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# Vulnerability and Risk Assessment

Report for the Department of the Environment, Sustainability, Climate Change and Heritage

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# Glossary

| Term | Definition |
|---|---|
| **Adaptation** | "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects." (IPCC, 2018, p.542) |
| **Adaptive capacity** | "The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences." (IPCC, 2018, p.542) |
| **Anthropogenic** | "Resulting from or produced by human activities." (IPCC, 2018, p.543) |
| **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." (IPCC, 2018, p.549) |
| **GCoM** | 'The Global Covenant of Mayors for Climate & Energy' brings together cities and local governments to advance the city-level transition to a low GHG emission and climate resilient economy |
| **GHG** | Greenhouse Gas – "Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere." (IPCC, 2018, pp.550-551) |
| **Hazard** | "The potential occurrence of a natural or human-induced physical event or trend 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." (IPCC, 2018, p.551) |
| **Impact** | "Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial." (IPCC, 2018, pp.551-552) |
| **Mass movement** | Refers to hazards involving the "mass movement" of land, such as landslides and rockfalls. |
| **Ocean acidification** | "Ocean acidification refers to a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon |

| | |
|---|---|
| | dioxide (CO2) from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean." (IPCC, 2018, p.555) |
| **Sensitivity** | "The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change." (IPCC, 2014, p.1758) |
| **UNFCCC** | United Nations Framework Convention on Climate Change – "The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement." (IPCC, 2018, pp.559-560) |
| **Urban heat island effect** | The urban heat island effect refers to the greater warming seen in cities compared to rural areas. This is due to heat being created from the energy produced by activity (e.g. people, cars, buses, and trains) in densely populated cities, and due to the dense construction of buildings from materials than retain heat well. (National Geographic, no date) |
| **VRA** | Vulnerability and Risk Assessment |
| **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." (IPCC, 2018, p.560) |

# 1 Introduction

## 1.1 Overview

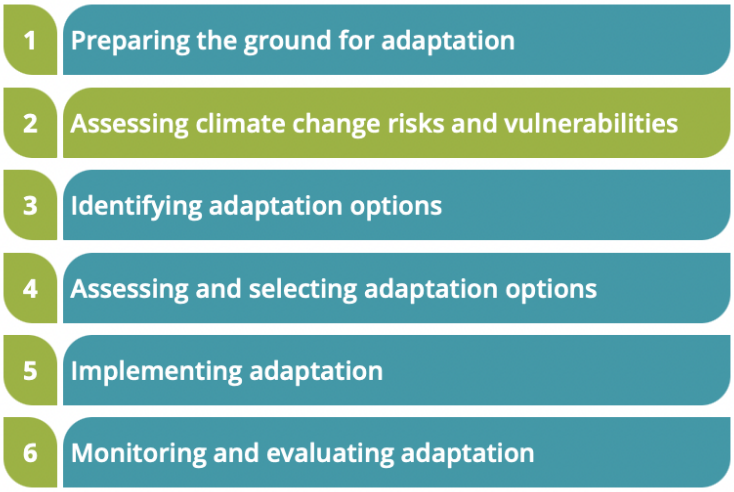
In October 2021, Emma Howard Boyd (Chair of the UK Environment Agency) said of the current state of climate change: "It is adapt or die" (Environment Agency, 2021). This is a direct acknowledgment of the more violent weather the climate emergency is bringing to all areas of the globe, and of the climate change impacts that are already experienced (which will most likely be worsened in the short- and medium-term). These impacts will occur even if temperature increases are constrained below 2°C. Moreover, the lagged response of Earth system processes to atmospheric $CO_2$ concentrations means these impacts will also occur even if greenhouse gas (GHG) emissions halted completely today. Following the 26th Conference of the Parties under the UNFCCC (COP26), experts still estimate that temperatures will increase by 2.1°C by 2100 even if all 2050 pledges and targets are delivered (Climate Action Tracker, no date). The impacts of such a temperature rise would be far-reaching, irreversible, and unconstrained by national borders.

Despite their relatively small contribution to GHG emissions on a global scale, small territories like Gibraltar will directly face climate-related hazards, and subsequently suffer such impacts that derive from historical and cumulative global GHG emissions. Gibraltar will also indirectly bear the climate change impacts from other countries, as supply chains will be disrupted, and migration patterns altered. The IPCC AR6 report on Impacts, Adaptation and Vulnerability includes a chapter on "Cities, Settlements and Key Infrastructure". This chapter reports on impacts from climate change experienced across urban areas due to single, compound and cascading events (IPCC, 2022). These include:

- Direct impacts of heat stress on human health
- Compound effects of individual climate hazards, given urban contexts' aggravating factors such as poor air quality (leading heatwaves to worsen traffic fumes), poor water quality (leading flooding to contaminate run-off and flood water), etc
- Cascading impacts, as damages in one system reduce resilience and/or generate impacts in another given the tight interconnectedness and proximity of urban systems (floods' damages on energy infrastructure causing financial and human impacts)

Ricardo Energy and Environment is supporting Gibraltar in its adaptation efforts, and simultaneously in fulfilling its commitments to the Global Covenant of Mayors, or GCoM (see Figure 1). The ultimate aim is to identify (and eventually implement) adaptation goals and actions. The first step of this process is to prepare the ground for adaptation by assessing Gibraltar's climate vulnerabilities and risks. As such, this Vulnerability and Risk Assessment (VRA) aims to assess the vulnerability (as a consequence of sensitivity and adaptive capacity) of Gibraltar's key economic sectors to future climate change, and evaluate which hazards are most likely to cause significant impacts. This assessment will help guide Gibraltar's adaptation priorities, and ultimately will help safeguard them from the impacts of future climate change.

Figure 1: Global Covenant of Mayor adaptation reporting requirements

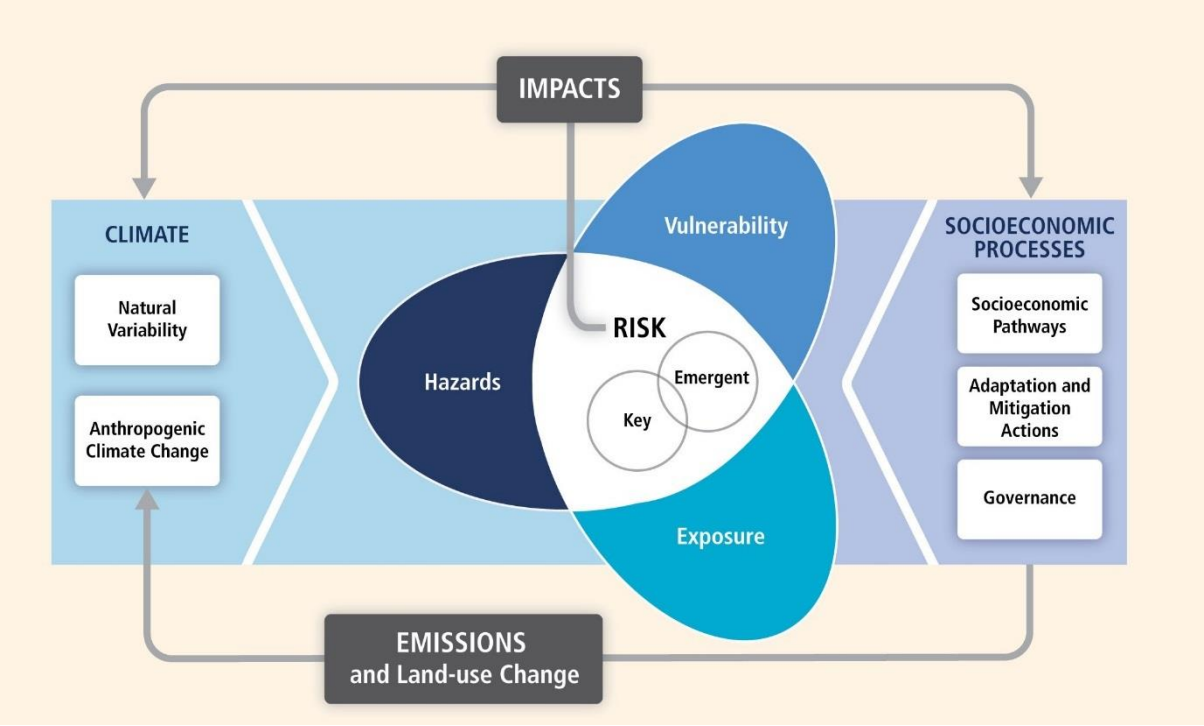



## 1.2 Methodology

This VRA was conducted using a combination of desk research and stakeholder consultations to extract key information on Gibraltar's vulnerability and the hazards it faces. The desk research involved analysing over 40 sources of information including targeted studies in Gibraltar, Intergovernmental Panel on Climate Change (IPCC) reports, and studies undertaken in geographies that have a similar geographical and biophysical profile as Gibraltar (Mediterranean, urban and coastal). The consultations involved interviews and questionnaires with over 70 key stakeholders in Gibraltar, including sectoral stakeholders, community stakeholders, and HM Government of Gibraltar officers. These interviews/questionnaires acted to extract important information on the lived experiences of people in Gibraltar. Results from both sources were cross-checked and combined, seeking additional information and using expert judgement gained through previous assessments where misalignment was identified.

This VRA is aligned with the latest definitions of terms from the IPCC's Fifth and Sixth Assessment Report (IPCC, 2014) (IPCC, 2022). As the United Nation's body for assessing the science related to climate change, the IPCC sets global standards for analysis and communication of climate risk. Use of the IPCC Fifth Assessment Report (AR5), Sixth Assessment Report (AR6) and Special Report on 1.5°C (SR15) definitions enables the assessment of climate vulnerabilities independently from hazards, focusing on sectors' "propensity or predisposition to be adversely affected". This is important to avoid relying on a preferred hazard scenario, and to ensure that the assessment does not incorporate uncertainties associated with climate projections. The IPCC terms, and their interactions, are illustrated in Figure 2 below.

Figure 2: IPCC AR5 interaction of key concepts.




Source: IPCC (2014) Figure 19-1

While the terms and interactions used in this assessment are based on those used by the IPCC, efforts were also made to align this methodology to the Global Covenant of Mayors (GCoM) format in which cities are required to report their VRA. This involved aligning the list of hazards used here with those defined by GCoM. However, while the GCoM format considers adaptive capacity separately to hazards and impacts, this approach considers adaptive capacity under the wider umbrella of vulnerability, alongside sensitivity (in line with IPCC terms). Furthermore, while the GCoM format has a separate section for health impacts, this assessment integrates health sector vulnerabilities and impacts into a sectoral analysis approach.

# 2 Vulnerability of Gibraltar

Vulnerability to climate change is defined as *"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"* (IPCC, 2022). Hence, the following sections explore the sensitivity and adaptive capacity of Gibraltar's main economic sectors.

A current limitation to adaptive capacity (a key component of vulnerability) for numerous sectors in Gibraltar is the lesser focus on adaptation planning in Gibraltar's recent Climate Change Strategy (HM Government of Gibraltar, 2021). The Climate Change Strategy is instrumental in shaping Gibraltar's climate response, prompting future actions, mobilising finance and encouraging stakeholders to take actions. All of these benefits represent elements of adaptive capacity. While climate-related risks related to urban flooding, water supply, biodiversity, health, and tourism are acknowledged in the Climate Change Strategy, it left more work to be done to identify specific actions to address them. The Strategy document itself does not fully integrate many of the adaptation measures required to ensure a reduction in climate risks.

This VRA is therefore a critical first step towards strengthening Gibraltar's adaptation response, which will be followed by the development of an enhanced and separate Climate Change Adaptation Strategy.

## 2.1 Energy sector

The energy sector is sensitive to climate change primarily due to the sensitivity of energy demand to temperature extremes. For example, extreme heat can see energy demand for air conditioning increase significantly, while extreme cold can see energy demand for heating increase. A particularly vulnerable population in relation to the energy sector is the elderly, who rely on heating/cooling to a greater extent than the general population due to their lower resilience to the health impacts of extreme temperatures. However, the current generating capacity exceeds needs, which provides some leeway to address changes in demand.

A more prominent factor of sensitivity is Gibraltar's almost complete reliance on imported fossil fuels. This lack of diversification in energy sources makes energy supply in Gibraltar particularly sensitive to events that may cause disruption of supply chains, such as extreme weather events causing physical damage to the infrastructure or disrupting transport routes (largely shipping). Gibraltar

To manage demand, adaptation measures are being put in place which increase the adaptive capacity of the energy sector. Gibraltar's Climate Change Strategy (HM Government of Gibraltar, 2021) highlights plans to produce 50% of all energy from renewables by 2030 and up to 70% by 2045. The existence of these plans increases the capacity of stakeholders to diversify their sources of energy by providing a policy framework that incentivises planning for, regulating, researching and investing in energy diversification, which would reduce the potential impacts that the sector may experience if the fossil fuel infrastructure is damaged. The Climate Change Strategy also states that "new buildings must use renewable energy to reduce dependence on the network and include green roofs to cool the building and reduce the heat island effect" (HM Government of Gibraltar, 2021, p.86). The Climate Change Strategy's focus on reducing demand from air conditioning also supports adaptive capacity by encouraging investments, plans research and regulation for better insultation in buildings which may, if successful, reduce the sector's sensitivity to temperature events in the long-term.

However, the capacity of the energy sector to fully adapt to future climate change is challenged by the potential political barriers to connecting its electricity supply with Africa via Morocco or Europe via Spain, which creates difficulty in diversifying the energy supply. Furthermore, consultation respondents noted that Brexit and COVID-19 have introduced significant financial/budgetary challenges, meaning that external funding could be required to finance renewable energy and decrease reliance on imported fossil fuels.

Overall, the assessment showed that the energy sector has a **high sensitivity** and **medium adaptive capacity**, making it **highly vulnerable** to climate change.

## 2.2 Transport sector

The transport sector is sensitive to climate change because the current materials and structure of the system cannot withstand the effects of extreme weather events. For example, extreme heat may melt and damage roads, while flooding and mass movement hazards (those associated with the mass movement of land, e.g. landslides, rockfalls) can physically block key transport routes, resulting in disrupting the movement of people and goods. Transport in Gibraltar is also dominated by private cars, meaning the transport sector is particularly sensitive to disruption/damage to road systems. Furthermore, the low-lying nature of most of Gibraltar's transport infrastructure (including the only airport) exacerbates this sensitivity. Shipping is a key mode of transport for the importation of goods (including fuel) in Gibraltar, and this mode of transport is sensitive to ocean conditions because severe weather can disrupt shipping pathways or damage infrastructure/equipment.

The elderly, children/youth, and people with chronic diseases or disabilities are particularly vulnerable to the disruption of the transport sector, as they generally have more limited mobility and greater reliance on others. These vulnerable populations may not be able to walk or transport themselves alone when public transport options are disrupted.

Adaptive capacity for the transport sector is adequate – despite competing budgetary demands, Gibraltar benefits from good economic health that should provide adequate funds for enhancing resilience in the transport sector. Furthermore, adaptation measures for transport have been proposed,

with the Climate Change Strategy stating that "*when designing new roads and thoroughfares, […] adequate provision should be made for water run off to limit the incidence of flash floods during heavy precipitation*" (HM Government of Gibraltar, 2021, p.86). Existing coastal flood defences in the city have also been designed with future climate change in mind, with upgrades made after the 2008 coastal storm taking into account sea level rise projections for Gibraltar (HM Government of Gibraltar, 2011). Nets have also been installed along the Rock to prevent rockfall. Long established processes and procedures are also implemented at the Port to monitor and respond to weather conditions in order the minimise any damage and disruption, such as by holding vessels in deeper water.

Overall, the assessment showed that the transport sector has a **high sensitivity** and **medium/high adaptive capacity**, making it **fairly vulnerable** to climate change .

## 2.3 Built environment sector

Residential, commercial, and industrial settings (here, all considered under the 'built environment' sector) are sensitive to climate change because the structural materials of buildings are often insufficient to withstand the effects of extreme weather events. For example, flooding can negatively impact the structural integrity of buildings, with the potential to cause significant physical damage to both the structure of the building and its contents. In Gibraltar, this sensitivity is exacerbated by the low-lying, coastal nature of the city (increasing sensitivity to coastal hazards) and the fact that much of the built environment is located at the base of the steep slopes of the Rock (increasing sensitivity to mass movement hazards). Furthermore, the design of the built environment itself can increase sensitivity to climate change, with Gibraltar's extensive urbanisation making the city more sensitive to temperature change from the urban heat island effect, and more sensitive to flash flooding hazards as a result of the prevalence of impermeable surfaces (Thinking Green, no date).

Key vulnerable populations for this sector are the elderly, children/youth, and people with chronic diseases or disabilities: these populations generally suffer more limited mobility and increased reliance on others, potentially reducing their ability to escape their homes in the incidence of an extreme event. Furthermore, the elderly are particularly vulnerable to the heat stress that may arise due to temperature increases coupled with the urban heat island effect.

Rapid urbanisation challenges adaptive capacity in Gibraltar's built environment sector, as the density of people and buildings in already densely populated low-lying areas continues to increase (Department of the Environment, 2009). Current land-use plans further exacerbate these issues; a new development project along the coastline aims to reclaim 60,000 sqm of new land from the sea within the harbour for residential/commercial purposes (HM Government of Gibraltar, 2019). This means more people/buildings will be placed in high-risk areas, making it even more difficult to adapt to the risks associated with future climate change. However, existing coastal flood defences in the city have been designed with future climate change in mind, with upgrades made after the 2008 coastal storm taking into account sea level rise projections for Gibraltar (HM Government of Gibraltar, 2011). Consultation respondents also highlighted the financial barriers reducing adaptive capacity in the built environment sector: homes in Gibraltar are not currently designed for intense heat, and increasing living costs and the unavailability of subsidies to invest in insulation, double-glazing and power saving technology limit the ability of residents to take adaptation measures at present. The Climate Change Strategy does, however, propose measures to address this, stating that "*new buildings must … include green roofs to cool the building and reduce the heat island effect*" (HM Government of Gibraltar, 2021, p.86).

Overall, the assessment showed that the built environment sector has a **high sensitivity** and **low adaptive capacity**, making it **highly vulnerable** to climate change.

## 2.4 Waste sector

In Gibraltar, waste is largely treated across the border at Los Barrios in Spain, meaning the waste sector is sensitive to extreme events in both Gibraltar and Spain that may impact the transport of goods (see section 2.2 for vulnerability of transport sector). Wastewater in Gibraltar is discharged to the ocean untreated, via a joint sewage-stormwater drainage system. This joint drainage system causes the wastewater system in Gibraltar to be sensitive to climatic changes that impact precipitation, sea level, or storms (all of which can cause flooding). Excessive water levels can overwhelm this drainage system

and bring floodwaters mixed with wastewater to street level (rather than draining straight to the ocean via the subsurface drainage system). The infrastructure conditions for this sector (i.e., the combined sewage-stormwater drainage system) are therefore deemed unfit for dealing with the increased pressure climate change may bring. Waste infrastructure is also sensitive to events that may cause physical damage.

Gibraltar's Climate Change Strategy (HM Government of Gibraltar, 2021) addresses this vulnerability by proposing that new roads and thoroughfares should make adequate provisions for water runoff to reduce flash flooding risks. This planned action acts to improve adaptive capacity of the transport sector (needed for transport of waste) as well as the wastewater system. The Climate Change Strategy also addresses the wastewater system through the proposed plan for sewage treatment.

Overall, the assessment showed that the waste sector has a **medium sensitivity** and **medium adaptive capacity**, making it **fairly vulnerable** to climate change.

## 2.5 Water sector

The water sector in Gibraltar is not sensitive to temperature and precipitation conditions, because water is supplied via desalination of seawater. However, water supply is sensitive to changes in the availability of energy (see section 0 for vulnerability of the energy sector), as the desalination process is highly energy intensive.

Key vulnerable populations in relation to the water sector are the elderly, children/youth, and people with chronic diseases/disabilities: these populations are often physically weaker or with pre-existing conditions, and are therefore more susceptible to health impacts related to water supply. For example, children drink more water relative to their body weight than adults (APHA, no date) meaning their health is particularly sensitive to changes in the availability of water.

A low reliance on natural water sources in Gibraltar increases adaptive capacity to hazards affecting natural water supply. HM Government of Gibraltar (no date) notes that droughts are not expected to significantly impact Gibraltar's population thanks to its reliance on desalination for drinking water. However, high reliance on energy for desalination means that the adaptive capacity challenges of the energy sector also apply to the water sector.

Overall, the assessment showed that the water sector has a **medium sensitivity** and **medium adaptive capacity**, making it **fairly vulnerable** to climate change.

## 2.6 Biodiversity sector

Ecosystems are highly sensitive to environmental conditions (and thus climate change) because species have specific tolerable ranges for such conditions. Terrestrial biodiversity is sensitive to temperature (e.g. extreme heat), precipitation (potential causing droughts), humidity, and salinity, while marine biodiversity is sensitive to temperature, pH, and the chemical composition of seawater (including pollutants). The drainage of sewage directly into the sea in Gibraltar exacerbates the sensitivity of marine biodiversity to future climate change, as this sewage pollution alters the environmental conditions to which marine life is highly sensitive, although some species do benefit. Similarly, high maritime traffic in Gibraltar (which also has the potential to cause marine pollution and negative changes to environmental conditions) is also likely to exacerbate the sensitivity of marine biodiversity to future climate change.

Adaptive capacity for the biodiversity sector in Gibraltar is fairly high, as Gibraltar is highly urbanised but with clearly defined areas of terrestrial biodiversity (i.e., the Upper Rock) which makes it easier to manage. Furthermore, the majority of terrestrial biodiversity in Gibraltar is located on high land making it easy to protect from sea level rise and flooding hazards. Adaptive capacity in relation to marine biodiversity, however, is challenged by the lack of control Gibraltar has over temperature and pH conditions of the ocean (which are impacted by processes occurring on a global scale).

Overall, the assessment showed that the biodiversity/forestry sector has a **high sensitivity** and **medium/high adaptive capacity**, making it **fairly vulnerable** to climate change.

## 2.7 Food and agriculture sector

Gibraltar is reliant on imported food products. Worldwide, agricultural production is highly sensitive to climatic conditions such as heat, humidity and precipitation, because these conditions define the growth rate and health of crops. As a result, Gibraltar's food systems are sensitive to climatic changes in the places from which they source their food, and also sensitive to events that disrupt the movement of goods (see section 2.2 for vulnerability of the transport sector).

Key vulnerable populations in relation to the food/agriculture sector are the elderly, children/youth, and people with chronic diseases/disabilities. These populations are often physically weaker or with pre-existing conditions, and thus are more susceptible to the health impacts of malnutrition.

Adaptive capacity for the food and agriculture sector is challenged by Gibraltar's reliance on imports (meaning adaptation in the earlier phases of the food production and supply chain is out of its control). However, adaptive capacity in this sector is supported by Gibraltar's good economic health, which should facilitate further diversification of food supply. Gibraltar is already securing food supplies from diverse countries, increasing its capacity to adapt in case events occur in a specific geography.

Overall, the assessment showed that the food and agricultural sector has a **high sensitivity** and **low/medium adaptive capacity**, making it **highly vulnerable** to climate change.

## 2.8 Public Health Sector

Public health systems are sensitive to climate change because environmental changes can alter the prevalence of illness and disease. For example, warming climates may increase the geographic range of insects associated with vector-borne diseases, while extreme heat may increase the prevalence of heat stress. In Gibraltar, up to half of hospital staff live across the border in Spain, meaning the public health sector is also sensitive to conditions affecting ease of crossing the border, such as transport (see section 2.2), political factors or extreme weather events. Furthermore, most medical care in Gibraltar happens at the only hospital. Having only one site for almost all medical care further increases the sensitivity of the public health sector to future climate change and the hazards it may bring because damage to the building could disrupt medical care for the entire population.

The elderly, children/youth, and people with chronic diseases/disabilities are all key vulnerable populations in relation to Gibraltar's public health sector. These populations are generally physically weaker and/or with pre-existing conditions, making them more susceptible to the health impacts of climate change. For children, excessive heat in schools during hotter months (often starting in May and extending into October) without adequate cooling facilities is a key health issue. In addition, the elderly and people with chronic diseases or disabilities are greater users of health systems generally, meaning closures or lack of resources affect them to a greater extent. Elderly people are also more prone to heat-related illness (CDC, 2017).

The high standard and high access to healthcare in Gibraltar supports the adaptive capacity of the health sector. Gibraltar's health sector has evidenced its ability to adapt rapidly when needed, with the height of the COVID-19 crisis seeing the rapid deployment of the Nightingale Ward at Europa Point. However, reliance on a single hospital for almost all medical care challenges adaptive capacity: having only one hospital means there is limited space/resources that may be more easily overwhelmed. Furthermore, high reliance on hospital staff living across the border in Spain means that adaptation measures for a significant proportion of healthcare providers is out of Gibraltar's control. Moreover, while the most recently built schools benefit from air conditioning, some still do not have the cooling equipment necessary to increase their capacity to adapt to heat. Students benefit from half-days for part of the year to help cope with heat stress, though this measure only applies for about 3 weeks at the end of June/beginning of July and one to two weeks in September.

Overall, the assessment showed that the public health sector has a **high sensitivity** and **low adaptive capacity**, making it **highly vulnerable** to climate change.

## 2.9 Tourism Sector

The tourism sector is sensitive to climate change because it relies on the proper functioning of other sectors. For example, it relies on land, sea and air transport (section 2.2) to enable tourists to visit, relies on biodiversity as a key touristic attraction (section 2.6) and on the built environment to safely host tourists (section 2.3). Changes in these sectors could reduce demand for tourism. Beaches are another key attraction for tourists, which are particularly sensitive to changes in coastal hazards (e.g. coastal erosion, coastal flooding, or sea levels).

Adaptive capacity in the tourism sector is supported by Gibraltar's generally good economic health (albeit currently still recovering from the impacts of Covid and Brexit) which means funds should be available to protect the tourism sector. Furthermore, the tourism sector is noted as one of the main contributors to Gibraltar's economy in the Climate Change Strategy (HM Government of Gibraltar, 2021), meaning it will likely take priority over competing budgetary demands. However, the importance of tourism to Gibraltar's economy also means that vulnerability in this sector is likely to increase the vulnerability of Gibraltar's economy as a whole; significant economic losses from tourism could reduce Gibraltar's financial adaptive capacity.

Some action has already been undertaken to protect Gibraltar's beaches, with significant works undertaken at Sandy Bay to build protective groynes and replenish the sand. Previously built groynes are also still in place at Eastern Beach and Camp Bay as well as sand replenishment at Catalan Bay.

Overall, the assessment showed that the tourism sector has a **high sensitivity** and **low adaptive capacity**, making it **highly vulnerable** to climate change.

## 2.10 Summary

The sensitivity, adaptive capacity, and overall vulnerability of Gibraltar's main economic sectors is summarised in Table 1.

Table 1: A summary of the sensitivity, adaptive capacity, and overall vulnerability of Gibraltar's main economic sectors.

| Sector | Sensitivity | Adaptive Capacity | Overall Vulnerability Rating |
|---|---|---|---|
| Energy | High | Low | **High** |
| Transport | High | Medium-High | **Fair** |
| Built Environment | High | Low | **High** |
| Waste | Medium | Medium | **Medium** |
| Water | Medium | Medium | **Medium** |
| Biodiversity/Forestry | High | Medium-High | **Fair** |
| Food and Agriculture | High | Medium-Low | **Medium** |
| Public Health | High | Low | **High** |
| Tourism | High | Low | **High** |

# 3 Hazards projections

The first instalment of the IPCC's Sixth Assessment Report (AR6: The Physical Science Basis) states that it is "unequivocal" that rising atmospheric greenhouse gas (GHG) concentrations are the result of human activities, and that these anthropogenic GHG emissions are the main driver of changes observed across the atmosphere, the ocean, the cryosphere, and the biosphere (IPCC, 2021). Anthropogenic GHG emissions continue to rise, and the resulting climate change is expected to

increase the frequency and intensity of many natural hazards. However, these changes will not be homogeneous across the world.

While climate-related hazards *within* Gibraltar should be of primary concern, it is also important to note that hazards in other countries may also have an impact on Gibraltar. In section 2, Gibraltar's reliance on food imports, fossil fuel imports, waste exports, and hospital staff from Spain were discussed in relation to vulnerability to events occurring outside of Gibraltar. As such, climate-related hazards in other countries will also be of concern to Gibraltar.

It is important to note that hazards alone do not result in impacts. It is only when assets/people are exposed to the hazard that impacts arise, and the extent of these impacts depends on the extent of exposure as well as the extent of vulnerability to the hazard. Gibraltar's vulnerability is discussed in section 2 while Gibraltar's present and future exposure to hazards will be discussed in the sections below. Section 3 describes the magnitude of hazards most relevant to Gibraltar (identified in the desk research and stakeholder consultations) and how these might change in the future. While the hazards assessment followed the GCoM list of hazards, some of these hazards have been combined (e.g. "meteorological flooding" considers the GCoM hazards "rain storms" and "flash/surface flooding" together).

## 3.1 Meteorological flooding

This section comprises the hazards "rainstorm" and "flash/surface flooding". The hazards "river flood" and "groundwater flood" are not included, as they have been deemed not relevant to Gibraltar – Gibraltar has no rivers, and a flood risk assessment for the city found that "*groundwater flooding is unlikely to occur in Gibraltar and there have been no recorded incidents of flooding from this source*" (HM Government of Gibraltar, 2011, p.11).

While river and groundwater flooding do not occur in Gibraltar, flash flooding (resulting from intense periods of rainfall, or rainstorms) is not uncommon. While the probability of meteorological flooding is fairly high (with HM Government of Gibraltar (2011) noting that it occurs frequently) this hazard currently occurs at low/medium magnitude (HM Government of Gibraltar, 2011; GBC News, 2018a).

Southern Europe is projected to see an overall decrease in rainfall, but shifting distributions of rainfall are expected to cause a future increase in the frequency and intensity of extreme precipitation events (or rainstorms) which, in turn, are projected to result in future increases in meteorological flooding (HM Government of Gibraltar, 2011; Kovats *et al.,* 2014). As such, meteorological flooding in Gibraltar is likely to increase in both frequency and intensity under future climate change.

## 3.2 Coastal flooding and sea level rise

This section comprises all hazards that are related to coastal flooding and sea level rise, including "storm surges", "permanent inundations", "saltwater intrusion" and "coastal erosion".

Gibraltar is almost completely surrounded by water and coastal flooding has historically occurred in Gibraltar, with the 2008 coastal storm (one of the most serious flooding events in Gibraltar's recent history) producing a notable storm surge that resulted in severe flooding (HM Government of Gibraltar, 2011). This was an extreme case that has not been seen since. The current probability and magnitude of this hazard have therefore been deemed medium.

Permanent inundation and saltwater intrusion have not occurred in Gibraltar historically (this is assumed, due to the lack of identifiable documentation on past instances of these hazards, and a lack of mention in the consultations). However, the frequency and intensity of these hazards is likely to increase in the future as sea levels continue to rise.

Sea level rise (SLR) increases the risk of coastal flooding hazards around the world, and Gibraltar is no exception. IPCC (2021) project global mean SLR of up to 0.55m by 2100 (relative to 1995-2014) under the lowest GHG emissions scenario, and up to 1.01m under the very high GHG emissions scenario.

While storm-tracks are projected to shift slightly northward under future climate change (Frame *et al.,* 2017), the frequency and intensity of rainstorms (see section 3.1) is projected to increase (HM Government of Gibraltar, 2011; Kovats *et al.,* 2014). This, alongside projections of future SLR, implies

a future increase in the frequency and intensity of storm surges and coastal flooding. The frequency and intensity of saltwater intrusion and permanent inundation are also expected to increase, in line with projections of significant SLR in the future.

## 3.3 Heatwaves / Extreme Heat

At the Southern tip of Europe, Gibraltar is no stranger to extreme heat, with the highest temperature recorded just topping 40°C (ECA&D, no date). Heatwaves have also historically occurred in Gibraltar, though often at a lower magnitude than other regions in Spain (ECA&D, no date). As such, the current probability of heat-related hazards is high, though the current magnitude is deemed medium/high.

Since 1950, extreme hot days and heat waves have become more frequent across Europe and this trend is projected to continue (Kovats *et al.,* 2014). The IPCC have previously stated that "*climate change is very likely to increase the frequency and intensity of heat waves, particularly in Southern Europe*" (Kovats *et al.,* 2014, p.1270). Similarly, Naumann *et al.* (2020) project that increases in exposure to extreme heat will be most profound in Southern Europe, and in particular Spain. As such, both the frequency and intensity of heatwaves/extreme heat events are expected to increase in Gibraltar in the future.

## 3.4 Drought

Droughts (or sustained periods of no rainfall) are not uncommon in Gibraltar, with summer droughts sometimes lasting up to 90 consecutive days (Gibnet, no date). The annual summer drought is characteristic of the Mediterranean climate, but these droughts can often become prolonged. The current probability of this hazard is therefore high, though the current magnitude of this hazard is deemed medium in line with consultation responses.

The IPCC have found that Southern Europe displays trends toward longer and more intense droughts and project that climate change will continue to increase water stress over Central and Southern Europe (Kovats *et al.,* 2014). Southern Europe is also expected to see an overall decrease in annual rainfall (Kovats *et al.,* 2014). As such, both the frequency and intensity of droughts are expected to increase in Gibraltar in the future.

## 3.5 Mass movement

This section considers the hazards "rockfall" and "landslides".

The presence of the Rock of Gibraltar means that mass movement hazards are highly relevant for the city, and both rockfalls (Lightbody *et al.,* 2015; Gibraltar Chronicle, 2018) and landslides (The Olive Press, 2015; GBC News, 2021) have previously occurred on a number of occasions. As such, both landslide and rockfalls are deemed to have medium current probability and medium current magnitude.

Lightbody *et al.* (2015) use IPCC model projections of future climate change to project future increases in both the frequency and magnitude of rockfalls, slope failures, and debris flow (i.e., landslides) in Gibraltar. These changes are projected to occur as a direct result of increased extreme rainfall events, and as an indirect result of decreased vegetation growth and increased wildfire incidence (resulting from increased summer temperatures; Lightbody *et al.* 2015). As such, rockfalls and landslides are projected to increase in both frequency and intensity in the future. Gibraltar's Climate Change Strategy notes that this hazard is expected to affect the Eastern side of the Rock to a greater extent (HM Government of Gibraltar, 2021).

## 3.6 Severe wind

The Levanter wind is a persistent wind that blows into the Strait of Gibraltar from the East, often causing strong winds in the Strait (Capon, 2006). As a result of this physical process, severe winds are not uncommon in Gibraltar (Capon, 2006; BBC News, 2019). Gale force winds also sometimes occur in association with storms. This hazard is therefore deemed to have medium current probability and medium current magnitude.

Increasing ocean temperatures under climate change are expected to increase wind speeds (Young and Ribal, 2019). This, alongside Gibraltar's coastal characteristics, implies that severe winds will increase in both frequency and intensity in Gibraltar in the future.

## 3.7 Lightning / Thunderstorms

Consultations revealed that lightning/thunderstorms currently occur in Gibraltar with medium probability and medium magnitude. This is supported by a study by Taszarek *et al.* (2019), who use measurements and observations to investigate the incidence of lightning and thunderstorms across Europe, including Gibraltar specifically.

Lighting and thunderstorms are projected to decrease slightly in Southwestern Europe under future climate change, because the occurrence of lightning and thunder is sensitive to humidity which is projected to decrease in this area (Radler *et al.,* 2019). As such, this hazard is projected to decrease in both frequency and intensity in the future. This is also supported by Taszarek *et al.* (2019), who found almost no change in the overall incidence of thunderstorms between the periods 1979-1997 and 1998-2017, but small decreases in some months.

## 3.8 Hail

Hail occurs occasionally in Gibraltar in association with storms, with a number of consultation respondents noting that they have experienced this hazard in the past. As such, this hazard is deemed to have medium current probability and low current magnitude.

Under future climate change, projected increases in convective storms (resulting from rising temperatures and increased lower atmosphere humidity) mean that the occurrence of hail (as well as large hail) is projected to increase across the whole of Europe, including Southwest Europe (Radler *et al.,* 2019). As such, Gibraltar can expect to experience an increase in the frequency and magnitude of hail in the future.

## 3.9 Fog

The Levanter wind (see section 3.6) often brings with it sea fog coming from the East, particularly during light levanter in the summer, making the Eastern coast more affected by this hazard (Gibnet, no date). As such, fog is deemed to have medium current probability and medium current magnitude in Gibraltar.

The link between climate change and fog is highly uncertain, due to the high number of influencing variables and geographic variation (Torregrosa *et al.,* 2014). As a result, future changes to the frequency and intensity of this hazard in Gibraltar are uncertain.

## 3.10 Wildfires

Numerous consultation respondents noted that wildfires have occurred in Gibraltar in the past. However, as vegetated areas in Gibraltar are almost exclusively limited to the Upper Rock, this hazard is deemed to have low current probability and low current magnitude.

The IPCC have projected that future wildfire risk will increase in Southern Europe, with an increase in the occurrence of "high fire danger" days and increases in the length of fire seasons (Kovats *et al.,* 2014). Lightbody *et al.* (2015) also note that Gibraltar can expect to experience increased wildfires in line with rising temperatures. Both the frequency and intensity of this hazard can therefore be expected to increase in Gibraltar under future climate change.

## 3.11 Ocean acidification

The dissolution of atmospheric $CO_2$ into the ocean causes decreases in ocean pH, or ocean acidification, across the world's oceans (Hoegh-Guldberg *et al.,* 2014). Mediterranean waters have seen pH decreases of 0.05-0.14 pH units since the preindustrial period, with anthropogenic $CO_2$ having penetrated the entire Mediterranean water column (Hoegh-Guldberg *et al.,* 2014). The western Mediterranean basin (i.e., near Gibraltar) has experienced greater decreases than the eastern basin

(Hoegh-Guldberg *et al.,* 2014). This hazard is therefore deemed to have high current probability and medium current magnitude in Gibraltar.

As anthropogenic $CO_2$ emissions continue, and atmospheric concentrations of $CO_2$ rise accordingly, this $CO_2$ will carry on dissolving in the upper ocean and being mixed throughout deeper ocean layers over time (Hoegh-Guldberg *et al.,* 2014). As a result, ocean acidification can be expected to increase across the world's oceans, including those surrounding Gibraltar. If current trends continue, the western Mediterranean basin may see greater increases than the Eastern basin.

## 3.12 Insect infestation & Vector-borne disease

The Asian Tiger mosquito has fairly recently arrived in Gibraltar (HM Government of Gibraltar, 2020). This acts as evidence that insect infestation has already occurred. Other instances of insect infestation in Gibraltar were not identified through the desk research or consultations which support this assessment, though this lack of documented evidence does not necessarily mean that they have not occurred. The current probability of insect infestation is therefore deemed to be medium, and the current magnitude is deemed to be low.

The Asian Tiger mosquito, like many other insects, can act as a vector for vector-borne disease. The Asian Tiger mosquito is considered a vector for chikungunya fever, dengue fever, and zika virus, while other vector-borne diseases of concern include malaria, Lyme disease, yellow fever, West Nile fever, and numerous others (ANSES, 2020; CDC, 2020). While the Asian Tiger mosquito does exist in Gibraltar, the vector-borne diseases associated with the species are not currently prevalent in the area (HM Government of Gibraltar, 2020), and as a result the current probability and current magnitude of vector-borne diseases in Gibraltar are both deemed to be low.

The effect of climate change on the distributions of insects as a whole is highly uncertain due to the ecological complexity of insect responses to changing environmental conditions (Lehmann *et al.*, 2020). As a result, future changes to the frequency and magnitude of insect infestation in Gibraltar are largely uncertain.

The effect of climate change on vector-borne disease, however, is slightly less uncertain – more specific studies on disease-spreading vectors (which may be insects, arachnids etc) have found that as temperatures rise, many vector species are projected to spread further throughout Europe, while new vector species from the tropics may also be introduced (Githeko *et al.,* 2000). As a result, the frequency and magnitude of vector-borne diseases in Gibraltar are both likely to increase under future climate change.

## 3.13 Air-borne disease

Air-borne disease has occurred in Gibraltar, with the COVID-19 pandemic highlighted by many respondents in the consultations. While many respondents felt that the current magnitude of this hazard was high, Gibraltar has actually benefited from fairly low exposure to this hazard compared to many other places in the world (Reuters, 2021). As a result, the current probability and magnitude of this hazard have been deemed medium.

Future changes to the frequency and magnitude of air-borne disease in Gibraltar are uncertain – the link between climate change and air-borne disease has been noted as highly uncertain due to the wide range of influencing factors (Wu *et al.,* 2016).

## 3.14 Summary

Current and projected climate hazards trends are summarised in

Table 2.

Table 2: A summary of the climate-related hazards faced by Gibraltar.

| Hazard | Current | | Future | |
|---|---|---|---|---|
| | *Probability* | *Magnitude* | *Frequency* | *Magnitude* |
| Meteorological flooding | Medium-High | Medium-Low | Increase | Increase |
| Coastal flooding and SLR | Medium | Medium | Increase | Increase |
| Heatwaves/ Extreme heat | High | Medium-High | Increase | Increase |
| Drought | High | Medium | Increase | Increase |
| Mass movement | Medium | Medium | Increase | Increase |
| Severe wind | Medium | Medium | Increase | Increase |
| Lightning/ Thunderstorm | Medium | Medium | Decrease | Decrease |
| Hail | Medium | Low | Increase | Increase |
| Fog | Medium | Medium | Uncertain | Uncertain |
| Wildfires | Low | Low | Increase | Increase |
| Ocean acidification | High | Medium | Increase | Increase |
| Insect infestation | Medium | Low | Uncertain | Uncertain |
| Vector-borne disease | Low | Low | Increase | Increase |
| Air-borne disease | Medium | Medium | Uncertain | Uncertain |

# 4 Impacts

Impacts from climate change refer to "*The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure*." (IPCC, 2022). This section summarises the potential impacts which may occur given sections 2 and 3.

## 4.1 Energy sector

The vulnerability of the energy sector to temperature extremes, alongside the expected increase in heatwaves/extreme heat, means that negative impacts on the energy sector are highly likely. While their magnitude is currently limited thanks to excess production capacity, energy demand for air conditioning is likely to increase as temperatures increase, and erratic spikes in energy demand are likely to occur during temperature extremes. Gibraltar's highly urbanised nature is likely to further exacerbate these negative impacts on demand due to urban heat island effects, as densely built and populated areas act to retain more heat than their rural counterparts (National Geographic, no date). This is likely to result in greater impacts from extreme heat in Gibraltar. However, actions within Gibraltar's Climate Change Strategy (HM Government of Gibraltar, 2021) to reduce overall energy demand will help to reduce the magnitude of these impacts through increasing adaptive capacity.

These impacts can add pressure on energy supply, and would ultimately cause shortages that will disrupt a number of key services and sectors, if needs were to exceed generating capacity. This is corroborated by Kovats *et al.* (2014), who note that increases in the frequency and intensity of heatwaves in Southern Europe are expected to have adverse impacts on numerous sectors, including energy production and use. Furthermore, as Gibraltar is currently almost entirely reliant on imported fossil fuels for energy, there is no alternate supply to call on in case demand spikes result in shortages.

As Gibraltar imports fossil fuels to supply all of its energy demand, this sector is also vulnerable to impacts on the transport sector (e.g. coastal storms may disrupt shipping) and climate change impacts in fuel exporting countries. Such impacts could disrupt the importation of fossil fuels, potentially resulting in energy supply shortages.

Negative climate change impacts on the energy sector are likely to also have cascading impacts on the water sector, due to Gibraltar's reliance on energy-intensive desalination for drinking water.

## 4.2 Transport sector

In Gibraltar, the transport sector has already experienced some negative impacts from numerous climate-related hazards. Landslides and rockfalls have both previously blocked roads (; Gibraltar Chronicle, 2018; GBC News 2021), roads have been flooded (HM Government of Gibraltar, 2011; GBC News 2018a), and severe wind often results in airplane diversions. This has resulted in temporary disruption to transport services, primarily impacting the movement of people, but also likely impacting the movement of goods.

Gibraltar can expect negative impacts from all of these hazards to increase, as all are projected to increase in both frequency and magnitude under future climate change. Flooding in particular poses a significant risk to key transport infrastructure, including the low-lying airport (the only airport directly serving the city). In Gibraltar, upgraded flood defences have been designed to withstand 0.5m of SLR, in line with projections for the Mediterranean (HM Government of Gibraltar, 2011).

Furthermore, other hazards (for which no previous impacts on the transport sector have been identified) are also likely to cause negative impacts in the future. Future increases in the frequency and intensity of heatwaves in Southern Europe are expected to result in adverse impacts (Kovats *et al.,* 2014). Extreme heat can melt and damage roads and may also increase demand for non-active transport (e.g., cars, buses). Future increases in the frequency and magnitude of fog and hail could result in visibility issues, temporarily disrupting transport and posing significant danger. Coastal storms may also act to disrupt shipping.

Gibraltar's highly urban setting is also likely to exacerbate future heat and flood impacts on the transport sector. The urban heat island effect is likely to intensify the impacts of extreme heat (National Geographic, no date), while impermeable urban surface such as pavements and roads reduce the ability of water to drain into underlying soils and thus increasing the impact of flash flooding (EEA, 2017).

The inherent interdependency between sectors magnifies the impacts of climate change on the transport sector. For example, disruption to transport may disrupt emergency services, food and energy imports, and waste exports. The economic (e.g. physical damage requiring costs to repair and disrupting commutes) and social (e.g. effects on community, how connected it is, its access to entertainment, etc) impacts of such disruption may therefore be significant.

## 4.3 Built environment sector

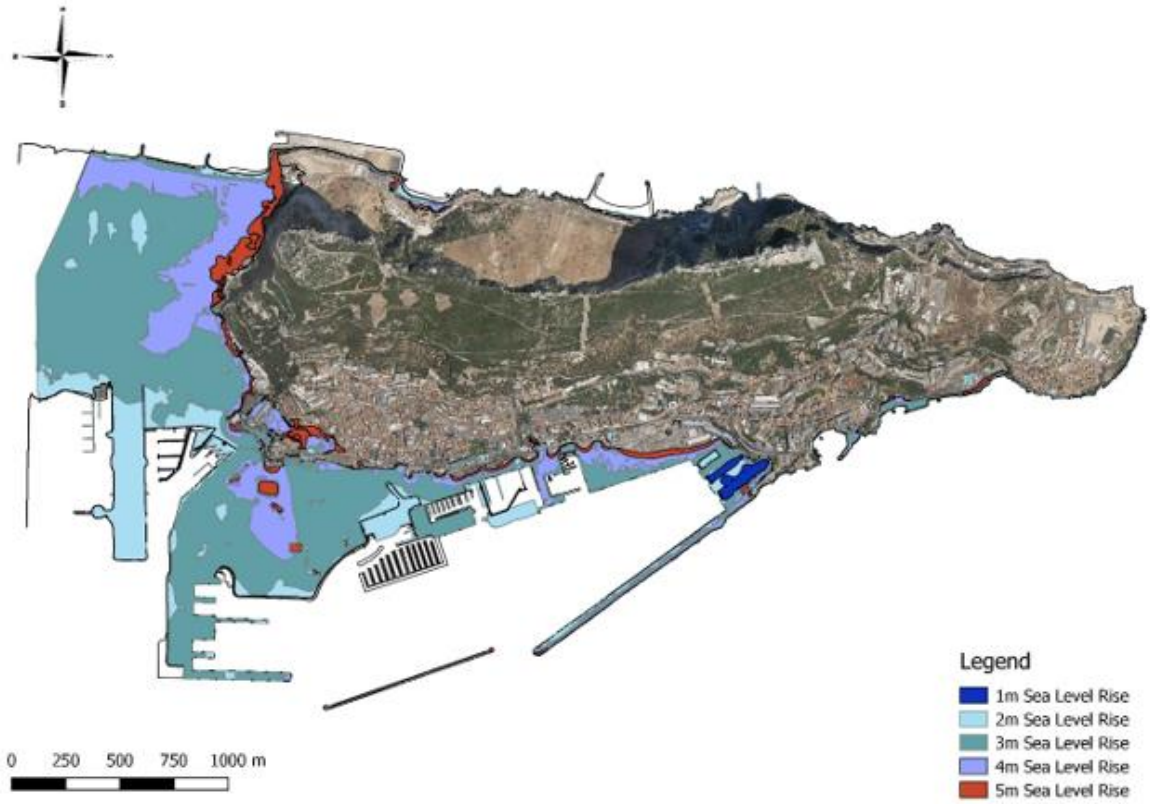
Climate-related impacts on the built environment sector have occurred in the past, with houses flooded during the 2008 coastal storm (EU Cities Adapt, 2013). This storm also resulted in economically significantly damage to the built environment, with costs of repair to sea defences exceeding £10 million (HM Government of Gibraltar, 2011). Negative impacts on the built environment from other climate-related hazards were not identified.

Climate-related impacts on the built environment are thus currently deemed fairly low, but negative impacts are likely to increase as extreme precipitation events and coastal hazards increase in frequency and intensity. Gibraltar's Climate Change Strategy (HM Government of Gibraltar, 2021) maps out the

areas of Gibraltar vulnerable to SLR, and also maps out the infrastructure at risk of impacts from coastal flooding hazards: Figure 3 and Figure 4 demonstrate that the future impacts on the built environment could be significant. In Gibraltar, upgraded flood defences have been designed to withstand 0.5m of SLR, in line with projections for the Mediterranean (HM Government of Gibraltar, 2011).

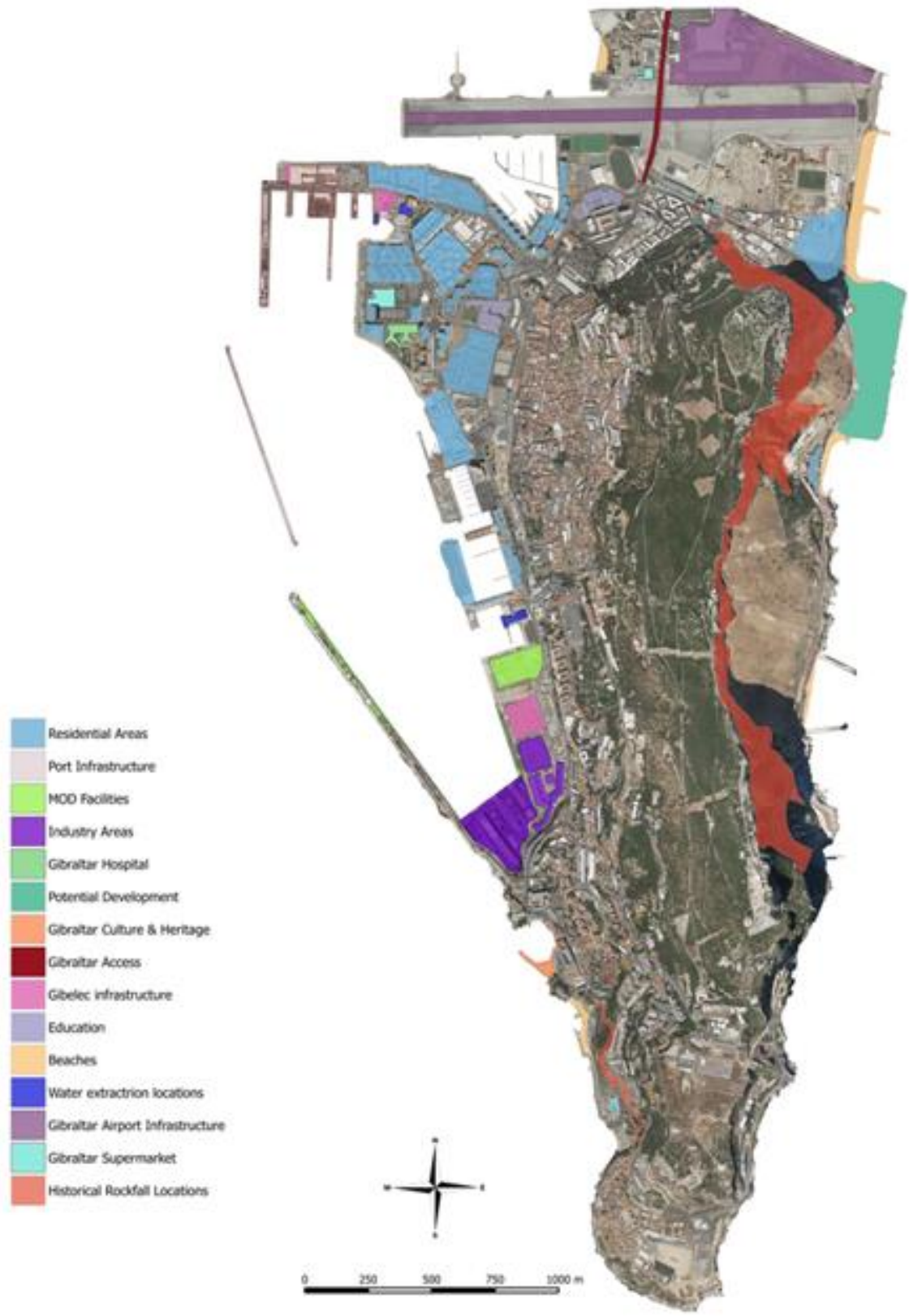
Kovats *et al.* (2014) also note that future increases in the frequency and intensity of heatwaves in Southern Europe are expected to have adverse impacts on the built environment. Gibraltar's highly urban setting is likely to exacerbate future heat and flood impacts on the built environment. The urban heat island effect is likely to intensify the impacts of extreme heat (National Geographic, no date), while impermeable urban surface such as pavements and roads reduce the ability of water to drain into underlying soils and thus increasing the impact of flash flooding (EEA, 2017).

Figure 3: Vulnerable areas of Gibraltar affected by sea level rise.




Source: Climate Change Strategy (HM Government of Gibraltar, 2021)

Figure 4: Infrastructure and areas of development identified as vulnerable in Gibraltar.




Source: Climate Change Strategy (HM Government of Gibraltar, 2021)

## 4.4 Waste sector

In the past, flooding has resulted in overflow of sewage from the drainage system onto streets and has also resulted in irreparable structural damage to Gibraltar's sewage pumping station (HM Government of Gibraltar, 2011). These impacts can be expected to increase in the future, as flooding hazards are expected to increase in both frequency and intensity. Gibraltar's impermeable urban surfaces are likely to exacerbate these impacts, as pavements and roads reduce the ability of water to drain into underlying soils and thus increase flash flooding risks (EEA, 2017). Drain blockages associated with improper disposal of waste may also exacerbate the impact of flash flooding.

The waste sector in Gibraltar is also vulnerable to impacts on the transport sector and, in the future, climate-related disruption to transport could have cascading impacts on waste exports to Spain.

## 4.5 Water sector

The 2008 coastal storm, and subsequent flooding, caused seawater extraction points to be lost underwater for 12 days (HM Government of Gibraltar, 2011; EU Cities Adapt, 2013). This event also resulted in the need to divert water supply, costing AquaGib somewhere in the region of £300,000 to £400,000 (EU Cities Adapt, 2013). These impacts can be expected to increase in the future, as flooding hazards are expected to increase in both frequency and intensity. Gibraltar's impermeable urban surfaces are expected to exacerbate these impacts, as pavements and roads reduce the ability of water to drain into underlying soils and thus increase the impacts from flooding (EEA, 2017).

Gibraltar's reliance on desalination for drinking water means droughts have not previously had significant impacts on the water sector. This reliance on desalination, and subsequent shielding to the human impacts of drought, is expected to continue. HM Government of Gibraltar (no date) note that "*droughts are not expected to affect the human population in Gibraltar very much, as our drinking water largely originates from desalination, but flora and fauna populations are likely to suffer from the decreased rainfall*". As such, future droughts are primarily expected to impact the biodiversity sector (see section 4.6) rather than the water sector.

## 4.6 Biodiversity sector

Biodiversity and forestry are highly vulnerable to environmental conditions, meaning future climate change is highly likely to impact this sector. Biodiversity in Gibraltar spans natural ecosystems on the Rock, along the coast and in the Mediterranean sea, as well as urban biodiversity including trees, insects, birds and other species living in urban areas. Future increases in the frequency and intensity of heatwaves in Southern Europe are expected to have adverse impacts on biodiversity as a whole (Kovats *et al.,* 2014), with extreme heat likely taking temperature conditions beyond the habitable range for some species. The urban heat island effect (National Geographic, no date) could exacerbate these impacts in urban areas, potentially disrupting the composition and number of insects species and disrupting neighbouring ecosystems.. Furthermore, decreased annual precipitation and increased instances of drought may cause water stress on both plants and animals. These environmental changes may result in biodiversity loss. Increases in wildfire incidence could also cause significant losses to biodiversity and forestry. However, as Gibraltar's biodiversity is largely located on high land (i.e., the Upper Rock) floods are not likely to significantly impact this sector.

Biodiversity losses resulting from these environmental changes may go on to alter ecosystem composition, potentially negatively impacting ecosystem health. Vegetation losses that may occur due to lower overall rainfall (i.e., drought) and wildfires are also likely to have cascading impacts on other sectors due the increased risk of mass movement hazards (rockfalls, landslides) that results from these losses (Lightbody *et al.,* 2015).

Marine biodiversity is also likely to be negatively impacted by ocean acidification – "*periods of high temperature can increase vulnerability to ocean acidification, thereby increasing the long-term risk posed to Mediterranean organisms and ecosystems as temperatures warm*" (Hoegh-Guldberg *et al.,* 2014, p.1685). Ocean temperature increases may also take environmental conditions beyond the habitable range for many native species. Climate change impacts on individual marine species may result in significant changes to marine ecosystem composition. For example, consultation respondents

noted an increase in jellyfish numbers in the ocean surrounding Gibraltar in recent years, although this may have other causes as well.

Changes to ecosystem compositions could have cascading impacts on the tourism sector, by causing a loss to touristic assets.

## 4.7 Food and Agriculture Sector

As Gibraltar imports the vast majority of its food, climate-related hazards within Gibraltar are not likely to have major impacts on food supply. However, negative impacts on the transport sector (see section 4.2) could have cascading impacts on the food and agriculture sector by disrupting the importation of food. Hazards occurring outside of Gibraltar may also impact Gibraltar's food supply (e.g. increases in the frequency and magnitude of heatwaves in Southern Europe (Kovats *et al.,* 2014) could result in food sources from nearby being negatively impacted).

## 4.8 Public health sector

Negative impacts on the public health sector from climate-related hazards have already been experienced in Gibraltar. In 2002, a 100-tonne rock fall at Dudley Ward resulted in a fatality (Lightbody *et al.,* 2015), while the 2008 coastal flood resulted in the temporary loss of emergency services (EU Cities Adapt, 2013). Furthermore, Southern Europe experienced almost 42,000 heat-related fatalities between 1980 and 2017 (Naumann *et al.,* 2020).

Future increases to the frequency and magnitude of mass movement hazards (i.e., landslides and rockfall) could also result in physical injury/fatality, while transport impacts from these hazards (see section 4.2) could further disrupt emergency services.

No significant human impacts from flooding hazards have yet been experienced (HM Government of Gibraltar, 2011). However, future increases to the frequency and magnitude of flooding hazards could result in damage to the low-lying hospital, disruption to the movement of hospital staff across the border, disruption to emergency services, or physical injury/fatality. Furthermore, wastewater overflow (a high risk in the instance of flooding) is unsanitary and could cause illness.

Increased vector-borne disease and increased instance of heat-related illness (due to an increase in heat-related hazards) could also put further pressure on health services. The urban heat island effect is also likely to increase the impacts of heat-related hazards on public health.

Finally, the loss of recreational assets such as beaches (due to coastal erosion, coastal flooding, or sea level rise) may impact community wellbeing and mental health– Gibraltar's beaches are used extensively by residents in the hot summer months, and their loss could result in increased reliance on indoor air conditioning in the summer months.

## 4.9 Tourism Sector

Cascading impacts from other sectors are likely to negatively impact the tourism sector. For example, considering its impacts on transport, severe wind may reduce the viability of air transport into Gibraltar (aircraft already divert to Malaga during periods of severe wind). Disruption to road transport (e.g. due to flooding) may also prevent tourists arriving over the land border. These impacts could result in a lower number of tourists entering Gibraltar, and thus reduced income from tourism (a key economic sector in Gibraltar).

Furthermore, increases in the frequency and magnitude of extreme heat may reduce the attractiveness of Gibraltar to tourists, while losses of biodiversity and ecosystem composition shifts due to climate change may result in a loss of touristic assets in the biodiversity sector. In particular, the loss of beaches (a key touristic asset) as a result of coastal erosion, coastal flooding, or sea level rise could significantly reduce tourist numbers.

As tourism is a key contributor to Gibraltar's economy (HM Government of Gibraltar, 2021) the economic impacts of climate change on the tourism sector could be significant. These economic impacts could go on to negatively impact Gibraltar's adaptive capacity, by reducing its financial health and thus reducing funding available for adaptation.

# 5 Summary

This VRA has assessed the sensitivity of Gibraltar's key economic sectors to future climate change, the capacity of these sectors to adapt to future climate change, and the climate-related hazards likely to impact Gibraltar in the future. This assessment has identified that the following sectors may be impacted the most in Gibraltar:

**Energy** – Energy demand is sensitive to temperature conditions, and projected increases in general temperatures, as well as the incidence of extreme heat events, means future spikes in demand are likely. This could result in energy shortages, which would impact numerous other sectors. A lack of alternative supply compounds this vulnerability. Furthermore, Gibraltar is currently reliant on fossil fuel imports, making the energy sector sensitive to disruption in the transport sector (in particular, shipping).

**Transport** – Land transport infrastructure is vulnerable to numerous hazards such as flooding, rockfall, landslides, and extreme heat, all of which can cause physical damage and thus disrupt key transport services. Shipping (key to the importation of fuel) is also vulnerable to oceanic hazards such as coastal storms. Such negative impacts on the transport sector will affect numerous other sectors. For example, Gibraltar imports all of its fossil fuels for energy and all of its food, while waste is exported to Spain and a large proportion of hospital staff live across the border in Spain.

**Built Environment** – Gibraltar's high density of buildings on low-lying coastal land makes this sector highly vulnerable to flooding hazards. The high density of assets also means that the economic impacts of extreme climate-related events could be significant.

**Food and Agriculture** – Gibraltar, with no agricultural land, is almost completely reliant on food imports. This makes the food sector in Gibraltar highly vulnerable to transport disruption, and also means that Gibraltar has no control over adaptation measures in places where food is produced.

**Public Health** – Public health is sensitive to numerous hazards, and this is especially the case for vulnerable populations such as the elderly, people with chronic illnesses or disabilities, and children/youth (all of whom are generally the greatest users of health services already). Gibraltar also has only one hospital, so that, disruption to this one site would disrupt healthcare for Gibraltar's entire population. Gibraltar also has a high reliance on hospital workers residing in Spain, making this sector particularly vulnerable to impacts on the transport sector.

**Tourism** – Tourism is highly sensitive to climate change impacts in other sectors – for example, impacts on the transport sector could reduce the number of tourists entering Gibraltar, while biodiversity losses could reduce touristic assets, particularly in the Upper Rock. The loss of beaches (another key touristic asset) to sea level rise or coastal erosion could also significantly reduce visitor numbers. Furthermore, tourism is a fundamental economic activity in Gibraltar, meaning tourism losses could cause significant economic impacts that could reduce Gibraltar's adaptive capacity as a whole.

# 6 Next steps

Having assessed Gibraltar's vulnerability to climate-related risks, Gibraltar should now prioritise the identification of suitable adaptation actions and goals to address these vulnerabilities and risks, and to ensure the timely implementation of adaptation efforts. There are a number of ways Gibraltar could adapt to future climate change:

- **By reducing the sensitivity of key economic sectors:** For example, ensuring new buildings and new infrastructure are designed and built to withstand extreme weather events.
- **By increasing adaptive capacity:** For example, improving government capacity for work on climate change issues would improve Gibraltar's ability to adapt to climate change in a timely manner.
- **By reducing exposure to key hazards:** For example, ensuring robust coastal defences when building on low-lying coastal land would reduce the exposure of assets to coastal flooding hazards.

In considering the need to adapt to future climate change, it is important to note the uncertainty surrounding projections of future climate change and the resulting climate-related hazards. Projections

of future climate change are largely produced using Earth System Models (ESMs) – these models simplify complex Earth system processes (to ensure computational efficiency), and the projections made therefore suffer from numerous sources of uncertainty related to process representation. Another key source of uncertainty (beyond model processes themselves) is the future of anthropogenic $CO_2$ emissions, and the outcomes of COP26 have highlighted the persistence of this uncertainty.

As such, it is important to base future action on Gibraltar's vulnerability, rather than on the expected impacts from a singular expected future emissions scenario. The need to adapt is also increasingly urgent: even if all of the 2050 pledges and targets from COP26 are delivered, which in itself is highly uncertain, temperatures are still expected to increase by 2.1°C by 2100 (Climate Action Tracker, no date) with potentially catastrophic impacts.

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