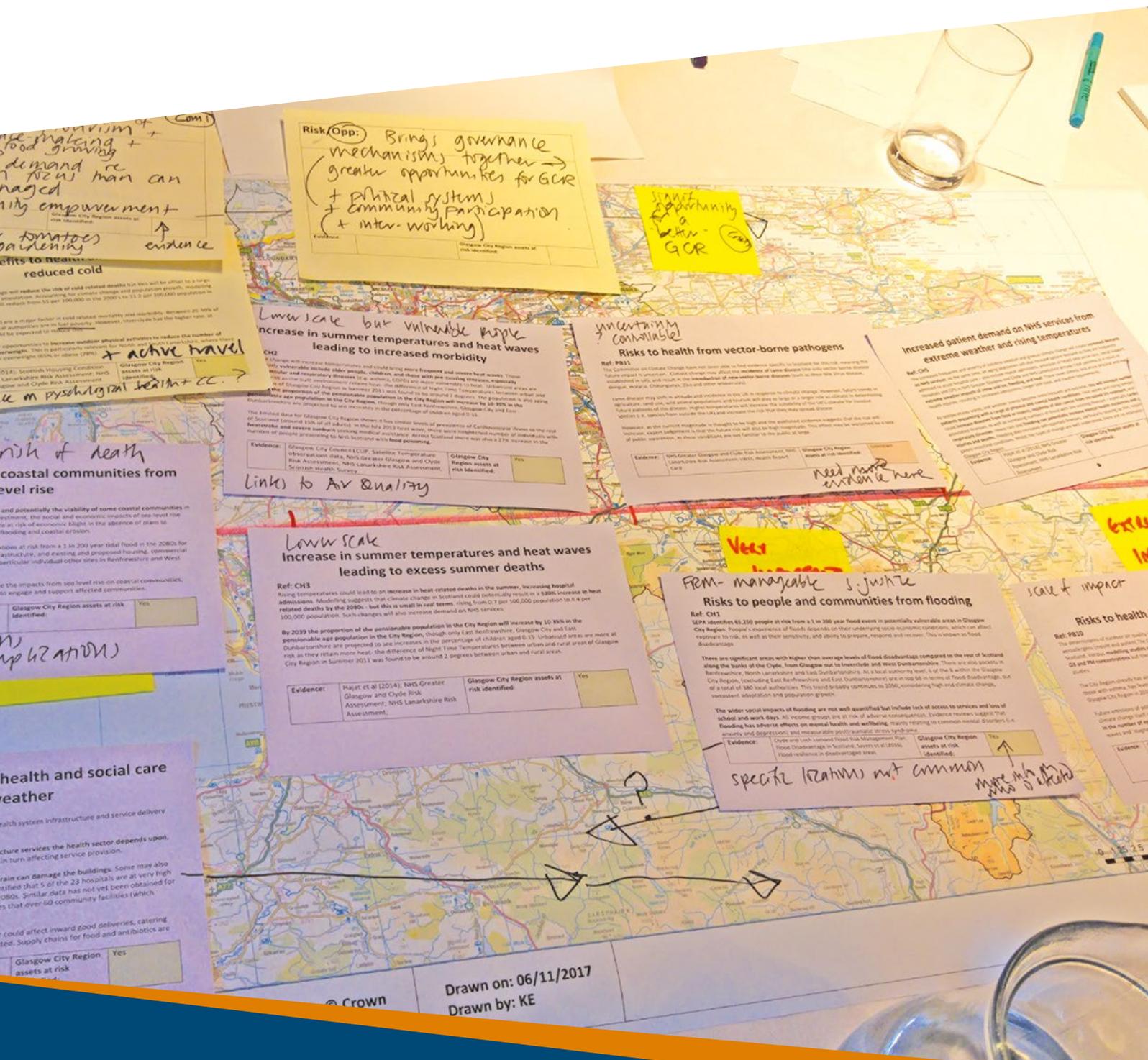


ClimateReadyClyde



TOWARDS A CLIMATE READY CLYDE: CLIMATE RISKS AND OPPORTUNITIES FOR GLASGOW CITY REGION

METHODS AND APPROACH

JANUARY 2019

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1. INTRODUCTION

This document sets out the overall approach taken to Glasgow City Region's first climate risk and opportunity assessment.

In doing so, it aims to:

- Ensure the way in which the assessment has been undertaken is clear and transparent to interested parties;
- Demonstrate the alignment with, and contribution to, other spatial scales of risk assessment in the UK, such as the UK Climate Change Risk Assessment and Scotland-level assessment; and
- Support replication and improvement of the process by other places and organisations.



2. PURPOSE, OBJECTIVES AND BENEFITS OF THE ASSESSMENT

To develop Glasgow City Region's Climate Adaptation Strategy and Action Plan, the Climate Ready Clyde Board requires an evidence base of where to place its efforts in order to ensure timely, proportionate actions to respond to climate change. Therefore the overarching objective of the assessment is to:

“Identify and prioritise the risks and opportunities from climate change to Glasgow City Region's economy, society and environment between now and 2080.”

The assessment process identifies priorities for further action at the city region level over the next five years (2020 – 2025). This could be where there is not enough action taking place, where research or capacity building is needed to address risks or realise opportunities that will materialise in future. It could also be where further no/low regret action could be taken which is relatively cost effective or delivers wider benefits, or there is a need to avoid locking in future risks and vulnerabilities.

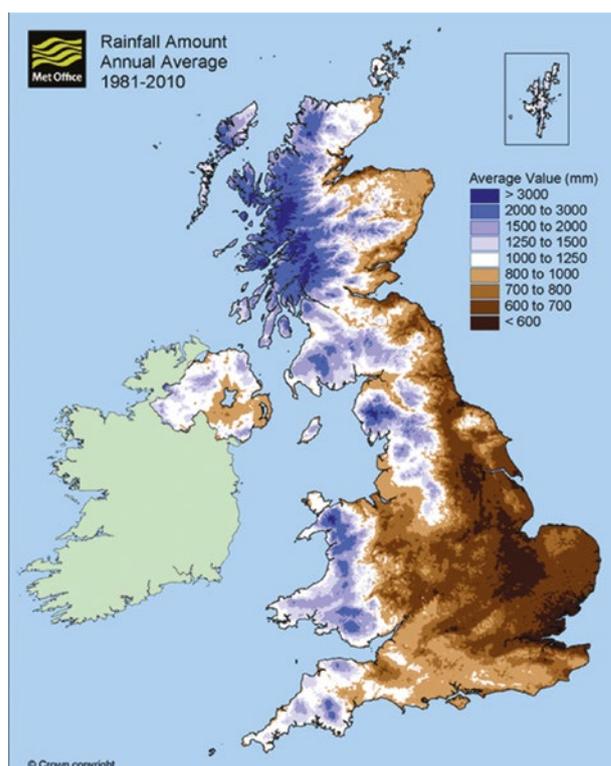
There are a number of additional benefits to conducting a local-level Risk and Opportunity Assessment. These include:

- **Generating consensus for action on the key climate change risks/opportunities** – a city-region specific process will ensure decision makers and the public recognise the unique challenges as a result of the local climate and the socio-economic characteristics of the city region.
- **Identifying how climate change will be experienced within Glasgow City Region.** Whilst the identified national risks and opportunities are likely to be relevant to Glasgow City Region, the risks and opportunities will be different to those in other parts of Scotland or the UK due to local factors. Most notably, Glasgow City Region is considerably colder and wetter than other parts of the UK. The risks and opportunities may also be modified by demographics, topography,

infrastructure, the built environment, land use patterns, and natural heritage. A local assessment will help account for these variations.

- **A holistic approach to understanding climate change risks and opportunities** – assessments of different climate change risks and opportunities have so far been conducted by different organisations. The assessment will draw this information together to enable a more holistic and shared understanding of the relative importance of action in each sector, or on each element of climatic change.
- **Identifying work that is currently underway to address climate risks and opportunities** – The assessment will help the partners understand where activity is already underway and those where new action will be required to help meet the scale of the challenge.

Fig 1. Annual average rainfall amount for UK 1981 – 2010. Source: Met Office, 2018.



2.1 Introduction

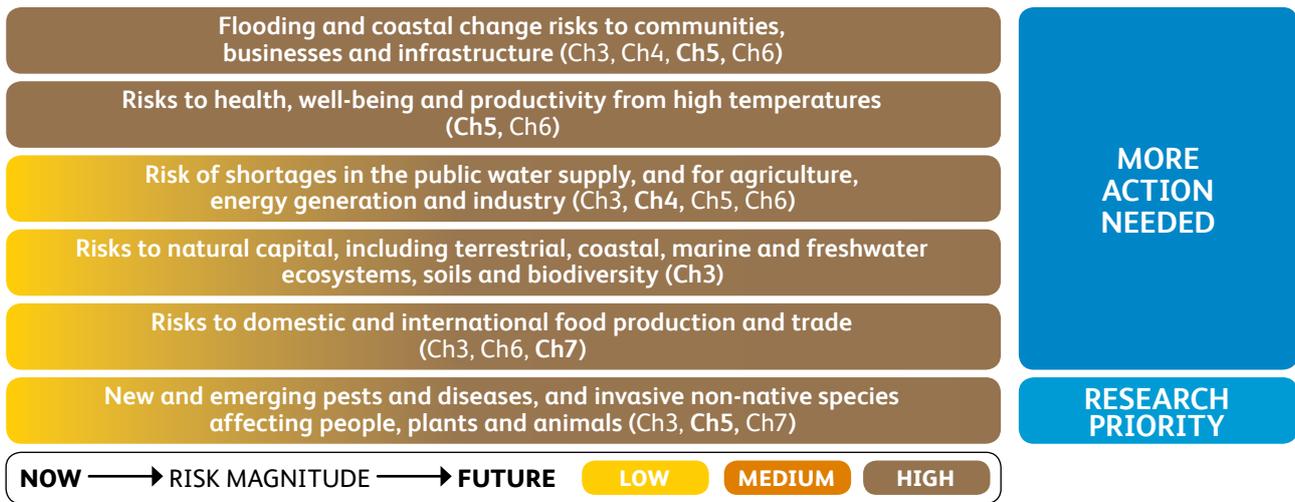
Since this is the first assessment of climate change risks and opportunities for Glasgow City Region the Climate Ready Clyde secretariat has developed a bespoke methodology appropriate to the resource and time constraints of the Climate Ready Clyde work programme.

A significant amount of effort has already been undertaken to quantify climate change risks and opportunities at the national and UK levels. The UK Climate Change Risk Assessment (Committee on Climate Change Adaptation Sub-committee, 2016) and the Summary for Scotland (ASC, 2016) have highlighted priorities (Fig 3), whilst the

ClimateXChange indicators project (ClimateXChange, 2016) and work in individual organisations provide further national and local information to ensure that Scotland has a coherent assessment of risk.

Given the availability of evidence, the secretariat is not seeking to undertake new analysis (except in relation to economic analysis), but instead is planning to draw the national assessments together alongside other evidence containing local spatial variability or specific context to provide a 'place-based' focus. This will involve not just collecting local studies, but also a desk-based literature review of relevant new academic outputs, supplemented by local expert knowledge. The overall set of inputs and deliverables can be seen below:

Fig 2. Top six areas of inter-related climate change risks for the United Kingdom. Source: Committee on Climate Change Adaptation Sub-Committee, 2016



Source: ASC synthesis of the main areas of risk and opportunity within the chapters of the Evidence Report.
 Notes: Future magnitude is based on a combination of climate change and other drivers of risk (e.g. demographic change), taking account of how current adaptation policies and plans across the UK are likely to reduce risks.

Fig 3. Inputs and deliverables for City Region Climate Risk and Opportunity assessment



2.2 Additional research on the economic implications of climate change

In parallel with the development of the risk and opportunity assessment, Climate Ready Clyde has commissioned two projects aimed at understanding the economic dimension to climate change in Glasgow City Region. The first, conducted by Paul Watkiss Associates, is an assessment of the economic implications. This work has sought to quantify the macroeconomic costs and benefits associated with the identified risks and opportunities. The second, delivered by k-Matrix, quantified the city region's adaptation economy – i.e. the economic activity generated through with adapting to climate change.

Together, these provide a strong evidence base for how climate change will affect Glasgow City Region's economy, as well as the financial implications for some of the city region's key public sector organisations. These reports have been published on the Climate Ready Clyde website alongside this main assessment, with key messages incorporated into the relevant risks and opportunities.

2.3 Climate projections and emissions scenarios

Climate projections and derived products have been used as part of the assessment to guide the scoring of risks and opportunities. The majority of information considered has used the 2009 UK Climate Projections

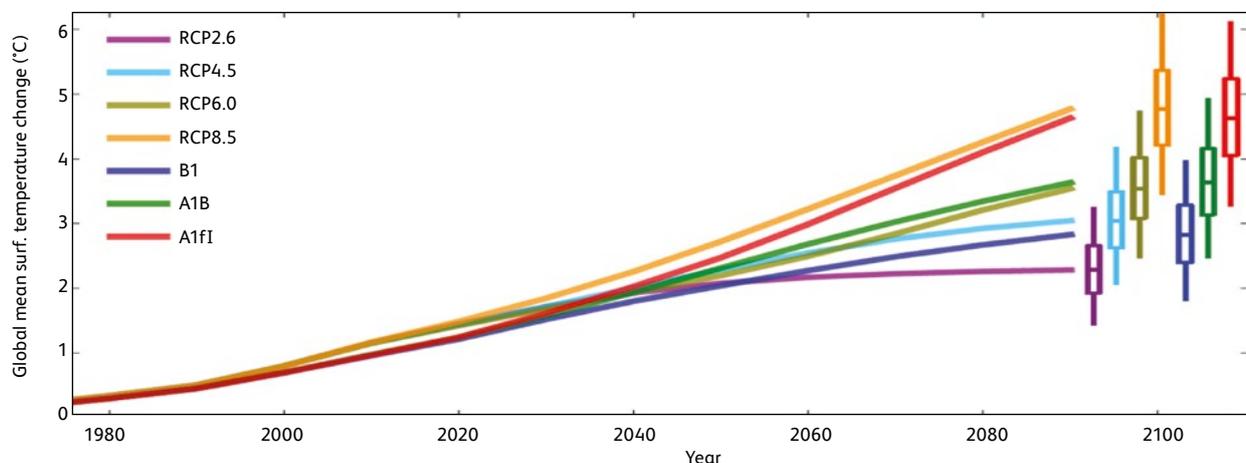
(UKCP09). Other complementary evidence has been included where it adds detail or understanding to the assessment process.

The Met Office will shortly publish an updated set of climate projections for the UK, the UK Climate Projections 2018 (Met Office, 2017). Given the timetable, the outcomes of this work have not been incorporated into this assessment. However, the most recent advice from the UK Government (DECC, DEFRA, Met Office and Environment Agency, 2016) states that UKCP09 remains an appropriate tool for adaptation planning. In future iterations, this assessment will be updated to account for new evidence based upon these projections.

Given current emissions pathways and the challenges in implementing the Paris agreement, the secretariat has used a 'high emissions' scenario as the main scenario for the assessment (A1F1 / RCP 8.5). However, these considerations have been limited by available evidence. Where such scenarios were not used by assessments, stakeholders or the secretariat made an expert judgement about the impacts of a high emissions scenario for a particular risk.

The use of a high emission scenario fits with adopting the precautionary principle. As shown in Figure 4, whilst there is little difference in scenarios in the 2050s; by the 2080s, the pathways rapidly diverge. Using a high emissions scenario has allowed the secretariat to screen for significant potential impacts or risks, and to identify areas for more detailed assessment prior to development of adaptation options.

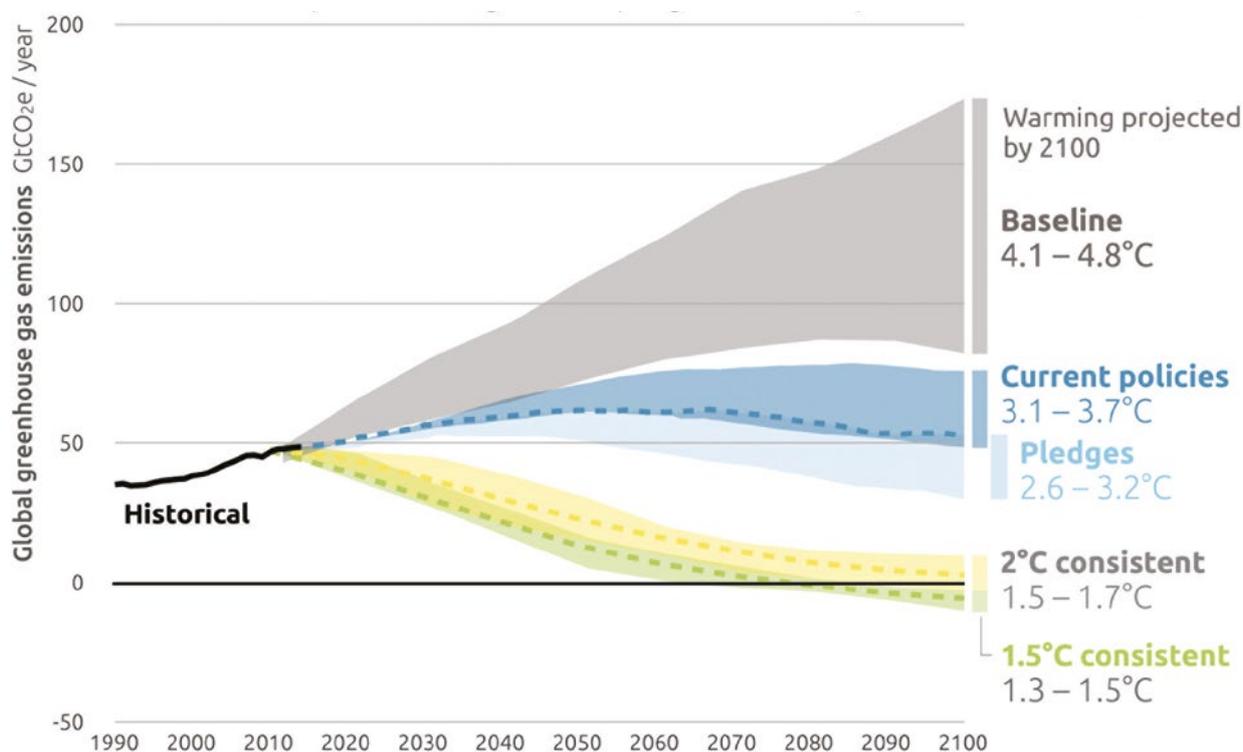
Fig 4. SRES scenarios and global emissions pathways. Source: Committee on Climate Change Adaptation Sub-Committee, 2016



Source: G. Harris (Met Office), based on Harris et al. (2013).

Notes: This plot shows projections for twenty year periods relative to 1860-1899, based on the UKCP09 methodology. The baseline is slightly different from the AR5 baseline of 1851-1900 because the UKCP09 climate model simulations started in 1860, but this is expected to have a negligible impact on the results. Boxes and whiskers show 5, 25, 50, 75 and 95% probability levels of the UKCP09 distributions of change for 2080 - 2099. Solid curves show time-dependent changes for the 50% probability level (median), referred to in the text as the 'central estimate'. The results consider uncertainties in converting carbon emissions to atmospheric CO₂ concentrations, as well as in the physical response of climate to raised CO₂ levels.

Fig 5. Effect of current pledges and policies on global temperatures. Source: Climate Action Tracker, 2018



Current policy projections put the world on a course of 3.1-3.7 degrees of warming by 2100. The agreement in 2016 at the United Nations Framework Convention on Climate Change Conference of the Parties 21 (commonly known as the Paris Agreement) aims to hold the increase in global average temperatures 'well below' 2°C degrees above pre-industrial levels, whilst also pursuing efforts to limit the temperature increase to 1.5°C (UNFCCC, 2015). Even under the Paris Agreement, the combination of current policies, and future pledges are due to reach between 2.6- 3.2 degrees of warming.

Whilst the IPCC's fifth assessment report suggests that is technically and economically feasible to hold warming below 2°C (and to below 1.5°C by 2100), there are also significant challenges (Anderson and Peters, 2016). These include the scale and pace of transformation needed, as well as reliance on negative emissions technologies.

Future assessments will consider the latest science and progress on mitigation and review appropriate use of scenarios as necessary.

Uncertainty

Whilst the assessment uses a high emissions scenario as the starting point for planning, there is also a need when looking at particular sectors or in developing

detailed actions, to consider a range of emissions scenarios and probabilities to ensure appropriate planning. Impacts may vary significantly across different emissions scenarios and probability levels. Therefore, where assessments of spread were undertaken, the authors have attempted to provide a commentary on the variation based on probabilities, scenarios or time horizons, including the uncertainty about the effects.

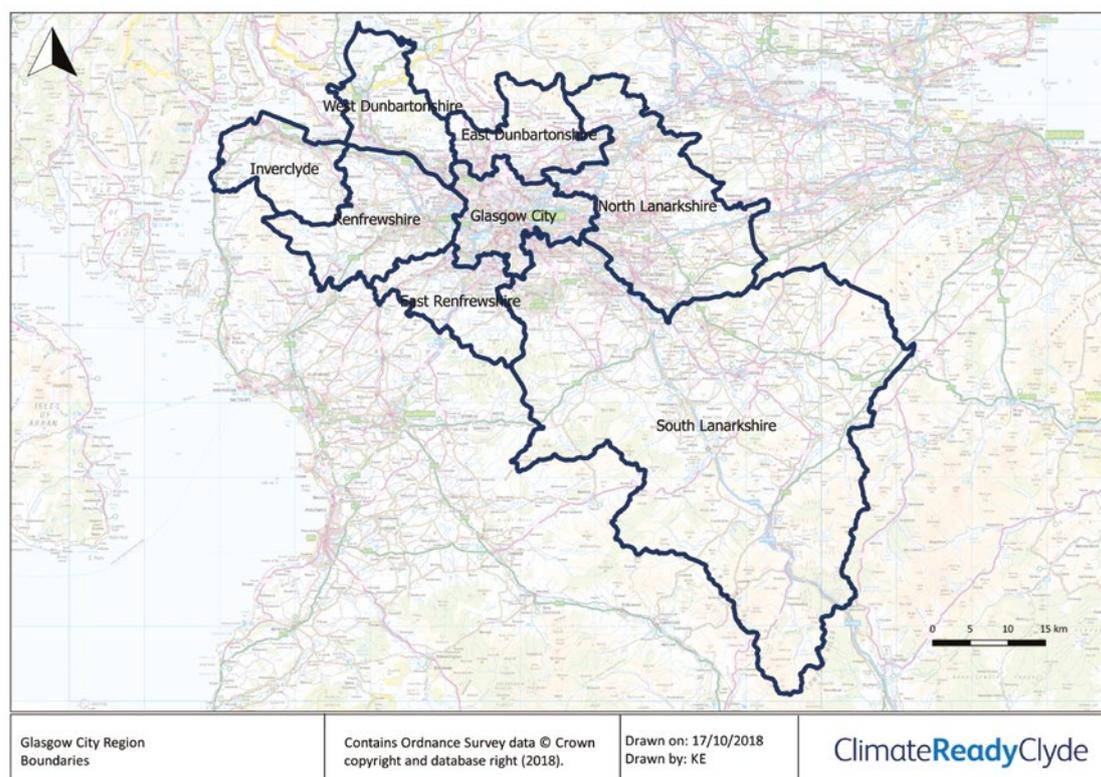
2.4 Time period of assessment

The assessment has attempted to evaluate risks and opportunities out to the 2080s (2070-2099), but the evidence on the risk or opportunity out to this period has varied. Where there is limited evidence on the risks this far into the future, risks and opportunities have been extrapolated based on expert judgement, stakeholder views and evidence on current trends and risk mitigation actions.

2.5 Geographical coverage

For the purposes of this assessment, the assessment covers the extent of Glasgow City Region, in line with emerging governance for Glasgow City Region City Deal. This comprises the eight local authorities

Fig 6. Geographical extent of Glasgow City Region



of East Dunbartonshire, West Dunbartonshire, North Lanarkshire, South Lanarkshire, Glasgow, Renfrewshire, East Renfrewshire and Inverclyde:

Given the predominantly terrestrial focus, the assessment has specifically excluded the wider Clyde Marine Region, though consideration will be given to marine and terrestrial impacts along the Clyde. Wider adaptation planning in the Clyde Marine Areas will be addressed by the Clyde Marine Planning Partnership through the forthcoming Regional Marine Plan.

A small part of the southern end of the Loch Lomond and the Trossachs National Park extends south into West Dunbartonshire. However, the impact on the national park has been explicitly excluded from this assessment, since the majority of is located in other local authority areas. In addition the National Park Authority has identified a dedicated risk assessment as a key activity in its 2015/16 public bodies reporting duty report and is progressing activity in this area (Loch Lomond and the Trossachs National Park, 2016).

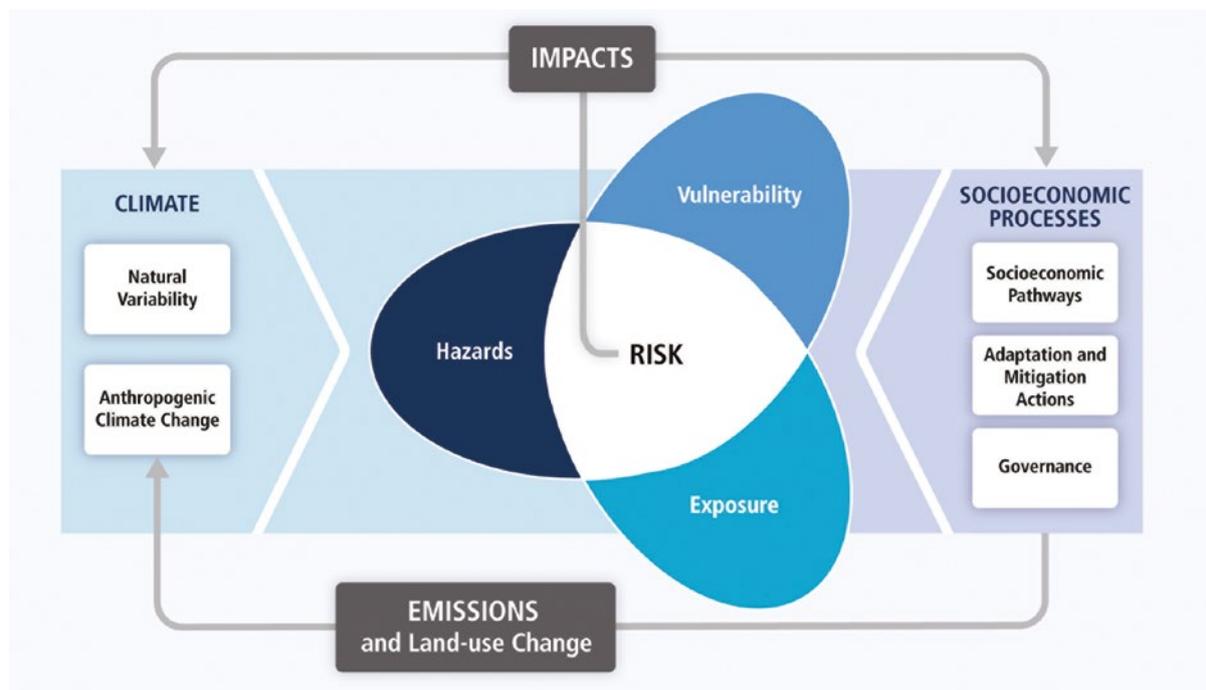
2.6 Risk definition

In undertaking this assessment, we have defined a climate change risk in line with the Intergovernmental

Panel on Climate Change's 5th Assessment Report definition. In this context, the risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. This identifies three significant components:

- **Hazards** – The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
- **Exposure** – The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
- **Vulnerability** – The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt

Fig 7. IPCC diagram of risk components. Source: IPCC, 2015



The combination of these factors lead to risks and opportunities within the Glasgow City Region. There is significant variation amongst individuals and organisations in their use of terms of risk and vulnerability and terms are often used interchangeably by organisations. In each instance, the evidence of each component has been qualitatively reviewed and assessed to draw an overall conclusion on the magnitude of the risk.

In drawing evidence together, it has become apparent that the differing time horizons for planning, regulatory requirements or risk appetites of organisations have resulted in differing views on the likelihood or impact of risks. Furthermore, some have defined risks without breaking down the varying roles of hazards, exposure, or vulnerability, whilst some have conducted assessments which look at exposure to hazards, or purely vulnerability. Where possible, all dimensions of this have been explored in this assessment. Where gaps remain, these have been identified as areas for future development.

In addition, the IPCC framework also acknowledges that changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are wider drivers of hazards, exposure, and vulnerability. In some cases, evidence has sought to include these changes, but in general

terms, a set of future socioeconomic scenarios have not been incorporated.

Hazards

The climatic hazards considered within the scope the assessment are based upon a tailored version of the C40 climate hazard taxonomy for Cities (C40, 2015). Although the most relevant hazards were defined by the secretariat at the outset of the assessment, they were refined further based on feedback from participants. The final list of hazards relevant to Glasgow City Region is found in Appendix 1, whilst the relevant set of future climate information that has been used to frame the assessment is included in Appendix 2. This includes further contextual information from a range of derived products from UKCP09 to help understand particular changes.

In addition to this, a range of evidence was used to communicate and understand the hazards. This included SEPA Flood Map extents (with uplifts for climate change) (SEPA, 2011), the National Coastal Change Assessment (Rennie et al., 2017), outlines of projected Sea Level Rise from the Clyde Marine Planning Partnership (SNH, 2017), and bespoke outputs/models produced as part of consultants reports. A table summarising the coverage of different hazards identified on a thematic basis is included as Appendix 3.

Exposure

The use of existing evidence means that not all risks and opportunities have considered exposure to all hazards. Instead, these have varied across the themes, and available evidence, depending on the individual assessments undertaken.

Vulnerability

Since vulnerability is specific to sectors, and to local circumstances, it has been considered through existing assessments or through discussions with stakeholders on the potential for the most significant, or widespread economic, social or environmental impacts on receptors. Where possible, effort has been made to ensure that any metrics considered have been in line with the information needs of policymakers and planners. For example, in transport, vulnerability could include *passenger numbers* – i.e. the number of journeys undertaken from different stations. In other instances, there have been recognised definitions of vulnerability based on aggregated indices (e.g. for communities, the indices of social vulnerability to flooding), and in these cases, these have been used.

2.7 Interdependent and interacting risks and opportunities

Whilst a sectoral approach has been adopted for the purposes of managing the assessment, many risks and opportunities interact or are interdependent across sectors. For example, there are risks for the

economy as a whole and interrelationships between natural environment changes and health, or economic consequences and livelihoods. Where possible, linkages have been acknowledged in chapters, but it has not been possible to systematically explore and document these given the scope of resources available.

2.8 Links to the National Performance Framework and wider economic, social and environmental impacts

The impacts of climate change will potentially affect wider economic, social and environmental ambitions across Glasgow City Region. And conversely, in managing them well, there can be a strong number of co-benefits. Work by LSE Cities for the C40 (Floater et al., 2016) highlights a wide number of economic, social, and environmental co-benefits for adaptation policies.

Whilst realising that the Regional Adaptation Strategy and Action Plan will take an outcomes-led approach, the secretariat has used the risk and opportunity assessment to identify how effective adaptation will contribute to both the National Performance Framework and the U.N. Sustainable Development goals. This is shown in Appendix 4.

Fig 8. Summary of U.N. Sustainable Development Goals. Source: U.N., 2018



3. METHOD

3.1 Process for undertaking the assessment

The secretariat has designed the assessment as a broad, inclusive process to overcome the initial challenge of producing accurate scoring, by ensuring input from a wide range of individuals with knowledge of the local context. This process is set out below:

- Step 1: Screen the UK Climate Change Risk Assessment (UKCCRA) Summary for Scotland** – The Climate Ready Clyde secretariat filtered the UKCCRA Summary for Scotland to identify a core set of risks and opportunities. Those with urgency scores of ‘watching brief’ were excluded, on the grounds that these warranted review by Scottish/ UK Government and would be addressed as such.
- Step 2: Desk-based evidence review and development of thematic chapters** – The secretariat conducted a desk-based evidence review, (accompanied with a call for evidence in November 2017) to identify relevant evidence to analyse the implications of these risks and opportunities for Glasgow City Region. The process also identified additional risks and opportunities beyond those included in the UKCCRA where suggested by local evidence. In some cases, the high-level nature of the risks in the UKCCRA summary for Scotland meant risks and opportunities were broken down into more detailed risks. The individual risk and opportunities were then drawn together into thematic sectors.
- Step 3: Develop thematic risk and opportunity registers** – The various risks and opportunities were reassembled into bespoke groups of risks and opportunities, grouped by themes.

- Step 4: Validate with stakeholders and develop impact chains** – The secretariat held a stakeholder workshop in November 2017 to confirm the risks and opportunities in scope, gather evidence of adaptation actions underway, and gain some early insights into priority areas. The workshop also focused on developing impact chains for a number of risks and opportunities, to identify the relationships between different systems involved.
- Step 5: Initial consultation** – The thematic chapters were updated to include identified adaptation actions in place, or those that were planned through to 2025. The draft chapters were then shared amongst relevant stakeholders for review.
- Step 6: Assign urgency scores to risks and opportunities** – The secretariat allocated provisional categories to each risk using the scoring method outlined below. A final workshop was held in September 2018 to validate scoring prior to completion of the report.

Role of the Advisory Board

Early drafts of the method and approach were shared with the Climate Ready Clyde advisory board for comment. The board comprises climate change experts across the UK, with a wide range of specialisms. A full list of this group is included in Appendix 5. Their comments were considered and used to refine the assessment. The advisory board also provided comments and expert input into the development of the chapter on cross cutting, international and adaptive capacity issues.

Fig 2: High level method for Glasgow City Region Climate Risk and Opportunity Assessment



Handling of confidential information

Wherever possible, the secretariat has sought to work with original information owners to release as much information as possible at the most granular scale. However, in a small number of situations, the secretariat was not able to directly access information held by partners for reasons of confidentiality and commercial sensitivity. In others, information was provided on the basis that outputs were not published or publicly acknowledged. In these cases, the organisations were invited to comment on a copy of the draft risk and opportunity chapters, to ensure their organisation's view on the risks and associated evidence they were drawing on to support their conclusions was adequately reflected.

3.2 Risk and opportunity scoring: the 'urgency framework' approach

Each of the risks and opportunities has been scored to ensure clear priorities for the Regional Climate Change Adaptation Strategy and Action Plan and individual stakeholder action. The Climate Ready Clyde urgency scoring framework is based on a modified version of the UK Climate Change Risk Assessment (Warren et al., 2016), tailored for use at

the city-region scale. The framework assigns one of four urgency scores to each risk or opportunity:

- ! **More action needed** – New, stronger or different policies or tangible implementation activities – over and above those already planned – are needed in the next five years to reduce long-term vulnerability to climate change.
- ▣ **Build understanding and capacity** – More work is needed in the next five years to develop the City Region's response to this risk or opportunity, including allocating resources, filling significant evidence gaps or reducing the uncertainty in the current level of understanding to assess the need for additional action.
- C **Sustain current action** – Current or planned levels of activity are appropriate, but continued implementation of these policies or plans is needed to ensure that the risk continues to be managed in the future. This includes any existing plans to increase or change the current level of activity.
- 👁 **Watching brief** – The evidence in these areas should be kept under review, with long-term monitoring of risk levels and adaptation activity so that further action can be taken if necessary.



This approach has been adopted to provide a common, comparable view across sectors and organisation whilst recognising that sources of evidence will have different parameters that may affect an assessment of risk, such as standards of resilience/protection, different climate scenarios and models, and that risks may materialise under different amounts of warming at different points at time.

The flow chart in Figure 10 provides an overview of the urgency scoring approach used. This breaks the assessment of urgency into three parts:

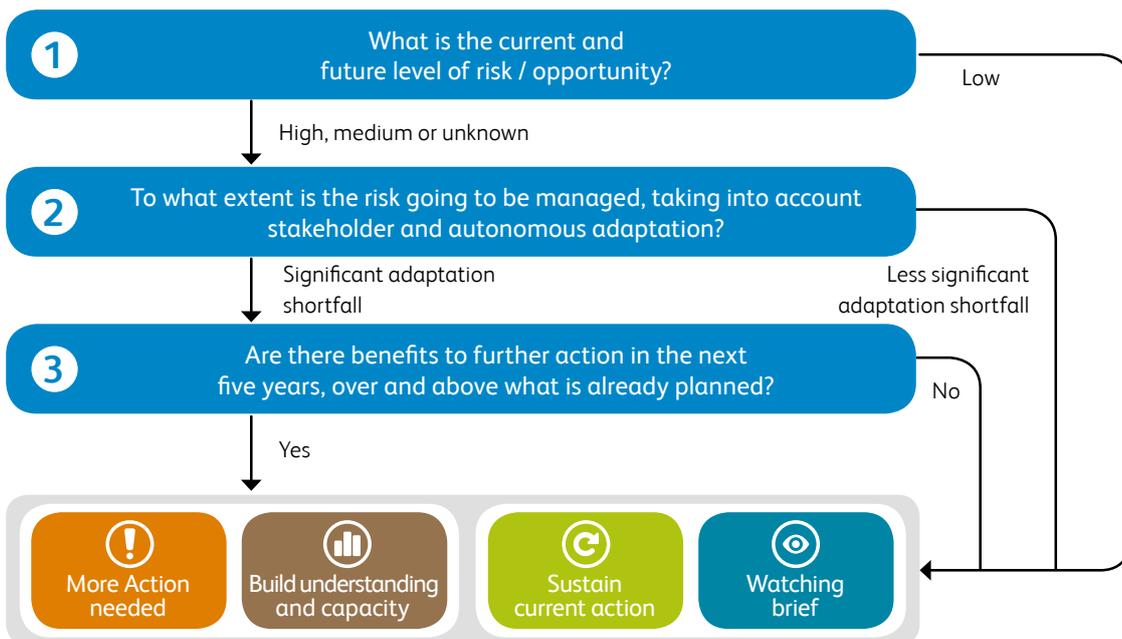
- 1 An assessment of the current and future (up to the 2080s) nature of the risk or opportunity (which would include an assessment of the uncertainty range and magnitude), assuming a 'current level of adaptation' scenario.
- 2 The effect of planned and autonomous adaptation on the size of the risk or opportunity in the future (up to the 2080s where there is evidence), assuming a 'current objectives' scenario.
- 3 An assessment of the benefits of further action in the next five years to manage the risk or opportunity.

For example, even if the future magnitude of a risk is classed as medium, the urgency might be high if plans do not exist to manage the relevant drivers of vulnerability, and it is necessary to put those plans in place in the next 5 years to start a process that ultimately manages the risk in the 2050s. There is, therefore, a potential opportunity, or a window of intervention that should be explored urgently in relation to whether to change the course of action today.

It is stressed that such changes can be extremely complicated. For example, it is relatively easy to design a building for a defined future climate, but it is much more difficult to design it for a highly uncertain future indeed a transient climate regime. Nonetheless, the result is that an adaptation opportunity exists, and this therefore deserves a higher urgency rating.

In all cases, the main assumptions for each step against each risk or opportunity have been discussed by the secretariat group. More detail on this scoring approach is provided in Appendix 6.

Fig 10. Urgency scoring framework for Glasgow City Region Risk and Opportunity Assessment



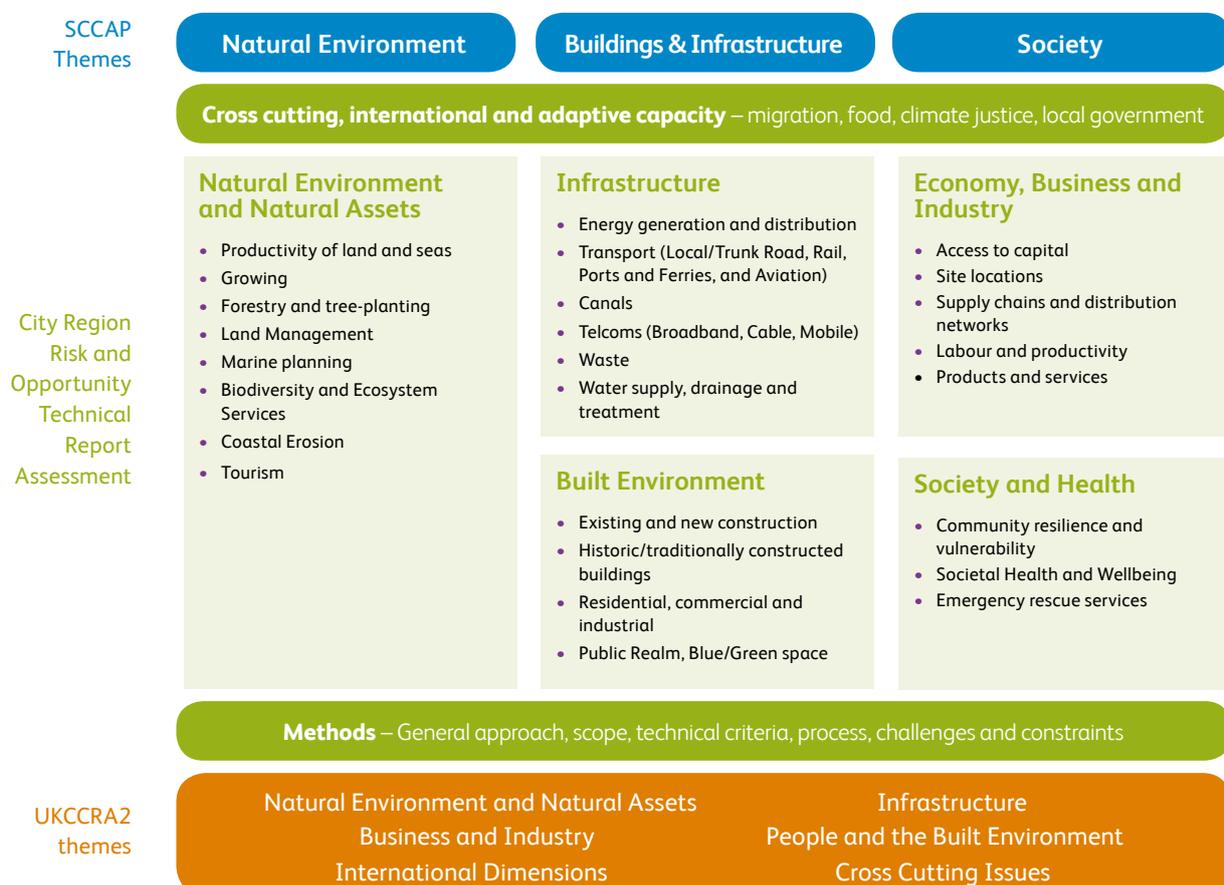
4. ALIGNMENT WITH NATIONAL, UK AND INTERNATIONAL POLICY FRAMEWORKS

In addition to being able to align to evidence on climate change risks, the proposed assessment has been mapped onto the themes of Natural Environment, Buildings and Infrastructure and Society included in the Scottish Climate Change Adaptation Programme (SCCAP). The secretariat has mapped the UKCCRA2 themes against the SCCAP, to develop the structure of the assessment:

Whilst SCCAP2 is due in 2019, this alignment provides a useful read across for understanding the fit with current adaptation planning framework in Scotland. However, going forward the Adaptation Strategy and Action Plan will be aligned with the new Scottish framework.

The Risk and Opportunity Assessment framework has been designed to ensure it is compliant with, and will support partners in reporting under domestic and international frameworks. These include the public bodies reporting duties under the Climate Change (Scotland) Act 2009 but also the Adaptation Reporting Power under the Climate Change Act 2008, and international reporting frameworks from C40, CDP and the Global Covenant of Mayors on Climate and Energy (Neves et al., 2016). All of these frameworks require an assessment of risks and opportunities prior to the development of an adaptation strategy. It has also been checked against drafts of the emerging ISO standards for climate risk and vulnerability assessment, ISO14091 (ISO, 2018).

Fig 11. Structure of city region assessment and alignment with UKCCRA2 and Scottish Climate Adaptation Programme



4.1 Knowledge gaps

Undertaking the assessment highlighted a number of knowledge gaps. In some situations, it was not possible to identify if there was credible evidence of a risk or opportunity at the local level, despite being identified as a national risk. In others, there was only limited available evidence to support the scoring for some risks or opportunities. There were also new potential risks and opportunities identified locally through documents such as Local Climate Impact Profiles (LCLIPs) where further information or more robust projections are needed.

A full list of these potential areas for future research was collated alongside the outcomes of this assessment. Over time, Climate Ready Clyde will seek to collaborate with others to fill the gaps in order to refine and develop the evidence base for future assessments. The list will be used to inform discussion with ClimateXChange, and the research councils (e.g. EPSRC, NERC and ESRC) as part of informing the future research agenda.



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APPENDIX 1 – GLASGOW CITY REGION CLIMATE HAZARD TAXONOMY FRAMEWORK

Hazard Group	Hazard (Main Type)	Type	Sub-Type
Meteorological	Precipitation	Rain storm	
		Heavy snow	Snowstorm/Blizzard
	Wind	Severe wind	
	Lightning	Electrical Storm	Lightning/Thunderstorm
	Fog	Fog	
	Extreme temperature – cold	Extreme winter conditions	Ice, Hail, Freezing Rain, Debris Avalanches
		Cold wave	
		Extreme cold weather	
	Extreme temperature – hot	Heat wave	
Extreme hot weather		Hot days	
Climatological	Sea Level Rise		
	Water Scarcity	Drought	
	Wild fire	Forest Fire	
		Land Fire	Bush fire, grass fire, pasture fire, scrub fire
Hydrological	Flood	Flash/surface flood	
		River flood	
		Coastal flood	
		Groundwater flood	Waterlogging
	Wave action	Storm surge	Seiche
	Chemical change	Salt water intrusion	
Geophysical	Mass movement	Landslide	
		Avalanche	
		Rockfall	
		Subsidence	
Biological	Insects and micro-organisms	Water-borne disease	E.g. Cholera, Typhoid, Legionnaires' disease
		Vector-borne disease	E.g. Malaria, Dengue Fever, Yellow Fever, West Nile Virus, Bubonic Plague
		Air-borne disease	Pneumonic Plague, Influenza
		Insect infestation	E.g. Pine beetles, killer bees, termites

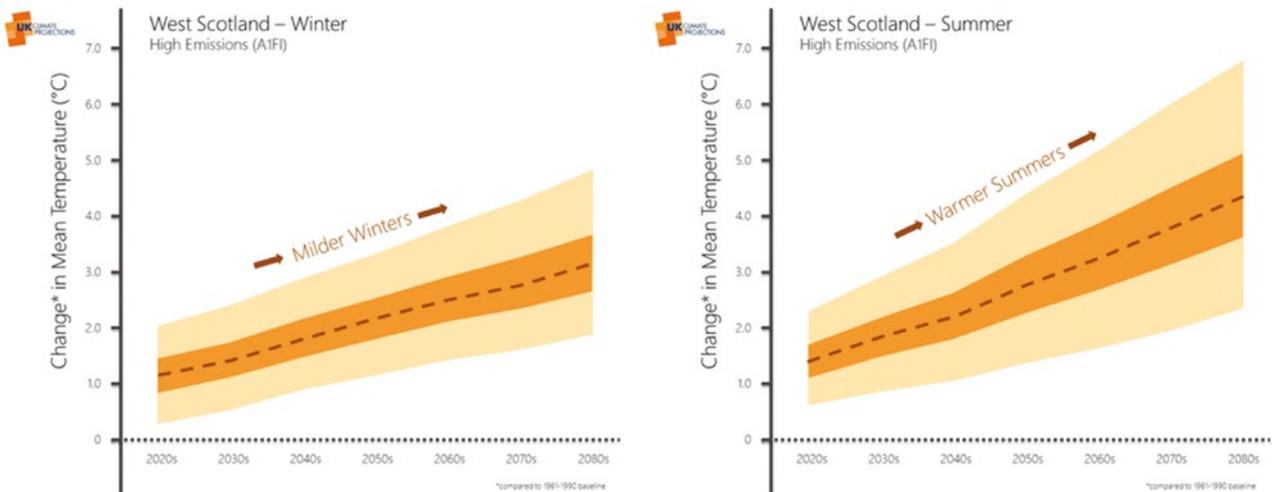
APPENDIX 2 – CLIMATIC INFORMATION AND PROJECTIONS FOR GLASGOW CITY REGION

This note sets out the range of information used to inform Glasgow City Region’s climate change risk and opportunity assessment. The predominant source of this information is the UK Climate Projections 2009.

1.1 Temperature and heatwave

Under a high emissions scenario, temperatures across Glasgow City Region are expected to rise gradually between now and 2080, creating milder winters and warmer summers.

Fig 12. Projected temperature rises for the West of Scotland



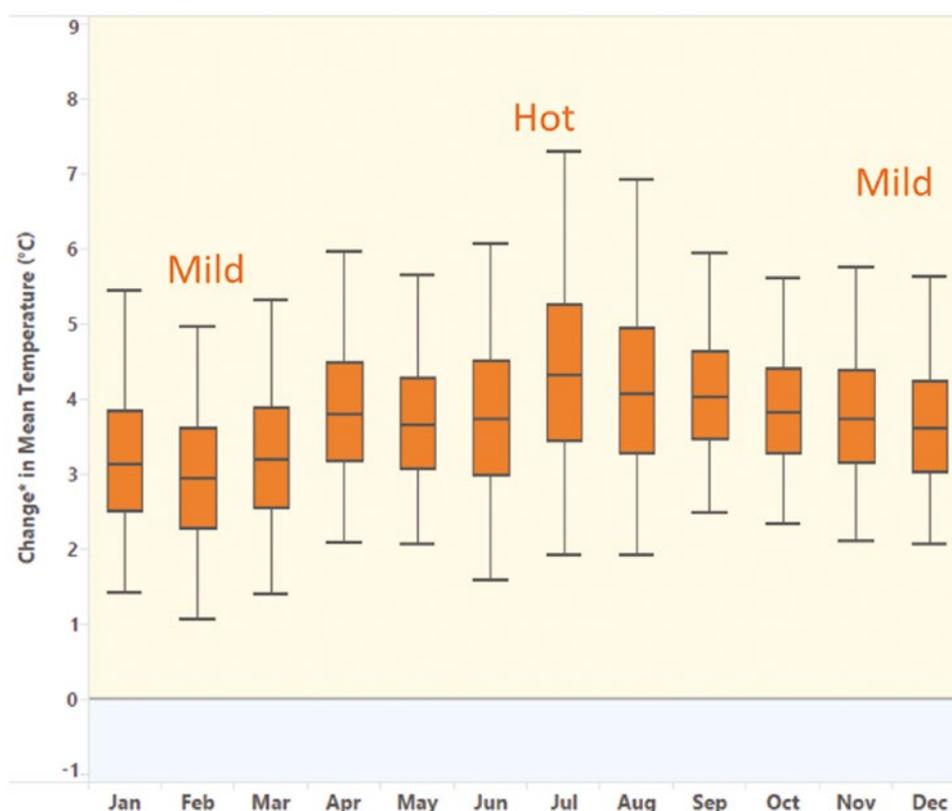
The following changes in mean seasonal temperatures are projected under a High Emissions scenario for the Clyde River Basin in the 2080s:

Table 2: Mean temperatures for Clyde River Basin, 2080s, High Emissions scenario

Variable	Change at 10% probability	Change at 50% probability	Change at 90% probability
Increase in mean winter (DJF) temperature (°C)	1.9	3.1	4.8
Increase in mean summer (JJA) temperature (°C)	2.4	4.4	6.9

The chart below shows the range of projected changes by month. It shows there is a higher degree of uncertainty around the precise range of rises in summer temperatures.

Fig 13. Projected monthly temperature rises, 2080s, West of Scotland



As well as the general changes in temperature, Glasgow City Region is projected to see more frequent and severe heat waves. Under a medium emissions scenario, by the 2050s, the likelihood of a heat wave¹ occurring in any year is 1 in 3, whereas during the 1961-1990 baseline period they were very much rarer (Jacobs and Scottish Cities Alliance, 2014).

Table 3. Average number of heat waves per year derived from the UKCP09 weather generator for the 1961-1990.
Source: Jacobs and Scottish Cities Alliance, 2014

Scenario	Percentile values		
	10 th Percentile	50 th Percentile	90 th Percentile
Baseline (1961-1990)	0.000	0.033	0.067
Future (2050s)	0.033	0.333	1.333
Difference	0.033	0.300	1.267

This is higher than any of the other cities in the Scotland, meaning Glasgow City Region will have a relative higher exposure to this hazard. In addition, given this work has only been conducted for the 2050s and considers a medium emissions scenario, it is likely to be an under-estimate given current emissions trajectories.

¹ For the purposes of the assessment, a heatwave was defined as a Daily Maximum temperature > 26°C, Daily Minimum temperature > 13°C, for a minimum of 3 consecutive days. This is in line with the regional variation of the trigger levels across England the definition of a heatwave.

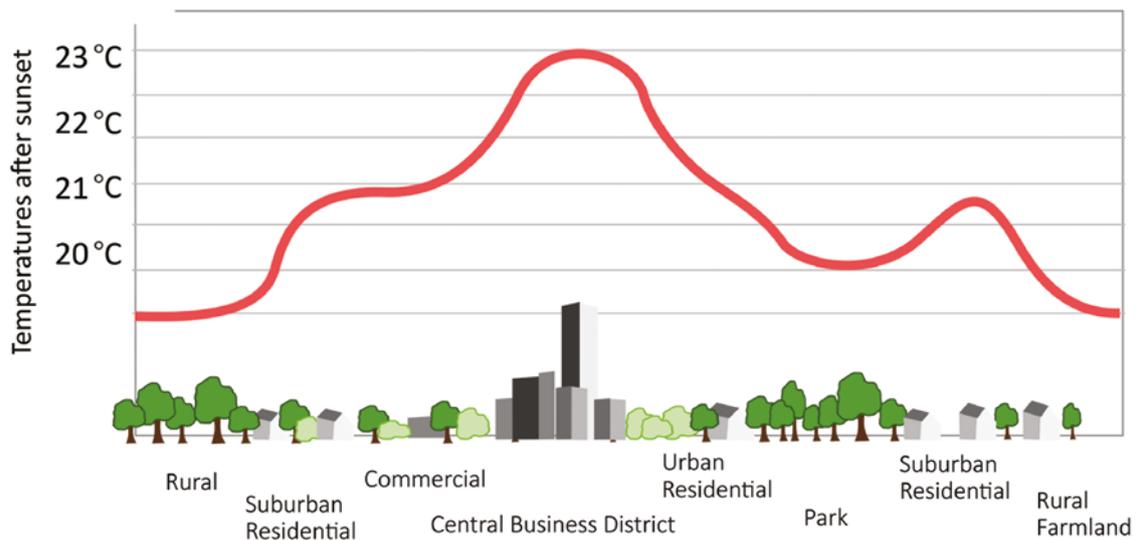
Table 4. Average number of heat waves per year for Glasgow derived from the UKCP09 weather generator for the 1961-1990 baseline and 2050s periods. Source: Jacobs and Scottish Cities Alliance, 2014.

City	Projected return period of heatwaves* by the 2050s (Years)
Glasgow	1 in 3
Stirling	1 in 4
Edinburgh	1 in 10
Dundee	1 in 10
Perth	1 in 4
Aberdeen	1 in 30
Inverness	1 in 12

Urban Heat Island effects

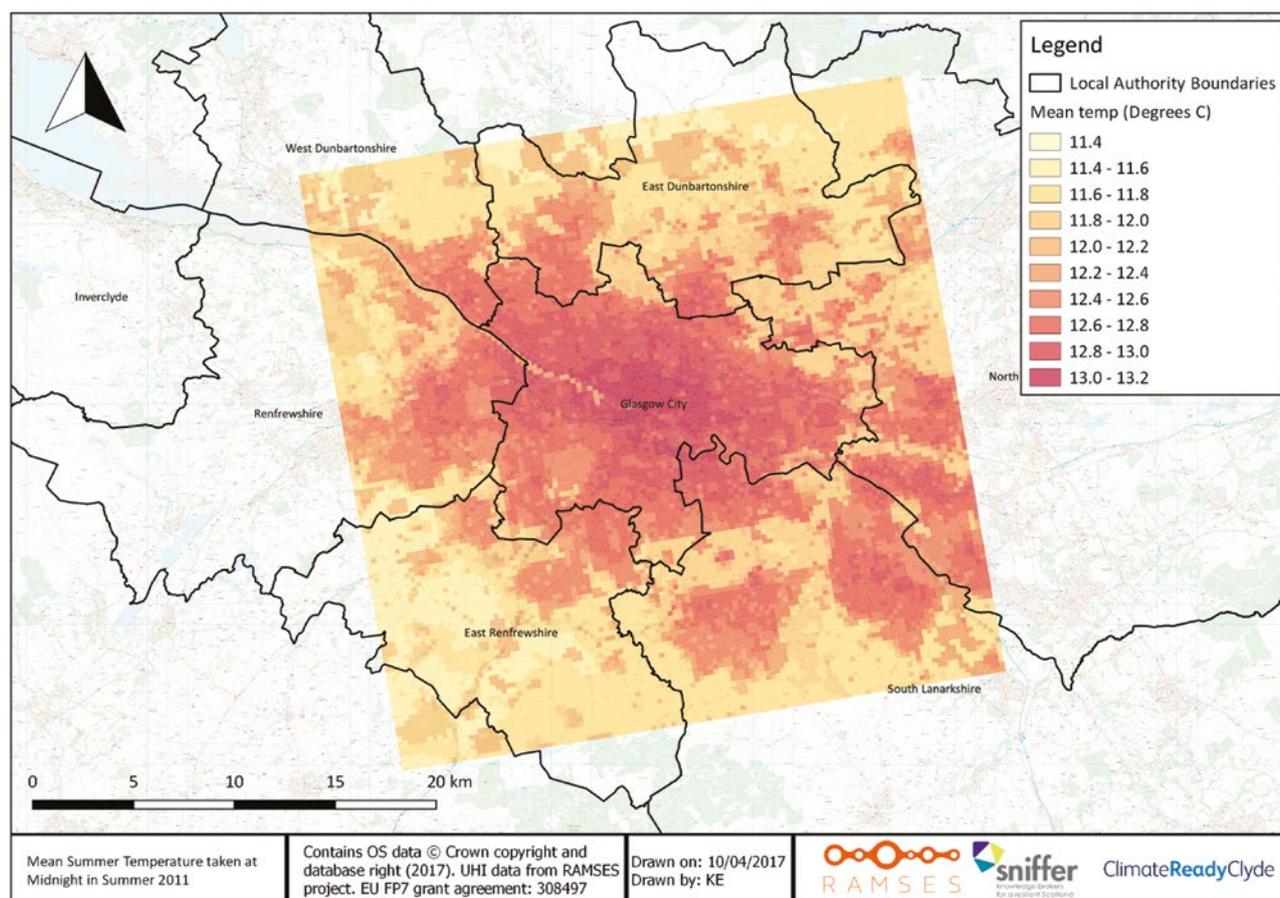
We also know that temperature is not experienced evenly across the city region, and varies between urban and rural areas. This is due to a range of factors, including less vegetation, reduced reflectivity and the storing of heat in the built environment. In addition, the extra heat generated from heating, cooling and transport also contributes to overall variations.

Fig 14. Example profile of Urban Heat Island. Source: Royal Metrological Society, no date.



Data from the RAMSES project captured night time temperatures across part of the Glasgow City Region. From the results, there shows a difference in two or three degrees between the densest urban parts of the city region, and more rural areas. However, there is only partial coverage of the city region, and no estimates of the effects of future climate change.

Fig 15. Mean Summer Temperature, Midnight Summer 2011, Source: RAMSES, 2017



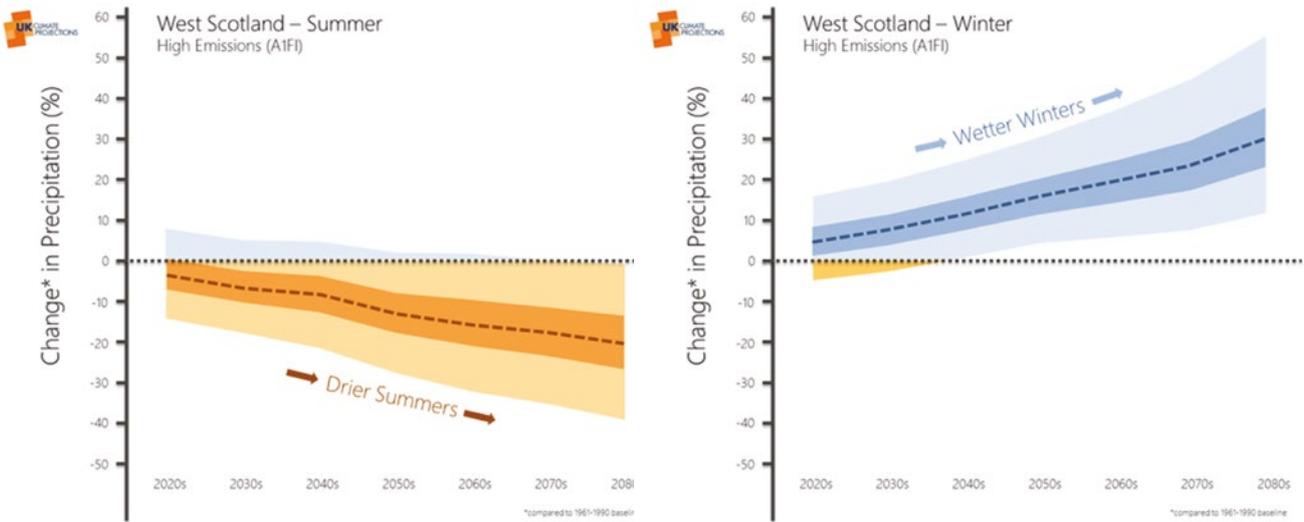
1.2 Precipitation and flooding

In general terms, Glasgow City Region is projected to see drier average summer precipitation, and increased amounts of winter precipitation.

Table 5: Mean temperatures for the Clyde River Basin 2080s, High Emissions scenario

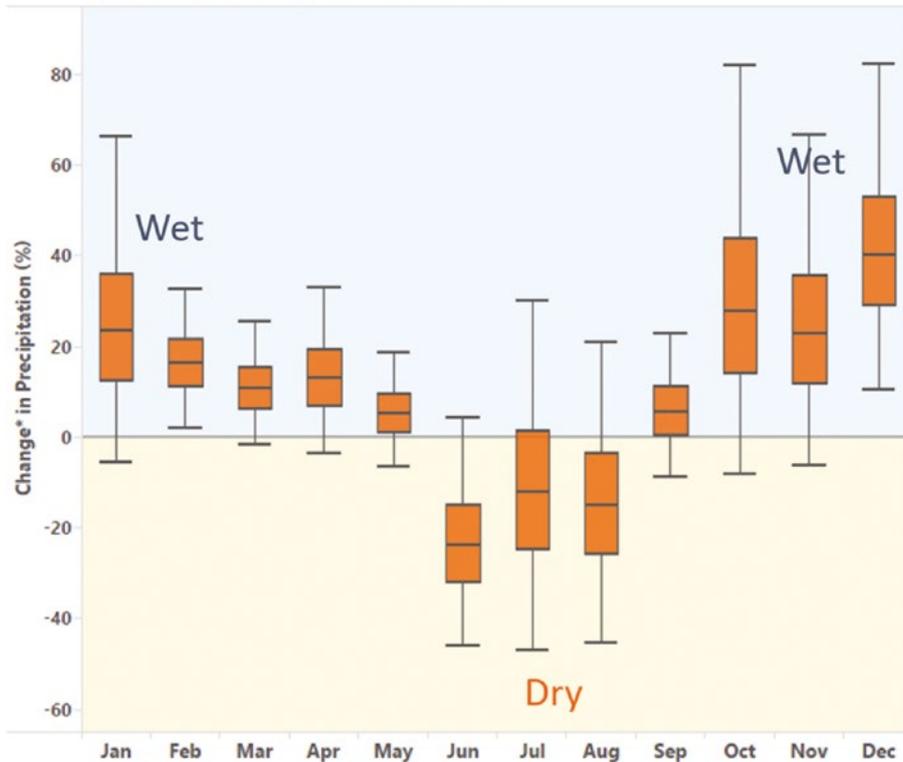
Variable	Change at 10% probability	Change at 50% probability	Change at 90% probability
Change in mean winter precipitation (%)	9.0%	25.6%	49.3%
Change in mean summer precipitation (%)	-43.4%	-22.8%	-1.1%

Fig 16. Projected changes in precipitation for the West of Scotland



Within this, it is possible to see a much clearer distinction in the range of patterns on a monthly basis, with winters becoming much wetter, and summers much drier.

Fig 17. Projected monthly precipitation, 2080s for West of Scotland

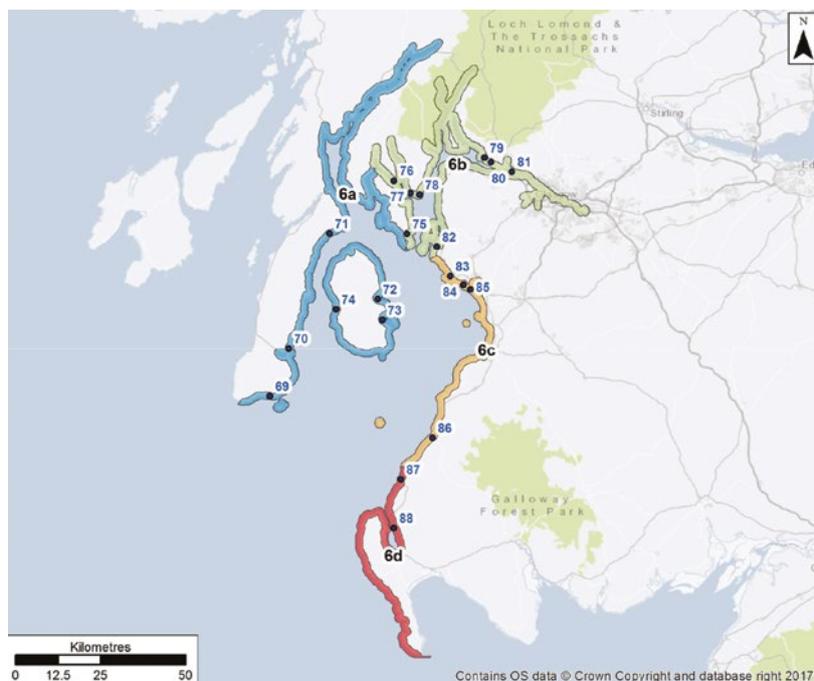


Unless specified elsewhere, for the purposes of assessing future flood risk, the majority of information has relied on the National Flood Risk Assessment (SEPA, 2011) for flood risk (coastal and river flooding, surface water flooding and groundwater flooding), with associated uplifts for climate change. Additional assessments of assets at risk were provided by Clydeplan’s own Strategic Flood Risk Assessment tool (Clydeplan, 2017).

1.3 Coastal Erosion

The outputs from the National Coastal Change Assessment, Dynamic Coast (Rennie et al., 2017), were used to inform possible risks from Coastal Erosion. This included an assessment of impacts on sites 80 and 81 identified in Cell 6, Sub cell b (Inner Firth of Clyde to Farland Head)

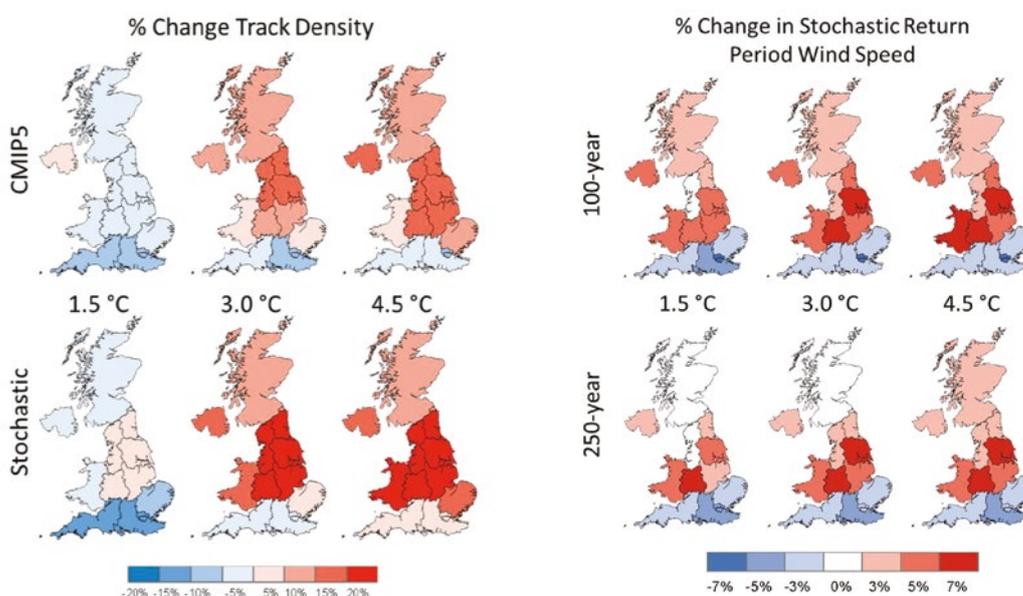
Fig 18. Cell 6 of the National Coastal Change Assessment. Source: Rennie et al., 2016



1.4 Wind and Storms

Scotland is likely to increase in the frequency or storms (also known as ‘Storm track density’) by around 10-15% under a three-four degree rise (Robinson et al., 2017). This is broadly in line with other studies, though it suggests that storm frequency will initially decline under a 1.5 degree rise. This suggests that there will be a general increase in storminess through to the 2080s, but that it is uncertain how storms will be experienced in the medium term. The work also suggests that there is an increased likelihood of more frequent extreme wind speeds in Scotland.

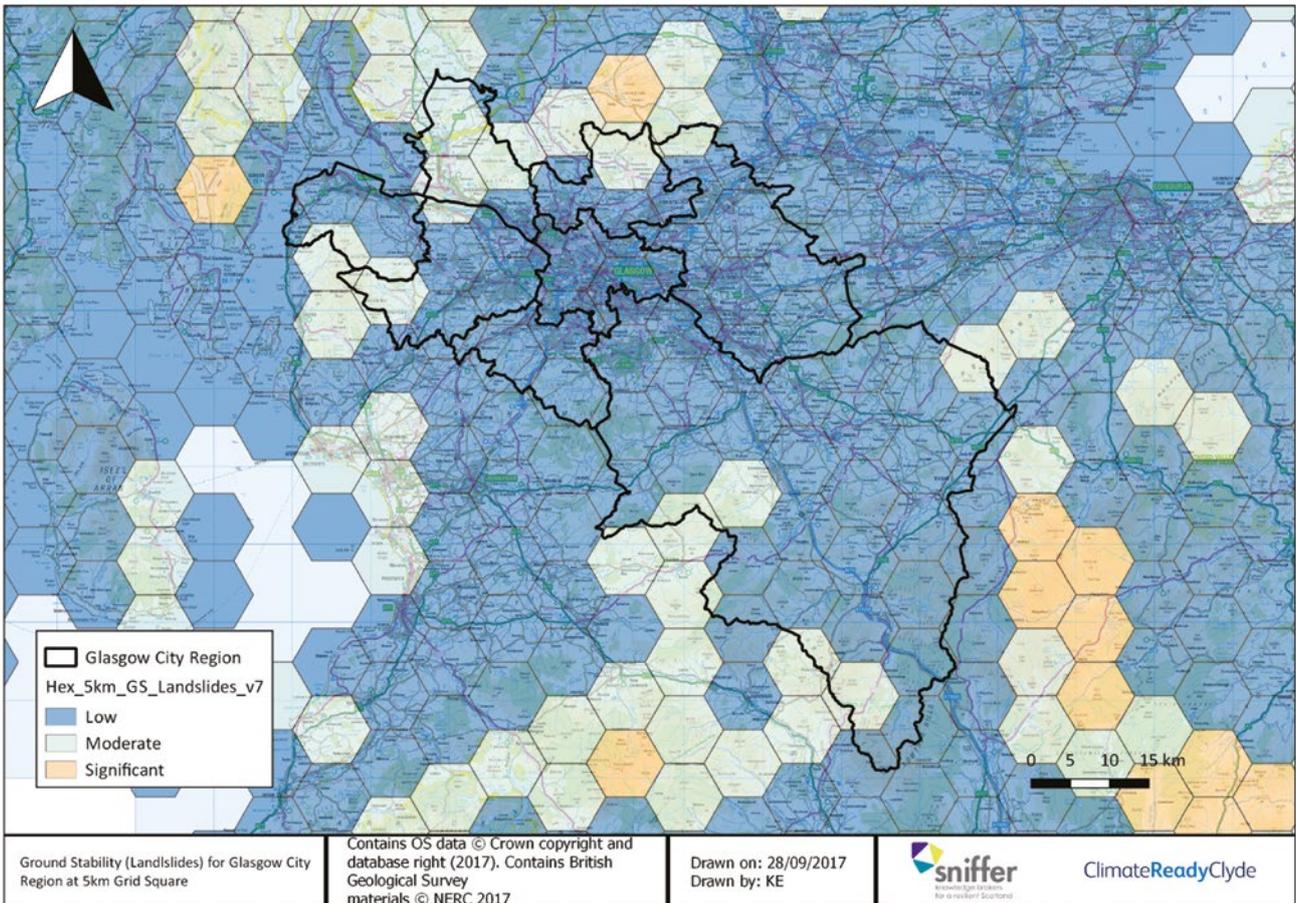
Fig 19. Percentage changes in storm track density and return period wind speed. Source: Robinson et al., 2017.



1.5 Landslides/Slope Instability

The British Geological Survey’s Geosure dataset indicates that there is not a high degree of susceptibility to landslides within Glasgow City Region.

Fig 20. Ground stability (Landslides) for Glasgow City Region. Source: British Geological Survey, 2018



A more detailed set of data is available for purchase to inform more specific project planning, but has not been purchased for the purposes of this assessment. Similarly, there is not a publicly available dataset on future susceptibility of landslides as a result of climate change.

APPENDIX 3 – SUMMARY OF CLIMATE HAZARDS CONSIDERED BY THEME

	GCR Climate Hazards															OVERALL
	Precipitation	Wind	Lightning	Fog	Extreme temperature – Hot	Extreme temperature – Cold	Water Scarcity	Wildfires	Flood & Coastal Erosion	Wave Action	Chemical Change (Saltwater Intrusion)	Mass Movement (Landslides)	Insects and Micro-organisms	Rising Average Temperatures	Sea Level Rise	
Infrastructure	F	F	P	P	F	F	P	N	F	P	N	P	N	F	F	P
Built Environment	P	N	N	N	P	P	N	N	F	N	N	P	N	N	P	P
Economy and Business	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Society and Health	F	P	P	N	P	P	P	N	F	N	N	N	P	F	N	P
Natural Environment and Natural Assets	P	N	N	N	P	P	P	P	P	N	P	P	P	P	P	P

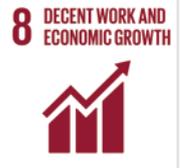
N.B. The above table is not an assessment of the magnitude, or likelihood of impacts but the extent to which the theme included a comprehensive coverage of the hazard.

(F) = Full: comprehensive coverage of the hazard

(P) = Partial: Some coverage of the hazard in evidence

(N) = None: Hazard not covered in any evidence reviewed

APPENDIX 4 – LINKS BETWEEN THEMES, NATIONAL PERFORMANCE FRAMEWORK OUTCOMES AND U.N. SUSTAINABLE DEVELOPMENT GOALS

Risk and Opportunity Assessment Theme	National Performance framework outcomes	SDGs	
Society and Health	<ul style="list-style-type: none">  We grow up loved, safe and respected so that we realise our full potential  We live in communities that are inclusive, empowered, resilient and safe  We have a globally competitive, entrepreneurial, inclusive and sustainable economy  We are healthy and active  We tackle poverty by sharing opportunities, wealth and power more equally 	<ul style="list-style-type: none">    	<ul style="list-style-type: none">  
Built Environment	<ul style="list-style-type: none">  We value, enjoy, protect and enhance our environment  We are healthy and active  We live in communities that are inclusive, empowered, resilient and safe 	<ul style="list-style-type: none">   	<ul style="list-style-type: none"> 
Economy, Business and Industry	<ul style="list-style-type: none">  We have a globally competitive, entrepreneurial, inclusive and sustainable economy  We have thriving and innovative businesses, with quality jobs and fair work for everyone  We are well educated, skilled and able to contribute to society 	<ul style="list-style-type: none">    	<ul style="list-style-type: none">   

Risk and Opportunity Assessment Theme	National Performance framework outcomes	SDGs
Infrastructure	<ul style="list-style-type: none">  We value, enjoy, protect and enhance our environment  We have thriving and innovative businesses, with quality jobs and fair work for everyone  We live in communities that are inclusive, empowered, resilient and safe  We have a globally competitive, entrepreneurial, inclusive and sustainable economy 	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%; text-align: center;">  <p>7 AFFORDABLE AND CLEAN ENERGY</p> </div> <div style="width: 50%; text-align: center;">  <p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p> </div> <div style="width: 50%; text-align: center;">  <p>11 SUSTAINABLE CITIES AND COMMUNITIES</p> </div> </div>
Natural Environment	<ul style="list-style-type: none">  We value, enjoy, protect and enhance our environment 	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%; text-align: center;">  <p>2 ZERO HUNGER</p> </div> <div style="width: 50%; text-align: center;">  <p>6 CLEAN WATER AND SANITATION</p> </div> <div style="width: 50%; text-align: center;">  <p>14 LIFE BELOW WATER</p> </div> <div style="width: 50%; text-align: center;">  <p>15 LIFE ON LAND</p> </div> </div>
International and Cross Cutting	<ul style="list-style-type: none">  We have a globally competitive, entrepreneurial, inclusive and sustainable economy  We are open, connected and make a positive contribution internationally  We tackle poverty by sharing opportunities, wealth and power more equally 	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%; text-align: center;">  <p>1 NO POVERTY</p> </div> <div style="width: 50%; text-align: center;">  <p>5 GENDER EQUALITY</p> </div> <div style="width: 50%; text-align: center;">  <p>10 REDUCED INEQUALITIES</p> </div> <div style="width: 50%; text-align: center;">  <p>13 CLIMATE ACTION</p> </div> <div style="width: 50%; text-align: center;">  <p>16 PEACE, JUSTICE AND STRONG INSTITUTIONS</p> </div> <div style="width: 50%; text-align: center;">  <p>17 PARTNERSHIPS FOR THE GOALS</p> </div> </div>

APPENDIX 5 – CLIMATE READY CLYDE ADVISORY BOARD

Name	Organisation
Sarah Anderson	Climate Resilience Specialist, Auckland Council, NZ
Gemma Holmes	Senior Analysts, (Cities), Committee on Climate Change
Richard Dawson	Newcastle University, Tyndall Centre on Climate Change / Technical Advisor, National Infrastructure Commission
Matt Ellis	Chair, Core Cities Climate Change Resilience and Adaptation working group
Kristen Guida	Manager, London Climate Change Partnership
Katharine Knox	Director, Katharine Knox Consulting / Research Associate, University of York
Nick Blyth	Policy Lead, Climate change, Institute of Environmental Management and Assessment

APPENDIX 6 – SUPPORTING INFORMATION FOR THE URGENCY SCORING APPROACH

The following information sets out the detailed scoring process used for assigning urgency scores to the climate risks and opportunities identified in the assessment.

Step 1: What is the current and future level of risk/ opportunity?

The purpose of this step is to describe the risk or opportunity today, and provide a summary of the evidence on the potential magnitude in through to the '2080s' (2070-2099). The assessment of current risk will include an assessment of the current level of hazard, vulnerability and exposure, and any action being taken to manage the risk. The assessment of future (up to the 2080s) risk will include, where possible, the effects of different climate scenarios, socio-economic change, a 'current level of adaptation' scenario, and the uncertainty range. The assessment of opportunities should include any evidence on the size of the opportunity under different scenarios. The range of risk/opportunity should be quantified as far as possible.

Table 1. Risk Magnitude Categories

	High Magnitude	Medium Magnitude	Low Magnitude
Quantitative evidence	<p>Major annual damage and disruption or foregone opportunities:</p> <p>£tens of millions damage, and/or</p> <p>Hundreds of hectares/km land lost or irreversibly damaged, and/or</p> <p>Hundreds of thousands affected, tens of deaths, or tens of people irreversibly harmed</p> <p>Changes to around half of UK's natural assets and their associated goods and services.</p>	<p>Moderate annual damage and disruption or foregone opportunities:</p> <p>Less than £10 million damage, and/or</p> <ul style="list-style-type: none"> Tens of hectares/km lost or irreversibly damaged, other reversible/localised damage occurs, and/or Thousands affected, a few deaths, or a few people irreversibly harmed <p>Changes to a minority of UK's natural assets and their associated goods and services.</p>	<p>Minor damage and disruption or foregone opportunities:</p> <p>Less than £1 million damage, and/or</p> <ul style="list-style-type: none"> Small multiples of hectares/km lost or irreversibly damaged, other reversible/localised damage occurs, and/or Hundreds affected, or a few people harmed <p>Changes to a minority of UK's natural assets and their associated goods and services.</p>
Qualitative evidence	<p>Expert judgement and widespread agreement across authors, CRC secretariat and consultees suggest there is a possibility of impacts of the magnitude suggested above.</p>	<p>Expert judgement and widespread agreement across authors, CRC secretariat and consultees suggest there is a possibility of impacts of the magnitude suggested above.</p>	<p>Expert judgement and widespread agreement across authors, CRC secretariat and consultees suggest there is a possibility of impacts of the magnitude suggested above.</p>

Step 2: To what extent is the risk/ opportunity going to be managed, taking into account stakeholder and autonomous adaptation?

The purpose of this step is to understand to what extent we can assume autonomous adaptation, or adaptation according to Government and stakeholder commitments will take place, and to what extent this will manage the risks or seize the opportunities to a degree described below.

For the purpose of this assessment, it is judged that there is a less significant adaptation shortfall if the following are true for risks:

1. The risk is projected to be low magnitude under any future climate scenario; **OR**
2. After consideration of Government commitments and autonomous adaptation action, the risk, across the equivalent of the UKCP09 10 – 90% uncertainty range, would be reduced to a low magnitude category by 2100 if these actions take place (see the table below for a description of magnitude); **OR**
3. The available evidence suggests that the key drivers of vulnerability/exposure to the risk are expected to be managed in the future (up to 2100) (with reasons why); **OR**
4. Where there is no evidence, there is widespread agreement between the assessment authors and the review group that the key drivers of vulnerability/exposure to the risk would be managed in the future (up to 2100), either because the market will incentivise appropriate action or because stakeholders have commitments in place to do so (with reasons why); **AND**
5. Stakeholder commitments and autonomous adaptation in relation to the risk in question, or as a result of dealing with other risks, do not lead to maladaptation.

For opportunities, there is deemed to be a less significant adaptation shortfall if there is evidence that the opportunity will be seized without the need for further public sector intervention.

The rationale for the assessment was discussed and agreed as part of the review process for the report. If the adaptation shortfall was agreed to be less significant, the risk was given a 'watching brief' or 'sustain current action' category.

Where any of the criteria above do not apply, or where there was a lack of evidence or agreement, we conservatively assumed there would be a significant adaptation shortfall, and the risk/ opportunity was taken to step 3.

Box 1. Definitions of stakeholder commitments and autonomous adaptation**Autonomous adaptation**

The assessment of autonomous adaptation considers the potential reductions in risk through the action of individual actors, the private sector, and at the aggregate level, e.g. from market adjustments.

A key issue is to identify whether the autonomous adaptation that may occur is appropriate, i.e. from an economic perspective, it is socially optimal. As an example, the increase of air conditioning as a response to building overheating is a potential autonomous adaptation response, but it would increase energy and carbon emissions, and possibly exacerbate social inequalities, and thus would be a form of maladaptation. Likewise, many farm-level responses (increased irrigation and fertiliser use) may involve wider cross-sectoral trade-offs that necessitate a role for planned intervention. This assessment also considers cases in which adaptation has unintended consequences, e.g. creating lock-in, or increasing risks in other sectors or associated with other development or social objectives.

Stakeholder commitments

The assessment of stakeholder commitments should consider firm policy goals and aspirations, both in relation to specific existing and announced climate or resilience policy but also broader policy interventions that will reduce climate vulnerability. Similarly to autonomous adaptation, the assessment of Government commitments aims to consider whether these commitments have unintended consequences, e.g. create lock-ins, or increasing risks in other sectors or associated with other development or social objectives.

Step 3: Are there benefits of further action – over and above what is planned – in the next five years?

The purpose of this step is to understand, for risks or opportunities where there is a more significant adaptation shortfall, whether additional actions to address the risk over the next five years would be beneficial, and in what way.

There may be benefits of different kinds of actions within the next five years as follows:

- **Retain flexibility**, avoiding lock-in to a particular pathway over the next few decades, or
- Help to **create the right conditions** to adapt later (e.g. put in place measures for changes that have long lead times, or create the right institutional conditions to adapt later), or
- **Provide the early steps**, e.g. capacity building, research, monitoring, that will enable better decisions in the near future (next five years), especially in relation to longer-term major risks, i.e. to build early interventions within an iterative adaptive management framework, or
- Have benefits for managing a **wide range** of climate and non-climate related risks, or
- Are **cost-effective** to implement now, or
- **Reduce vulnerability** now.

In order to undertake this step, authors made some high level assessment of the types of actions that could be employed to manage the risk, but did not describe the benefits of a particular set of actions over another set of actions or recommend a particular set of actions to take.

If action was beneficial over the next five years to manage the risk, the risk or opportunity was identified as more urgent. If action in the next five years was not deemed to be beneficial, the risk or opportunity was assigned a less urgent category.

ABOUT CLIMATE READY CLYDE

Climate Ready Clyde is a cross-sector initiative funded by public and private member organisations and Scottish Government to create a shared Vision, Strategy and Action Plan for an adapting Glasgow City Region.





The Climate Ready Clyde programme is managed and delivered by Scottish sustainability charity Sniffer

Disclaimer:

This report summarises the work undertaken by Sniffer in their role as secretariat to Climate Ready Clyde, based on desk review of available information and broad consultation with stakeholders across Glasgow City Region and beyond. The views contained in this assessment are the collective view of Climate Ready Clyde partners. They do not necessarily represent the views of individual agencies, Glasgow City Region or Scottish Government. Sniffer take no responsibility for losses incurred as a result of information used in this report.

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