overall availability and affordability concerns are relatively low, except for SMEs (CCRA stakeholder engagement; Surminski, Merhyar and Golnaraghi, 2020). However, going forward this is expected to change: recent reports highlight that with better risk disclosure and reporting the cost of insurance could increase and reduce company values by 2-3% (Economist, 2019). This corroborates with Schrodgers' (2018) findings that insuring against physical risk could cost companies 4% of market values. Increasing costs of insurance is also expected to reduce demand and uptake, intensifying the current trend of underinsurance or non-insurance: Globally, only 50% of losses are insured, and non-or underinsurance is expected to increase as extreme events become more frequent. Insurance models suggest that if extreme events with an exceedance probability of 1 percent manifest, non-or underinsurance could be as high as 60 percent (Mckinsey, 2020).

Overall, as per Bank of England (2017), UK insurers are well placed to deal with current risk levels but less so for future risks: “insurance firms are reasonably well equipped to manage the current level of physical risks to the liability (claims) side of their balance sheets. At the same time, continued diligence is required, particularly if, as expected, the impacts of climate change drive greater volatility and higher potential losses” (Bank of England, 2017).

6.5.1.3 Reduction in the value of assets for investors and stranded assets arising from physical risks (B4)

There is a possibility of stranded assets due to physical risks. As IADB (2020) outline, assets can be stranded as a result of environmental challenges and changing resource landscapes. For example, coastal flooding may produce stranded assets like port facilities and railroads if left unmanaged (Buhr, 2017). Physical climate risks can also strand assets throughout the agricultural supply chain (Caldecott et al, 2013). Whilst many fund managers are offering equity strategies with low-carbon options, there are few tools available to reduce stranding risk for other asset classes (IADB, 2020). Value impairment may not instantaneously lead to SA classification. However, stranded assets can have negative credit consequences, as seen in the case of asset impairments in the German utilities sector in 2013 (EY, 2014). Write-downs can occur due to high exposure to natural hazards and high adaptation costs for retrofitting (EU-CRREM, 2019). Thus, asset damages can directly affect the longevity of physical capital due to increased speed of capital depreciation (BIS, 2020).

These risks are in addition to SA risk due to transition, litigation, regulation and behavioural changes discussed earlier in this section (Carbon Tracker, 2017; EU-CRREM, 2019). There are also discrepancies with regards to the value of stranded assets with some estimates focusing on the

value of fossil fuel assets whereas others focus on stranded capital (losses related to the capital invested in a project subject to stranding) (BIS, 2020).

According to the Carbon Disclosure Project, firms anticipate a potential \$250 billion of asset loss due to climate change, while \$1 trillion is at risk over the next five years, of which 80% is in the financial services sector (CDP, 2019). In this context, the Coalition for Climate Resilient Investment has been mobilising since its launch in 2019 to develop methods for assessing and including physical climate risks in investment decision-making, with the objective of creating climate resilient economies (CCRI, 2019). Recognizing risks is not only important to devise strategies for greater resilience of investments, it also provides investment opportunities in various new asset classes such as green bonds, low-carbon or fossil-fuel equity, sustainable public or private equity and sustainable infrastructure (Association of British Insurers, 2019; Mercer, 2019). Opportunities are discussed in risk B7.

Importantly, current physical risks to assets are not considered material if they are insured. This dependence on insurance poses systemic risks and can trigger financial instability should affordability or availability of cover change, as first reported by the insurance regulator PRA in 2015 (BoE 2015). This interplay between physical risks, insurance and finance is particularly visible in the context of real estate – where mortgage providers as well as real-estate investors rely on insurance to protect them from losses arising from physical risks (Westcote et al., 2020).

Real Estate is a significant asset class (Bikakis, 2020), as the size of the professionally managed global real estate investment market was worth US\$9.6 trillion in 2019 (Teuben and Neshat, 2020). Mercer's Modelling the Investment Impacts of Climate Change tool (Mercer, 2019) identifies real estate, infrastructure, agriculture and timberland as the sectors showing the greatest negative sensitivity to the impact of physical damage. While for equities, physical risk sensitivity is most negative for utilities and energy, but some sensitivity is relatively widespread across sectors, including industrials, telecoms, financials, and consumer staples and consumer discretionary (Mercer, 2019). UNEP-FI's analysis of physical risks to real estate assets note that buildings provide valuable income and capital appreciation possibilities to investors, but, as long-life fixed assets, face unique climate change related physical and transition risks (UNEP-FI and Acclimatise, 2018). With their relative illiquidity compared to many other asset types, and from their physical permanent locations and long investment cycles, it is essential that real estate owners and managers identify long-term climate change trends and take adequate risk mitigation measures to maintain and enhance value. (UNEP-FI, 2019) The report conducts 1.5°C, 2°C, and 3°C global warming scenario-based analysis of sudden and slow-onset physical risks as well as transition risks. The analysis combines historic loss data and future climate models with information about exposure and vulnerability to provide financial information to real estate investors. An important observation is the need to consider regional differences: "From a physical risk perspective, while average risks can be low, certain buildings may be high risk from one or more hazards. Assessing the outliers can allow investors to mitigate risks for particular assets by ensuring that building design is fit-for-purpose; transferring the risk through insurance; or, at the extreme, offloading the risk by selling the asset." (UNEP-FI, 2019) This is also a conclusion from the Cambridge Institute for Sustainability Leadership (CISL) report into climate modelling for real-estate portfolios that shows significant increases in

losses impacting real-estate assets due to changes in windstorm and flooding hazards as outlined in Box 6.3.

Box 6.3. Recognising risks in investment portfolios. Source: CISL, 2019.

- For investment portfolios in the UK, the increase in AAL is 40 per cent.
- For investment portfolios, in a 4°C warming scenario, the increase in AAL from flood risk across four UK portfolios is modelled to be 70 per cent higher in the 2050s than today.
- Especially in a 4°C warming scenario, the modelling finds significant differences in the risk of different portfolios of mortgage and investor assets.
- UK flood risk by investment portfolios is a 70% increase in AAL by 2050s if warming continues to 4 degrees by portfolios of mortgage and investor assets.

See also Westcott et. al. 2020.

Box 6.3 Table 1. Modelling shows increased losses are expected across all perils, but they are lower if global efforts to reduce emissions are successful. Reproduced from CISL, (2019).

Peril	Asset type	Risk Metric	2°C warming by end of century	4°C warming by end of century
UK flood risk	Residential mortgages	% Increase in AAL by 2050s	61%	130%
		% increase in number of properties at significant risk of flooding (annual probability of 1.3% or above)	25%	40%
UK flood risk	Investment portfolios	% Increase in AAL by 2050s	40%	70%
North America and Pacific Rim tropical cyclones	Investment portfolios	% Increase in AAL by 2050s	43%	80%
European winter windstorms	Investment portfolios	% Increase in AAL by 2050s	6.3%	3.6%

Market intelligence provider Four Twenty Seven and real estate technology company GeoPhy have partnered to assess the exposure to the physical impacts of climate change of 73,500 properties owned by 321 listed Real Estate Investment Trusts (REITs) Four Twenty Seven and GeoPhy, 2018). Main findings include that 35% of REITs properties are exposed to climate hazards. Of these, 17% of properties are exposed to inland flood risk, 6% to sea level rise and coastal floods, and 12% exposed to hurricanes or typhoons (Four Twenty Seven and GeoPhy, 2018).

6.5.1.4 Risk of increased cost of capital (B4)

The risk of increased cost of capital is currently low, however evidence is hard to establish as some institutions adjust their capex (capital expenditure) required for adaptation or climate transition, without detailing climate risks (Colas et al., 2019). Moreover, cost of capital depends on the size of the business, with barriers higher for SMEs (NDF, 2020; UNEP-FI, 2016). Capital requirements are usually calculated on a one-year horizon and are based on credit ratings that rely on historical records of counterparties. Nonetheless, due to climate risks, future capital requirements may not be the same as current capital requirements, creating discrepancies (BIS, 2020).

Future impacts from extreme weather events are expected to increase capital costs due to impairment of fixed assets, inventory write-downs, costs of repair, retrofitting and acquisition of new sites (EBRD & GCECA, 2018). Businesses can also experience employment or asset shocks from natural disasters transmitted via banks, mainly banks with less regulatory capital (Rehbein, 2018). The CCRA3 stakeholder discussions and the LSE Climate Risk Business Survey (2020) indicate that a number of businesses are expecting a future increase in the cost of capital due to rising climate risks. Future increase in capital costs are expected to drive capital reallocation from productive investment to adaptation capital, and drive investment from high risk investments to low risk. Reallocation from “brown” (or carbon-intensive) to “green” (or low-carbon) assets is also expected to occur (BIS, 2020). Increased capital costs can threaten price stability and cause supply shocks, which can have inflationary effects (BIS, 2020). Capital costs are expected to be most significant in the case of tail risks, as capital in institutions will be insufficient to absorb climate-related losses.

There are also some opportunities for returns on capital and value creation resulting from sustainable operations, value chains and green sales and marketing (UNEP-FI, 2017). For example, Mercer (2019) found that investment in climate-resilient infrastructure can increase upfront capital costs by roughly 5%. However, resilient infrastructure can generate lower operating costs over the life of the investment and reduce repercussions of longer-term hazards.

6.5.1.6 Risk of lack of private sector finance for adaptation (B4)

A further link between finance and physical risks is the flow of capital, which can either increase risk levels (for example through risk-insensitive investments or into high-emissions sectors) or help manage and reduce risks (for example through private sector finance for adaptation and low-carbon investments). Globally, the Global Commission on Adaptation calculated necessary adaptation investments between 2020 and 2030 of \$1.8 trillion, equivalent to less than 1 percent of projected total gross fixed capital formation in the period (McKinsey, 2020). While a significant chunk is projected to come through public investments, this sheer scale shows that private sector capital is essential in financing the transition to a climate resilient future, similar to what’s needed in the transition to a low carbon economy. There is evidence that a lack of adaptation and resilience metrics is a key constraint for channelling capital into adaptation and resilience investment opportunities. There are a number of initiatives in place to address this challenge, such as the Carbon Bonds Initiative “Principles for Resilience Investment” and a Climate-KIC project “Real Estate Climate Asset Mapping”, which is developing models for investors in real estate on transition and physical risk. The concept of the triple resilience dividend (Tanner et.al .2015; Surminski and Tanner 2016; Roezer et.al. 2021), i.e. the net co-benefits from investing in increased resilience, is being used to guide investment decisions towards more resilient structures. The payback of such investments is

estimated to be high, averaging a 4:1 return (CCRI, 2019), but there is still significant underinvestment in adaptation and resilience (UNDRR 2019).

While underinvestment poses a current risk, there are also signs that adaptation and resilience are being recognized as strategic objectives under the banner of ‘green finance’ as the UK Government acknowledges the need for more government support ‘to unlock new revenue streams in areas such as natural capital, carbon finance and resilience’ (BEIS, 2019). The Green Finance Strategy, published by Government in 2019, identifies resilience and adaptation as objectives “to align private sector financial flows with clean, environmentally sustainable and resilient growth, supported by Government action” (BEIS, 2019). Despite this recognition, the government does not provide further details on providing funds or financial mechanisms for these goals. More broadly, the CCC’s adaptation progress report (CCC, 2019a) notes that there is no overarching resilience investment plan and the available data does not demonstrate the extent to which businesses are realising the opportunities from climate change. Inclusion and clarification of the role of adaptation and resilience investments as part of efforts to agree on a sustainable finance taxonomy (European Union, 2019) is also important in order to enable private sector finance to support resilience.

Identifying synergies between adaptation investment and mitigation investment can provide opportunities for a two-pronged approach undertaken by the private sector (Mckinsey, 2020). There is evidence that physical risks and resilience are starting to be considered within a wider green finance landscape where the UK finance sector has clear opportunities (UK Government, 2018). The Department for Business, Energy and Industrial Strategy (BEIS) and Her Majesty’s Treasury (HMT) convened the Green Finance Taskforce, bringing together leading experts from the financial sector, academia and civil society to provide recommendations to support the delivery of our strategic objectives in green finance. This now also considers climate resilience and physical risks: “Green finance is about both clean growth and resilience; in addition to maximising the opportunity presented by the global transition to a low-carbon economy, the UK must also be resilient to the physical threats of climate change” (Green Finance Taskforce).

In CCRA2, green bonds were mentioned as a future opportunity to be realised by governments. The UK has nearly 80 green bonds already listed on the London Stock Exchange, raising more than US\$24bn. Green bonds have focused on mitigation to date (Climate Bonds Initiative, 2020), and there is no information on the level of resilience bonds. However, the first major resilience bond (\$700 M) was recently launched by EBRD¹⁰. This is a clear opportunity for the UK to use multi-lateral expertise, especially harnessing “catastrophe risk modelling firms, specialist credit ratings and accounting teams and financial regulators and research teams” (Green Finance Initiative, 2018).

¹⁰ Note that there are different types of resilience bonds. This can be a standard bond, i.e. a debt instrument to raise finance for investing in resilience (as in the EBRD resilience bond). However, there are also resilience bonds which are a variant of catastrophe bonds, designed to help manage the financial risk from catastrophes, while simultaneously promoting investment in infrastructure that mitigates physical risk (Vaijhalal and Rhodes, 2018).

In addition, the CCC's progress report (CCC, 2019a) highlights the opportunities to lending and advisory services and green 'securitisation', which will help provide finance from institutional investors, and opportunities for banks as underwriters or issuers of green bonds. This also extends to natural capital – UK is a leader in knowledge and services for natural capital as highlighted in 25 Year Environment Plan, which will build on the Green Finance Taskforce to further explore opportunities for the financial sector to fulfil opportunities in natural capital and environmental protection. Recent developments that indicate UK firms and regulators are capitalizing on opportunities include Flood RE, the Centre for Disaster Protection (funded by DFID and WB), data hubs such as OASIS, and the funding for a new centre on Climate and Environmental Risk Analytics for Resilient Finance by the Natural Environment Research Council in 2021.

Banking and green finance have the potential to direct more finance towards adaptation and develop new adaptation products and services. One example of this is private sector engagement in the UK with flood protection schemes and partnership funding of resilience measures (Surminski, Mehryar and Golnaraghi, 2020). Further opportunities for the financial sector arising from adaptation is explored further below for opportunity B7. And Section 7.10 of Chapter 7 (Challinor and Benton, 2021) explores further opportunities internationally for investment into adaptation and mitigation for UK based firms, and the international leadership position the UK has developed.

6.5.1.3 Lock-in and thresholds (B4)

6.5.1.3.1 Are there lock-in risks?

The main risks of lock-in are associated with long-lived investments that have a degree of irreversibility. This can include financial investments, thus there is a risk of lock-in to those that provide the capital for these investments, i.e. the financial markets, and in particular the risk of stranded assets. While these have been explored more in the mitigation domain (Caldecott, 2021) there are some increasing areas of potential risk for climate risks. These issues may be made more acute by other factors (e.g. insurance affordability) or for specific investment classes (e.g. property portfolios). These issues can include lock-in risks that occur from investments in the UK, but more difficult to capture, lock-in risks associated with investments overseas, especially in countries where climate risk profiles are much higher.

There are significant lock-ins where current action or inaction means that magnitude of future risk will be higher. Risk creation through risk-insensitive behaviour is a key issue: Examination of insurance data shows that most financial losses from natural disasters has come from greater exposure rather than increases in the climate hazards themselves which highlights that there is a significant amount of risk creation through non-risk sensitive investment (Mckinsey, 2020). In the face of projected climate change impacts in the future this current trend can be expected to increase the magnitude of risks significantly. Another lock-in can arise from underestimating risks: While the use of climate risk assessments for disclosure and regulatory purposes is increasing, there are still significant limitations when interpreting or comparing results from different methodologies (Mercer, 2019). The magnitude of physical damage results is likely underestimated, and therefore it is important to understand model assumptions, data limitations and treatments of timeframes, asset classes and other risk factors when interpreting the model output. Whilst scenario analysis can be

conducted to predict physical impacts of climate change, psycho-social dynamics cannot be predicted. Moreover, the lock-in to certain policies and technologies remains uncertain. Therefore, understanding the true extent of financial market response to climate risks remains complex (CISL, 2015). Communication in terms of climate scenarios brings key limitations (Mercer, 2019), and firms are locked-in to existing accounting standards which fail to capture the extent of non-financial risks such as climate change, which may lead to underestimation of risks (Deloitte, 2017, GRI 2020). With these interconnected financial risks, businesses can experience employment or asset shocks from natural disasters transmitted via banks, seen mainly via banks which are disaster-exposed and with less regulatory capital (Rehbein, 2018).

6.5.1.3.2 Are there potential thresholds? (B4)

As per CISL (2015), “climate change policy, technological change, asset stranding, weather events and longer- term physical impacts”, can all cause threshold effects for which investors are not prepared. The insurance industry has indicated that 4°C warming presents a threshold, beyond which insurability would be severely constrained (Tesselaar *et al.* 2020). Examples of biophysical thresholds include limits to insurability as the frequency and scale of extreme weather events becomes common (ABI, 2019). In the real estate market, lenders may bear some of the risk if the homeowners default. This is observed in Florida, USA, where asset repricing and losses from flooding could devalue exposed homes by \$30 billion to \$80 billion, or about 15 to 35 percent, by 2050, all else being equal. Therefore, “current levels of insurance premiums and levels of capitalization among insurers may well prove insufficient over time for the rising levels of risk” (Mckinsey 2020). If threshold effects are breached, Mckinsey (2020) note there can be large knock-on impacts on local economies tied into financial systems. This is particularly true if people, assets or industries affected are central to the economy. Current climate scenario analysis does not necessarily assess low likelihood, high impact extremes scenarios and therefore is likely to hide potential exposures and vulnerabilities. The proposed Bank of England climate stress tests offer an opportunity to address this and could include higher impact and lower-probability physical and transition risks. This would include thresholds and non-linearities and capturing climate, social and policy changes lying outside the central estimates of the probability distributions (Grantham Research Institute, 2020). Threshold effects will persist unless longer-term investment horizons are considered. As per a response to stakeholder discussions, even conducting a stress test to bond prices that is climate-related is projected to yield inconsequential results compared to other short-term risks that most businesses face.

Another aspect raised in discussions with the insurance sector during our CCRA3 stakeholder engagement activities was the heavy reliance on general insurance as an adaptation mechanism, and the need to include life insurance in risk assessments. This is especially true for climate scenarios with extreme weather, such as extreme heat (Risk B5) or severe flooding and storms (Risk B1 and Risk B2) which could increase mortality and morbidity. There is also a need for greater focus on low likelihood, high impact risks of climate change. Whilst there is some analysis (Mandel *et al.* 2020) addressing climate impact assessment on the risk of catastrophic outcomes, this requires further attention.

6.5.1.4 Cross-cutting risks and inter-dependencies (B4)

CCRA2 called for more research into interacting risks. These are also important for the impact on the financial sector, given the close interplay with the real economy and the danger of systemic risks through overreliance on insurance and under-estimating physical climate risks. However, these are still not well understood and lack recognition in current assessments. This includes lack of multi-hazard assessments, no quantification of indirect risks and impacts, and limited analysis of interplay between transition, physical and liability risk. This is a key challenge, as these interdependencies can potentially have significant influence on the magnitude of risk. The occurrence of multiple risk factors in a particular geography, like high reliance on a particular sector and exposure to multiple hazards, will make the ability to finance adaptation investments non-linear (Mckinsey, 2020). Climate change is a meta-risk, as opposed to a risk silo, and must always be viewed multilaterally. The amplification of climate-related shocks in the financial system is also conditional on the reaction of actors in play. For instance, the propagation mechanism depends on sequential reassessment by financial institutions of counterparty associated risks (Mandel et al, 2020).

6.5.1.5 Net-Zero implications (B4)

Delivering Net Zero will require significant investments, including in infrastructure and building retrofit (see also Chapter 4: Jaroszweski, Wood and Chapman; and Chapter 5: Kovats and Brisley, 2021). Without attention to future climate risks, this could create broader vulnerabilities which could increase this risk. Instead, investment in net zero and climate resilience should go hand in hand and mutually reinforce the ambitions of low-carbon and resilience.

6.5.1.6 Magnitude scores (B4)

The magnitude scoring for Risk B4 (Table 6.16) is based on the evidence presented above and our expert judgement. While insurance absorbs a large amount of the current risks this is still scored at medium given the overall economic scale of damages (£ tens of millions for the UK). The future magnitude is expected to increase across the UK compared to current risk, with medium magnitude for the pathway to 2°C global warming by 2100 and high for 4°C global warming at the end of the century (£ hundreds of millions economic damage and foregone opportunities for the UK). Confidence is medium for the 2050s for the 2°C warming pathway, low for that time on the pathway to 4°C global warming, and also low for the 2080s on both pathway, reflecting that there is still more focus and subsequent evidence for near-term impacts on a pathway to 2°C global warming. The magnitude of risks can substantially increase given the lock-ins, threshold effects and interaction of risks. Moreover, future risks are expected to increase as more businesses face financial impacts such as substantial losses or exit from the market due to high insurance claims. This is also reflected in the finance community's own perception of risk, as seen in the World Economic Forum Global Risk Report (2019). It is expected that the increasing use of climate scenario analysis and climate stress testing by financial sector companies will provide further insights into the magnitude scoring.

Table 6.16 Magnitude scores for risks to finance, investment and insurance including access to capital for business.					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Medium (Medium confidence)	Medium (Medium confidence)	High (Low confidence)	Medium (Low confidence)	High (Low confidence)
Northern Ireland	Medium (Medium confidence)	Medium (Medium confidence)	High (Low confidence)	Medium (Low confidence)	High (Low confidence)
Scotland	Medium (Medium confidence)	Medium (Medium confidence)	High (Low confidence)	Medium (Low confidence)	High (Low confidence)
Wales	Medium (Medium confidence)	Medium (Medium confidence)	High (Low confidence)	Medium (Low confidence)	High (Low confidence)

6.5.2 Extent to which the current adaptation will manage the risk or opportunity (B4)

6.5.2.1 Government and regulatory action (B4)

6.5.2.1.1 UK-wide

The overall aim of government intervention is to protect financial stability and strengthen the resilience and competitiveness of the UK financial sector. Over the last two to three years there has been a significant increase in regulatory activity to encourage physical risk analysis and disclosure across the financial sector– framed in a voluntary and exploratory context and focused on governance related aspects– which is encouraging firms to internalize climate risks, including physical risks. For example, banks and insurers in the United Kingdom are now required to allocate responsibility for identifying and managing climate-related risks to senior management functions (PRA, 2019). Moreover, Power et al (2020) note that Bank of England’s Prudential Regulation Authority’s statement (PRA, 2019b) suggests that firms should expect that disclosure will be mandated in the near future. This is potentially critical as, contrary to mitigation, companies are often reluctant to share information on adaptation: Not only can adaptation measures and their benefits be more difficult to communicate, the information could be a source of competitive advantage or disadvantage (WBCSD, 2019; Agrawala et al., 2011). From a regulatory angle, UK regulators are also reporting under the Adaptation Reporting Power on their activities taken to

strengthen preparedness to climate change. This triggered the early assessments of climate risks conducted by the insurance regulator PRA (Bank of England 2015). The Government's UK Green Finance Strategy published in 2019 mentions physical risks and resilience, and highlights opportunities for insurance domestically and abroad, particularly given the level of non-or underinsurance of assets.

The Government has also pledged to promote the greening of the financial system internationally. This included taking a leadership role on the adaptation and resilience strand at the United Nations (UN) Climate Action Summit which built on earlier work of the Green Finance Taskforce. The Government's Green Finance Strategy could become an opportunity to direct more finance towards adaptation, as recommended in the CCC Progress Report (2019a).

In addition, the Government has committed funds to address information gaps (highlighted in the Green Finance Taskforce report) (2018) that set out the need for a climate analytics centre. As stipulated, the research council UKRI-NERC and Innovate UK will allocate £10m over the period 2020/21 –2024/25 to develop a new institutional framework for scientifically-robust, open-access climate and environmental risk (CER) information to support the financial services sector to materialise these risks on the balance sheet. Overall, the ambition of the programme is to support innovation and private sector investment in the development of new CER information services for the financial services sector. This will inform disclosure and decision-making to enable more effective, efficient, and sustainable allocation of investments, reduce climate and environmental change-related losses, and stimulate economic growth in the CER services sector and related green finance products.

Other governance-supported initiatives include the Coalition for Climate Resilient Investment (CCRI), created in 2019 by the UK Government alongside private actors to support:

- National decision-making – by facilitating an understanding of the economic and social value at risk associated to physical climate risks;
- Project valuation and investment appraisal – by providing investors with greater predictability of longer-term cash flows;
- Financial innovation – by identifying innovative taxonomies for financial instruments capable of guiding a more efficient allocation of capita.

In particular CCRI aims to address inconsistent approaches to the assessment of risk in time horizons relevant to investment decision-making which constitute a case of imperfect information, and market failure. It capitalises on the momentum of TCFD to provide solutions in investment decision making and has numerous UK-based businesses and institutions onboard like Willis Towers Watson, Aberdeen Standard Investments, Schroders, HSBC, Arup, Mott Macdonald and The Prince's Accounting for Sustainability Project.

Other regulatory changes that have targeted the UK financial sector have had impacts in terms of disclosure, the level of analysis and internal governance processes, as well as collaboration between companies and regulators. One example of collaboration is the Climate Financial Risk Forum, where financial services companies and the regulator come together to explore key issues related to

climate risk. The forum is organized through four technical working groups on disclosure, scenario analysis, risk management, and innovation (FCA, 2020).

Section 7.10 of Chapter 7 (Challinor and Benton, 2021) explores further the UK's involvement in climate finance on the international scale.

Business and financial regulation are reserved matters, however some specific actions at the devolved level are also highlighted below:

6.5.2.1.2 England

The assessment above for the UK also covers England as most are being led by the Department for Business, Energy and Industrial Strategy, and there are no separate 'England-only' initiatives. The second National Adaptation Programme (2018) notes the very wide-ranging goal from Defra's 25 Year Environment Plan to "ensure that all policies, programmes and investment decisions take into account the possible extent of climate change this century" and discusses the role of green finance as set out above. The specific actions listed in the appendix to NAP2 relevant to this risk include taking forward the Government's Greening commitments, working with the British Standards Institute on resilience standards (now published) and the recommendations (at the time) of the Green Finance Taskforce.

6.5.2.1.3 Northern Ireland

The second Northern Ireland Climate Change Adaptation Programme (DAERA, 2019) highlights that businesses in Northern Ireland (99.9% of which are SMEs) are being impacted by severe weather, and lists actions related to helping businesses adapt to climate impacts. Specific actions in the programme are targeted at particular sectors (water and energy) as well as provision of guidance. There are no actions specifically listed for the finance sector.

Technical consultancy is available to businesses from Invest Northern Ireland with an annual energy and resource spend in excess of £30k. This support consists of fully funded technical audits, feasibility studies and advice, complete with a report and recommendations to help participating businesses identify cost savings. Specialist areas of support include aspects that touch on physical risks from climate change; energy management and efficiency; resource efficiency including water and waste management; transport and logistics; sustainable business collaborations; clean technologies; investigation of new technologies; standards and accreditations; renewable technology systems and packaging solutions. This bespoke support is brokered by Invest Northern Ireland technical advisors and delivered by a framework of procured experts across the range of specialisms (Invest Northern Ireland, 2020).

6.5.2.1.4 Scotland

The second Scottish Climate Change Adaptation Programme (SCCAP2) also highlights the finance sector's experience in considering physical risks and suggests learning for other sectors such as forestry. It includes a dedicated section on risks related to access to capital and highlights the SME Loan Fund as relevant to supporting businesses to consider their physical risks to finance. In Scotland

in 2017, the First Minister announced plans to establish a Scottish National Investment Bank, which officially opened in 2020. The aim is to support innovative, high growth firms that have a positive impact in Scotland (Scottish Government, 2020b).

6.5.2.15 Wales

Some recent developments in Wales have triggered a greater focus on resilience as part of the sustainable finance agenda: The Wales Pension Partnership (WPP) that pools assets from eight local government pension schemes announced in July 2020 that climate change represents a material financial risk to its stakeholders and its constituent authorities (the eight local Government pension schemes). The WPP expects its investment manager to ensure that all underlying active managers integrate the consideration of climate-related risks including physical risks into their investment process and to regularly challenge underlying managers to evidence their approach. (WPP, 2020). In addition, the Development Bank for Wales was established in 2017 to support Welsh businesses with loans, equity investment, and seed finance. This replaced many of the functions of Finance Wales £103 million invested directly into Welsh businesses; £76 million additional investment from banks and other private-sector funders; £179 million growth capital injected into the Welsh economy; 457 investments made 3,964 jobs created or safeguarded in Wales (Figures as of 31st March 2020). Climate adaptation is one of the key priorities for the development bank, although generally, their environmental policy seems to be broad and focused on reducing impact. Nevertheless, the approach may provide an opportunity to ensure investment in businesses are factoring in climate risk to their plans in the future. However, the official report 'Prosperity for all: A Climate Conscious Wales (Welsh Government, 2019b) also highlights the risks for businesses from reduced access to capital for their resilience and low-carbon activities, underpinning the need for Government support.

6.5.2.2 Effects of non-government adaptation (B4)

There has been a significant shift in climate analysis and disclosure across the financial sector and other businesses. Worldwide banks and financial institutes have already started performing scenario analysis, and 25% of surveyed UK banks indicate that they are in the process of introducing scenario analysis (Colas et al., 2018). Moreover, the Bank of England identified that the majority of banks are beginning to treat the risks from climate change like other financial risks, but many have yet to begin to measure the risks from climate change comprehensively, including in a range of future scenarios spanning global warming levels of 2°C and 4°C (CCC, 2019). However, whether or not this improved understanding is being translated into adaptation action remains unclear.

There is limited evidence of how companies are using physical risk information and whether this is impacting investment decisions. There is also limited evidence of physical risk considerations leading to capital reallocation in terms of (1) reduced risks through divestments or re-pricing, or (2) through investment into adaptation and resilience. These are supported by findings of Mandel et al (2020). Conversely, with regards to carbon emissions, there is strong evidence that investment companies in particular, including pension funds and banking, are beginning to take climate risks into account and realigning their portfolios. Over 340 investors with nearly \$34 trillion in assets are now asking

companies to report under TCFD (Power et al., 2020). “A survey of 90% of the UK banking sector representing over £11 trillion in assets found that 70% of banks recognise that climate change poses financial risks” (PRA 2018). Credit Ratings Agencies are also starting to incorporate climate risk into their assessments of creditworthiness. (CCC, 2019a).

The increase in disclosure of physical risks through TCFD as mentioned above can be seen as a first step towards adaptation action. Significant progress has been made towards better assessment and disclosure of the physical risks from climate change in the finance sector, mostly driven by FTSE100 companies. However, the initial focus was on a 2°C global temperature rise and not a range up to the 4°C relevant for adaptation risks. The adoption of scenario analysis is expected to influence investment decisions (UNEP-FI, 2019)– exemplified through high market sentiment, with investors and markets signalling a diversion of financial flows as a result of climate change. While expectations may have increased, evidence for the integration of scenario analysis into decision making processes and financial flows is limited (Climate Policy Initiative, 2019). Additionally, the incorporation of physical risk and resilience into investment strategies is growing. For example, the UK FRC’s UK Stewardship Code 2020 integrated climate risks in investment approaches of signatories for the first time (FRC, 2019b). However, this continues to be mostly considered in the context of emission reduction and wider green credentials, with resilience and adaptation only starting to be recognized as material. While clear investment shifts are visible in the context of transition risks like fossil-fuel divestment (Mercer, 2019), physical risks tend not to be considered as material for most investments because of the perception that risk will continue to be insured or because physical risks are only expected to be materialized in the longer-term. It is uncertain whether the true impact of the disclosed actions will occur and can be measured (Deloitte 2020).

In some sectors this long-term view appears to be shifting. Stress testing is being enhanced, but key limitations remain. 4°C degree global warming scenarios are being considered, but it is a work in progress and there is limited evidence that it is leading to adjustments and/or less risk creation. The CCRA2 Evidence Report noted anecdotal evidence that mortgage lenders had started to use insurance industry data and techniques to stress test their portfolios for exposure to extreme weather events (Climatewise, 2015), but this appeared to be more of an exception than a rule. Currently, there is discussion of climate risk at the asset and portfolio level within the real estate sector (ULI, 2019). Whilst there is some evidence of scenario analysis incorporation within commercial real estate (Blackrock, 2019), broader adoption in the real estate market is limited with little or no shift in capital allocation and investment have been noted in terms of physical risks (Carbon Risk Real Estate Monitor, 2019). Moreover, whilst the financial sector is seeing a significant increase in risk analytics and disclosure from a small number of sectoral leaders, think tanks and SMEs that offer climate services, a wide range of methodologies exists, raising questions about accuracy, transparency, and issues from misinterpreting model outputs. This is seen in climate scenarios for stress testing: Assessing a firm’s resilience under different future scenarios is complicated by deep uncertainties around climate change impacts, socioeconomic pathways and technological progress, as well as by the fundamental limitations of currently available modelling techniques (see e.g. Chenet et al., 2019; Stern 2016). It is important that the Bank of England recognises those uncertainties and includes sensitivity analyses of the underlying assumptions and parameters in the biennial exploratory scenario (BES) exercise (GRI, 2020). It is valuable to view this not just as a tool, but a larger organisational learning exercise encompassing multiple sectors.

Although the process is still driven by the largest groups and companies and it is now spreading across other sectors, uptake remains very low across smaller firms. For those firms engaged in climate risk assessments and disclosure this tends to be seen not strategically, but as an immediate obligation to be a responsible company or it is derived in response to regulatory or public pressure. As per Bank of England, only 10% of UK banks said that their approach is strategic, compared to 30% 'responsible' in terms of CSR, and 60% as responsive. Most companies that are implementing the TCFD recommendations expect governance measures to be implemented within less than a year in their businesses. A majority of companies foresee strategy and risk management metrics and targets to be implemented in the next 2-3 years. Complying with the requirements of the Task Force on Climate-related Financial Disclosures (TCFD) creates an incentive for businesses to plan for how they may be impacted by climate change, though this is less likely to influence SMEs, the majority of businesses in England (CCC, 2019).

In our view, there is a disconnect between the current low risk consideration and the high risk of missing adaptation opportunities due to limited investment into resilience and the lack of financial instruments that allow this resilience investment.

Several studies have highlighted the need for insurance in the UK to support physical risk reduction (de Ruiter et. al., 2017; EC 2017; Hudson et.al., 2019; Surminski, 2018). While implementation is still limited, there are some encouraging signs. For example, Flood Re (2020) announced its support of policy holders in their resilience efforts. The Defra Property Flood Resilience FR Roundtable, a cross-industry and cross-sector alliance that includes insurers, has a 5-year plan to promote Property Flood Resilience (PFR) measures and property-level protection measures (PLPMs). These are understood to have a high cost-benefit ratio, potentially reducing property damage by around 75%, reducing financial impacts insurance claims, and limiting disruption to business, schools, and communities (Defra, 2019). These shifts should be closely monitored in the next few years to understand the impact of the pivot towards resilience in the government-supported insurance sector.

With regards to adaptation finance via financial markets there appears to be some innovation in the context of funds for infrastructure and utilities. Some pilot mechanisms like green bonds used by water companies and resilience bonds are being tested. For example in 2017, Anglian Water became the first European utility company to issue a sterling green bond, followed by a second in 2018. The first bond of £250 million will mature in August 2025 and offers a return to investors of 1.625%. The money raised is intended to finance a range of activities, including water abstraction projects, drought and flood resilience schemes, and water recycling projects. So far, Anglian Water has spent £276 million on schemes funded by the green bond, including a wetland restoration project in Norfolk. (Anglian Water, 2020).

6.5.2.3 Shortfall in adaptation (B4)

The advances in regulatory action summarised above have led to more disclosure, better governance, and analysis, but these shifts have been limited to large companies and it is unclear how this impacts decision-making and current firm behaviour. Overall, the focus of businesses on adaptation is low compared to mitigation efforts. As per European CFO Survey 2019, only a minority of businesses (249) are reporting adaptation action (Deloitte, 2019). This includes renewing facilities to make them more resistant to extreme weather (14%), purchasing insurance (11%), relocating to

areas less prone to extreme events (2%), reporting risk of climate change (27%), and management and monitoring of climate change in corporate governance processes (25%).

There also appear variation across different sectors regarding adaptation, with some sectors having made significant advances since CCRA2, and others less. Current action is being taken by the government, as evidenced by the Bank of England, PRA, Climate Financial Risk Forum (CFRF), TCFD and UNEP-FI. Scenario analysis is also being adopted by some investors. Additionally, sector specific adaptation is being seen in insurance, banking and investment, with efforts are underway by investors in response to initiatives like the TCFD or UK Stewardship Code. Some companies acknowledge the need for more location-specific information and have announced work to develop a process to produce detailed quantification of physical climate impacts and adaptation measures that can be applied across asset portfolios (Mercer, 2019).

Despite the progress outlined above, there is some evidence indicating an adaptation shortfall. The assessment here highlights several gaps where there is a lack of evidence of action; (1) current lack of quantification of risks, (2) lack in standardisation of risks, and (3) where limited consideration of physical risks when setting investment criteria (for example ‘sustainable real-estate investment’ focuses on climate mitigation issues but does not set out criteria for resilience or adaptation) (Blackrock, 2019). Climate risks are not adequately represented in the market (Black Rock, 2019). There are numerous assumptions being made about climate trends, adaptation and mitigation. Next, risk management can be attributed to investors who are adopting scenario analysis prior to making investments as outlined in UNEP-FI (2019). However, in our view a more active role of investors is required, using these results to be ‘future market makers as opposed to takers’. Investors also have an increasing legal and regulatory obligation to do this (Mercer, 2019). Finally, accounting for adaptation needs to be made more holistic. While exposure and sensitivity of counterparties are commonly assessed, few methodologies include measures of their adaptive capacity to mitigate physical climate risk. Across the four impact channels, methodologies consistently cover a counterparty’s exposure and sensitivity, but there are few methodologies that include its adaptive capacity in their impact assessment. Existing analysis tends to be highly regionally focused (as in ClimateWise with Vivid Economics) or highly aggregated (as in Moody’s Investors Service and Carbone 4). This is due to a lack of available data on the resilience of individual physical assets at the global scale. Increased disclosure as encouraged by the TCFD recommendations could play a vital role in making this data available and corresponding types of assessments possible in the future (UNEPFI 2019a). In addition, an analysis of climate risk screening for companies by the INVEST project finds most of these are based on ‘black box’ tools, that current treatment of financial impacts is limited and rarely specific, and that they have very little robust analysis (RClimINVEST, 2019; de Bruin et al., 2017). Finally, there are concerns around diminishing finance and investment in adaptation post-EU exit due to a governance gap, drawdown of EU financial support, and inability of UK firms and to access EU research funding streams such as Horizon Europe (Acclimatise, 2020). In terms of financing adaptation and resilience it is unclear how EU exit will impact existing mechanisms such as the Green Climate Fund and the subsequent impact on the private sector as a result.

Overall, there is medium confidence of the adaptation shortfall. This is because some existing measures taken by firms may not be specifically classified under adaptation. There is a possibility that many existing corporate actions to address this risk, such as standard risk management planning, may not be explicitly classified under adaptation efforts (Frey et al, 2015).

6.5.2.4 What are the barriers preventing adaptation to the risk? (B4)

Perhaps the largest barrier to current action on adaptation continues to be the perception of adaptation as a long-term ambition, where the material impacts of physical risk expected are long-term. Many businesses – especially SMEs - do not understand the risks and more importantly do not know what risks they need to be assessing. To illustrate, only 52% of the surveyed businesses reported that climate change risk is discussed at the Board-level in their organisation, as per the CCRA3 Business Survey. Subsequently, climate risks are not priced in and markets remain “blissfully ignorant” (Black Rock 2019) regarding assumptions about climate trends/adaptation/mitigation. As per the CCRA2 Evidence Report, there is evidence that some companies experience difficulties in accessing finance for implementing their own adaptation and resilience measures. The water, energy, airports, rail and telecommunications sectors can be susceptible to regulatory restrictions that prevent investments in resilience to varying degrees. This corroborates with recent CDP 2018 Business Survey results (CDP, 2018). Beyond the lack of funds, businesses face a number of challenges in integrating adaptation to operations and future planning:

- The majority of financial institutions indicate that climate risks are not captured in the credit-rating process (Marsh & McLennan Companies. 2018) and uptake of tools is low. Moreover, businesses may not have the right data or infrastructure in place to monitor and mitigate climate risks using scenario analysis. Businesses may also not have the right level of skills, training or in-house capabilities to interpret the climate scenarios generated.
- There are many challenges to integrating long-term forecasts and scenario analysis into business planning which leads to discrepancy in the timescales adopted in finance and climate-modelling (Frey et al, 2015). For instance, risks may only be considered at critical points such as making investment decisions.
- There is a lack of incentives for adaptation action in companies’ performance management systems, for example, very few have resilience-based teams and management indicators (Frey et al, 2015).
- There are risks of moral hazard. Reduced access to finance is not assumed to be a business threat given perceived government intervention to fill financing gaps (Frey et al, 2015). A similar moral hazard exists in the assumption of insurance availability.
- Businesses are not rewarded for early action, for instance incorporation of climate risk exposure is not reflected in many insurance rates, discouraging firms from further undertaking this (Frey et al, 2015).
- There remains lack of engagement from infrastructural investors despite top-down policies to support sustainable infrastructure (Marsh & McLennan Companies 2018).
- The risk analysis currently only captures direct impacts, and not the indirect ones. For instance, there are reasons to believe that physical risk will impact economic growth and GDP (and transition risk in some geographies), which in return would cause indirect impacts on real estate investments. Moreover, the indirect impacts related to supply chain are also not included in the model as of today (UNEP-FI 2019).
- Different sectors may have varying capabilities given time-horizons of investments. For instance, according to a survey cited in the Our Future in the Land Report (Farming and Countryside Commission, 2020), most farmers are planning 2-5 years ahead, with >50% flexibility in planning

in the five-year time horizon. This time horizon may act as a barrier in accessing innovative finance required in the sector (RSA 2019). Whilst larger players such as Unilever and Nestle (Landworkers' Alliance, 2019) are using scenario analysis to assess longer-term climate risks, small agricultural business usually don't.

Stakeholder discussions during the workshops carried out to support CCRA3 show that companies find it easier to manage carbon emissions than identifying and measuring adaptation action. Recognizing adaptation as a continuous process that needs to be adjusted and developed rather than a one-off exercise requires a different strategy and approach within a company. Adaptation needs and risk profiles are different for each business so establishing what adaptation metrics and information can help with business decisions is very company- and sector specific. While there are a growing number of sources of information to measure risk and adaptation, there is no clear metric to assess the level of adaptation at company or location level, as one metric is not a realistic goal for adaptation. This has become a key issue, also in the application of scenarios and risk assessments for financial decisions. There are a variety of standards, tools, indices, and other assessment mechanisms that aim to address this issue, but no singular assessment is utilized, and the information is often qualitative, self-reported and not consistently validated. In the UK, several companies are currently exploring this challenge under the UN's ARISE initiative and the Bank of England has also asked for further clarity on this to support climate stress testing and climate scenario analysis. CCC (2019a) also expands on these barriers:

- While many large businesses have expressed support for the TCFD, this has not yet led to better assessment and planning for climate change risks and the current guidance does not require the consideration of higher climate change scenarios.
- Many businesses still do not have basic continuity plans for extreme weather, and there are no indicators available that help to show whether vulnerability and exposure is increasing or decreasing.
- Complying with the TCFD recommendations will lead to more useful information being reported and create incentives for businesses to assess how they may be impacted. However, the current guidance does not encourage consideration of higher climate change scenarios (up to 4°C global warming) and the voluntary approach is unlikely to be strong enough.
- The Government's Industrial Strategy makes no mention of climate change as a risk to meeting its goals, nor as an opportunity for UK skills, services, and technologies to support adaptation efforts. Some action by businesses is underway to address the risks and take advantage of opportunities from climate change, but significant gaps remain in considering the risks to trade, international flows of finance and the need for new skills, for example in the housing and infrastructure sectors.
- While many large UK organisations have expressed support for the TCFD, it is not yet clear that this is necessarily leading to alignment with the recommendations and better assessment and planning for climate risks.
- The adoption of climate modelling and consideration of climate risks in investor decision-making will have significant knock-on effects, encouraging firms to reconsider their own adaptation strategies but the financial sector currently has limited the tools to incorporate level of adaptation into decision-making.

The financial sector has the incentives to remove some of these barriers without Government intervention. For example, mechanisms to partially alleviate asymmetric information issues can be addressed, and information on credit and insurance products can be made more easily accessible to businesses. Pricing (credit interest rates and premiums) could better reflect externalities to create the appropriate incentives for businesses to adapt. However, in the future the industry might respond to rising risks and liquidity issues by finding new ways to re-insure risks through alternative risk transfer markets, by raising premiums, or by withdrawing from the market. Government intervention is therefore needed to ensure the financial and insurance markets are provided with the appropriate information and regulatory framework which would ensure they can continue to provide access to capital and insurance to help people increase their adaptive capacity and resilience to climate risks. In particular, the Government role would be the development of climate models and information sharing of risk data, regulation, protecting the most vulnerable, managing moral hazard and implicit liabilities, and ensure policy coherence between different sectoral policies (Cimato and Mullan, 2010).

6.5.2.5 Adaptation scores (B4)

Table 6.17: Adaptation scores for risks to finance, investment and insurance including access to capital for business.			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)

6.5.3 Benefits of further adaptation action in the next five years (B4)

6.5.3.1 Additional planned adaptation that would address the adaptation shortfall? (B4)

There have been significant shifts in assessing, disclosing and analysing climate risks and more is expected in light of expected shifts from voluntary to mandatory action driven by regulators. However, translating this increased risk knowledge into action and drawing conclusions is equally important, and the extent to which companies will successfully do this remains unclear. While it is clear that the extent of physical risks is currently low and expected to become significant in the longer-term there are clear dangers in considering physical risks ‘as under control’: lock-ins for example in terms of real-estate investment but also lack of insurance uptake, particularly on business continuity.

Since CCRA2, changes have mainly been made in climate risk regulation and reporting as opposed to changing capital flows. Moreover, given the tightening climate policy landscape, there are significant lock-in effects if there is no substantial redirection of financial flows. Whilst banking and insurance sectors have effectively responded to current extreme weather events, the increase in magnitude and frequency of impacts in the future means the likelihood of “unhedgeable risk” is higher – straining the insurance sector. Given that financial risks are still not integrated within firm operating

models or in financial markets as a whole, there are still significant systemic risks (Mandel et al, 2020). Whilst companies have started adopting TCFD recommendations, identifying climate risks is only the first step. TCFD's most recent status update report acknowledges that there needs to be a better understanding of how disclosing climate-related financial information is changing corporate strategies on adaptation, and how investors are using the disclosed information to inform their decisions (Power et.al. 2020; TCFD, 2020). CISL (2019) recommends early action in addressing risks to accessing finance and investment is predicted to lead to higher economic growth rates and returns over the long run when compared to scenarios of inaction. Moreover, further investment is required to scale-up pre-existing resilience solutions and technologies (NDF, 2020).

The following are a number of key areas that could be addressed in the next five years:

- Requirements imposed on banks and insurers: Based on Pillar 2 of the supervision of institutions' risk management, regulators could prescribe additional capital on a case-by-case basis, for instance if a financial institution does not adequately monitor and manage climate-related risks. This would first require new expectations to be set in this regard (BIS, 2020). Further action is required by banks in order to meet Bank of England stress testing requirements. Currently there is very little data and organisational capacity to collect information in the aftermath of disasters (e.g. collection strategies after a flood) (Deloitte, 2020). Banks require data (e.g. location of collateral, exposure to carbon intensive industries etc.) in order to better respond to physical and transition risk. For instance, green vs brown exposure and funding of carbon intensive industries is not being considered (Deloitte, 2020). In scenario analysis, the banking sector needs to adopt and consider much longer timelines than it is used to at present (Deloitte, 2020).
- Broadening scope of existing regulations: The current review of climate stress testing by the Bank of England's PRA (Bank of England, 2019) provides an opportunity to broaden the scope, identify limitations and important constraints, and support companies in their internal interpretation of scenario analysis results. Whilst the stress-testing is intermittently paused due to COVID-19 (IMF, 2020), this could be a step towards encouraging more scenario-based analysis among financial institutions on a regular basis. In the future, regulators could make it mandatory for financial institutions to stress-test their portfolios against a common set of scenarios. (UNEP-FI / Vivid 2019). Mandatory disclosure is also called for by the IMF (2020). Stakeholder engagement suggested there is insurers support for this, with mandatory disclosure of methodologies and impact recommended.
- Insurability: Given rising uncertainty, McKinsey (2020) recommend risk-sharing agreements between private and public financial institutions, similar to that seen in flood insurance, in order to meet financing gaps. Given that Flood Re is only available to non-businesses, there should be increased incentives for resilience to businesses. This also directly relates to uptake of insurance. Whilst there is an increase in the uptake of climate related insurance products, products need to be more streamlined, made cost-effective and user-friendly to promote further business uptake (Marsh & McLennan Companies 2018). Insurance can be used to incentivise risk-reducing behaviour, for example by rewarding adaptation measures like hardening of physical assets (McKinsey, 2020). As highlighted in section 7.10 of Chapter 7 (Challinor and Benton, 2021), this

uptake in insurance from the UK's expertise within re-insurance companies and catastrophe risk modelling organisations is an opportunity for the UK insurance market to grow.

- **Disclosing and reporting:** Further standardisation and clarification on scenario analysis models are required so comparisons can be made. Moreover, inclusion of additional asset classes will make these models more useful for investors (Mercer, 2019). Standardisation can occur through investor collaboration facilitated by government-led initiatives (UNEP-FI, 2019). Scenario analyses currently do not cover the entire value-chain of businesses and further integration is required between transition and physical risks as well as the link between micro and macroeconomic impacts (UNEP-FI, 2019). Further developments of dashboards and monitoring mechanisms are required to capture “investors and markets channelling finance to climate solutions” and change in financial flows are a response to climate risk (CPI, 2019). Additionally, more bottom-up information, such as KPIs from businesses, need to be incorporated in scenario analyses which have predominantly been top-down. A push for disclosure of granular, asset level data is required from businesses for scenario analysis to be successful (UNEP-FI, 2019).
- **Financial and physical risk metrics:** It is important to recognise the interplay of financial metrics and physical risk metrics: for example, the credit risk of a bank from increasing physical risk can be low if it does not lend to companies in high-risk areas. Finity (2019) show it is important to distinguish between risk to individual financial companies versus wider financial implications. Unless physical risk is being reduced through more adaptation investment and action, those damages will occur and have financial implications.
- **Incorporating risk reduction and data into insurance requirements:** One proposed solution relating to the short-term valuation cycle issue is that policymakers and insurers could incorporate risk reduction and adaptation measures into insurance requirements (CISL, 2019). Other options include making sure risk data is populated across a wide range of sectors and groups, including a focus both on the current symptoms and problems and the underlying causes incorporated into day-to-day decision-making. Surminski (2017) showed that it is essential to first address the use of data and transparency around risk levels. This foundational trust and understanding is needed to reduce the risk of the private sector withdrawing altogether from the flood insurance space or consumers not being able or willing to pay high premiums (Surminski, 2017).
- **Financing adaptation:** Where funding pools exist, like bond markets, better education is required to match counterparties (Marsh & McLennan Companies 2018). Further research is required in the area of new products, such as resilience bonds, which would use premium discounts for long-term planning, such as investment in sustainable infrastructure, in the catastrophe bond market. Synergies between climate financing and risk management strategies in the banking and insurance sector must be further explored (Marsh & McLennan Companies 2018).
- **More collaboration between different parts of the financial system:** Capital providers to investors and lenders will likely want to understand how such location decisions, intermediated by insurance availability (discussed above) and adaptation action (discussed below), are taking account of the physical risks of climate change. To the extent that investors and lenders do alter

location decisions, it is projected to be much less disruptive to the real economy if this happens over a long period of time rather than as an abrupt response to one or a series of particular events (CISL, 2019). However, investors and lenders, combined with policymakers, may find it easier to take a longer-term perspective. They could work in concert with insurers to encourage the uptake of adaptation measures, for instance, by making both loans and insurance contingent on the installation of relevant adaptation measures (CISL, 2019). This is in line with UNEP-FI (2018) who encourage improved collaboration between banks, borrowers, governments and the insurance industry, and would increase the quality of forward-looking disclosures.

6.5.3.2 Indicative costs and benefits of additional adaptation (B4)

It is difficult to estimate the potential costs and benefits of adaptation. However, what is clear is that the potential risks to the financial markets from climate change are extremely large, and because of the role of UK financial services, very large for the UK. EIU (2015) estimated the value at risk, as a result of climate change, to the total global stock of manageable assets (currently \$143 trillion) as \$4.2 trillion (mean expected losses, discounted in present value terms) between now and the end of the century, and still half this even under a pathway to 2°C global warming by 2100.

6.5.3.3 Overall urgency score (B4)

Table 6.18 Urgency scores for risks to finance, investment and insurance including access to capital for business.				
	England	Northern Ireland	Scotland	Wales
Urgency Score	Sustain current action	Sustain current action	Sustain current action	Sustain current action
Confidence	Medium	Medium	Medium	Medium

Note: The 'sustain current action' score is based on understanding of the current magnitude and the emergence of regulatory and corporate activities to increase the resilience of the financial sector. However, given the medium and high future magnitude scores this urgency score needs to be watched and if necessary revised to 'more action needed' should the current activities not lead to tangible changes in exposure and vulnerability of the sector. Monitoring if and how the above barriers and gaps are addressed will be important. It is expected that businesses will be impacted by changes to cost of capital, as measures taken by banks, investors or insurers to reduce climate risk exposure are expected to come at a cost to those at risk who require capital. Similarly, there is potential for systemic risk due to lock-ins via risk-insensitive investment decisions and overreliance on insurance, which may become a less viable adaptation option in the future if climate risks start to become 'unhedgeable'.

6.5.4 Looking ahead (B4)

This section has explored a range of topics under one heading, which is understandable as the issues covered are interconnected. However, given the growing prominence and evidence base it might be

advisable to separate out the four specific risks (insurance, investments, costs of capital, finance for resilience) for UKCCRA4. Similarly it is important to conduct further research on the interplay between direct physical and indirect financial risks from climate change and also consider the interdependencies between transition, liability and physical risks. As outlined by Bowen et.al. (2020) “physical and transition risks tend to be assessed separately, given the complexity involved in modelling and quantifying each case, (...) but it is important to avoid investors focusing on ‘transition risks’ and insurers on ‘physical risks’, given that physical risks are also important for investments, while insurance decisions are also important for transition risks as well as for liability risks including litigation.” (Bowen et.al. 2020). This will also require methodological amendments to CCRA4, for example a joint investigation of physical and transition risks and how they interact. The Government’s recently announced centre for Climate and Environmental Risk Analytics (CERAF) could help facilitate this (University of Oxford 2021). Similarly there will need to be more engagement between the finance sector and its clients as well as regulators to ensure that advances in climate analytics are transparent and correctly interpreted for day-to-day decisions.

6.6 Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments (B5)

Employee productivity in this section encompasses work output, as opposed to labour productivity which refers more to workplace efficiency - output per worker, per job and per hour. A changing climate (average temperatures) has the potential to affect productivity, potentially both negatively and positively, as well as indirect impacts as a result of infrastructure disruption (Chapter 4: Jaroszweski, Wood and Chapman, 2021) and higher temperatures in working environments. There are also risks associated with changing extremes, particular high temperatures, which can have negative impacts on employees’ health and wellbeing (Chapter 5: Kovats and Brisley, 2021) and their ability to commute to work. There is some evidence that businesses are experiencing these impacts already. The risks are likely to vary widely across business sectors and geographies, with a range of factors determining risk levels, such as the type of work (e.g. construction or industrial processes), whether it takes place indoors or outdoors, and the local built environment and infrastructure (e.g. passive ventilation). The COVID-19-related shift to home-working is likely to offer insights on overall productivity drivers but does also create a new risk, particularly for those employees working from homes prone to overheating. There are no specific studies which examine the differences between England and the other Devolved Administrations.

6.6.1 Current and future level of risk (B5)

Note: it has not been possible to split the evidence by UK country for this risk.

6.6.1.1 Current risk (B5)

6.6.1.1.1 Current risk - UK wide

Heat and humidity impact employee productivity (Kjellstrom et al., 2009; Kjellstrom et al., 2014). In order to cope with heat, there is typically a reduction in work intensity or an increase in breaks. This occurs through self-pacing which results in lower employee output. These reductions in work intensity can translate through into labour productivity, which is an aggregate measure of output per employee or unit of labour. Labour productivity measures the volume of gross value added (GVA) produced per unit of labour input, with hours worked as the preferred labour input (NAO, 2020). In extreme heat, there are also risks of heat stress, heat exhaustion, heat stroke and even fatality. These effects apply to outdoor workers in particular, but also to indoor workers who are not in a temperature-controlled environment.

Extreme weather events, such as heat waves, can also impact productivity by denying workers access to their work sites, preventing them from, or impairing their ability to work remotely, or causing them to have to take leave to deal with problems at home caused by extreme weather. As described in the CCRA2 Evidence Report and outlined in the National Business Resilience Planning framework, severe weather that causes transport disruption and other infrastructure failure also leads to staff absence (Cabinet Office, 2014; Trade Union Congress, 2009). See also Chapter 4 (Jaroszweski, Wood and Chapman, 2021) for infrastructure disruptions. The LSE Climate Risk Business Survey (2020) shows that businesses are already impacted by reduction in labour productivity due to heatwaves and due to physical damages to infrastructure – with respondents in England significantly more impacted than those located in Wales, Northern Ireland or Scotland.

A limited number of studies have considered the impacts of higher temperatures on productivity in the UK, meaning there is therefore considerable uncertainty about the magnitude of impacts. There is also considerable uncertainty in the results of these studies, and the degree of the risk to the UK. Importantly the risk is not evenly spread, and varies between geographical locations, indoor and outdoor workers (Trade Union Congress, 2009) and across workers engaged in particular sectors or occupations. For example, heavy outdoor manual labour or maintenance employees (e.g. in telecommunications, IT and those working on industrial infrastructure such as oil refineries, chemical and petrochemical plants, gas processing plants) working outdoors, are likely to be at greatest risk of heat stress, dehydration, UV radiation and potentially skin cancer, though overheating indoors will also impact employee productivity from other sectors. Workers engaged in particular occupations, for example heavy outdoor manual labour, are likely to be at the greatest risk of heat stress. Recent evidence from the social care sector points to detrimental impact of heat on staff wellbeing: In a case-study of both an older and a modern care home in London (Gupta and Howard., 2020) it was reported that staff found the summertime thermal conditions more uncomfortable than the residents did.

Our UKCCRA3 stakeholder engagement revealed some anecdotal reports of labour productivity being impacted by other climate-related variables, notably rain, wind, snow and cold temperatures, which can affect productivity because of the need to withdraw work due to accident risks, for example in sectors such as construction or transport. However, evidence is limited and no assessments exists.

6.6.1.1.2 Current risk - England

No evidence is available for England.

6.6.1.1.3 Current risk - Northern Ireland

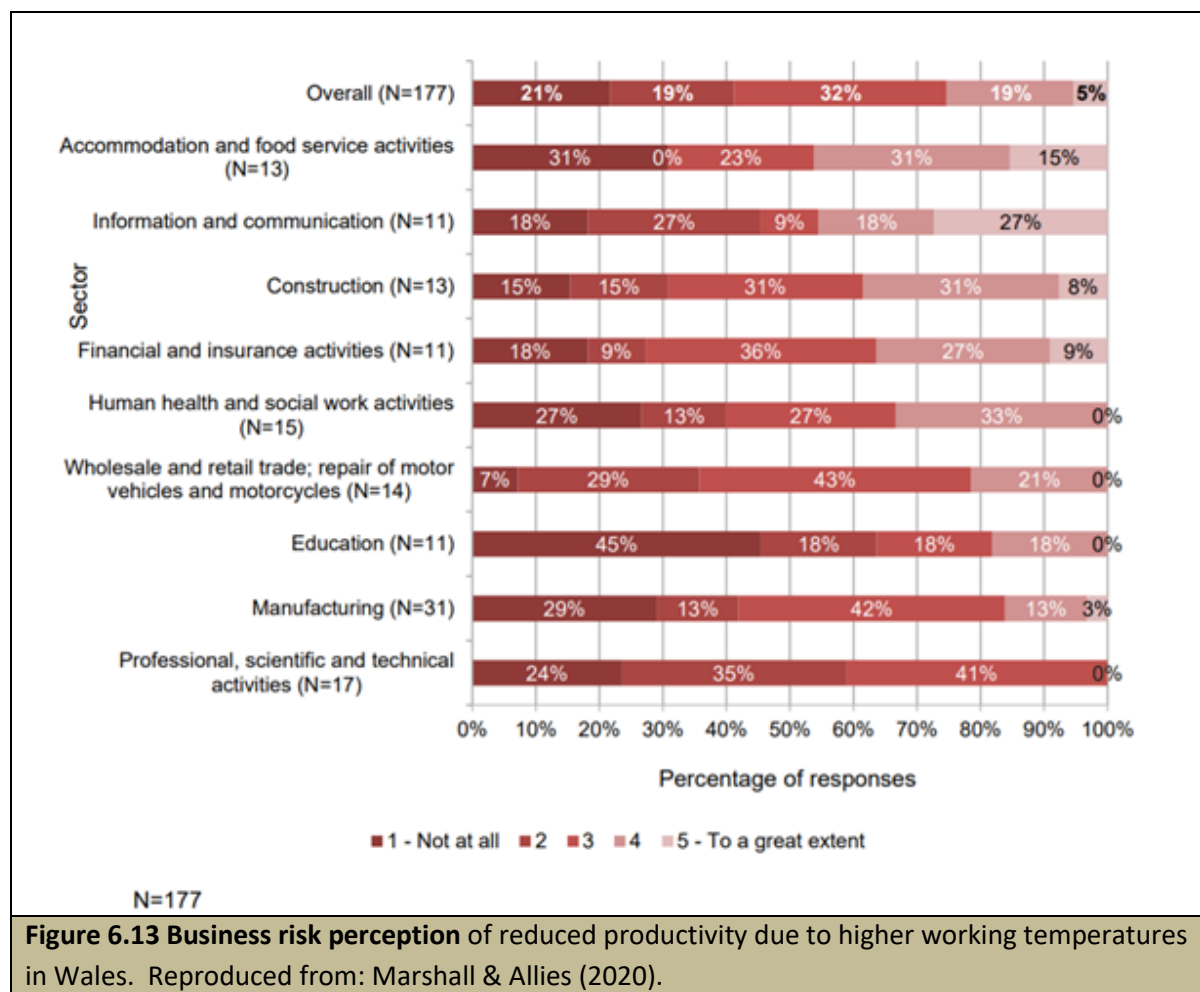
No evidence is available for Northern Ireland.

6.6.1.1.4 Current risk - Scotland

Anecdotal evidence collected during stakeholder discussions conducted as part of the CCRA3 engagement with adaptation experts in Scotland suggests that heat resilience of the workforce, particularly in agri-businesses and process related sectors is lower than of those working in commercial buildings mainly due to existing building regulations for offices in Scotland.

6.6.1.1.5 Current risk - Wales

As shown in Figure 6.13, the Welsh Government's business survey (Marshall & Allies, 2020) indicates 21% of respondents do not at all think their business is at risk of reduced productivity due to higher working temperatures. 70% of respondents fall somewhere in the middle of the scale. Only 5% of respondents believe their business is at risk to a great extent.



6.6.1.2 Future risk (B5)

A key measure of the effect of temperature on humans is known as the Wet Bulb Globe Temperature or WBGT (Lemke and Kjellstrom, 2012), which is used in international and national standards to specify workplace heat stress risks. However, no aggregate analysis is available for WBGT across the UK, and there is only limited evidence on future risks to labour productivity in the UK. Past events in the UK suggest extreme outdoor temperatures can have significant effects on production. This was reported in CCRA1 (Baglee et al. 2012) which suggested potential impacts for indoor work (in the absence of additional air conditioning uptake) that were very large. More recently a study by Lloyd et al (2016) estimated the loss of productivity (days lost) from climate change. For the UK, the values were relatively low when compared to southern regions of Europe, and especially to Asia, where these losses could be very high. These findings are supported by Gosling et al. (2018). However, it is difficult to establish a temperature threshold at which productivity starts to decline. Costa et al. (2016) found that a stabilisation trajectory of a 2°C increase by 2100 would represent a medium¹¹ risk for businesses due to the decline in employee productivity (high for England, low in the other three countries) in 2080, while an increase of 4°C by 2100 would represent a high risk across the UK (Costa et al., 2016). Costa et al (2016) also assess this

¹¹ The magnitude rating applied by Costa et al. 2016 is different from the CCRA3 magnitude rating outlined in Chapter 2 and underpinning the urgency scores in this chapter.

in terms of impact on city economies. They find that total losses to the urban economy could range between 0.4% of Gross Value Added (GVA) for London in a warm year in the far future (2081-2100), with a specific focus on impacts in the financial sector.

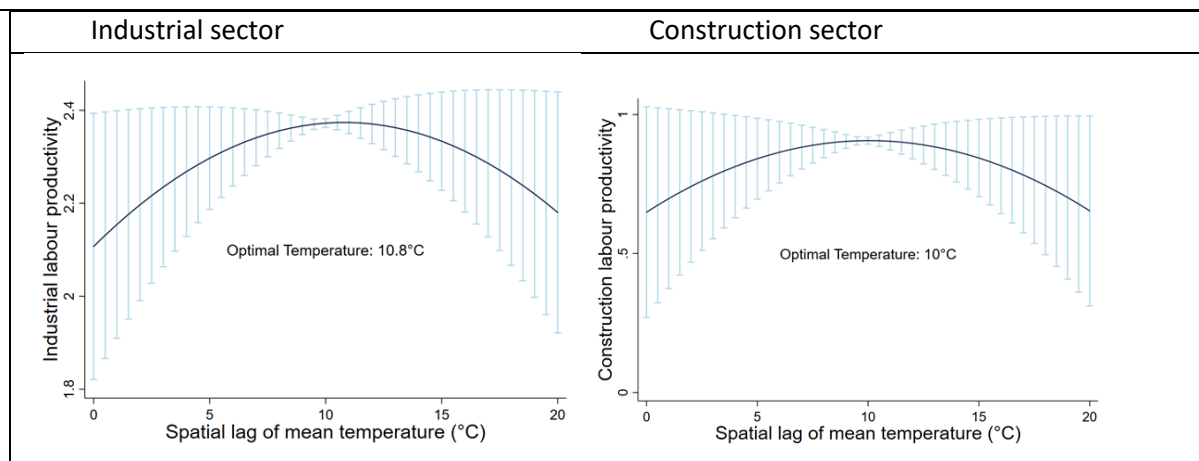
Results from the EU-funded COACCH research project (Schleypen et al., 2019) suggest that for industrial and construction sectors, the UK is likely to be less impacted than many other areas of Europe, under a RCP8.5 scenario (see Box 6.4).

Box 6.4 Impact of temperature increase on labour productivity in the EU: evidence from the COACCH Project (Interim Results).

The European Union funded COACCH (Co-designing the Assessment of Climate Change costs) project assesses the economic cost of climate change in Europe (Schleypen et al., 2019). The results found gradual changes in temperature and extreme heat events have significant negative direct impacts of on both industrial and construction labour productivity. They report a non-linear relationship between outdoor temperature and labour productivity in industry and construction sectors. Productivity decreases below and above thresholds, and thus depending on the baseline climate, further increases in temperature can result in a negative impact.

In the agricultural sector, future climate change was estimated to affect labour productivity for the EU by 2% under RCP2.6, 4.2% under RCP4.5, 5% under RCP6.0, and 6.3% under unmitigated climate change scenario of RCP8.5 by 2070. In the industrial sector, these impacts are expected to be 1.3% (RCP2.6), 2.5% (RCP4.5), 3% (RCP6.0), and 4.5% (RCP8.5), respectively. For the UK, productivity losses were estimated to be between 1% (RCP2.6) and 5% (RCP8.5) by 2070.

The optimal temperature for the services sectors is higher, as workers are not as exposed to outside temperatures, noting also that higher temperatures benefit the attractiveness of certain sectors, such as summer tourism. However, the study did not pick up large statistically significant effects on the services sector.



Box 6.4 Figure 1 Relationship between mean temperature and productivity. Reproduced from Schleypen *et al.* (2019).

Whilst studies at the UK level are sparse, there is evidence of heat risk impact on employee productivity on a global and regional scale (ILO, 2019; Kjellstrom et al., 2016) that may also be informative for the UK and has the potential to impact UK businesses through supply chains. The associated social and economic impacts of heat risk could be considerable. In a scenario of approximately 5°C global warming at the end of the century¹², global gross domestic product (GDP) losses are projected to be greater than 20% by 2100 (Kjellstrom et al., 2016). While this is more extreme than the scenarios considered here for the magnitude scoring, it can be inferred that a scenario of 4°C global warming at the end of the century would also lead to substantial impacts on GDP. Environmental heat stress is likely to have reduced labour capacity by 10% in peak months over the past few decades and is projected to reduce labour capacity to 80% in peak months by 2050 (Dunne et al., 2013). In a scenario of approximately 4°C global warming at the end of the century¹³, labour capacity could reduce to less than 40% by 2100 in peak months globally, with most tropical and mid-latitudes experiencing extreme climatological heat stress.

Decline in employee productivity may also be cumulative, depending on the number of days off work or frequency and duration of commute delays. The magnitude of the risks associated with heat may also be higher than expected due to under-reporting of heat related illnesses (Xiang et al., 2016).

6.6.1.3 Lock-in and thresholds (B5)

6.6.1.3.1 Are there lock-in risks?

Business decisions today about design and operation of office buildings or operational sites and manufacturing processes have high capital expenditure and will determine future risk levels. Examples are choice of material, building type and office set-up when refurbishing or building new. The performance of these under heat stress is an important factor for productivity. See Chapter 5 (Kovats and Brisley 2021) on the built environment.

For many businesses air conditioning is the main solution to heat stress impacting indoor workplaces, as Deschênes and Greenstone (2011) highlight. However, Power et al (2020) identify various drawbacks to this coping strategy. First, air conditioners place increased stress on electricity networks, which may already be experiencing stress due to high temperatures and peak demand, though this has not been historically an issue for the UK, where the grid is sized for the winter peak, However this may change: see Chapter 5, risk H6 (Kovats and Brisley, 2021). Secondly, air conditioners contribute to greenhouse gas emissions and air pollution emissions through their use of electricity (when generated with fossil fuels- see Net Zero section below). Though decarbonisation and efficiency gains arising from the shift to Net Zero will actually remove these emissions, some warming impact will still remain due to the fact that they involve the use of refrigerants with high Global Warming Potential which result in direct GHG emissions through leakage (Dreyfus et al., 2020). Finally, air conditioners generate waste heat during operation that compounds heatwave

¹² With the HadGEM2-ES climate model driven by the RCP8.5 concentration pathway, see Betts et al. (2015)

¹³ With the ESM2M climate model driven by the RCP8.5 concentration pathway. ESM2M has a medium climate sensitivity whereas HadGEM2-ES has a relatively high climate sensitivity, so ESM2M warms slower than HadGEM2-ES with the same concentration pathway.

conditions (Salamanca et al., 2014). It is, however, possible that more energy-efficient air conditioning technology will be developed in the coming years (IEA, 2018) and that waste heat will be captured and resupplied to support hot water and heating demand (CIBSE Journal, 2020). Also, cooling demand could be met through reversible heat pumps, particularly in public and commercial buildings with mechanical ventilation. A large number of these units are already in use (though exact estimates vary) - their prevalence is expected to grow as part of the shift off fossil fuels (stakeholder discussion). The implications of a COVID-19-induced trend to working from home for overheating and cooling are not yet clear and should be monitored, particularly in terms of labour productivity and heat stress as most home offices do not have air conditioning.

6.6.1.3.2 Are there potential thresholds?

The literature suggests thresholds associated with levels of work output for different types of indoor and outdoor work, for example in the construction industry, in service sectors and tourism (Schleypen et al., 2019). This corroborates with other findings for outdoor tourism facilities, which may become unsafe due to heat and Ultraviolet (UV) exposure after a certain temperature (CEU, 2019a). This indicates there are also likely to be associated thresholds for other sectors and industries, which involve high temperature environments, such as some food production and manufacturing. Some of these thresholds are set down in policy, in the form of occupational health standards and temperature limits (see adaptation section). Observed behaviour amongst populations also highlights that there may be biophysical/policy thresholds – e.g. when temperatures reach a point such that there is social consensus or trade union intervention, and staff need to be sent home. Another threshold relates to natural capital and cooling effect provided, particularly in urban areas: Irreversible natural capital loss poses a threshold for these heat-reduction benefits (UK Centre for Ecology and Hydrology 2020).

6.6.1.4 Cross-cutting risks and inter-dependencies (B5)

There are interacting risks with infrastructure disruption and the built environment which includes risks of overheating in homes and in non-domestic buildings (discussed in Chapter 4: Jaroszweski, Wood and Chapman, 2021). There may also be cascading risks due to infrastructure disruptions arising from extreme weather events. For example, overheating of electricity substations may also compound risks from higher temperatures in working environments (IEMA, 2013) by disrupting availability of air conditioning, in turn further exacerbating risk to employee productivity. In addition, reduced employee productivity reduces overall health and wellbeing (discussed in Chapter 5: Kovats and Brisley, 2021).

6.6.1.5 Implications of Net Zero (B5)

There appear to be synergies as well as trade-offs between Net Zero and adaptation efforts in response to heat. First, changing temperature patterns will affect the energy demand of businesses. There will be higher energy demand from cooling, to the extent that air conditioning, rather than building designs and behavioural measures might be used to manage the impacts of higher temperatures (see Chapter 5: Kovats and Brisley, 2021). The greater uptake of air conditioning in commercial premises could pose challenges for a decarbonised power system in the summer, although the demand peak in the hot midday hours also coincides with peak sunshine and therefore

solar production. Second, some air conditioning devices also use high Global Warming Potential (GWP) refrigerants, which could result in increased greenhouse gas emissions through leakage.

Conversely, there may be less demand for spatial heating in winter, creating some benefits in the hard-to-decarbonise heating sector (see risk H6, Chapter 5: Kovats and Brisley, 2021).

The second synergy or trade off relates to waste heat from air conditioning and urban heat island effects, where a feedback loop exists. As temperatures rise, and are exacerbated by urban heat island effects, there is the potential for greater air conditioning to be employed, with waste heat further contributing to higher temperatures in urban heat island effects. Conversely, there may be some synergies, with the potential for such heat to be captured and used for space and hot water heating. However, there is limited research on this issue, and it warrants further investigation.

6.6.1.6 Magnitude scores (B5)

Table 6.19 Magnitude scores for risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments.					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Low (Medium confidence)	Medium (Medium confidence)	Medium (Low confidence)	Medium (Low confidence)	High (Low confidence)
Northern Ireland	Low (Medium confidence)	Low (Medium confidence)	Low (Low confidence)	Medium (Low confidence)	High (Low confidence)
Scotland	Low (Medium confidence)	Low (Medium confidence)	Low (Low confidence)	Medium (Low confidence)	High (Low confidence)
Wales	Low (Medium confidence)	Low (Medium confidence)	Low (Low confidence)	Medium (Low confidence)	High (Low confidence)

The magnitude scoring (Table 6.19) is based on expert judgement, as quantified estimates of risk are not available. In net terms, i.e. sum of positive and negative, we deem the current risk to be low across the country, with annual economic damages less than £10 million in England and less than £1 million in the rest of the country. Future risks are low, medium to high depending on sectors and

geographies and temperature pathway. For England the 2050s projections are higher than for the rest of the country due to higher temperature projections, with economic damages going into the hundreds of millions. Studies indicate a possible 2% reduction in labour productivity by 2100, which is a significant figure.

6.6.2 Extent to which the current adaptation will manage the risk or opportunity (B5)

6.6.2.1 Effects of current adaptation policy and commitments on current and future risks (B5)

6.6.2.1.1 UK-wide

The productivity of the UK's workforce depends on a range of different factors but is 16% below the other 6 of the G7 economies (ONS, 2018), and closing this gap remains a priority for the UK, as set out in the Industrial Strategy (BEIS, 2018). Globally, early guidance is beginning to emerge on the strategies that can be employed to manage future risks of heat to productivity. The EU Heat Shield project has explored the impact of heat on productivity across Europe, and developed a series of guidelines and resources to mitigate heat stress in the tourism, transport, manufacturing, construction and agriculture sectors, as well as the development and roll out of a personalised alert service (Morris et al., 2019). However, despite the availability of resources, there is limited impact of this work being translated into domestic policy (Morabito et al., 2019).

Across the UK, there are existing Health, Safety and Welfare Regulations that also cover temperature in indoor workplaces, such as the Workplace (Health, Safety and Welfare) Regulations 1992 and the Management of Health and Safety at Work Regulations 1999. These apply to most workplaces except those involving work on construction sites, those in or on a ship, or those below ground at a mine. These require employers to address temperatures that are uncomfortably high, by taking all reasonable steps to achieve a reasonably comfortable temperature (though note that what these temperatures are is not defined and left to individual discretion). Examples of actions include insulating hot plants or pipes, providing air-cooling plants, shading windows and siting workstations away from places subject to radiant heat. If a reasonably comfortable temperature cannot be achieved throughout a workroom, local heating or cooling (as appropriate) should be provided if it cannot be achieved through lower carbon interventions such as increased use of shade and natural ventilation, use of insulation, or relaxation of workplace dress codes. In extremely hot weather, fans and increased ventilation may be used instead of local cooling. The Health and Safety Executive (HSE) provides guidance on temperatures, as well as heat stress and thermal comfort including the provision of a Heat Stress Checklist for businesses.

6.6.2.1.2 England

In England, the National Health Service (NHS) Outcomes Framework and Heatwave Plan include specific outcomes to reduce summer deaths and illness, but these have not yet fed through into other policies related to overheating, including for businesses. The updated National Planning Policy Framework includes a requirement to consider risks from overheating in new developments but has also removed support for energy efficiency improvements to buildings. In terms of sectors, there is

evidence that labour productivity will impact heritage organisations, particularly those that undertake fieldwork such as archaeological organisations and businesses and building conservation, as per Historic England.

6.6.2.1.3 Scotland

In Scotland, support to businesses is provided by Adaptation Scotland programme, whose guide 'Climate Ready Business' provides tools and resources to businesses to adapt, although heat is not included as a major factor for consideration. And there is emerging evidence of some sectoral responses. In Scotland, the Cultural Adaptations project, led by Creative Carbon Scotland is working to develop bespoke tools and support for the Cultural Sector to manage a wide range of climate risks, and is working to pilot it across cities in Europe (Creative Adaptation Scotland, 2018). Realising adaptation opportunities also depends on the support of trade unions and their ability to realise this is a thermal comfort issue. As per the Power et al, (2020) study, the most widespread activities employed by businesses are temporarily decreasing activity as a coping mechanism for extreme heat. Other very or moderately common approaches include keeping windows open at night, using personal fans at work, drawing curtains, providing protective clothing or sunscreen, changing routines (e.g. changing work hours to be out of the heat of the day) and installing air conditioning units.

6.6.2.1.4 Wales

The Welsh Government has a Climate Risk Business Tool as highlighted in Section 6.3, enabling businesses to go through likely risks and their management, including high temperatures and infrastructural disruption (Welsh Government, 2016). In 2020 the Welsh Government commissioned a survey of Welsh Businesses to identify how best to support them to adapt to higher working temperatures and infrastructure disruption as a result of climate change. 243 SMEs responded via survey and interview. Key findings are that most business don't see climate risk as a pressing issue, that they are unclear on the risks, that few are taking action and they have insufficient information. Generally speaking, the research showed that Welsh Businesses didn't differentiate either higher working temperatures or infrastructure disruption (from flooding or otherwise) as climate risks. As committed in its adaptation plan, Prosperity for All: A Climate Conscious Wales (Welsh Government, 2019b), the Welsh Government plan to take recommendations from the report to develop guidance and support to businesses, focussing on provision of appropriately framed information and work with early adopters from the target group (Marshall & Allies, 2020).

6.6.2.2 Effects of non-government adaptation (B5)

The most common adaptation for commercial building is air conditioning, which is already being fitted in many new offices (Modern Building Services, 2017). In such a case, the impact of reduced labour productivity is removed, but at a cost (increased carbon emissions if air conditioning is not ultimately run off renewable sources, plus the expulsion of waste heat outside which can exacerbate the urban heat island effect). For instance, one large UK employer has set the objective of installing natural ventilation systems into all its offices instead of using air conditioning. This company has also introduced systems to encourage flexible working by promoting smart travel plans, enhancing video

and tele-conferencing facilities, providing employees with individual travel-reduction targets and reducing pressure on employees to attend face-to-face meetings. The company is inadvertently creating a work structure that is more adaptable to climate events – even though the main objective of their introduction was to reduce carbon emissions from work travel (a ‘no-regrets’ adaptation measure) (Trade Union Congress, 2009). Another example is Cleone Foods (Sustainability West Midlands, 2014), which has a local employment policy, with the majority of staff living in close proximity to the site. Remote working is encouraged by management, however new ways of working depend on access to resilient ICT and electricity infrastructure (for example, the company maintains dual main servers and mirrored hard drives).

It is unclear at the time of writing if the shift to higher levels of remote (home) working due to COVID-19 will be a long-term trend, but the current changes in working pattern effectively transfers management of a proportion of overheating risks from non-domestic buildings to private individuals. The latter may have much less adaptive capacity to undertake substantial modifications to their premises to manage overheating risks. However, it does increase the potential for softer measures such as appropriate clothing.

For infrastructure disruption, in our view it is unlikely that this will be remedied by non-governmental adaptation, and strong public action will be needed to ensure the productivity-related disruption due to infrastructure is minimised.

6.6.2.3 Adaptation shortfall (B5)

It is difficult to judge whether there is an adaptation shortfall on the basis of the evidence available because it is difficult to say how much autonomous adaptation will occur in the response to the risk. As such, the degree of current adaptation is likely to partially, but not fully address the risk.

6.6.2.4 What are the barriers preventing adaptation? (B5)

Overall the evidence of adaptation action being taken on the basis of existing guidance and regulations remains fairly anecdotal. There are a number of barriers to adaptation for this risk. The first relates to knowledge and risk information- there is a lack of widespread, robust estimates of the impacts of heat disruption on UK productivity – such information acts as a barrier. There is also a lack of meaningful evidence on the effectiveness of heat related interventions in improving productivity. The recent survey commissioned by the Welsh Government shows that Welsh businesses do not have the adequate information needed to mitigate risks, including information about how to assess risk (although there are plans to improve this). In addition, the financial costs of adaptation and the lack of internal capacity are cited as barriers to adapt. Support is needed in all three areas of risk management: understanding risks, measures, and how to act (Marshall & Allies, 2020).

Adaptation at the employee level depends on level of awareness and individual uptake and marginal gains from adaptation uptake remain unknown or vary by employee. As Xiang et al., (2013), highlight, reduced employee productivity has both physiological and psychological effects on high-

risk manual workers. More investigation is required into how employees can behaviourally adapt to increased workplace heat exposure (Xiang et al., 2013). Overall it appears that employees are willing to adjust working habits as a response to increased temperatures and receive more occupational health and safety training to do this (Xiang et al., 2016).

Business ability to address the shortfall depends on factors such as decision-making and employee consultation structure within an organisation and supply chain resilience to minimise infrastructure disruption (Trade Union Congress, 2009; IEMA, 2013). However, many of the physical measures are expensive, whilst others require additional time to prepare and implement. We believe that for small businesses such costs could be unaffordable, suggesting that governmental intervention (such as subsidy or regulation) will be needed to create enabling conditions. There are also potential areas for government to act, e.g. with efficiency standards for mechanical cooling.

Furthermore, there are also governance barriers, in that there is not a meaningful way for government, infrastructure operators and businesses or landlords to collaborate to better understand the issue and take further action.

6.6.2.5 Adaptation scores (B5)

Table 6.20 Adaptation scores for risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)	Partially (Medium confidence)

6.6.3 Benefits of further adaptation action in the next five years (B5)

6.6.3.1 Additional planned adaptation that would address the adaptation shortfall? (B5)

The CCRA2 Evidence Report (Surminski et al., 2016) outlined a need to further research and understanding of the key interdependencies between business and infrastructure, the types of employment at greatest risk and the effectiveness of planned or autonomous adaptation. Collecting business continuity information on productivity and extreme weather is critical to understanding this risk better.

Adaptation reporting could help to increase uptake and encourage businesses to prioritise this risk, but a requirement would be needed to include productivity risks in reports, which is challenging given the current voluntary approach to reporting adopted by the UK Government.

Very few studies have looked at either the risk or adaptation underway in the UK, suggesting further investigation is required across the UK to better quantify both the scale of the problem, and the

benefits of implementing measures to address it both in current and future climates. In particular, evidence for future risk from reduced employee productivity is limited.

6.6.3.2 Indicative costs and benefits of further adaptation action (B5)

There is some information on various adaptation options to reduce heat in commercial buildings and also linkages to the information available for domestic buildings (see the discussion of low and no-regret options for risk H1, Chapter 5: Kovats and Brisley, 2021). Day et al. (2019) assessed 17 adaptation measures (drawn from a longer list of over 30), including both solutions for indoor and outdoor work, to address higher base temperatures as well short-term temperature peaks. The authors estimated the 'potential scale of impact' as well as the 'feasibility' of the measures. This also includes analysis of which actions can be taken forward by the private sector, by government and by individuals. The study also considers the economic costs of each adaptation measure including direct financial costs of implementing the measure, and a range of 'indirect' costs. Costa et al. (2016) also estimated averted losses from alternative adaptation measures for three case study cities (Antwerp, Bilbao, and London) for a warm year at the end of the century (2081-2100). These studies identify a range of low and no-regret adaptation actions.

Some opportunities for labour productivity adaptation are identified such as transition to new ways of working (remote working, flexible working) and low carbon and energy efficiency buildings to maintain employee productivity (ILO, 2019, Day et al., 2019). These behavioural changes have been tested and employed by various businesses with the onset of the COVID-19 pandemic, but longer-term behavioural change is yet to be seen. Moreover, there are occupational and sectoral divergences in the uptake of new ways of working, with some professions lending themselves better to flexible working than others.

Increasing collaboration and strengthening governance in this space may also deliver benefits in the next five years. Better collaboration between business, building owners, government and infrastructure operators could help facilitate adaptation. These efforts could replicate the engagement and collaborations seen in the flooding space and be linked to net-zero initiatives, recognizing that heat poses challenges for reaching net-zero.

With regards to nature-based solutions as a potential adaptation response to extreme heat, there is emerging literature estimating the climate benefits of urban natural capital at the UK scale (Eftic et al., 2018). This valuation methodology provides estimates of temperature reduction in city areas and benefits, which feed into the Natural Capital Accounts by ONS (ONS 2018). Although experimental in nature, these estimates give a sense of the scale of benefits (particularly in terms of avoided loss of productivity) and how these might rise over time with an increasing frequency of 'hot' days. For instance, in 2017, the annual benefits of cooling from green and blue space in urban areas was estimated at £244m, with London dominating the benefits (reflecting the climate of London, the scale of its economy and the unusually large area of green space for such a big city). The ONS 2018 assessment uses analysis from Eftic (Defra, 2018a) and is based on Costa et al.'s (2016). However, increasing the area of large natural spaces in urban areas, in response to rising climate risks, appears challenging, not least because of the opportunity cost of land. Initiatives led by the private sector such as 'Living roofs and walls – from policy to practice' aim to address these issues.

6.6.3.3 Overall Urgency scores (B5)

Table 6.21 Urgency scores for risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments.				
Country	England	Northern Ireland	Scotland	Wales
Urgency Score	Further investigation	Further investigation	Further investigation	Further investigation
Confidence	Low	Low	Low	Low

Despite growing understanding of heatwaves and infrastructure disruptions there is still little assessment of labour productivity implications across different sectors and context, including indoor and outdoor processes, although Wales has recently gathered additional survey evidence. Across the UK the risk is currently deemed low but could increase to medium and high if not managed. There are benefits to further investigation over the next five years, in particular considering the interplay between changes to infrastructure resilience, employee health, and net zero ambitions. This urgency score is predominantly based on expert judgement.

6.6.4 Looking ahead (B5)

A key focus here is on improving the evidence base through further investigations. Reporting will play a role. Adaptation action will also depend on level of collaboration between businesses, infrastructure providers and government. CCRA4 should consider the interplay between air conditioning and other cooling devices and investigate how hotter summers could put a strain on the feasibility of reaching Net Zero carbon targets.

6.7 Risks to business from disruption to supply chains and distribution networks (B6)

Extreme events are already a significant cause of supply chain disruption across all sectors with exposure to climate hazards set to increase in the future. Some action has been taken by business and there are opportunities from advances in technologies and from the learning and increased focus on supply chain resilience following the COVID-19 crisis. However, it is unclear if this will keep pace with the increasing risk or how effective it will be. Therefore, more action is needed but with a low certainty in the evidence, which is skewed towards larger companies, the food sector and self-reporting. This is applicable across England and all DAs, but more work is needed to understand regional differences. The evidence base is strongest for England, followed by Scotland, with less for Northern Ireland and Wales. International supply chain aspects are covered in Chapter 7 (Challinor and Benton, 2021).

6.7.1 Current and future level of risk (B6)

Note: it has not been possible to split the evidence by UK country for this risk.

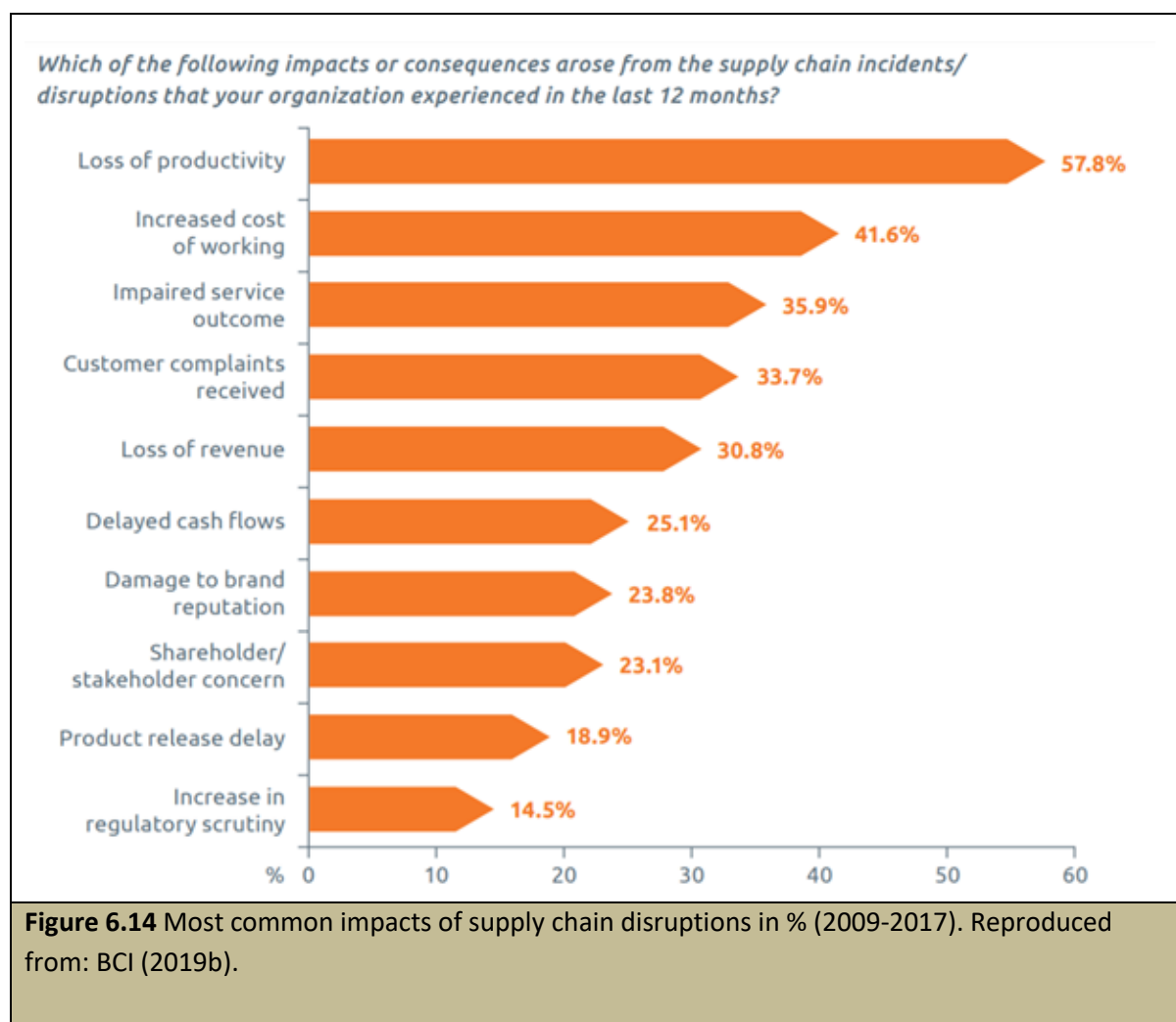
6.7.1.1 Current risk (B6)

The risk level varies according to location and sector. Factors such as reliance on single transport routes or how specialised the supply chain is can have an influence. McKinsey (2020) suggested that highly specialised supply chains e.g. for semi-conductors, lead to more severe impacts for downstream players as supply of a critical input may only be available from the source that has been disrupted. However, the more commoditized the supply chain is, the larger the number of downstream players that may be affected by spiking prices from a sudden reduction in supply. Looking specifically at disruption to the agriculture products supply chain, the UK food supply system has shown to be overall resilient. However, this cannot be taken for granted as the experience with COVID-19 and the disruption due to sudden border closures over Christmas food (affecting ports such as Dover) show. Overall CCRA2 established lack of evidence on how business disruption translates to UK risks, as also highlighted by Manning and Soon (2016). More recently a survey by the Business Continuity Institute found extreme weather to be the second most highly rated cause of disruption in 2018 (after IT outages) and has been consistently highly rated over a number of years (BCI, 2019a; BCI, 2018a). Weather hazards also contribute to other causes of supply chain disruption reported separately, such as travel network disruption, outsourcer failure, Health and Safety (H&S) incident and fire.

These disruptions have various negative impacts, as outlined below looking at a disruption distribution between 2009-2017, as highlighted by a BCI survey (Figure 6.14).

The LSE Climate Risk Business Survey (2020) finds that only 9.9% of the respondents who experienced losses due to supply chain and distribution network disruption were able to quantify the impacts. And while here there is little evidence to relate the source of disruption to the consequences, adverse weather events tend to particularly aggravate logistics costs (BCI, 2018a). For example, a preliminary analysis by UNCTAD (2020) shows that a 2% reduction in China's exports to foreign car manufacturers could lead to a \$7 billion reduction in global automotive exports. When companies have to cease trading the average period of shutdown is 3 months. 1 in 5 small businesses say they would not survive more than a month of shutdown (Crisis Control, 2017).

HSBC (2020) differentiate between acute one-time climate disruptions and chronic, longer-term disruptions which can increase supply cost, lower quality, delay delivery or lead to the need to use alternative supplies. They also note that climate change is different than other shocks for supply chains due to more frequent, severe and longer-duration supply chain disruptions, disruptions in more places, disruptions during transitions and focusing more investor attention on a company's supply chain related greenhouse gas (GHG) emissions (HSBC 2020).



Some organisations and sectors are more exposed to climate hazards through their supply chains than others. Industries that are part of the food system, for example, rely on agriculture, which is particularly exposed to weather and climate, and long distribution networks, with 50% of food consumed in the UK imported from 180 different countries (Watkiss, 2019; Defra, 2017; Defra, 2018a). Even within the UK, agricultural and food supply chains experience disruptive impacts with milk and beef processors suffering most impact from reduced raw materials (Farmers Weekly, 2020).

The Climate Resilience in the UK Wine Sector project (CREWS-UK, 2021) looks at how climate variability interacts with the broader viticulture value chain that connects producers to final markets. It describes how the impacts of climate shocks can be transferred through the activities, resource flows and actors along value chains (Carabine et al., 2018; Canevari-Luzardo, 2019; Codjoe & Owusu, 2011) while business networks and interdependencies also dampen impacts to other actors along the chain (Canevari-Luzardo, 2019) and support access to resources, (e.g. inputs and downstream activities such as storage, processing and marketing activities) and adaptation of other actors within value chains (Carabine et al., 2019; Gannon et al., 2021a). Stakeholder discussions as part of the CREWS project highlight several supply-chain issues (CREWS-UK, 2021):

- *‘E.g. with restaurants and retailers – hard to build reliable longstanding relationships when can’t reliably meet demands. Variability puts challenges on that. Especially it’s very difficult to turn*

taps on and off with these things. If you can't, if you are supplying someone and then next year you can't, it's very difficult to build that trust relationship back up again. To increase volume. So, maintaining long-term relationships can be more challenging with variability.

- *Business relationships structured vulnerabilities and adaptive capacities – e.g. contracts. These business relationships – and thus adaptive capacity – are not stable, with climate and variability in yields shaping them too.*

Section 7.3 of Chapter 7 (Challinor and Benton, 2021) considers risks to UK food availability from climate change overseas, including the potential for cascading and interacting risks associated with supply-side disruptions.

It is not just individual companies that are exposed to supply chain risks. Extreme events have the potential to affect the profitability of entire sectors through impacts on local and global supply chains. For example, in the US, Hurricane Harvey in 2017 caused disruption to oil transport and distribution networks and led to a 20% increase in fuel prices across the country (Marsh & McLennan Companies, 2018; Department for International Trade, UK Trade in Numbers, February 2020). In 2016/17 the UK saw shortages and high prices of an array of vegetable crops due to a combination of weather factors (storms, cold, snowfall, heavy rainfall, flooding) affecting growers in Spain, Italy and across Europe. In particular, courgette prices rose by 60%, aubergines by 132% and tomatoes by 45% and UK retailers resorted to air freighting lettuces and other items from the US to plug the gap (Crisis Control, 2017). However, so far the UK food system has been resilient to supply chain disruption due to diversity, flexibility and the competitive nature of the industry (Colwill et al., 2016; Defra, 2017b; Defra, 2018; Watkiss, 2019). This has been demonstrated during disruptive challenges in recent years e.g. 2015 flooding, 2009 H1N1, 2010 volcanic ash and 2014 industrial action (Cabinet Office, 2019). However, very short lead times and non-warehousing of stock is likely to cause challenges in times of disruption, as seen with COVID-19-related disruptions in 2020.

There is a lack of UK based evidence to support any analysis of the risk to entire sectors from supply chain disruption beyond the food system. But it is worth noting that other sectors are at least as important, if not more so, to the UK economy. According to McKinsey (2019) the top five commodity groups in terms of share of total UK trade in 2018 were transport equipment (17%), chemicals (15%), non-electrical machinery (14%), minerals and metals (14%) and agricultural products (9%).

At the time of writing there has not yet been a full analysis of the supply chain effects of COVID-19 pandemic in the UK. There is anecdotal evidence of market effects and demand side disruption, caused by behaviour change (e.g. stockpiling) and the economic impacts of the lockdown, but this requires further investigation to understand the significance of these factors with respect to climate related disruptions.

6.7.1.2 Future risk (B6)

Climate change is likely to contribute to an increase in exposure to supply chain disruption by driving an increasing frequency of adverse weather events and evolving climate hazards both in the UK and overseas. Unsurprisingly, businesses are self-reporting that weather and climate hazards are a driver

of future supply chain risks (CDP, 2018; LSE, 2020). Respondents to the LSE Climate Risk Business Survey (2020) reported that while heavy rainfall and surface water flooding and high temperatures, including heatwaves, will continue to dominate, coastal and river flooding and water scarcity will also become more significant drivers. In the CDP survey (2018), those supply chain risks with a substantive financial or strategic impact were mostly scored as medium term, of medium magnitude and (with less agreement) likely. This evidence, although self-reported and uncertain, suggests future risks to be greater than current.

The reliance of UK businesses on overseas markets creates exposure to climate change impacts abroad. For example, the combination of changing rainfall patterns and increased temperature could lead to a reduction in crop production in arid and semi-arid lands (ASAL) of 20-50% by 2070 (Sarr, 2012; Alberto et al., 2015). Similarly, risks from pests and diseases, long term soil erosion, port closures, power outages, oceans acidification effects on cod (WWF, 2018), extreme heat effects on workers (Alberto et al., 2015) and financial pressures on the supply chain, particularly farmers, in the wake of severe events (WWF-UK, 2018) could all increasingly find their way to UK businesses via supply chains. The manufacture and supply of food, clothes and electronic equipment are understood to be particularly exposed to international climate change impacts (CCRA2). Industries with single key supplier locations in areas subjected to significant climate change impacts are more exposed e.g. significant sea level rise will adversely impact manufacturing and shipping routes located around the main Chinese river systems (Xu, 2016). This underpins the UK's vulnerability to global supply chain, which is covered in greater detail in Chapter 7, Section 7.2 (Challinor and Benton, 2021).

As risks to individual businesses increase and effects become more frequent and widespread, there are social and economic risks due to the effects on exchange rates, of commercial failure, higher prices, shortages or fluctuations in quality of food or other vital materials. For example, UNEP-FI and Acclimatise projected yield decreases in US coarse grains, oil seeds, wheat and rice of up to 25% by 2050s for a scenario of approximately 4°C global warming by the end of the century¹⁴, and that correspondingly commodity prices are expected to rise by up to 20% (UNEP-FI and Acclimatise, 2018). Meanwhile, recent research carried out on the impacts of climate change on the dairy industry on the island of Ireland, revealed emerging concerns among farmers and agri-food businesses about extreme weather events globally, and the indirect, economic impacts on feed grain prices (Safefood, 2017). Another study looked at the potential impacts of climate change on the interplay of supply chain shocks and a sector's export value (COACCH, 2019), based on input-output connectivity between sectors and countries, along with data on extreme weather. The findings suggest that, if no additional adaptation were to occur, climate change will reduce a sector's export value by up to 16 percent. However, these findings vary strongly between countries as well as sectors with the strongest impacts in the tropics due to the stronger projected climate impacts, which are then transmitted over interregional supply chain connections.

Future risk will also depend on the attributes of future supply chains (e.g. length, complexity, interconnectedness and nature of relationships). The current trend for increasing complexity and interconnectedness brings growing uncertainties and challenges relating to managing risk through

¹⁴ Multi-model mean of the CMIP5 ensemble with the RCP8.5 concentration pathway.

others (Crisis Control, 2017) but could also provide flexibility that helps systems absorb shocks (Colwill et al., 2016). Companies may take action in response to EU exit or the COVID-19 pandemic or other priorities, changing strategies and setting new trends that affect the future climate risk (discussed further below).

The potential impact of EU exit on UK supply chains has created the need for additional understanding on climate risks and opportunities. The UK currently imports mainly from Germany (11.6% of total value of imported goods and services), followed by the US (11.4%) and the Netherlands (7.3%) (DIT, 2020), but this distribution is likely to change depending on new trading relationships. For food supply chains in particular, the UK currently performs highly on sustainable agriculture indexes at the EU level (Agovino, 2019) but as trading partners change, there is a need to reassess extreme temperatures and water scarcity in source countries (Benton et al., 2019). One example is the UK's increased dependence on imports of fruit and vegetables; UK domestic production of fruit and vegetables decreased from 42% in 1987 to 22% in 2013. Importing more from climate-vulnerable countries could reduce the availability, price and consumption of these products in the UK.

6.7.1.3 Lock-in and thresholds (B6)

6.7.1.3.1 Are there lock-in risks?

Supply chain risks can be locked in if UK companies invest in transport routes, distribution hubs or production centres that are more exposed or vulnerable to climate hazards. It is not clear from the evidence if these factors are taken into account in investment decisions of this nature. However, there is some evidence that other priorities may be leading to trends that increase lock in. Such as centralised production for reasons of efficiency or over reliance on technology and software. While these offer huge opportunities for understanding and managing supply chain risks, they could bring new problems as has been seen in finance and banking sectors (Colwill et al., 2016). This also underlines the importance of infrastructure to ensure that technology can be used.

6.7.1.3.2 Are there potential thresholds?

Thresholds that exist for producers and transport operators will also have significance throughout their supply chains. A global survey of ports found that less than 40% are able to report the availability of thresholds for climatic stressors that could impair the integrity and functionality of infrastructure and equipment (Asariotis et al., 2017). This indicates either information or internal communication gaps. There may also be thresholds for switching suppliers based on prices including the cost of air freighting from alternative sources or of alternative products. For example, disruption to soymeal supply, gives rise to use of alternative chicken feeds such as insects and algae (WWF-UK, 2018). An example of thresholds potentially being breached are the increased customs requirements as a result of new trade deals which might see a shift in trading patterns or a re-orientation of some businesses.

6.7.1.4 Cross-cutting risks and inter-dependencies (B6)

Supply chains create a network of interdependencies, through which UK businesses can be exposed to all of the risks faced by their suppliers, producers, transport routes and customers with significant potential for interaction between (Alberto et al., 2015). In particular, transport network disruption, which is often triggered by adverse weather (BCI, 2019a), was reported as a source of significant disruption in the BCI survey by 27% of companies (BCI, 2018b). Ports are vital to UK supply networks and can be affected by weather and climate change in a variety of ways, including effects on the operation of port infrastructure which is explored further in Chapter 4 (Jaroszewski, Wood and Chapman, 2021). A survey of global ports found that the majority suffered some or significant impacts due to weather/climate related events including 60% reporting delays. However, European ports seem to be less affected (Asariotis et al., 2017). Since ports are not subject to economic regulation, there is a general lack of data on the resilience of ports compared to regulated sectors, as outlined in Chapter 4 (Jaroszewski, Wood and Chapman, 2021).

Socio-political factors specific to suppliers' countries can interact with the climate, such as conflict, migration, global financial pressures and political protectionism (Marsh & McLennan Companies, 2018). In particular, firms in arid and semi-arid lands face significant constraints from degraded natural resources and infrastructure; conflict over resource allocation and; increasing population (pressure on resources, food security) (Alberto et al., 2015). Alternatively, the effects of climate change can simply coincide with other factors exacerbating the consequences of both. For example, in 2008 drought, rising oil prices and competition for land were all factors in a food crisis which saw wheat prices increase by 130%, soy by 87% and rice by 74% (WWF, 2018). Similarly, the price of avocados increased by 50% in the first half of 2017 when a late harvest and floods coincided with a worker strike in Peru. There may also be issues for domestic food production. For example, The Welsh's Government's Capability, Sustainability and Climate Report (CSCP05), looks at the effects on crops and shows a clear risk with greater volume and intensity of rain in the winter / spring periods and changing timing of access to land. However, there are also potential greater cultivation opportunities (Welsh Government, 2020).

Disruption to supply chains and distribution networks due to physical risks can also link to transition risks or legal risks (see implications of Net Zero below). Moreover, as the NFU highlights (NFU, 2020), businesses may fail to meet supply contracts as a result of supply chain disruption (e.g. crop failure during extreme dry weather). This poses additional legal risks to businesses which are beyond the scope of CCRA3.

The LSE Climate Risk Business Survey (2020) suggests UK businesses are exposed to weather related supply chain risks through dependencies on suppliers and transport networks in equal measure. The latter may be more significant in Scotland, Wales and Northern Ireland due to dependence on a more limited number of transport hubs. However, The Welsh Government survey of businesses referenced in section 6.7 did not show evidence of perceived infrastructure disruption as a risk to their supply chains.

In Section 7.2 of Chapter 7 (Challinor and Benton, 2021) we present a framework of the most common transmission pathways in which risk may cascade into the UK: through energy, finance and markets, governance, IT and information, movement of goods, movement of people and wellbeing.

6.7.1.5 Implications of Net Zero (B6)

The UK Net Zero target only applies to domestic emissions, and not emissions associated with international production and transport to the UK. It does, however, apply to emissions associated with production and transport within the UK, and these supply chains will need to move to Net Zero over time. It is not clear how this difference will affect the structure of supply chains, but if it does, it will have implications for climate risk profiles. For instance, reduced stock holdings and centralised production may be more resource efficient but less resilient (Colwill et al., 2016).

The trend for shorter supply chains and localised production, driven by resilience considerations or in response to climate hazards, could affect Net Zero ambitions. While this could reduce transport-driven emissions, in many cases, much higher emissions are associated with local production, and thus the net effects (local versus international supply) depend on the comparative emissions from production (for an example, see the food miles debate, Webb et al., 2013). Nonetheless, emissions reductions may be in conflict with resilience objectives.

There is anecdotal evidence that during disruptive events, business responses can be energy and emissions intensive (e.g. sourcing from further away including air freighting) (PES Media, 2020). Thus it is possible that, with rising climate extremes, supply chain risks could make Net Zero slightly harder to achieve.

The drive for Net Zero could also result in supply chain pressures for materials such as rare earth metals due to rapid growth in clean technologies, leaving them more vulnerable to climate related disruption (McKinsey, 2020).

6.7.1.6 Magnitude scores (B6)

While organisation-level information exists, there is little UK-wide information on the current size of extreme weather disruption to supply chains of business sectors outside of the food sector, and no national estimate for any sector of the total average annual economic damage exists. Expert judgement leads to a medium magnitude with £tens of millions economic damage or foregone opportunities for England and £millions for the rest of the country. However, there is only low confidence due to a limited evidence base. For future risk, numerous studies point to supply chain shocks as a potentially large driver of risk, particularly for food supplies, but the evidence available does not provide a measure of estimated annual damage in £ and so cannot be estimated using the CCRA methodology at present.

Table 6.22 Magnitude scores for risks to business from disruption to supply chains and distribution networks.					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Medium (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)
Northern Ireland	Medium (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)
Scotland	Medium (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)
Wales	Medium (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)	Unknown (Low confidence)

6.7.2 Extent to which the current adaptation will manage the risk or opportunity (B6)

6.7.2.1 Effects of current adaptation policy and commitments on current and future risks (B6)

6.7.2.1.1 UK-wide

Since CCRA2 some progress has been made in driving adaptation in supply chains through government organisations' own procurement processes. Furthermore the UK Government has announced a consultation to improve the way in which it takes account of social value in awarding contracts to suppliers, including adapting to climate change.

However, the UK Industrial Strategy does not make any references to helping supply chains become more resilient to the impacts of climate change. According to the LSE Business Survey businesses are unlikely to turn to government for information and support when seeking to manage climate risks to their supply chain, instead preferring to make use of their own in-house expertise or consultant services.

6.7.2.1.2 England

The plans for supply chains in the second National Adaptation Programme (NAP2, Defra, 2018b) focus on food security and Defra has well established mechanisms for working with the food sector, helped by contingency planning for EU exit and working with the Food Chain Emergency Liaison Group to build on research into food supply resilience (UNEP-FI, 2019). However, NAP2 does not set out actions to address the risks that England faces from the international impacts of climate change on supply chains, or sectors other than food. There are also no stated goals for adapting supply chains to climate change or specific planning for scenarios of either 2°C or 4°C global warming by the end of the century. The Environment Agency have also amended their procurement process to take account of changing risks from weather and climate.

6.7.2.1.3 Northern Ireland

In Northern Ireland, supply chain disruption caused by the recent COVID-19 pandemic affected the supply of core components for manufacturing companies and also the supply of key PPE items. This has highlighted the need for companies to put more emphasis on understanding and managing the risk in their supply chains to ensure that they can build in resilience. Invest Northern Ireland have developed a supply chain risk assessment checklist to support companies to review this and are actively working on further solutions to support supply chain resilience (Invest NI COVID-19 Response, 2020). These include dual sourcing, re-shoring or near shoring elements of their supply chain. Regarding the agriculture sector in Northern Ireland, the Going for Growth (GfG) report proposes an integrated supply chain from farm to customer but does not explicitly address critical elements of the supply chain that are upstream from regional farm production processes, such as, imports of feed, fuel/energy, fertilizer and other agri-chemicals (Safefood, 2017).

6.7.2.1.4 Scotland

In Scotland, the supply chain disruption faced by businesses is addressed via the Scotland's Climate Ready Business Guide (Adaptation Scotland, 2019) and SCCAP2 (Scottish Government, 2019). Businesses are encouraged to consider alternative suppliers, diversify their network and focus on local markets.

6.7.2.1.5 Wales

The Welsh Government's CSCP05 Report considers crop suitability and implications for food supply chains. This report uses soil, site and climate information to model the potential land suitability for 118 crops under nine projected UKCP18 climate change scenarios, as well as under present day conditions (Welsh Government, 2020). This builds on earlier work from ADAS Research (2014), who conducted a Review of Land Use and Climate Change, assessing the evidence base for climate change action in the agriculture, land use and wider food chain sectors. The research identifies risks to domestic and business property, livestock grazing; availability of feed, yield impacts in the arable/horticulture and forestry sectors; pest and disease pressure; species water stress and wind throw in forestry; wildfires, affecting both grassland and forestry areas (ADAS Research 2014).

6.7.2.2 Effects of non-government adaptation (B6)

In terms of business actions an analysis by HSBC (2020) divide these into bridging and buffering: Bridging involves the buying organisation taking action to help build up the capacity of its suppliers to manage through and recover from disruptions. Buffering involves the buying organisation taking action to protect itself from the consequences of supplier failures. Bridging strategies include collaborative planning and control, financial support and strengthening relationships with suppliers. Buffering strategies include inventory, capacity, liability, lead time and cost buffer (HSBC 2020). Survey evidence from the Business Continuity Institute (BCI, 2019a; BCI,2018a) shows that many businesses are taking buffering action to manage risks from supply chain disruption. These are not specifically in response to climate risks. Plans includes some hard engineering solutions, such as improved storage facilities and the building of fusion centres, which enable resilience by bringing down silos (BCI, 2018a reported that 30% of organisations have fusion centres and 14% planning to build one in the next 2 years) and technology for monitoring, measuring and reporting on performance affecting supply chain disruption. However, softer measures such as engaging with staff and business continuity planning (BCI, 2019a) seem to be on an equal footing for supply chain risks (CDP, 2018 and LSE, 2020). The majority of businesses have business continuity arrangements in place to deal with supply chain disruption and are increasingly aligning with or being certified to the ISO 22301 international standard on supply chain management (BCI, 2019a). The Co-operative Group for example, has established business continuity programmes, mandatory supplier checks and monitoring, and conducts disaster recovery tests (The Co-operative Group, 2018). There has also been an increase in insurance coverage although supply chain losses are rarely fully covered (BCI, 2018b).

In terms of bridging actions, most companies talk to new and existing suppliers about their business continuity plans: the 2018 BCI supply chain survey found that 72% of respondents do this. Almost half of the survey respondents claimed that more than 60% of their suppliers have business continuity in place to deal with supply chain disruptions, while roughly a quarter report that to be the case for 80% or more of their suppliers (BCI, 2018b). The number of organisations requesting alignment to a known standard has increased from 36.5-51% since the launch of ISO22301 in 2012 and checks for certification increased from 11-51% (BCI, 2019b). However, a global survey of ports found that, despite extensive past experience of impacts, most ports had not received any related requests for effective response measures from their users/clients (Asariotis, R. et al., 2017).

More collaborative approaches along supply chains are also on the rise. According to BCI's survey (BCI, 2019a) there has been an increase from 13.3% (2018) to 25.6% (2019) of respondents carrying out joint exercises with their suppliers. This trend appears particularly evident in the highly competitive food retail sector, with companies engaging with their suppliers, driven by the desire to expand globally to source cheaper raw materials (Colwill et al., 2016).

6.7.2.3 Is there an adaptation shortfall? (B6)

It is unclear how the plans and actions described above will actually reduce the risk to supply chain disruption from climate change. Business continuity arrangements mean supply chain risks are more likely to be insured (BCI, 2018) and less likely to lead to (Crisis Control, 2017). However, most

businesses don't analyse the original source of disruption when recording, measuring and reporting supply chain disruption (BCI, 2019a; BCI, 2018b) so it is not clear how these arrangements are reducing climate driven supply chain risks specifically. Moreover, they do not seem to affect the level of loss when one does occur (BCI, 2018b).

Nevertheless, over the past decade, supply chain partners (along with customers and investors) have started raising issues regarding climate change with increasing urgency and frequency (Marsh & McLennan Companies, 2018).

The evidence, although weak, implies an adaptation shortfall. Some of the shortfall can be expected to be addressed by business action, in particular in building business continuity capability and driving resilience through supply chains. This is demonstrated by increasing use and uptake of the ISO standard on supply chain management. EU exit preparations and the COVID-19 response may accelerate this as experience during 2020 suggests that companies that prioritised efficiency over resilience are ill-prepared for disruptions (YGCP, 2020).

However, it is not clear from the evidence how these actions will translate to reduced risks from climate-related disruption as the source of disruption is not routinely analysed.

6.7.2.4 What are the barriers preventing adaptation? (B6)

There appear several cultural, institutional and commercial barriers to adaptation including:

- **Integration in business processes:** Only 36% of businesses integrate business continuity in their procurement process, while 20% don't mention it in supplier discussions according to BCI, 2018a.
- **Traceability:** According to the WEF survey fewer than 15% of executives feel that their current capabilities are sufficient to track physical risks consistently (WEF, 2020). This was also confirmed in stakeholder discussions, with a leading climate adaptation advisory firm stating that many of their clients cannot provide the necessary level of traceability in product components/ ingredients that allow for an assessment of physical climate risks in their supply chain to be undertaken with sufficient granularity (Stakeholder discussions).
- **Data barriers:** This includes unreliable data from supply chain partners and a lack of standardisation for data exchange and the calculation of metrics. There are also technological barriers, such as the absence of end-to-end platforms, and organisational barriers, such as untrustworthy data-sharing mechanisms or privacy concerns. (WEF, 2020), making it difficult to validate supplier's business continuity arrangements (BCI, 2018a).
- **Knowledge and understanding of risks:** Scenario analysis is constrained by gaps in knowledge or understanding for example due to modelling uncertainty (Marsh & McLennan Companies, 2018) and a risk perception that may be out of step with reality. Adverse weather is only ranked 4th in terms of concern over next 12 months and 3rd over next 5 years despite being the second most prevalent cause of supply chain disruption (BCI, 2019b).
- **Institutional constraints,** particularly for international contexts: For example, crop insurance is not readily available in many developing countries and comes with limitations such as lack of data or unaffordability for farmers (Marsh & McLennan Companies, 2018).

- **Competing objectives:** There are tension between goals on resilience, sustainability and efficiency. For example, the dominance of lean manufacturing principles driven exclusively by cost control tends to result in concentrations in areas of cheap labour and shrinking numbers of key suppliers (BCI, 2018b). This increases both the likelihood (due to length of supply chains) and consequence (due to high dependencies on single suppliers or places) of weather-related disruption. It also increases vulnerability to the weather. See also section 6.7.1.5 on Implications of Net Zero.
- **Commercial barriers:** Demand for low prices and evolving customer requirements (retail and food industries in particular) could be constraining resilience (Marsh & McLennan Companies, 2018; Colwill et al., 2016).

Overall, the confidence in evidence about adaptation action remains low – it is mostly from surveys and based on assumptions about the relationship between business continuity and climate change.

6.7.2.5 Adaptation scores (B6)

Table 6.23 Adaptation scores for risks to business from disruption to supply chains and distribution networks.			
Are the risks going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)

6.7.3 Benefits of further adaptation action in the next five years (B6)

6.7.3.1 Additional planned adaptation that would address the adaptation shortfall? (B6)

The majority of further actions involve capacity building, institutional changes, or the development of new strategies, technologies or ways of working, which will take time to develop, test and implement. Therefore, there is a benefit to putting these in place within the next five years even where the climate-related risks are not immediate. Indeed, the BCI recommends an offensive rather than a defensive approach (Marsh & McLennan Companies 2018), while McKinsey (2020) finds significant potential for many industries to adapt in the next decade. For example, in the case of rare earth metals they estimated that 50-80% of risk could be eliminated if adaptation measures were implemented (McKinsey 2020). Furthermore, many of the actions can be seen as ‘no-regrets’ options business continuity planning that builds resilience in supply chains or improves the quality of business relationships offers immediate benefits.

Strategies that businesses could take to further build resilience include:

- Product diversification or geographical diversifying (WWF, 2018).

- Scenario analysis to ensure plans are robust under different plausible outcomes by explicitly defining and separating external scenarios from internal plans (Marsh & McLennan Companies, 2018).
- Ensuring risks are incorporated into risk registers and management programmes so that optimal resources and opportunities to improve corporate performance and earnings can be identified (BCI, 2018a).
- Intensification in the use of storage facilities (COACCH, 2019).
- More 'bridging' actions, that is, inclusion of supply chain partners in risk assessments, planning and communications (Crisis Control, 2017). Given the post-EU exit uncertainty due to changing supply chains Tim et al. (2019) recommend more investment in the agricultural systems of source countries in order to minimise climate risk. And the World Business Council for Sustainable Development (Landworkers' Alliance, 2019) recommends adopting a circular model for resilience, with shocks and stressors in the food, agriculture and forestry sector, being met with adaptation response and transformation of existing business models and supply chains.
- Making more use of technology to improve traceability mechanisms (YGCP, 2020) and to predict, monitor, record, measure or report supply chain risks and communicate with suppliers. For example, using automated communication and notification systems, BCM platforms, incident management platforms or social media monitoring (favoured by SMEs) (BCI, 2018b; BCI, 2019a).
- Expanding firm level insurance coverage of physical risks to supply chains, including by use of new products such as non-damage supply chain insurance plans and parametric insurance (for example, with pay-outs based on a drought duration index or rainfall data rather than losses) or captive insurance solutions. The latter can improve climate resilience by strategically funding risk exposures, preparing for a worst-case scenario in the face of increasing frequencies and by accessing reinsurance markets and alternative capital markets to fund less predictable risks (Marsh & McLennan Companies, 2018; BCI, 2019a).

There are roles for both the public and private sector in driving resilience through supporting or/ incentivising their own supply chains to implement adaptation measures by:

- Requiring physical risk disclosures and setting contractual arrangements that take adaptation into account (UNEP-FI and Acclimatise, 2018).
- Using resilience criteria with choosing suppliers as part of procurement processes (Crisis Control, 2017). For public sector procurement, the Public Services (Social Value) Act provides a potential tool by requiring commissioners of public services to think about how they can also secure wider social, economic and environmental benefits. (Source: CCRA3 Stakeholder Event, February 2020)
- Helping suppliers reduce their own risks (Crisis Control, 2017). For example, the water stewardship approach provides companies with a means of committing resource and using influence to support good water practices in areas of weak governance.
- Promoting business continuity, with a particular focus on strategies that achieve multiple goals including resilience and sustainability for which there may be market failures. For example, distributed manufacturing, seasonal produce and local sourcing have a role to play in achieving both sustainability and resilience goals (Colwill et al., 2016).

There is also a role for government in capacity building and setting the right institutional environment (COACCH, 2019), such as by:

- Promoting the establishment of binding supply chain due diligence legislation on a national level while ensuring international alignment (YGCP, 2020).
- Promoting the coherent use and development of modern traceability technology, namely blockchain (YGCP, 2020).
- Supporting improved climate and location-based information and integration with other types of information (UNEP-FI and Acclimatise, 2018).

Taking into account all three steps of the urgency assessment we conclude that more action is needed, but with a low certainty in the evidence, which is skewed towards larger companies, the food sector and self-reporting. The reliance on overseas markets means UK supply chains are exposed to climate impacts abroad with exposure increasing due to climate change. While some action has been taken by businesses and others on supply chain resilience and there are opportunities from advances in technologies, there are many barriers to adaptation. It is unclear how effective current and planned actions will be in managing climate or weather-related disruption specifically. The COVID-19 crisis may lead to companies and entire industries rethinking their global supply chain model. This presents an opportunity for step change in government action to facilitate this and achieve multiple benefits.

This is applicable across all DAs, but more work is needed to understand regional differences. The evidence base is strongest for England, followed by Scotland, with less for NI and Wales.

6.7.3.2 Indicative costs and benefits of additional adaptation (B6)

There are some aspects of climate change risks and responses that have been quantified for food supply chain resilience. Even here, however, there is little information on the associated costs and benefits (in aggregate), as identified by recent review of food supply chains and adaptation (Watkiss et al., 2019), though it did identify potential adaptation measures and their potential (qualitative) benefits and costs, indicating net beneficial further actions exist.

6.7.3.3 Overall urgency scores (B6)

The urgency score is driven by the medium current magnitude and the potential for major disruption to supply chains from extreme weather in future, although future magnitude is unknown. There is limited evidence for effective analysis and adaptation measures. There are benefits to more action to help quantify and manage risks. The majority of these beneficial actions involve capacity building, institutional changes, or the development of new strategies, technologies or ways of working, which will take time to develop, test and implement.

Table 6.24 Urgency scores for risks to business from disruption to supply chains and distribution networks.				
Country	England	Northern Ireland	Scotland	Wales
Urgency Score	More action needed	More action needed	More action needed	More action needed
Confidence	Low	Low	Low	Low

6.7.4 Looking ahead (B6)

For the next CCRA there should be more learning from COVID-19, such as the scale of the consequences of supply chain disruption upon which to draw. It would also be useful to understand more about the behavioural aspects associated with supply chain disruption. For example, could climate hazards cause markets to disappear or cause shortages through stockpiling? If CCRA4 takes a more systems-based approach, perhaps this risk would not be assessed as a risk in its own right but considered as part of the food system or economic system as an interconnection between elements of the system. Furthermore, both national and international trade implications should be investigated, including assessments of climate impacts on trade relationships and the nature of trade routes. This should include consideration of international dimensions.

6.8 Opportunities for business from changes in demand for goods and services (B7)

Physical climate risks pose a threat to companies operating in the UK, but there are also some business opportunities arising from these impacts, including through shifts in demand for certain goods and services. The CCRA2 Evidence Report found that with sufficient information and climate change expertise, businesses could be expected to respond to market signals and exploit opportunities as they arise. However, the academic literature has only assessed a limited number of opportunities from climate change, mostly related to changing conditions for food and drink production (e.g. growth in the UK wine industry) and therefore the business response suggestion as set out in CCRA2, remains mainly untested. The most significant change has been the growing prominence of climate advisory services in recent years. In general terms businesses that anticipate changing markets may be able to gain an advantage, but various barriers exist that seem to prevent this (e.g. upfront cost barriers to entering new markets, as well as inertia, especially for SMEs), suggesting a role for government intervention to help companies realise these opportunities, similar to measures that have supported businesses to commence carbon management and within the context of developing industrial strategy.

6.8.1 Current and future level of opportunity (B7)

Note: it has not been possible to split the evidence by UK country for this opportunity.

6.8.1.1 Current Opportunity – UK wide (B7)

CCRA2 noted that the provision of products and services can be impacted by climate both directly and indirectly through changes in costs or operating expenditure; changes in demand; and through regulatory and other public policy responses. It noted limited evidence of the scope and scale of opportunities arising for companies in the UK and argued that unless prevented by regulation or hampered by low adaptive capacity it could be expected that companies will respond to growing risks and opportunities (Surminski et al., 2016). CCRA2 also warned that the adaptation action of one sector could have negative implications for other sectors or society at large – for example the potential withdrawal of insurance cover, or misguided flood defence investments and small businesses may need support in identifying and realizing opportunities arising from physical climate risks.

Since then, the evidence base has increased (for a summary of methods and approaches see Bonaventura et al., 2018). Earlier studies such as the K-Matrix for BIS (K-Matrix, 2013) fed into UKCCRA2 and have been updated or repeated for example by Ricardo Energy & Environment 2017, who estimated the size of the UK's 'adaptation market' (made up of commercial activities delivering public and private adaptation, flood risk management, research and advisory services) as £1.3bn in turnover with 9,860 jobs. (Ricardo Energy & Environment, 2017). However, these figures should be seen as very preliminary indications, subject to potential double-counting and omission of some adaptation activities, as acknowledged by the report's authors.

Other studies have used business disclosure reports under the CDP to assess the scale of opportunities (see for example Acclimatise for the Environment Agency in 2016). 62% of the market opportunities identified related to increased demand for existing and new products and services (Acclimatise, 2016). From CDP data (CDP, 2018), sectors identifying the highest number of market opportunities were manufacturing (e.g. water efficient products), financial and insurance (e.g. insurance and direct investment in climate resilience), construction, professional, scientific and technical activities (e.g. incorporating climate resilience into new developments and existing infrastructure) and information and communication (e.g. cloud-based computing to promote remote working). In a report based on its surveys, CDP (2019) reported that 225 companies had identified between them US\$236 billion in revenue globally from the provision of adaptation goods and services.

The CCC (2019a) noted a range of current opportunities including in the adaptation goods and services sector with consultancy and adaptation advice; engineering and manufacturing products to manage climate risks; cooling services in transport, construction and real estate, retail and manufacturing; tourism; insurance and other finance products; as well as agriculture, horticulture and food products (see also Chapter 3 (Berry and Brown, 2021) and Chapter 7 (Challinor and Benton, 2021). The extent to which these can be capitalised rest on factors such as: demand response, turnover time, adjustment of product lines, alongside quality and design of products/services,

retraining and restructuring of the workforce, organisational culture and agility. Moreover, most opportunities are coupled with risks or threshold effects, with many parallels to be drawn from the COVID-19 crisis and post-recovery opportunities.

Below we summarize evidence of current opportunities and where possible we report on scale and magnitude of the opportunity.

6.8.1.1.1 Advisory services

There are a wide variety of services being offered to support climate adaptation and risk management. Two European Horizon (2020) projects, MARCO (Market Research for a Climate services Observatory) and EU-MACS (EUropean MARket for Climate Services), which included UK case studies, conducted a systematic review. This analysed the current state of affairs regarding the uptake of climate services, assessing the development prospects, and proposing remedies to promote a larger utilization of the development and use of climate services. UK specific examples identified were in the legal sector (e.g. Client Earth, Clyde & Co). Other examples of climate services include providers of adaptation and engineering solutions (e.g. Acclimatise, ICF, AECOM, Arup, WSP), risk assessments and reporting (e.g. ERM, South Pole, Systemiq), climate models and scenario analyses (e.g. PwC, Vivid Economics, Cambridge Econometrics), climate finance (e.g. Mirova, Ortec Finance), climate data (e.g. Moody's, FourTwentySeven, Carbonne 4, CDP, MSCI, Jupiter Intelligence, RMS), climate communications (e.g. Climate Outreach) and climate intelligence (GRI, E3G, Tyndall Centre). Section 7.10 of Chapter 7 (Challinor and Benton, 2021) explores further how the UK is a leader internationally in climate risk disclosure best practices. The recent take-over of Acclimatise by insurance broker Willis Towers Watson underlines the current and future business opportunities in the resilience and adaptation advisory space. Development in risk analytics poses an opportunity for UK companies to lead the market in turning these tools into client offerings with a competitive advantage. The range of efforts to assess and share information about current exposure with investors, regulators and others alludes that current climate risks are beginning to be considered by those providing capital or making investment decisions. In addition, tools that help companies and investors with risk management also are present, such as the Future Fit Business Benchmark. This is a strategic management tool for companies and investors to assess, measure and manage the impact of their activities in alignment with the UN SDG's, available in a public commons license. Professional bodies have also developed guidance that seeks to increase adaptation awareness and integrate into assessments (better addressing opportunities and risks). For example, IEMA published updated guidance in 2020 for the consideration of climate change resilience and adaptation in the EIA process - EIA Guide to: Climate Change Resilience and Adaptation (2020). Guidance has also been developed by the Institute and Faculty of Actuaries, with IEMA as a user guide relating to Climate Related Financial Disclosures.

One example of a service-related opportunity are adaptation standards for businesses. The British Standards Institution (BSI) has developed adaptation standards that companies can use to identify internal roles and responsibilities and demonstrate their adaptation efforts to clients, investors and peers. This can lead to greater recognition and realisation of adaptation opportunities. A summary of recent standards can be found in Box 6.5. Existing standards also hold opportunities for action on Adaptation. The 2015 revised [ISO 14001 environmental management systems standard](#) has many

useful provisions, which include requiring the organisation to consider the wider context and expectations of interested parties, an enhanced focus on leadership and embedding a lifecycle perspective across the value chain. Also, to analyse risks and opportunities and to consider the potential impacts of changing environmental conditions, such as adaptation and climate change impacts. Some organisations such as IEMA have developed guidance to encourage more expansive use of these International Standards to help address adaptation. Many organisations have a form of Management System Standard (MSS) whether based on ISO 14001 or on other ISO standards (e.g. ISO 9001). All ISO MSS are based on the same high-level structure, thus allowing for climate change adaptation issues to be addressed via that MSS's relevant existing standard.

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Box 6.5 : Climate Change Adaptation Standard. Source: Communication from BSI Group during CCRA3 stakeholder engagement.

BSI (British Standards Institute) are the UK's National Standards Body, creating documents of good practice for industry. In July 2019 BSI produced the first adaptation to climate change standard: 'ISO 14090 Adaptation to Climate Change, Principles, Requirements and Guidelines'. This sets out actions for any organisation to create a plan or to enhance its plan for climate resilience and was led by Civil Engineer, John Dora. BSI are currently working with ISO (International Standards Organisation) to create a document on using [ISO 14090](#) as part ISO 14001 'Environmental Management Systems' (the most extensively used environmental standard in the world with over 17,000 certifications in the UK – recommended by agencies such as the Environment Agency).

As a wider part of the BSI programme of work on climate adaptation BSI are working with ISO on the preparation ISO 14091 on impacts, risk and vulnerability for adaptation (due to publish Q1 2021) and [ISO 14092](#) on climate adaptation for local authorities. BSI themselves have started work on a standard on adaptation pathways – a decision making process for short to long term and at any stage (due to publish Q2, 2021). All of these pieces of work have included contributions from organisation such as the CCC, Defra, HS2, Mott Macdonald, Anglian Water, Atkins and many others.

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structure, thus allowing for climate change adaptation issues to be addressed via that MSS's relevant existing standard.

6.8.1.1.2 Retail

For the retail sector increased sales of seasonal garments in the retail sector were noted when significant temperature change occurred (Bahng, et al., 2012). However, the increased variability in weather means production lines and global retail supply chains have to be better equipped to respond to change quickly, as discussed in Risk B6. Thus, projected retail opportunities may be hard to capitalise, particularly for small businesses who may be operating under just-in-time manufacturing and are unable to diversify production (PwC, 2015). Set against this economic opportunity, reports such as the enquiry in 2019 by the Environmental Audit Committee have recommended against escalating consumption, especially in terms of waste impacts and called for an Extended Producer Responsibility scheme for textiles, stronger eco-design principles and clear incentives for design for recycling, design for disassembly and design for durability. Weather variability as an additional demand consideration for seasonal garments may be addressed and considered within this broader context of sector sustainability.

6.8.1.1.3 Food and drinks

The sector has identified opportunities from reductions in water usage, as highlighted by the Food & Drink Federation's challenge to its members to reduce water usage by 20% by 2020, with British Sugar reducing water usage across its operational activities by 26% (FDF 2019).

6.8.1.1.4 Finance

In the finance sector there are opportunities linked to the sustainable finance and ESG agenda, including improved credibility and potential for market leadership, competitive advantage through early adaptation and being first movers, attracting clients and talent aligned to climate objectives and improved reputation (UNEP-FI, 2016). These opportunities are supported by studies, for instance, Deloitte EIB and Global Alliance for banking with values (2019) find that banks with good performance on material ESG issues outperform banks with bad performance on the same issues by more than 2%. Adaptation and resilience investment opportunities (discussed in B4) are growing but there are still few examples of realising those through innovative financial instruments (see for example Climate Bonds Initiative 2019 or GCA 2020).

In terms of specific product opportunities CCRA2 highlighted the insurance sector and identified three key opportunities: new insurance products, methodologies in flood insurance and British insurers scoping business opportunities in emerging markets with little insurance penetration (Surminski et al., 2018). Such opportunities continue to exist. New tools include parametric insurance for extreme weather events (Mercer 2018; Horton, 2018) which has the potential to avoid the incongruities of legal liability to climate change and is a promising alternative to loss-based insurance, especially because of the additional advantage of predictability. In addition, market opportunities for catastrophe bonds and resilience bonds are growing. There is also the potential for insurance to be used as a catalyst for government planning, as climate risk information from

insurance processes can support public sector anticipatory climate risk management, including loss prevention and adaptation (Surminski, Barnes and Vincent, 2019). There is also a promising partnership opportunity between the UK public and private sector on flood insurance, as increased partnership beyond just the national government and industry can help reduce flood risk and maintain affordable insurance premiums (Crick, Jenkins and Surminski, 2018).

6.8.1.1.5 Construction

Across the UK, there is evidence of further opportunities in the construction industry as businesses change their premises to adapt to climate change. This provides an opportunity for an increase in repairs, maintenance or clean-up contracts. For example, Northern Ireland has guides on their government website for the potential of entirely new projects and services, such as improved waste management or preventing soil damage during construction projects (Northern Ireland Business Information, 2019). This opportunity however will be set against impacts on public sector bodies who will face associated increased costs (for example within the NHS and Local Authorities). One further example identified in UKCCRA3 stakeholder engagement is urban green infrastructure and its provision and maintenance, such as green roofs, urban tree planting, park expansion and maintenance to maintain quality. Examples of value benefits within the UK have been recorded by tools such as the Greenkeeper project (Greenkeeper, 2020). However, how these opportunities are being realized by businesses is unclear.

6.8.1.1.6 Heritage sector

For the heritage sector increasing temperatures and extreme weather events intensify the need for repair and maintenance of heritage sites. Therefore, more will need to be spent on the materials industry (sandstone, slate etc) and on sector-specific skills (employees to repair traditional/historic buildings). As an example, an estimated £1.2bn (including grants) was spent on repairing and maintaining the historic environment in 2017 and private investment accounts for three quarters of all funding. At present, some bodies like COVID Historic Environment Resilience Forum (CHERF) are facilitating rebuilding, recovery and resilience opportunities. The industry supports 66,000 jobs (as per 2017 figures), and the skills investment plan for Scotland's Historic Environment accounts for new job creation (Historic Environment Scotland, 2019). Nonetheless, there are critical barriers that prevent these opportunities from being realised. For instance, rebuilding requires particular skill sets and thus, industry-wide retraining may be required. This may create bottlenecks and delay overall reconstruction response. Many businesses operate out of heritage assets such as traditional buildings and/or rely on heritage-driven tourism. Income loss due to COVID –19 and the lockdown may lead to further delays in addressing climate risks.

6.8.1.1.7 Agriculture

Opportunities for the agriculture, forestry and marine sectors are outlined in Chapter 3 (Berry and Brown, 2021). Recent evidence shows that many Northern Ireland farms have diversified, expanding business into other crops they do not currently grow and using land for business activities beyond traditional farming (Northern Ireland Business Information, 2019). New business activities can include energy or non-food use crops such as crops grown to generate heat and electricity or to

produce transport biofuels (Defra, 2013). The Nordic Development Fund (NDF 2020) identifies a range of opportunities for climate resilience products in agriculture (Box 6.6).

Box 6.6: Opportunities for suppliers of climate resilient products in agriculture. Source: NDF, 2020.

A report from the Nordic Development Fund (NDF) (2020) highlights that there are numerous opportunities for climate resilient products, services and technologies in private markets. Whilst most companies are not capitalising on this opportunity, those that are providing adaptation products/services are gaining a competitive advantage.

For instance, in the agricultural sector, most innovative resilience services are coming from small businesses. Moreover, businesses that have incorporated adaptation in their business models are best able to respond at the local scale. However, specific adaptation technologies and agricultural equipment are still being provided by large corporations.

NDF identify key barriers faced by suppliers of climate resilience products:

- Factors affecting business growth:
 - Limited access to credit and financial support.
 - Difficulties in proving a business case for individual products or services.
 - Difficulties in communicating instructions or product specifications to end users.
 - Regulatory, tax and financial frameworks are not sufficient to provide support for small businesses.
 - Limited support for innovation.
 - Constantly changing international standards.
 -
- Climate specific factors:
 - High 'switching' costs and risks in transitioning from existing practice to climate-resilient practice.
 - Limited integration of climate change into regulation.
 - Lack of incentives for addressing resilience.
 - Poor awareness of climate-change impacts as a business opportunity.
 - Final users are not aware of, or interested in, climate solutions and prioritise more urgent risks.
 - Difficulties in predicting climate risks accurately and quantifying future impacts in financial terms.

Addressing these challenges will expedite adopting opportunities in the agricultural sector, and specifically help SMEs. SMEs have been identified by NDF as leaders in climate resilient products, most likely to be adopting adaptation solutions and selling climate products to others.

6.8.1.2 Future Opportunity - UK wide (B7)

A number of possible opportunities for new or expanding sectors are known by stakeholders, but there is little or no literature available quantifying the size or potential future for these industries. Stakeholder engagement in the course of the UKCCRA3 project noted future opportunities for rural land use industries, such as afforestation, peatland restoration, on-farm reservoir creation and maintenance, paludiculture, different types of agricultural diversification. And there may be significant opportunities in the UK energy sector in the next 5 years as discussed in the UK'S Draft Integrated National Energy And Climate Plan (NECP government document) 2019 (BEIS).

6.8.1.2.1 Food

As highlighted in section 7.4 of Chapter 7 (Challinor and Benton, 2021), climate change impacting global patterns of food production could create need opportunities from imports and/or exports. It is important to assess agriculture in the context of trade effects, not just productivity – a recent PESETA 4 publication (2020) shows the UK benefits. In addition, IIASA modelling work with GLOBIOM finds any negatives are reduced considerably as a result of market adjustments due to more severe climate change impacts on agriculture outside Europe. Changing the type of seafood available within UK waters through wild capture fisheries, via potential changes in species and distribution within the fishery. In addition, there is an opportunity to increase productivity of the fishery through enhanced production at higher latitudes (Garrett et al., 2015). Within the seafood industry, opportunities could arise in wild capture fisheries, from potential changes in species and distribution and the productivity of the fishery, e.g. enhanced fisheries production at higher latitudes (Garrett et al, 2015). More information on opportunities within the seafood industry is found in Chapter 3 (Berry and Brown, 2021).

6.8.1.2.2 Tourism

Further opportunities might arise from extending the local tourist season due to warmer summers: there are numerous studies that show in Northern European regions and the British Isles, tourism activity increases from climate change (for beach and summer tourism) could lead to limited and localised economic benefits (e.g. Perrels et al., 2015)¹⁵. Barrios and Ibañez Rivas (2013) used a travel cost approach and hedonic valuation of recreational demand and amenities in a scenario of approximately 4°C global warming at the end of the century¹⁶. They estimated that in Southern EU Mediterranean countries, that climate change scenario would lower tourism revenues between - 0.45% and -0.31% of GDP per year. In contrast, in Northern European regions and the British Isles, tourism activity could lead to benefits, with the British Isles gaining +0.3% of GDP per year respectively. However, the impacts depend on whether holiday duration and timing are fixed, or whether there is a redistribution to shoulder seasons. If these adaptations occur, the gains to the UK fall, to 0.2% of GDP if tourists change duration, and gains are negated if tourists change duration and timing. Clearly any economic benefit that is identified, will have to be transparently communicated

¹⁵ Tourism is a major business in the UK and there are many subtleties associated with climate change and tourism. We therefore recommend further work in this sector.

¹⁶ ECHAM5 climate model with the SRES A1B scenario

within a broader and balanced explanation of the extensive costs to the economy and society from the changing climate.

6.8.1.2.3 Digital innovation

Digital innovation plays a key role for businesses (Power et al., 2020). There is an opportunity for in-house climate data analytics within businesses, as firms are increasingly adopting scenario analysis for risk management, investment decisions, and identification of investment opportunities (Mercer, 2019) in response to the growing ratings risk posed by climate change (Economist, 2019). With the abundance of data and the rapid development of predictive modelling, decision-making based on algorithms has potential to change the way businesses view, understand, and analyse risks, as well as adopt adaptive behaviours (Ford et al., 2016). Algorithmic modelling and big data are perceived as a promising way to support climate change adaptation and can reduce research costs for businesses (Huntingford et al., 2019). Businesses increasingly rely on algorithmic reasoning for decision-making, such as using artificial intelligence to process large datasets to discover historical weather patterns, optimise climate forecasting, predict early crop yield or crop issues, and real time disaster risk mapping. Water companies are exploring these technologies applied to smart metering or analysing demand and consumption trends. Nonetheless there are caveats to this. For example, artificial intelligence (AI) early disaster warning systems are trained using historical data on weather patterns, but there is a lack of understanding of future model predictions. This could result in false or negative alarms (Sakata, 2018). To ensure AI is used responsibly, government and industry leaders need to work closely to use its potential to aid corporate decision-making. Frameworks for decision-making under uncertainty suggest that it can feel rational to delay significant and irreversible investment (Agrawala et al., 2011), but if evidence generated through AI or otherwise shows that benefits will eventually be accrued, this supports a business case for investing in adaptation.

6.8.1.2.4 Shipping

A nascent literature is identifying opportunities for shipping, for example, UKCP18 identifies that average significant wave height may reduce under climate change, which could improve access windows for safer at-sea working (Palmer et al., 2018). Further insights from the UKCP18 projections can be found in Chapter 4 (Jaroszweski, Wood and Chapman, 2021). In addition, the shipping industry could see large fuel savings and associated reductions in greenhouse gas emissions by using transit shipping through the Arctic (Masselink et al., 2020) – this is covered in the risk analysis in Chapter 7 (Challinor and Benton, 2021). As highlighted in Section 7.8 of Chapter 7 (Challinor and Benton, 2021), due to the construction and launching of the RSS Sir David Attenborough the UK maritime sector is now well-placed to advise the rest of the world on how to implement the Polar Code (mandatory requirements relating to the operation of ships in polar waters).

6.8.1.2.5 Wine

Some UK-based work has been done on the current and future opportunities provided by the UK wine sector (Box 6.7), but no analysis of the potential future size of the opportunity has been found for other sectors in the literature. New opportunities for UK growers can arise both from changes in UK climate as well as from deteriorating conditions for wine growers in other regions across the

world, making wine production in the UK more viable. See Chapter 7 (Challinor and Benton, 2021) for international issues.

Box 6.7: Opportunities for the UK Wine Sector. Source: CREWS-UK (2021); Nesbitt et al., 2021, 2018, 2016; Gannon et al., 2021a; Watkiss et al. 2019.

Watkiss et al., 2019 reported that:

- There is no specific policy objective for English wine production, and this was not identified in the Government’s National Adaptation Programme.
- However, in 2016 the English Wine Round Table with the Wine and Spirit Trade Association and Defra made pledges to increase the hectares of vineyards from 2,000 to 3,000 ha by 2020, and to increase wine production to reach 10 million bottles in 2020, with the ambition that 25% of this would be exported, generating £30 million in export revenues (WSTA, 2016). Looking further, Wines of Great Britain has estimated that in 2040 annual production could reach 40 million bottles (WGB, 2018).
- The analysis quantified the potential benefit of ~£50Million/yr by the 2050s but only if climate variability is addressed in planning by growers and local authorities.
- There are high potential economic benefits from creating enabling environment and enhancing uptake of low regret adaptation, with high benefit to cost ratio.

The CREWS (Climate resilience in the UK wine sector) Report offers the following insights:

- Viticulture in the UK expanded 370% (761 to 3579 hectares (ha)) between 2004 (when sparkling wine started to dominate production – Nesbitt et al., 2016) and 2019 (WineGB, 2020a) (Nesbitt et al., 2021).
- Growing season average temperatures (GSTs) in the main UK viticulture regions have warmed ~1°C between the 1981-2000 and 1999-2018 periods to a recently more consistent >14°C GST (Nesbitt et al., 2021). This warming underpins the recent rapid growth of the UK wine production sector and its dominant focus on sparkling wine varieties, described by producers in Gannon et al., (2021a): “we can ripen grape varieties that we couldn’t ripen 20 years ago... we couldn’t make the wines that we are making today, 20 years ago”.
- The sector’s market capacity remains unclear. However, where viticulture investment is sought, the potential already exists to further develop prime vineyard land, predominantly in southern and eastern England (Nesbitt et al., 2016; Nesbitt et al., 2018).
- The very nexus that facilitated the introduction and current ‘success’ of dominant varieties in the UK – climate change – may continue to provide opportunities for further varietal or wine style change. Nesbitt et al., (2021) model near term (2021-2040) trends and variability in the vine-growing season, using the latest high-resolution (2.2km) ensemble of UK climate change projections (UKCP18) for the UK. In this analysis:
 - o Growing Season Temperatures (GST) are projected to increase by a further 1-2.5°C.
 - o Significant areas within Eastern England, the Midlands, south-central and south-eastern England are projected to have over 50% of years, during 2021-2040,

within the range of growing conditions that led to a bumper UK grape harvest in 2018.

- o Top vintage Champagne 'conditions' are re-produced in English sparkling wine producing areas more consistently and new areas of suitability are projected to emerge.
- o Growing season temperatures from 1999-2018 in Burgundy (France) and Baden (Germany) in high quality vintage years within that period, when projected over the UK for the next 20-years as a climate analogue, cover large areas in southern and eastern England, suggesting potential for still Pinot Noir production in the near-term.

6.8.1.3 Lock-in and thresholds (B7)

6.8.1.3.1 Are there lock-in risks? (B7)

There is a risk of lock-in related to land use change to take advantage of new forms of food production. For example, land-use change for new wine production needs to consider the changing climate when considering varietal choice for new planting as it involves high capital investment and the payback time for wine is longer than for many other agricultural crops due to the time needed for vines to mature (Watkiss et al., 2019). The risk of lock-in emphasises the urgent need to increase adaptation action now, even in the short-term (Watkiss et al., 2019). There are risks of lock-in additionally from potential poor soil management due to lack of crop rotation or reliance on particular varieties.

The CREWS-UK project (CREWS-UK, 2021) highlighted examples of lock-in within established viticulture landscapes, limiting adaptive capacity (Gannon et al., 2021b). Certain adaptation options, including the decision of where to plant vines and which varieties and rootstock to plant – notably adaptation options which are often held to have some of the highest adaptation potential (Nicholas & Durham, 2012; Watkiss et al., 2019) – require much larger investments in terms of finance and effort within established vineyards and thus produce intransigence within viticultural landscapes when climate risk is not incorporated into vineyards' initial design. Cultural and economic factors shape this intransigence, including through marketing decisions. For example, the world's most famous wine regions are often associated with a very small number of varieties, concretised in protected designations of origin (PDO). Analysis in Gannon et al., (2021b) suggests the young, and much less established UK viticultural landscape has much greater flexibility, to establish development trajectories that account for changing climate risk. Yet, the authors also identify multiple ways in which the UK landscape is reproducing patterns of lock-in seen in more established viticultural regions, for example through sector concentration on a limited range of grape varieties in sparkling wine production and through regulatory structures, including PDOs.

As discussed in the case of opportunities in retail and consumer spending, there are also risks locking in to mal-adaptative products and services, such as air conditioning. Moreover, business as usual responses to changing demand for services, such as seasonal clothes, without identifying climate

change as a risk driver, compromises production line's ability to respond to weather variability or extreme weather events.

6.8.1.3.2 Are there potential thresholds? (B7)

There are a very large number of potential opportunities, each with particular threshold effects, either in terms of biophysical thresholds (e.g. thresholds for suitability for new crops, comfort levels for beach tourism), but also potential investment return thresholds, when it makes sense for the private sector to enter and scale-up.

Watkiss et al., (2019) found studies projecting that 2°C global warming would change England into an 'intermediate climate' wine region, i.e. a major positive outcome compared to the current climate (Georgeson and Maslin, 2017). Extrapolating further, 4°C of warming could make England into a 'warm' wine region. Therefore, while climate change could open a range of opportunities for growing different varieties of grapes which are currently cultivated in Europe, the level of warming will affect the type of opportunity. Further, there are likely to be a number of other threshold effects: while there is likely to be a fall in lower temperature threshold levels for wine growing, possible threshold risks are identified around water availability, and the temperature suitability ranges (and heat limits) for some current colder temperature wines. There is potential for inter- and intra-annual temperature and precipitation variability to increase under climate change (Beniston et al., 2007; Fraga et al., 2013). Moreover, warmer spring temperatures are advancing the grape-growing season, with earlier bud burst bringing the period of time that vines are vulnerable to frost-risk forward in the year (CREWS, 2020). Weather thresholds are suspected to have similar effects in the case of tourism and leisure and recreation opportunities.

The ClimateWise physical risk study (Westcott et al., 2020) shows that the effectiveness of adaptation measures such as property level protection decreases once certain temperature degree thresholds are reached – pointing out that there are limits to adaptation and that action now is required to keep risks at a manageable level.

6.8.1.4 Cross-cutting risks and inter-dependencies (B7)

The opportunity for business from changes in goods and services depends on consumer demand and business ability to respond to this. Consumer demand may be hampered by climate impacts – for example for location specific services, such as tourism, where flooding (Risk B1) and coastal erosion (Risk B2) at sites might hamper the size of the opportunity. Moreover, business capacity to respond to food and agriculture opportunities are constrained by water scarcity (Risk B3) and supply chain (Risk B6) risks. The inability for supply chains to respond to shocks and changes in demand has been noted in the COVID-19 crisis response (WEF, 2020).

In some cases, opportunities may encourage maladaptation – such as the increased supply of air conditioning cooling products, which could exacerbate long-term climate risk. This was considered in the case of air conditioning units in Risk B5. Moreover, short-term opportunities in reconstruction are far outweighed by the infrastructural damage of extreme weather events and associated lost

business revenue streams. This is seen in the case of heritage tourism sector, where frequent site damage threatens overall firm survival, despite short-term job creation.

Opportunities also depend on the macroeconomy. For instance, recession, employment loss and health risks post-COVID-19 could limit opportunity realisation. This is especially true for the climate advisory sector, as demand for services may fall in cash-strapped sectors and amongst SMEs. Ultimately, increased variability of extreme events and longer-term climate impacts mean most opportunities depend on numerous factors in order to be realised.

6.8.1.5 Implications of Net Zero (B7)

Business opportunities related to climate resilience will have to be aligned with the UK's path to Net Zero. The scope for increased summer tourism, for example, will have to account for the carbon footprint of tourists. Similarly, the growth in wine making will have to be embedded into a wider strategy for reducing land use-related greenhouse gas emissions. There may be business opportunities in design and deployment of zero-carbon flood resilience solutions (Risks B1, B2) and the design, manufacturing, installation and maintenance of zero-carbon cooling technologies (Risk B5).

There may also be business opportunities arising from the need to make Net Zero solutions climate-resilient, which may have implications on their design. Sometimes this creates synergies (e.g. nature-based solutions) and sometimes it might create trade-offs for example energy efficiency vs overheating in the case of low-carbon retrofits (as suggested by the CCC, 2020a).

6.8.1.6 Magnitude scores (B7)

The magnitude scores (Table 6.25) are based on expert judgement and anecdotal evidence for the scale of current and future opportunities. The magnitude of this opportunity is expected to increase however there are likely to be thresholds (adaptation limits) such as with higher warming scenarios such as 4°C by the end of the 21st Century. A range of UK-wide sector-specific opportunities are discussed in the literature, the size of which varies based on the sector, but little quantification. Hence there is low confidence across magnitude scores.

Table 6.25 Magnitude scores for opportunities for business from changes in demand for goods and services.					
Country	Present Day	2050s		2080s	
		On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century	On a pathway to stabilising global warming at 2°C by 2100	On a pathway to 4°C global warming at end of century
England	Low (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)
Northern Ireland	Low (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)
Scotland	Low (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)
Wales	Low (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)	Medium (Low confidence)

6.8.2 Extent to which the current adaptation will manage the opportunity (B7)

6.8.2.1 Effects of current adaptation policy and commitments on current and future opportunities (B7)

6.8.2.1.1 UK-wide

Given the low level of understanding of the opportunities to businesses from climate change, and the likely barriers to small businesses in particular to enter new markets, there is likely to be a role for Government in providing evidence and supporting businesses to transition to new functions as the climate changes.

An example of this is the UK's 'resilience offer', which is promoted internationally across a range of sectors (e.g. in finance, infrastructure), aiding other countries' efforts to increase their own resilience to the effects of climate change. UK Export Finance is, for example, working with the Environment Agency and OGDs to develop a UK offer in the Climate Resilience space, specifically, in the area of Flood Control Risk Management (FCRM). This work is focussed on the internationalisation of a domestically-focussed supply chain. This remains a work in process, with the aim of producing a UK FCRM supply chain and export finance prospectus in 2021.

The Department for International Trade (DIT) is working across government to influence policymaking and ensure UK businesses and the City of London can capture opportunities and demonstrate leadership in finance and insurance, including through the Global Resilience Summit in 2021. DIT will promote a consolidated resilient infrastructure offer (e.g. resilient infrastructure offer in water; G2G campaigns; linking UK firms with international partners to deliver infrastructure in third countries).

The Government's UK Industrial Strategy also does not reference climate change adaptation and it is left up to the industries who could benefit from climate change to consider the opportunities. The CCC (2019a) concluded that further research is needed to understand the size of direct and contributory climate-related business opportunities across the UK. They also recommended that BEIS should set clear deadlines for ensuring listed companies and large asset owners report on climate-related risks and opportunities, as recommended by the Green Finance Taskforce and Environmental Audit Committee (see risk B5 above). This should include committing to new legislation if reviews find that the quality of reporting does not improve.

Similarly, the Government's 2019 Green Finance Strategy provides an opportunity to direct more finance towards adaptation and develop new adaptation products and services but does not provide a detailed plan on how to stimulate the adaptation economy, which is lagging behind growth in other countries (UNEP, 2018; Georgeson et al., 2016). The Budget announced in March established a £10 million Natural Environment Impact Fund to help prepare green projects that could be suitable for commercial investment in order to encourage private sector support for environmental restoration, including climate adaptation benefits.

6.8.2.1.2 England

The CCC (2019a) found that there is no overarching plan in the second National Adaptation Programme (Defra, 2018b) to support businesses to realise the opportunities from climate change. Local Industrial Strategies (LIS) do mention climate related action, but not in the specific context of the reduction of climate risk driving economic policy. For example, the North East Local Enterprise Partnership responded to inquiries about climate action following their July 2019 strategy summit, stating that the priority focus for LIS continues to be productivity, but there is work focused on North East's opportunities to invest into decarbonisation and wider climate related action. In addition, the North East Strategic Economic Plan does recognise the need to tackle climate change and promote clean growth (NELEP, 2019). Another example of this is using natural capital in a Local Industrial Strategy (LIS) to protect infrastructure from climate risks, such as flooding, drought and extreme temperatures, to secure industrial supply chains against climate-induced shortages of raw materials, and to provide uninterrupted supplies of water to industrial water users (Rural Enterprise UK, 2019).

6.8.2.1.3 Northern Ireland

Northern Ireland has a free service offered by Invest Northern Ireland – the government’s official online channel for business advice and guidance, including a dedicated information guide on how to “Adapt your business to climate change” (NI Business Info, 2020). This guidance offers best practice advice on why Northern Ireland businesses should adapt to the effects of climate change. It highlights the risks and opportunities that could result from climate change and how businesses can manage these. Helpline numbers and external links signpost local businesses from the online guidance to the relevant experts, including government departments and business support organisations, who can assist them. In 2019-20, customers made 12,500 views of climate change adaptation and prevention guidance on nibusinessinfo.co.uk. The ongoing maintenance and development of this guidance ensures the communication of key future changes and the highlighting of climate-related support to Northern Ireland businesses. The site is a channel for communicating climate adaptation support and business-related initiatives via its Business News section, Events Finder, Business Support Finder, monthly newsletter and social media channels.

6.8.2.1.4 Scotland

In April 2018, ClimateXChange published a paper on ‘Scoping and Sizing the Scottish Adaptation & Resilience Economy: An overview of methods’ (Bonaventura, 2018). This paper made recommendations on how to progress the scoping and sizing of the ARCC economy in Scotland, by establishing a baseline assessment of the Scottish A&RCC Economy and developing a method to support periodic updates to the baseline dataset. The newest Scottish Adaptation Programme published in 2019 (SCCAP2) includes a sub-outcome on business opportunities from climate change. Included under this theme is the provision of guidance for businesses to be climate-ready, though it is not known how this has yet translated into a change in the size of the adaptation economy in Scotland.

6.8.2.1.5 Wales

Welsh Government’s climate adaptation plan, Prosperity for All: A Climate Conscious Wales includes a theme for ‘successful businesses’ and sets out multiple actions to support businesses in understanding climate risk and adaptation. This includes plans to review and republish its current Climate Change Business Adaptation tool. No references are made to support business in finding opportunities from climate change, however revision of the adaptation tool may prove to be a useful channel to do this. Post-EU exit support in Wales includes farm payments as outlined in the ‘Sustainable Farming and Our Land’ document, and this support based around sustainability will support farm income and rural economies while delivering interventions in land management to support climate resilience. Landowners seeking support must now enter into an ongoing dialogue with Welsh Government and commit an approach that is built firmly on the principles of collaboration – while progress in reducing carbon footprint is part of this agreement, adaptation will be an important part of farm business development for the future and Welsh Government intends to provide a range of support for that purpose via the proposed new scheme. The Welsh Government also includes actions to maximise adaptation benefits in the design of the ambitious plan for a National Forest in Wales as well as encouraging farmers and other land managers to plant

new areas of woodland through the Woodlands for Wales Strategy, and to identify opportunities for housing retrofits as part of efforts to decarbonise the housing stock. The Welsh Government is researching land suitability through their CSCP09 report, and sustainable development principles guide the fisheries post-EU exit strategy as well.

6.8.2.2 Effects of non-governmental adaptation (B7)

Overall one can argue that it is down to individual businesses to identify, assess and realize business opportunities. However, there is evidence (Watkiss et al., 2019) that Government can support this by creating an enabling environment. Public private partnerships could play a significant role in supporting corporate adaptation. This was recently investigated by the ESRC-funded 'Place-based Climate Action Network' (PCAN) which is working with businesses in city-specific, cross-sector Climate Commissions across several cities in the UK. The Commission aims to catalyse the projects and partnerships that reduce carbon emissions and increase climate resilience in a way that is tailored to particular locations with their mix of physical and economic geography, cultural and historical legacy, and demography. Business activity in city commissions can be concerned with improving operational efficiency and risk profiles, future-proofing existing activity, creating new products and services for new markets, or, often, a mixture of all of these. Developers– like Citu and CEG in the Leeds Climate Commission and CCG in the Edinburgh commission – are seeking to reduce the energy costs associated with new projects, but also to be part of creating a city-wide demand for low energy and resilient housing, whilst collaborating with infrastructure providers and public sector agencies. Privately Owned Public Utilities are well-represented in local Commissions, with water companies (e.g. Yorkshire Water), gas network operators (e.g. Northern Gas Networks) and electricity providers, exploring their role as incumbents in a system undergoing rapid change. Professional services firms in law and finance are also engaged with city commissions, often seeking ways to deploy more locally expertise gained internationally, such as green bond issues or private wire supply agreements (PCAN 2020).

6.8.2.3 Is there an adaptation shortfall? (B7)

From the available data it is not possible to tell the extent to which UK businesses are identifying and realising the opportunities from climate change. The lack of data on business opportunities suggests that opportunities may be limited and/or not being recognised by businesses. For instance, Deloitte et al., (2019), recognise that not all ESG issues matter equally for financial performance, and the relevance and opportunities vary depending on the sector and firms in question. There are also gaps in sizing the potential size of the adaptation goods and services sector across the UK and separately for each administration.

6.8.2.4 What are the barriers preventing adaptation to the opportunity? (B7)

In our view there is still a large awareness gap and limited technical understanding of climate opportunities. Although climate change awareness overall is growing, the business sector is currently dominated by short term concerns around EU exit and COVID-19. Medium- and longer-term risks are overlooked and could benefit from Government prompting.

6.8.2.5 Adaptation scores (B7)

Table 6.26 Adaptation scores for opportunities for business from changes in demand for goods and services.			
Are the opportunities going to be managed in the future?			
England	Northern Ireland	Scotland	Wales
Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)	Partially (Low confidence)

6.8.3 Benefits of further adaptation action in the next five years (B7)

6.8.3.1 Additional planned adaptation that would address the adaptation shortfall? (B7)

Identifying opportunities in increased demand for goods and services, such as climate advisory or adaptation products are important to make a business case for climate adaptation in the next five years. This requires greater evidence, such as case-studies, and further investigation into emerging sectors. Currently, there is low confidence in information available, and some opportunities, such as in the retail sector, require further investigation. Business capacity needs to be assessed post-COVID-19, to determine whether these opportunities will be realised, and what barriers exist.

Across the country there appear significant opportunities linked to retro-fitting of the building stock. Most initiatives such as the smart energy programme, are currently aimed at achieving low-carbon targets. Using these investments to also increase climate resilience of buildings would bring employment and profitability to construction and advisory services.

Opportunities in some sectors, like increased use of air conditioning due to hot weather, must be reassessed, especially in view of lock-ins, maladaptation, threshold effects and associated transition risks, such as changes in energy policy.

In view of COVID-19, a greater emphasis must be placed on transformational adaptation, and the opportunities this brings (Tompkins et al., 2010; UKCIP, 2015). Changes in demand for goods and services must be viewed in tandem with sectoral change, technological advances and the institutional and labour-market changes. The emphasis placed on 'green stimulus' presents government-backed demand in sectors. Whilst the UK currently ranks highly in the 'Green Stimulus Index', this is largely due to underlying environmental performance.

There are also some new opportunities in transport, industry and energy (Vivid Economics and Finance for Biodiversity Initiative, 2020). Opportunities for financial investments have also been identified. However, it remains to be seen whether there is industry-wide demand for adaptation solutions (Vivid Economics and Finance for Biodiversity Initiative, 2020).

Further investigation is required into the regulatory and institutional networks that can facilitate these opportunities. The LSE Climate Risk Business Survey (2020) found that respondents engaging

with suppliers, regulators, banks, investors and insurers are undertaking a more diverse range of adaptation actions. It remains to be seen whether recommendations for investment in adaptation technologies presented by the CCC (2020) or expert calls for a Sustainable Recovery Alliance (Allan et al., 2020; Hepburn et al., 2020) proposed to the Government will occur and produce benefits.

6.8.3.2 Indicative costs and benefits of further action (B7)

Given the range of sectors and opportunities it is difficult to identify specific costs and benefits of adaptation. There are sectors where analysis has been undertaken (e.g. Watkiss et al., 2019 for wine) which indicates that under a scenario where wine growers were able to realise the benefits of climate change due to better information (and appropriate response), and at the same time introduce adaptation measures to address potential variability risks, there would be very large economic benefits, and a high benefit to cost ratio.

6.8.3.3 Overall urgency scores (B7)

Table 6.27 Urgency scores for opportunities for business from changes in demand for goods and services.				
Country	England	Northern Ireland	Scotland	Wales
Urgency Score	Further investigation	Further investigation	Further investigation	Further investigation
Confidence	Low	Low	Low	Low

Note: The urgency score is based on expert judgement due to lack of quantified analysis. The magnitude of this opportunity is expected to increase however there are expected to be thresholds (adaptation limits) with higher temperature increases such as 4°C global warming. Overall, the costs and benefits of adaptation solutions are likely to vary on a case-by-case basis, and this is one area where the evidence base is especially low and would benefit from more investigation over the next five years.

6.8.4 Looking ahead (B7)

Looking ahead, more evidence is required for CCRA4 on business opportunities. Most case-studies available merely present a superficial overview of short-term demand for products/services, without commenting on opportunity realisation and business capacity to respond. Academic evidence in particular, is lacking, and further investigation is required to assess the robustness of findings in this section. The reliability of sources and validity of claims made in the grey literature require further investigation.

Opportunities must be systematically linked to the business and institutional capacity for realisation. Opportunities arising from the COVID-19 recovery requires particular attention. Longevity of

demand for goods and services must be considered, as well as the demand variability (e.g. fluctuation in seasonal retail sales).

Importantly, any opportunities should be viewed in tandem with the risks they are arising from. Benefits must be weighed alongside the larger-scale costs and damages involved. Evidence on climate risks must extend its reach beyond governmental institutions by working co-productively with businesses. Such inclusivity is paramount to promote more robust evidence-based local climate adaptation strategies where different approaches are needed for identifying risks and how these risks affect different decision-makers (Howarth et al., 2020).

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6.10 APPENDIX

The Business function approach

We apply a business function approach as per CCRA2 to investigate if and how climate impacts can disrupt current business practices or create new opportunities across six key business functions.

These functions are:

- **‘Access to capital’** business function reflects on the implications for access to finance, including insurance, loans, investor relations and credit ratings.
- **‘Distribution’** function is referring to logistics, which includes utilities and transport infrastructure. ‘Distribution’ addresses the downstream side of the production process and business interaction, in other words, the ways in which finished products and services are distributed across customers and markets.
- **‘Employees’** looks at the implications for workforce in terms of working environment and recruitment. It also refers to aspects related to customers’ and suppliers’ comfort as well as changing lifestyles and social trends. Labour productivity is an important aspect in this context.
- The **‘products and services’** business function refers to the business area of markets and processes. Markets include the changing demand for goods and services as well as altering consumer behaviour. It also takes into account emerging markets for new products and the early movers’ perspective in developing products and services. The function also incorporates impacts on production processes and service delivery under given regulation. In other words, products/services look at economy-wide aspects, rather than firm specific. It includes markets and the structure of the economy.
- **‘Site locations’** refers to the way in which buildings and site properties are designed, constructed and maintained, as well as how these facilities are managed. It considers how the choice of location drives climate risks and opportunities.
- **‘Supply chain’** covers the upstream part of the production process as it refers to searching and extracting materials and resources.

This business function approach allows for analysis of risks and opportunities from climate impacts across business and industry sub-sectors as well as across regions (UKCIP, 2014). Businesses first choose their site location. They then access capital and depend on employees to transform intermediate goods procured through the supply chain. These are distributed via networks as final products and services. Thus, the business function approach allows us to capture how and where goods and services are being produced, and how a company interacts with the rest of the economy. It is hoped it will assist businesses in climate risk preparedness. As a respondent to the LSE Survey (Matthews and Surminski, forthcoming) notes, “We need some joined up thinking from all sectors, with a long-term strategy...using sound and fully measured science to give informed decisions on issues”. For each of these functions we ask how this is currently impacted by climate, what impacts are expected for the future, and what responses are already being taken. Risks across functions are outlined above.

