# Guide on climate proofing for investment preparation in EU programming period 2021-2027

Proposed update of the Guide to investment preparation, respecting climate change mitigation and adaptation and resilience to natural disasters (2017)

Version 1.1

# Contents

## Preface

The EU funds in the programming period 2021 – 2027 (Invest EU, Connecting Europe Facility - CEF[1], European Regional Development Fund – ERDF, Cohesion Fund – CF and Just Transition Fund – JTF) aim, among other objectives, at promoting the transition towards a net zero carbon economy and a resilient Europe. The legislation governing their operations therefore requires that the various supported projects – many of which include major infrastructure investments - undergo climate proofing to determines whether they are aligned with climate mitigation targets (emission reduction) and are adapted to climate change, that is, to the conditions of a changed and changing climate that affect and will progressively affect projects during their lifetime (project cycle).

The EC Technical guidance on climate-proofing of infrastructure projects for the period 2021-2027[2] represents the main document of reference for the present guidance which also builds upon the current available Polish Project preparation guide that was used for the programming period 2014 - 2020[3].

Chapter 1 of this guide presents the relevant regulations and guidance documents concerning EU climate objectives, funding requirements and, more in particular, the referred technical guidance which supports integrating climate change considerations in project preparation.

Chapter 2 and 3 propose the practical implementation of this guide in Poland and they also build upon the currently available Polish guide. They provide specific considerations for the project preparation stages, particularly, from early strategy level as well as feasibility studies stage for infrastructural projects in Poland.

This updated guide however does not repeat all the details of the EC Technical guidance on climate-proofing or other relevant reference documents at the EU and national level. It rather summarises them and present their key provisions, established links between them, as well as lists the key documents and resources that should be used during the climate proofing process for infrastructure investment projects.

Additional information on the resources that can be used in the climate proofing process and sectoral guidance on climate proofing are presented in the annexes.

It should be noted that a properly done climate proofing assessment can inform the DNSH assessment for the climate change mitigation and adaptation objectives.

This document was prepared by JASPERS[4] for the Polish Ministry of Climate and Environment with Piotr Czarnocki as the project coordinator. It should be noted that the original JASPERS document was prepared

[1] For CEF projects please refer to CEF requirements about climate proofing

[2] Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (2021/C 373/01), European Commission, 2021

[3] Project Preparation Guide: Taking Into Consideration Climate Changes, Mitigation Thereof, Adaptation and Disaster Resilience, Ministry of the Environment Department of Sustainable Development, 2015 (1st version) and 2017 (update)

[4] JASPERS is a joint initiative between the European Investment Bank (EIB) and the European Commission that provides advisory, appraisal and capacity building support for the preparation and implementation of programmes

in English and it was translated in Polish using the terminology used in the Polish version of the EC climate proofing guidance.

and projects financed by EU Cohesion policy, including Just Transition Fund and the Connecting Europe Facility. For more information please visit : https://jaspers.eib.org/

# 1 Part I: European Commission's recommendations for climate proofing

## 1.1 Introduction

Following the adoption of the Paris Agreement, the EU has adopted two cornerstones of its climate policy for the next decades – the **European Green Deal** presented in December of 2019 and the **European Climate Law** adopted in June 2021.

The **European Green Deal** is a comprehensive package of measures ranging from cutting greenhouse gas emissions, to investing in cutting-edge research and innovation and to preserving EU's natural environment. It sets out the EU's strategy for increasing the EU's climate ambition; supplying clean, affordable and secure energy; mobilising industry for a clean and circular economy; promoting sustainable construction, use and renovation of buildings; accelerating the shift to sustainable and smart mobility; creating zero pollution and a toxic-free environment; preserving and restoring ecosystems and biodiversity; and developing fair, healthy and environmentally friendly food systems. It also commits the EU actions and policies to 'doing no harm' in environmental terms and facilitating just transition towards a sustainable future.

The **European Climate Law** pursues two primary objectives: climate-neutrality and adaptation to climate change. It sets a legally binding target of net zero greenhouse gas emissions by 2050 as well as 55% emission reduction target for 2030. As for the Adaptation to climate change, the European Climate Law requires the relevant EU institutions and the Member States to ensure continuous progress in enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change.

The **Common Provisions Regulation (EU) 2021/1060** (CPR) laying down common provisions for some EU Funds – such as the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Just Transition Fund and the European Maritime, Fisheries and Aquaculture Fund - in its Recital 10 states that in the context of tackling climate change "the Funds should contribute to mainstreaming climate actions and to the achievement of an overall target of 30 % of the Union budget expenditure supporting climate objectives". Art. 6 of the CPR also clarifies that ERDF and the Cohesion Fund shall contribute with 30 % and 37 % respectively of the Union contribution to expenditure dedicated to the achievement of the climate objectives. Recital 10 also states that "the Funds should support activities that would respect the climate and environmental standards and priorities of the Union and would do no significant harm to environmental objectives within the meaning of Article 17 of the EU Taxonomy Regulation". In this respect it calls for "adequate mechanisms to ensure the climate proofing of supported investment in infrastructure should be an integral part of programming and implementation of the Funds".

Comprehensive information concerning Polish context on all aspects of EU funds legislation, with glossary can be found in the document prepared by the Ministry of Development Funds and Regional Policy: "Komentarz do rozporządzeń UE dla polityki spójności na lata 2021-2027" and additional information in this website.

Also, the **Recovery and Resilience Facility Regulation (EU) 2021/241** stipulates in Article 5 that this Facility can only support measures that respect do no significant harm principle within the meaning of Article 17 of the EU Taxonomy Regulation. Therefore, when it comes to climate change mitigation and adaptation, all infrastructure projects funded by the EU should undergo climate proofing as a way to addressing the 'do no significant harm' principle for climate change mitigation and adaptation.

To this effect, the European Commission published in September 2021 the **Technical guidance on climate-proofing of infrastructure projects for the period 2021-2027** (from hereby the "EC Guidance"). The EC Guidance aims to help the EU deliver the European Green Deal, implement requirements under the European Climate Law and fulfils the climate-related requirements set out in the legislation for several EU funds such as InvestEU, Connecting Europe Facility (CEF), European Regional Development Fund (ERDF), Cohesion Fund (CF) and the Just Transition Fund (JTF). It also includes recommendations to support national climate-proofing processes in Member States and strongly encourages infrastructure projects to carry out climate proofing following the guidance.

The climate proofing, as recommended or in alignment within the EC Guidance, represents best practice in this field; therefore, it may be applied in any project irrespective of the funding source and may become standard practice along project development cycle in Poland. This Guide document therefore aims to contribute to establishing the standard application of climate proofing in the preparation of infrastructure projects in Poland.

## 1.2 Undertaking climate proofing within infrastructure investment preparation in Poland

Climate proofing was already a requirement for Major Projects in the EU Programming Period 2014-2020 and in Poland, climate risk assessment was also included in smaller projects. Under OPI&E 2014-2020, all infrastructure investments were required to carry out a climate risk assessment. The requirement to apply the analysis for smaller projects stemmed from the horizontal instruction to the template of the application for funding for all sectors covered by OPI&E 2014-2020.

In the EU 2021-2027 programming period, the requirement applies to a wider range of EU Funds (including CEF, Invest EU, ERDF, CF and JTF) available for the financing of infrastructure projects. Climate proofing is not supposed to be one more additional bureaucratic procedure but should actually help to develop climate neutral and resilient projects. It should be integrated in the existing process and procedures of infrastructure planning and project preparation, assessment and approval, and preferably early in the project cycle (e.g. preparation of relevant strategies and plans or pre-feasibility/feasibility studies) when wider set of options to ensure low-carbon and resilient development might be considered. It should be noted that climate proofing should be incorporated in all the phases of the project cycle including the decommissioning phase.

According to the EC Guidance, infrastructure includes:

- buildings, from private homes to schools or industrial facilities, which are the most common type of infrastructure and the basis for human settlement;
- nature-based infrastructures (see Box 1) such as green roofs, walls, spaces, and drainage systems.
- network infrastructure crucial for the functioning of today's economy and society, notably energy infrastructure (e.g. grids, power stations, pipelines), transport (fixed assets such as roads, railways, ports, airports or inland waterways transport infrastructure), information and communication technologies (e.g. mobile phone networks, data cables, data centres), and water (e.g. water supply pipelines, reservoirs, waste water treatment facilities);

- ‘green’ infrastructure and mixed forms of ‘grey/green infrastructure’ as planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings’
- systems to manage the waste generated by businesses and households (collecting points, sorting and recycling facilities, incinerators and landfills);
- other physical assets in a wider range of policy areas, including communications, emergency services, energy, finance, food, government, health, education and training, research, civil protection, transport, and waste or water;
- other eligible types of infrastructure may also be laid down in the fund-specific legislation, for instance, the InvestEU Regulation includes a comprehensive list of eligible investments under the sustainable infrastructure policy window.

In addition to this traditional ‘grey’ infrastructure, the EC Guidance suggests that climate proofing – when performed – should also consider ‘green’ infrastructure and mixed forms of ‘grey/green infrastructure’. More information on green infrastructure is provided in the Box 2.

It is essential that climate proofing is integrated into the different stages of project cycle management. Not all low-carbon and/or climate adaptation options are always available at all stages of the project cycle – some decisions are better taken at the level of strategy and/or plan, some are more suited for the operational management of specific projects. If climate change considerations are included starting from earlier stages of project, preparation, a broader set of potential climate resilient and low-carbon solutions might be considered, including potentially more cost-effective ones.

The following sections provide an overview of the climate proofing process, the links with the EIA and SEA processes but also more practical information on the implementation within the Polish context.

**Box 1: Nature-based solutions**

EC defines nature-based solutions as *"Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."*

Nature-based solutions are considered a sub-set of green infrastructure (see Box 2).

Under Horizon 2020 and Horizon Europe, the European Commission funds research and innovation projects that propose nature-based solutions (NBS) to fight climate change and biodiversity loss, while improving our health and creating jobs. In May 2022 the Commission has published `Evaluating the impact of nature-based solutions: a handbook for practitioners`. The Handbook aims to provide decision-makers with a comprehensive NBS impact assessment framework, and a robust set of indicators and methodologies to assess impacts of nature-based solutions across 12 societal challenge areas. The publication also includes a summary for policymakers and an appendix of methods.

In addition the Commission has published another two reports on `Public procurement of nature-based solutions` and on `The vital role of nature-based solutions in a nature positive economy`. The latter is a first step in addressing knowledge gaps in the potential economic benefits of Nature-Based Solutions (NBS) and the challenges facing Nature Based Enterprises (NBE).

The European Investment Bank (EIB) has also published in 2023 a report on "Investing in nature-based solutions", aimed at fostering nature-based solutions to climate change and reversing biodiversity loss. The report assesses the current state of deployment of nature-based solutions in Europe — in large part supported by the EU budget — and draws lessons from the implementation of the pioneering Natural Capital Financing Facility pilot programme, which ran from 2015 to 2022. In particular, the report makes recommendations to increase support for nature-based solutions at scale across our continent's varied landscape, from forests and cities to coastlines and cultivated fields.

**Box 2: Green infrastructure**

Commission Communication COM/2013/249 describes *Green Infrastructure (GI) as following:*

*'Green infrastructure is a successfully tested tool for providing ecological, economic and social benefits through natural solutions. It helps us to understand the value of the benefits that nature provides to human society and to mobilise investments to sustain and enhance them. It also helps avoid relying on infrastructure that is expensive to build when nature can often provide cheaper, more durable solutions. Many of these create local job opportunities. Green Infrastructure is based on the principle that protecting and enhancing nature and natural processes, and the many benefits human society gets from nature, are consciously integrated into spatial planning and territorial development. Compared to single-purpose, grey infrastructure, GI has many benefits. It is not a constraint on territorial development but promotes natural solutions if they are the best option.*

Green infrastructure *is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings'.*

Such services include, for example, water purification, improving air quality, providing space for recreation, as well as helping with climate mitigation and adaptation. This network of green (land) and blue (water) spaces improves the quality of the environment, the condition and connectivity of natural areas, as well as improving citizens' health and quality of life. The Natura 2000 network of protected areas constitutes the backbone of the EU's green infrastructure.

Green infrastructure provides alternatives to traditional 'grey' infrastructure, often at a lower cost. The multi-functionality is one of the key attractions of green infrastructure. Some examples of green infrastructure and their multi-functionality include [EC, Green infrastructure website]:

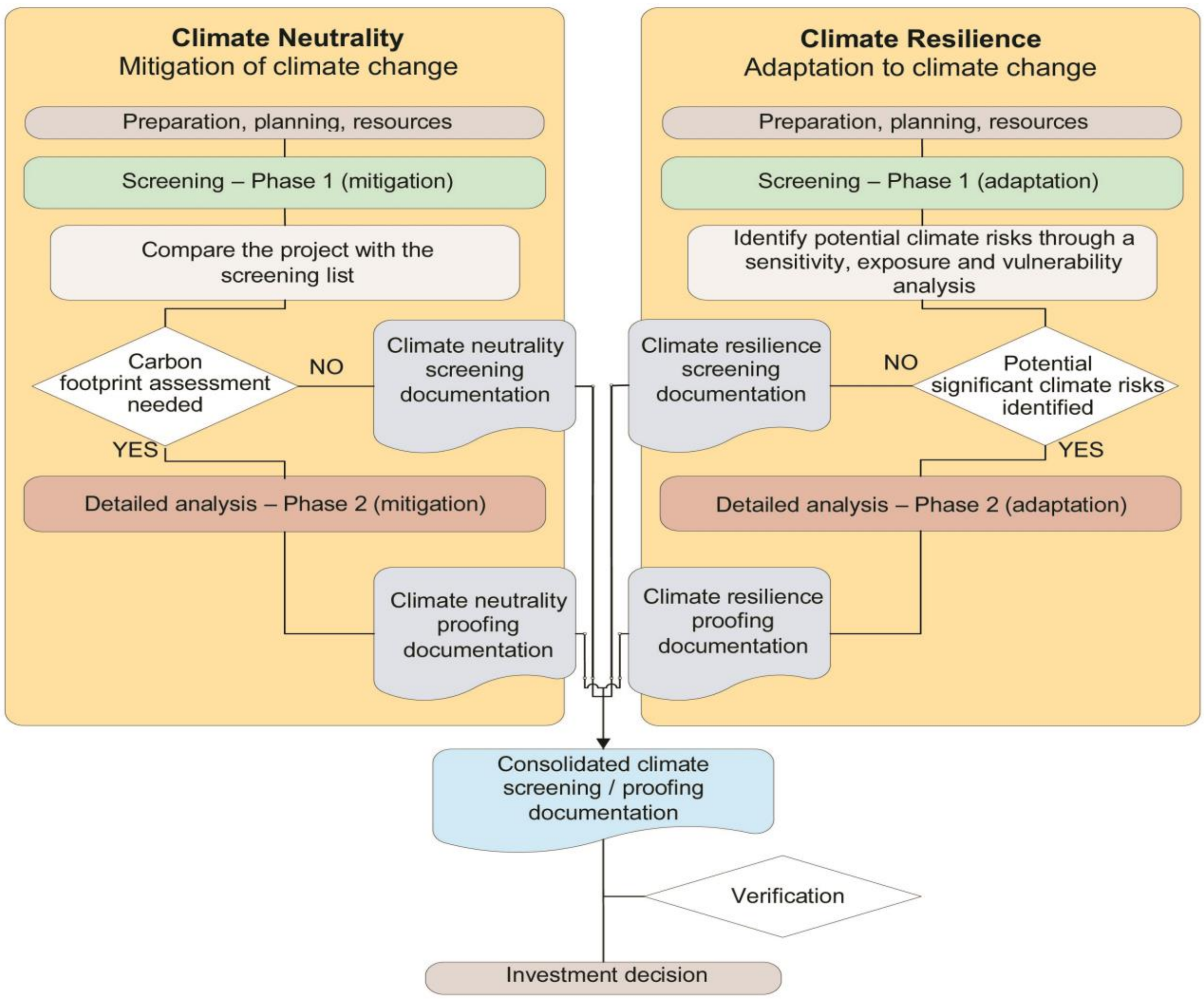
- Well-designed urban green spaces, (parks, gardens, green roofs, allotments…) can contribute to protecting biodiversity, while helping to tackle climate change, keeping cities cool, reducing flood risks and enhancing the health and well-being of urban residents.
- Restoring wetlands is a suitable, often cheaper, alternative to building a new water treatment plants, that can also provide many other natural services, including space for migrating birds, and for pollinators to thrive;
- Restoring floodplains is also much cheaper and often much more effective at preventing floods than building a new, higher dykes.

Other useful references related to green infrastructure include: "Green infrastructure resource library" and "Building with Nature" which is an assessment and accreditation service for green infrastructure in housing and commercial development.

## 1.3 Key elements of climate proofing

According to the EC Guidance, climate proofing includes two pillars (see Figure *1*): a climate neutrality proofing that validates the project's compatibility with the objective of climate neutrality by 2050, and the climate resilience proofing that verifies the resilience of the infrastructure to foreseeable climate risks during its lifetime since its very initial phases to the decommissioning phase[5]. A climate proofing assessment helps identifying the significant risks for climate generated by the infrastructure project and climate risks for the infrastructure project. It is the basis for identifying, appraising and implementing the optimal option for the planed infrastructure project and for indicating possible targeted mitigation and adaptation measures which will help reduce the above-mentioned risks to an acceptable level.

Figure 1 Climate proofing and its two pillars: 'climate neutrality proofing' and 'climate resilience proofing'




Source: European Commission (2021a)

[5] See "Project development cycle" on the example of adaptation in https://jaspers.eib.org/knowledge/publications/the-basics-of-climate-change-adaptation-vulnerability-and-risk-assessment-polish, Figure 1

For each of the 2 pillars, the actual climate proofing approach involves two steps – a screening and a full assessment. Both steps can be easily integrated into the entire project cycle management for infrastructure projects.

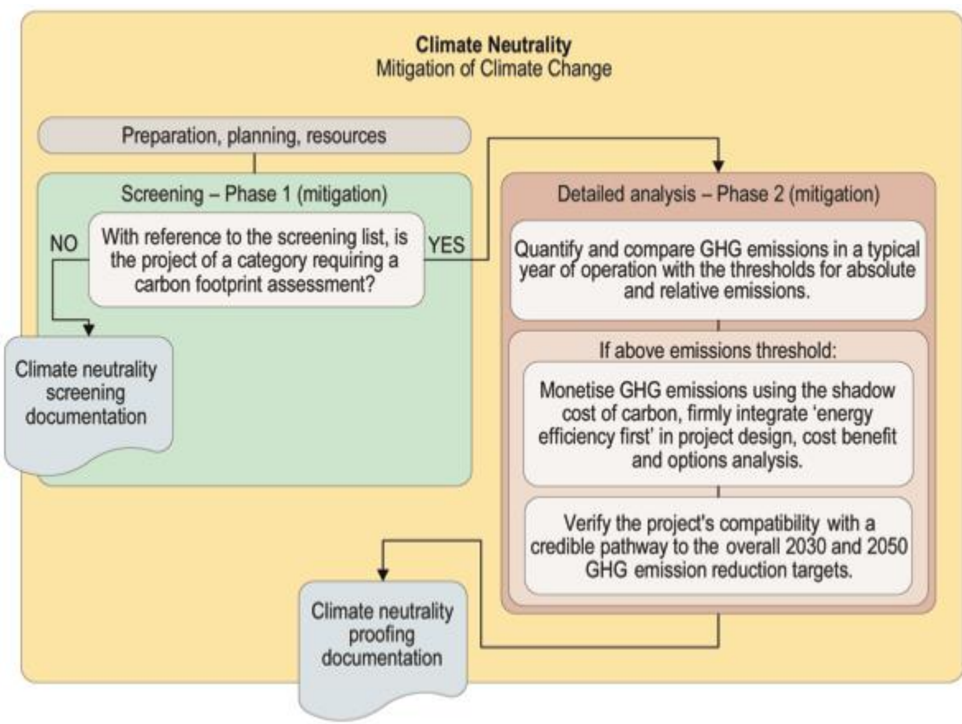
The screening involves a relatively simple determination whether the proposed infrastructure may cause significant emissions of greenhouse gasses (so-called climate neutrality screening) and whether it could potentially be vulnerable to present and future climatic conditions (so-called the climate resilience screening). The second step – the detailed analysis – is conducted only when the screening indicates that the project requires more detailed scrutiny on each of the two assessments.

The results of the climate proofing process – covering at least the screening phase and, if conducted, the full assessment - need to be reported. These can be presented separately or integrated into relevant technical reports that supports financing requests for the proposed infrastructure, and should be closely coordinated with the analysis of its expected environmental impacts that are normally conducted within the SEA or EIA processes.

## 1.4 Climate neutrality proofing

The specific guidance for climate neutrality proofing is provided in sub-chapter 3.2 of the EC Guidance. The entire process is illustrated by Figure 7 of the EC Guidance (reproduced below). The following text summarises key provisions in the scope of the present Guide.

Figure 2 Overview of the climate mitigation related process for climate proofing (hereafter referred to as climate neutrality proofing)




Source: European Commission (2021a)

The EC Guidance recommends that the climate neutrality proofing that involves calculation of the greenhouse gas (GHG) emissions and their monetisation should be conducted for individual investments that may cause significant GHG emissions. It is noted that some sectoral guidance is available to support calculation of GHG emissions for projects and, when duly aligned with EC Guidance methodology, can be used for climate proofing such as the Blue Books[6] for transport.

Given the EU climate neutrality target, it is important that all investments that may cause significant GHG emissions[7] are assessed for their alignment with the climate neutrality pathway.

**Phase 1 - Climate neutrality screening**

The EC Guidance recommends that the countries use the EIB carbon footprint methodology and assess all projects that may cause significant emission greater than 20,000 tonnes CO2e/year (absolute or relative).

**ABSOLUTE GHG EMISSIONS: Project's emissions estimated for an average year of operation.**

**RELATIVE GHG EMISSIONS: The difference (delta) between the absolute project emissions and the baseline scenario emissions (for an average year of operation).**

To simplify the initial determination whether the infrastructure may – or may not – cause significant GHG emission, the EC Guidance suggests to simply screen the infrastructure based on indicative examples of infrastructure categories presented in

[6]Blue Books (JASPERS) are guidance for preparation of detailed cost-benefit analyzes and feasibility studies considerations in the transport sector for EU co-financing (those include detailed guidance on related GHG emissions calculations and proposed emission factors): https://www.cupt.gov.pl/strefa-beneficjenta/wdrazanie-projektow/analiza-kosztow-i-korzysci/metodyka-analizy-kosztow-i-korzysci/metodologie-szczegolowe/ (TO BE UPDATED VERY SOON) and last update of Blue Book unit costs including latest emission factor calculations https://www.cupt.gov.pl/wp-content/uploads/2022/06/koszty-jednostkowe_v_14_20_105.xlsx.

[7] According to the EC Guidance it is absolute and/or relative emissions above 20,000 tonnes CO2e/year (positive or negative).

Table *1*. The first category of infrastructure listed in this table will likely not require the calculation of GHG emissions but the second one will need it. Projects that fall under the second category will further require detailed climate neutrality assessment (see below). In case of uncertainty as to whether the project's absolute and/or relative emissions could exceed 20,000 tonnes CO2e/year (positive or negative), a preliminary carbon footprint calculation should be performed. If a type of infrastructure is not explicitly mentioned in

Table *1* then the beneficiary should do a preliminary carbon footprint calculation to check if the GHG emissions (absolute and relative) are above or below 20,000 tonnes $CO_2e$/year.

Table 1 Climate neutrality screening list

| Screening | Categories of infrastructure projects | Comment |
| --- | --- | --- |
| In general, depending on the scale of the project, ***carbon footprint assessment WILL NOT be typically required*** for these categories of projects. | - Telecommunications services<br>- Drinking water supply networks<br>- Rainwater and wastewater collection networks<br>- Small scale industrial wastewater treatment and municipal waste<br>- Water treatment<br>- Property developments[8]<br>- Mechanical/biological waste treatment plants<br>- Research and Development activities<br>- Pharmaceuticals and biotechnology | The climate neutrality proofing for these project categories requires only phase 1 (screening) and will conclude with it. |
| In general, ***a carbon footprint assessment WILL[9] be typically required*** for these project categories. | - Municipal solid waste landfills<br>- Municipal waste incineration plants<br>- Large wastewater treatment plants<br>- Manufacturing Industry<br>- Chemicals and refining<br>- Mining and basic metals<br>- Pulp and paper<br>- Rolling stock, ship, transport fleet purchases<br>- Road and Rail infrastructure[10], urban transport<br>- Power transmission lines<br>- Renewable sources of energy<br>- Fuel production, processing, storage and transportation<br>- Cement and lime production<br>- Glass production<br>- Heat and power generating plants<br>- District heating networks<br>- Natural gas liquefaction and re-gasification facilities<br>- Gas transmission infrastructure<br>- Any other infrastructure project category or scale of project for which the absolute and/or relative emissions could exceed 20,000 tonnes CO2e/year (positive or negative) according to EIB Carbon Footprint methodology | The climate neutrality proofing for these project categories will include both phase 1 (screening) and phase 2 (detailed analysis). |

Source: European Commission (2021a)

**Phase 2 - Climate neutrality detailed analysis**

The EC Guidance recommends that the detailed analysis in climate neutrality proofing includes quantification and monetisation of GHG emissions (and reductions) and their consistency with the climate change mitigation targets for 2030 and 2050. The assessment typically involves the following main steps:

[8] Including among other safe and secure parking and external border checks.
[9] Any infrastructure that is not eligible for funding should be excluded.
[10] Measures addressing road safety and reduction of rail freight noise may be exempted

- Setting up boundaries of the GHG emissions assessment
- Determining baseline situation and the project alternative(s)[11] to be considered in the assessment
- Estimating the GHG emissions for baseline and project alternative(s) according to the EIB carbon footprint methodology
- Estimating the carbon externalities using shadow carbon prices and including them in the CBA or alternative Economic Appraisal method used
- Verifying compatibility with a credible GHG pathway based on the EU's 2030 and 2050 emissions targets

While it is understood that each project is unique, the following principles should be used during the assessment steps:

### *Determining the baseline situation and the project alternative(s) to be considered in the assessment*

The baseline for the carbon footprint methodology is often referred to as the "likely alternative" to the proposed developments, and the baseline for the calculation of the relative GHG emissions or emission reductions that will be achieved through the project. The baseline situation should outline the situation without the project and should ideally consider the not only the absence of the project but also the likely changes in the baseline conditions in the absence of the proposed project over its lifetime – e.g., the expected future transport flows without the project. The baseline conditions will become 'zero alternative 'to consider in the GHG emission calculations and their monetisation. It is also noted that often the baseline scenario is the one that is assessed in the context of the Project's CBA or Economic Appraisal. The different project alternative(s) that are defined of the project options analysis should be assessed in respect of GHG emissions (and related externalities) as part of the options comparison.

This assessment might also be part of criteria for comparing options at different stages of the project preparation together with other relevant criteria/objectives.

### *Setting up boundaries of the GHG emissions assessment and estimating the GHG emissions*

The project boundary defines what is to be included in the calculation of the absolute and relative emissions. The EC Guidance suggests that the GHG emissions assessment should quantify both absolute and relative GHG emissions for a typical year of the project operation. The GHG emissions assessment may cover the following scopes of GHG emissions:

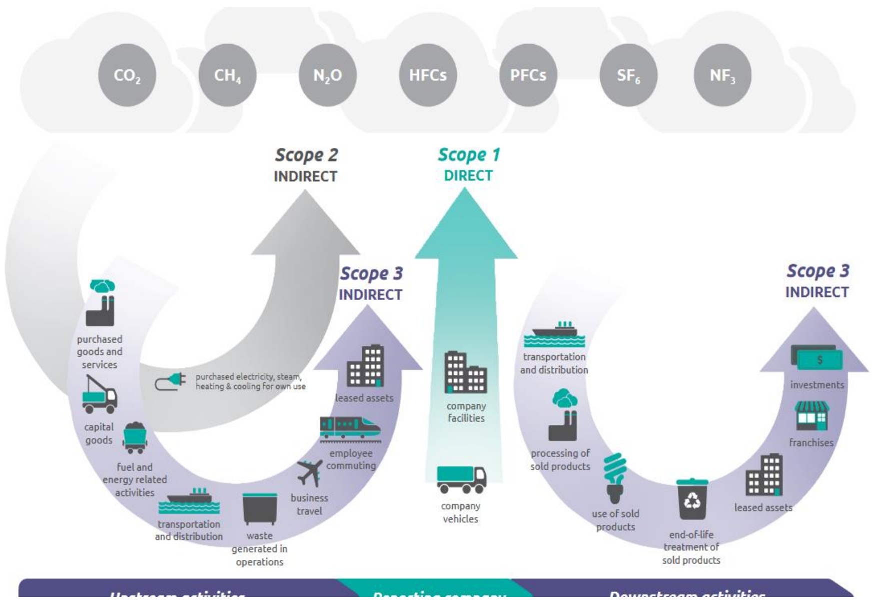
- Direct (Scope 1) GHG emissions. Direct GHG emissions physically occur from sources that are operated by the project. For example, emissions produced by project with the combustion of fossil fuels, by industrial processes and by fugitive emissions, such as refrigerants or methane leakage.

- Indirect (Scope 2) GHG emissions. Scope 2 accounts for indirect GHG emissions associated with energy consumption (electricity, heating, cooling and steam) consumed but not produced by the project. These are included because the project has direct control over energy consumption, for example by improving it with energy efficiency measures or switching to consume electricity from renewable sources.

[11] Project alternative(s) are understood as project option(s) considered in the relevant project preparation stage.

- Other indirect (Scope 3) GHG emissions. Scope 3 emissions are all other indirect emissions that can be considered a consequence of the activities of the project (e.g. emissions from the production or extraction of raw material or feedstock and vehicle emissions from the use of road infrastructure, including emissions from the electricity consumption of trains and electric vehicles).

Figure 3 Overview of GHG Protocol scopes and emissions across the value chain




Source: [GHG Protocol Figure 1.1 of "Scope 3 Standard"]

### *Estimating the GHG emissions for project alternative(s) and counterfactuals*

The EC Guidance recommends conducting the GHG emission calculations primarily with the help of the **Carbon Footprint Methodologies of the European Investment Bank**. The EIB methodology mainly includes Scope 1 and 2 emissions in the carbon footprint. However, for certain sectors in which the scope 3 emissions associated with the projects are significant and can be estimated (e.g., transportation or biofuel production and bioenergy projects), scope 3 emissions may be included as well in the carbon footprint. As noted above, the Blue Books provide guidance on calculation of GHG emissions for transport projects in Poland and are based on above presented EIB methodology.

### *Estimating the carbon externalities using shadow carbon prices and using them in the CBA*

Indications of financial profitability do not necessarily provide reliable estimates of the value of a project from a "social" point of view, as they focus rather on the investors' perspective. Many development projects have important spillovers or externalities. These can be costs or benefits that would arise as a direct consequence of a project, but which accrue to agents in the economy other than those who sponsor the project or who are outside the primary market. Such indirect effects can be very important and they should be considered when deciding whether or not to accept a project proposal. The analysis has to be broadened to include these externalities (benefits or costs) of projects in order to provide a more complete picture of the project.

In order to facilitate the proper reflection of the carbon externalities of proposed projects a monetisation of the GHG emissions need to be done and included in the project's cost-benefit analysis (CBA) or alternative Economic Appraisal methodology. Further guidance on the economic appraisal of investments can be found in the EC Guide to Cost-Benefit Analysis of Investment Projects – Economic appraisal tool for Cohesion Policy 2014-2020 and the Economic Appraisal Vademecum 2021-2027. The Commission Guidance on climate proofing suggest to use the shadow cost of carbon published by EIB to estimate the value of net carbon savings or emissions to be included in a cost-benefit analyses. As indicated in the table below, the shadow costs of carbon are expected to increase over-time and they may become an important factor for the economic appraisal of proposed projects.

Table 2 Shadow cost of carbon for GHG emissions and reductions in €/tCO2e, 2016-prices

| Year | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| €/tCO2e | 80 | 165 | 250 | 390 | 525 | 660 | 800 |

Source: EIB Group Climate Bank Roadmap 2021-2025

The Partnership Agreement Coordinating Authority (Department for Coordination of Implementation of European Funds at the MFiPR) has developed the application form for funding which stipulates for Annex 2 - Feasibility Study (or business plan in the case of a productive investment) and cost-benefit analysis, along with a spreadsheet containing a financial and economic model.

### *Verifying compatibility with a credible GHG pathway based on the EU's 2030 and 2050 emissions targets*

Verification of the project's compatibility with a credible GHG pathway based on the EU's 2030 and 2050 emissions targets and with the goals of the Paris Agreement and the European Climate Law could be based on long-term strategy, National Energy and Climate Plans (NECPs) covering ten-year periods starting from 2021 to 2030, and corresponding integrated national energy and climate progress reports by Poland and integrated monitoring arrangements by the Commission.

It is noted that the currently available National Energy and Climate Plan (NECP) for Poland[12] sets the following targets: (i) 7% GHG emissions reduction of non-ETS in 2030 compared to 2005 level; (ii) 21-23% RES in gross final energy consumption in 2030; (iii) 23% in energy efficiency by 2030. The Ministry of Climate and Environment) is carrying out preparatory work for the update of the National Energy and Climate Plan 2021-2030 (NECP) in accordance with the timeframe set out in the 2018/1999 Regulation on Energy Union Governance. The revised NECP is expected to be aligned with EU targets.

Based on the analyses outlined above, the EU-funded projects should demonstrate that the GHG emissions will be reduced in a way that is consistent with the overall Union objectives for 2030 and 2050, and with any other relevant more ambitious targets for the sector to which the project belongs.

For some sectors (e.g. transport) the project-level decisions are often constrained by choices made at the higher-level strategies and plans (being at local/regional or national level), and thus it is highly recommended to conduct proper climate neutrality proofing for those (sectoral) strategies and plans. It means assessing GHG reductions resulting from those sectoral strategies (e.g. transport strategies) and their alignment vis-à-vis the relevant sector targets when available and/or with the overall pathway to

[12] Krajowy plan na rzecz energii i klimatu na lata 2021-2030 - Ministerstwo Klimatu i Środowiska - Portal Gov.pl (www.gov.pl)

neutrality. Therefore, for these sectors the assessment at strategy level (where the project is identified) can effectively generate information to support and streamline the proofing of specific projects[13].

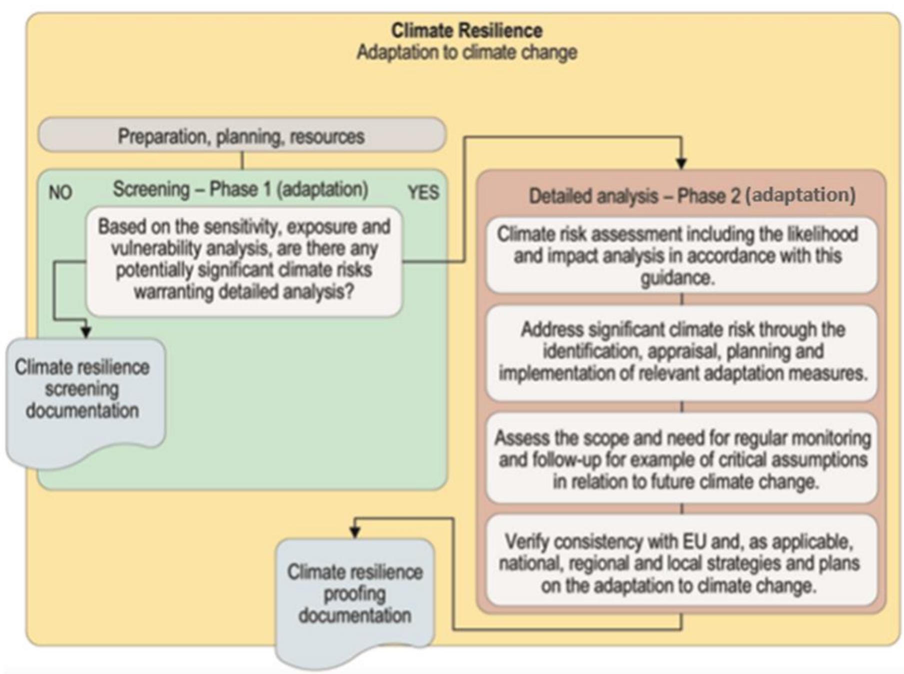
## 1.5 Climate resilience proofing

Specific guidance for climate resilience proofing is provided in sub-chapter 3.3 of the EC Guidance. The entire process is illustrated in Figure *4* below. The following text summarises key provisions that are relevant for the Polish decision-making context. Annex 1 provides the key sources of climate change data that could be used in the climate resilience proofing process while Annex 2 provides more detailed sectoral guidance.

Climate resilience proofing aims to ensure an adequate level of resilience of the infrastructure to the impacts of climate change over its lifetime. These impacts include extreme events such as more intense floods, cloudbursts, droughts, heatwaves, wildfires, storms and landslides, as well as chronic events such as projected sea-level rise and changes in average precipitation, soil moisture, air humidity, etc.

At the same time, it should be ensured that the project is aligned with the EU requirements and, as applicable, with the national, regional and local adaptation strategies and plans.

Figure 4 Overview of the climate adaptation-related process for climate proofing (hereafter referred to as climate resilience proofing)




Source: European Commission (2021a)

[13] For some projects (e.g. road infrastructure), the positive conclusions of the assessment of compatibility with EU GHG emissions reduction targets might only be possible when it is effectively demonstrated at the level of the strategy the project is part of, particularly for those projects which represent an increase of GHG emissions.

**Phase 1 - Climate resilience screening**

As per the EC Guidance (section 3.3.1.) the first phase in the climate resilience proofing is a screening that aims to identify the most relevant climate hazards for the project at the planned location. It comprises of three steps:

1. **Sensitivity analysis** – which aims at identifying the climate hazards that are relevant to the specific type of infrastructure irrespective of its location.
2. **Exposure analysis** – which aims at identifying the climate hazards that are relevant for the specific location, at present and in the future, irrespective of the infrastructure type being assessed.
3. **Vulnerability analysis** – which combines the outcomes of the previous two steps (sensitivity and exposure analysis) and determines the climate hazards that are relevant for the project being assessed, based on the type of infrastructure and its location. When a high or medium level of vulnerability is identified, a more detailed risk analysis will be required in the detailed analysis phase that would also help in identifying the required adaptation measures.

### *Climate hazards*

The climate resilience proofing needs to consider climate hazards associated with the expected changes of the climatic conditions. To this end, the climate hazards that will be considered can come from the list of climate hazards presented in JASPERS working paper "The Basics of Climate Change Adaptation, Vulnerability and Risk Assessment (see Table *3*) or the EU Taxonomy Climate Delegated Act (see Table *4*), or any other reliable source. The sensitivity and vulnerability analysis will determine the exact climate hazards that are relevant for a specific project at a given location in Poland. For example, some places, like cities, are more vulnerable to flooding caused by torrential rain and the damage caused by these events is becoming more frequent and greater than the damage caused by river floods. In turn, communities supplied with water from rivers or shallow groundwater intakes are at risk of water shortages as a result of extreme droughts, causing hydrogeological and hydrological droughts (rivers during drought are fed only by groundwater until the groundwater level drops below the river bottoms).

Table 3 List of climate hazards according to the JASPERS working paper "The Basics of Climate Change Adaptation, Vulnerability and Risk Assessment"

| Climate Hazard | Description |
|---|---|
| Average air temperature increase | Increases in average temperatures over time |
| Extreme temperature occurrences (including heat waves) | Changes in the frequency and intensity of periods of high temperatures, including heat waves (periods of extremely high maximum and minimum temperatures) |
| Average rainfall change | Trends over time of either more or less precipitation (rain, snow, hail, etc.) |
| Extreme rainfall events | Changes in the frequency and intensity of periods of intense precipitation |
| Water availability | The relative abundance or lack of water |
| Water temperature | Changes in the temperature of surface and ground water |

| Climate Hazard | Description |
|---|---|
| Flooding (coastal and fluvial) | Flooding from the sea or from rivers |
| Seawater temperature | Changes in the average sea surface water temperature |
| Relative sea level rise | Caused by a combination of increased sea temperatures (expanding the volume of water) and melting ice sheets and glaciers |
| Storm surges | An abnormal rise of seawater generated by a storm, over and above the predicted astronomical tides |
| Saline intrusion | Movement of salt water into freshwater aquifers, which can lead to contamination of drinking water sources and other consequences |
| Ocean salinity | Changes in the concentrations of salt in seawater |
| Ocean pH | Acidification of the oceans |
| Coastal erosion | The wearing away of land and the removal of beach or dune sediments by wave action, tidal currents, wave currents, drainage or high winds |
| Soil erosion | The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds and underground water |
| Ground instability/ landslides/ avalanche | Ground instability: movement of the ground; Landslide: A mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated; Avalanche: a rapid flow of snow down a sloping surface |
| Soil salinity | Changes in the salt content in the soil |
| Average wind speed | Changes in average wind speeds over time |
| Maximum wind speed | Increases in the maximum force of gusts of wind |
| Storms (tracks & intensity) | Changes in the location of storms, their frequency and intensity |
| Humidity | Changes in the amount of water vapour in the atmosphere |
| Droughts | Prolonged periods of abnormally low rainfall, leading to shortages of water |
| Dust storms | A storm of strong winds and dust-filled air |
| Wild fire | Unwanted, unplanned and damaging fires such as forest fires and fires of shrub and grasslands |
| Air quality | Increased concentrations of pollutants locally, including incidents such as smog |
| Urban heat island effect | Cities or metropolitan areas which are significantly warmer than the surrounding rural area, caused by higher absorption of solar energy by materials in the urban area, such as asphalt |

| Climate Hazard | Description |
|---|---|
| Growing season length | Changes in the seasons during which certain flora species grow, either longer or shorter |
| Solar radiation | The energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy |
| Cold spells | Prolonged periods of extremely cold temperatures |
| Freeze-thaw damage | Repeated freezing and thawing may cause stress damage to structure such as concrete |
| Melting permafrost | Melting of previously permanently frozen soil (Not applicable in Poland) |

Source: JASPERS (2017)

Table 4 List of climate hazards according to the EU Taxonomy Climate Delegated Act

| | Water-related | Temperature-related | Wind-related | Solid mass-related |
|---|---|---|---|---|
| Chronic | Changing precipitation patterns and types (rain, hail, snow/ice) | Changing temperature (air, freshwater, marine water) | Changing wind patterns | Coastal erosion |
| | Precipitation and hydrological variability | Heat stress | | Soil degradation |
| | Ocean acidification | Temperature variability | | Soil erosion |
| | Saline intrusion | Permafrost thawing (not relevant for Poland) | | Solifluction |
| | Sea level rise | | | |
| | Water stress | | | |
| Acute | Drought | Heat wave | Cyclone, hurricane, typhoon | Avalanche |
| | Replenishment of groundwater | Cold wave/frost | Storm (including blizzards, dust and sandstorms) | Landslide |
| | Heavy precipitation (rain, hail, snow/ice) | Wildfire | Tornado | Subsidence |
| | Flood (coastal, fluvial, pluvial, ground water) | | | |
| | Glacial lake outburst | | | |

Source: European Commission (2021b)

### *Climate data sources*

The identification of present and future climate variables and hazards should ideally take into account the differences between historic meteorological data and relevant climate forecasts. The differences between historic and expected future climate variables should ideally reflect both mean and extreme values (e.g., 10th and 90th percentile) as illustrated e.g., in Figure 5 that offers an illustrative example of the average temperature expected in Poland for different RCP scenarios according to Klimada 2.0 data.

***REPRESENTATIVE CONCENTRATION PATHWAYS (RCPs)***

***Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. RCPs were used to develop climate projections in CMIP5***

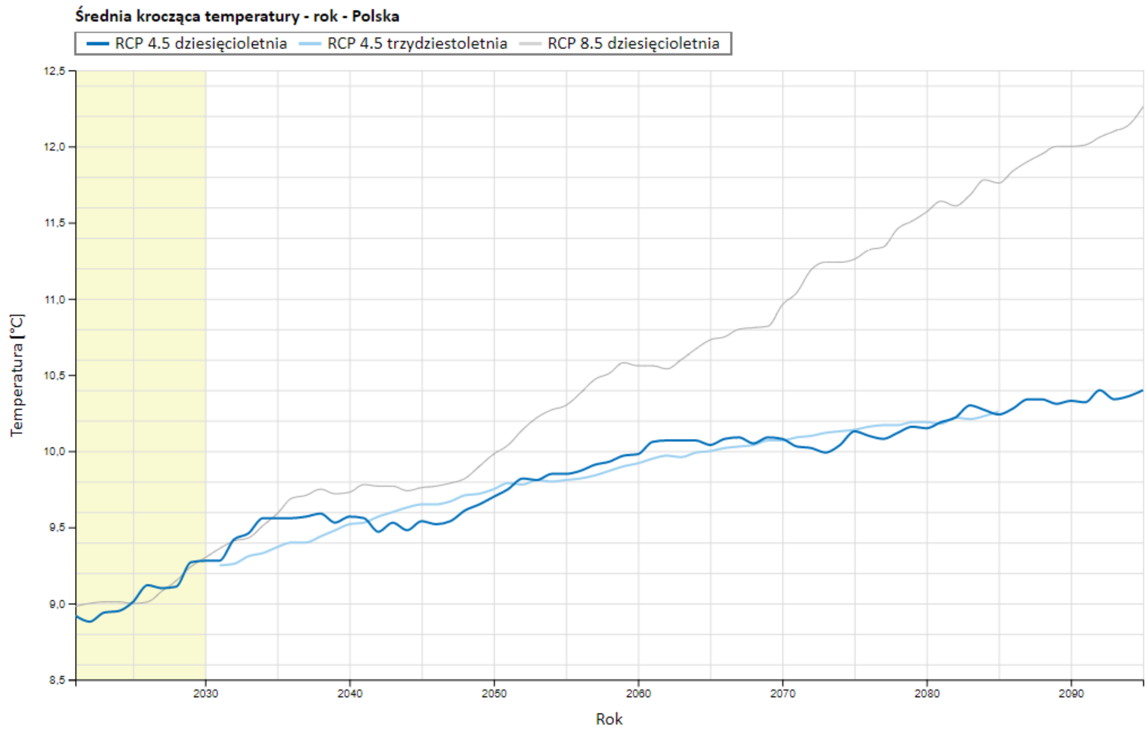
***RCP-based scenarios are referred to as RCPy, where 'y' refers to the level of radiative forcing (in watts per square meter, or W m-2) resulting from the scenario in the year 2100.***

Relevant information on climate forecasts for Poland is available from KLIMADA 2.0 project. The current available climate scenarios in Poland are based on the RCPs. The EC Guidance recommends using the RCP 6.0 or RCP 8.5 for the initial screening under the climate proofing assessment. For the detailed analysis, RCP 4.5 scenario is recommended for projects with a lifespan until 2060 and the ones that are flexible enough to increase the level of climate resilience during their lifetime as and when needed (for instance, where it is feasible to increase gradually the height of flood defence systems as part of water resource management). For projects with longer life span as well as those that cannot be upgraded during their lifetime (for instance bridges or new railway lines) it is recommended to consider the expected changes in the climatic variables based on the RCP 8.5 scenario.

In the future RCPs might be replaced by the Shared socio-economic pathways[14] (SSPs) from the VI IPCC Report but currently the RCPs should be used for the climate proofing exercise.

[14] The 6th IPCC report is based on the Shared Socio-economic Pathways (SSPs). These were developed to complement the RCPs with varying socio-economic challenges to adaptation and mitigation. Based on five narratives, the SSPs describe alternative pathways for future society. Each SSP looks at how the different RCPs could be achieved within the context of the underlying socioeconomic characteristics and shared policy assumptions of that world. The SSPs five alternative socio-economic futures compromise: Sustainable development (SSP1); Middle-of-the-road development (SSP2); Regional rivalry (SSP3); Inequality (SSP4); Fossil-fuelled development (SSP5). The combination of SSP-based socio-economic scenarios and Representative Concentration Pathway (RCP)-based climate projections provides an integrative frame for climate impact and policy analysis. SSP-based scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway describing the socio-economic trends underlying the scenarios, and 'y' refers to the level of radiative forcing (in watts per square meter, or W m-2) resulting from the scenario in the year 2100.

Figure 5 Projected moving average temperature for 2020 – 2100 for Poland under RCP 4.5 10 years, RCP 4.5 30 years and RCP 8.5 10 years)




Source: [Klimada 2.0]

### *Identification of project vulnerabilities*

The climate resilience proofing starts by considering the project's vulnerabilities to the changing climatic conditions. This is a very important step as not all projects are vulnerable to the same climate hazards.

While there might be different approaches in presenting project vulnerabilities, the main elements that determine them are the type of project and the location.

Table *5* presents the approach proposed in the EC guidance that considers and visualizes the sensitivity, exposure and the resulting vulnerability to climate hazards. This approach starts with the sensitivity analysis that determines the sensitivity of the critical elements of the project to the relevant climate variables and hazards irrespective of the project location. The subsequent exposure analysis considers the relevant climate variables and hazards in present and future climate for the selected location. The results of these two analyses are then combined into a vulnerability analysis which shows the vulnerability of the infrastructure to climate variables and hazards at the given location.

Table 5 Example of screening based on vulnerability analysis framework recommended in the EC guidance

**SENSITIVITY ANALYSIS**

| Indicative sensitivity table: *(example)* | | Climate variables and hazards: Flood | Heat | ... | Drought |
|---|---|---|---|---|---|
| Themes | On-site assets, ... | High | Low | ... | Low |
| | Inputs (water, ...) | Medium | Medium | ... | Low |
| | Outputs (products, ...) | High | Low | ... | Low |
| | Transport links | Medium | Low | ... | Low |
| | Highest score 4 themes | High | Medium | ... | Low |

The output of the sensitivity analysis may be summarised in a table with the sensitivity ranking of the relevant climate variables and hazards for a given project type, irrespective of the location, including critical parameters, and divided in e.g. the four themes.

**EXPOSURE ANALYSIS**

| Indicative exposure table: *(example)* | Climate variables and hazards: Flood | Heat | ... | Drought |
|---|---|---|---|---|
| Current climate | Medium | Low | ... | Low |
| Future climate | High | Medium | ... | Low |
| Highest score, current+future | High | Medium | ... | Low |

The output of the exposure analysis may be summarised in a table with the exposure ranking of the relevant climate variables and hazards for the selected location, irrespective of the project type, and divided in current and future climate. For both the sensitivity and exposure analysis, the scoring system should be carefully defined and explained, and the given scores should be justified.

**VULNERABILITY ANALYSIS**

| Indicative vulnerability table: *(example)* | | Exposure (current + future climate): High | Medium | Low |
|---|---|---|---|---|
| Sensitivity (highest across the four themes) | High | Flood | | |
| | Medium | | Heat | |
| | Low | | | Drought |

| Legend: Vulnerability level |
|---|
| High |
| Medium |
| Low |

The vulnerability analysis may be summarised in a table for the given specific project type at the selected location. It combines the sensitivity and the exposure analysis. The most relevant climate variables and hazards are those with a high or medium vulnerability level, which are then taken forward to the steps below. The vulnerability levels should be carefully defined and explained, and the given scores justified.

Source: European Commission (2021a)

The example above aims at providing a methodological framework to structure vulnerability assessment and its steps. The tables and the critical elements that will be included in the assessment could be adjusted to the project and/or sector particularities. The main aim of this screening step is identifying in a solid and clear manner the main climate hazards of the project, to determine those that would eventually require a more detailed risk analysis.

The EC guidance also recognizes practices that assess vulnerability and risk jointly. In any case, the screening should identify those relevant climate hazards. This type of combined assessment could be of relevance at early stages of project cycle (e.g., strategies, plans, and pre-feasibility studies) when the key decisions are to be taken.

An example of an alternative Rapid Risk Screening approach that incorporates elements of preliminary risk assessment is presented in Table *6*. Even though the proposed template is different compared to the EC Guidance template, it is important to note that the assessment follows the same logic and steps as the EC Guidance methodology (i.e. identification of vulnerabilities, likelihood, impacts/consequences and potential need of detailed assessment for relevant hazards).

Table 6 Example of rapid screening table template based on the CEDRIG Light developed by the Swiss Agency for Development and Cooperation (SDC)

| NATURAL HAZARDS (HYDRO-METEOROLOGICAL AND GEOLOGICAL HAZARDS) | | | | | | |
|---|---|---|---|---|---|---|
| **Step A1** | | | | **Step A2** | **Step A3** | **Step A4** |
| Hazards | Yes | Not sure | No | Likeli-hood | Conse-quences | Risk significance and need for any further in-depth risk assessment |
| Hazard 1 | | | | | | |
| Hazard 2 | | | | | | |
| Hazard 3 | | | | | | |
| Hazard 4 | | | | | | |
| Hazard 5 | | | | | | |
| Hazard … | | | | | | |

Source: SDC

***NOTE:***
***If the vulnerability assessment concludes that the project is not vulnerable to any climate hazards (i.e identifies only low or insignificant vulnerabilities), and this conclusion has been duly justified, there may be no need to undertake further risk assessment.***

**Phase 2 - Detailed analysis (Risk assessment)**

The detailed analysis in the climate resilience proofing should focus on climate hazards that warrant attention because of their potentially significantly impacts on the proposed project (i.e. those hazards that have been assessed with medium or high vulnerability in the screening phase). The ***assessment should be proportionate to the scale of the activity and its expected lifespan*** and should consider plausible climate projections across the existing range of future scenarios over the expected lifetime of the infrastructure.

The risk assessment considers the **likelihood (i.e. probability) and the potential consequences (i.e. impacts)** of what could happen to the project if the relevant hazard occurs.

### *Likelihood analysis*

There are various approaches for describing the likelihood of a hazard to occur. It is important in the beginning of the assessment to set out what sort of scale will be used to assess probability and explain what each term of the scale means in terms of likelihood of a hazard to occur. The EC Guidance suggests that the likelihood of any particular risk event may be described in qualitative or quantitative terms and presents potential indicative scales (see Table *7*). For example in the scale presented in Table *7* there is a qualitative or quantitative explanation for each term used: "Possible" could mean that an incident has occurred in a similar country/setting (qualitative) or that there is a 50% chance of the hazard to occur (quantitative). The scale that will be chosen should be relevant to the specificities of the project and the same scale should be used throughout the assessment. Other approaches may use other scales. SDC for example categorises hazards as "unlikely" if they occur once in a lifetime (i.e. in 80-100 years), "likely" (once in a generation i.e. in 20-30 years), "very likely" (very few years i.e. in less than 10 years). In all cases, the scale needs to be explained and each category used needs to be clearly described (for example what is understood by "likely").

Table 7 Example Scales for Assessing the Probability of Hazards to support likelihood assessment

| Term | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Rare | Unlikely | Possible | Likely | Almost Certain |
| Qualitative: | Highly unlikely to occur | Given current practices and procedures, this incident is unlikely to occur | Incident has occurred in a similar country / setting | Incident is likely to occur | Incident is very likely to occur, possibly several times |
| **OR** | | | | | |
| Quantitative: | 5% chance of occurring | 20% chance of occurring | 50% chance of occurring | 80% chance of occurring | 95% chance of occurring |

Source: European Commission (2021a)

It is underlined that there is a continuous growing repository of knowledge, data, platforms on climate hazard and related risk assessments. Those might be at national level (e.g. KLMADA 2.0, National Crisis Management Plan - Government Centre for Security - Portal Gov.pl (www.gov.pl), etc.) as well as at European level (e.g. CLIMATE-ADAPT, ....). Therefore, those might be used as initial reference for probability assessment.

### *Impact analysis*

When it comes to the assessment of **consequences** of the potential hazard events, the EC Guidance emphasizes the need to consider not only its direct consequences but also any potential knock-on effects. The assessment may need to cover the adaptive capacity of the system in which the project operates. According to the EC Guidance, adaptive capacity is the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Consequences should be assessed on a scale of impact for each relevant hazard. This is also referred to as severity or magnitude. Again, it is important that the methodology used sets out the scale for assessing severity and that this is explained clearly in relation to the project. Each category needs to have a clear description about what that event means for the project in qualitative or quantitative terms (for example: what "Catastrophic" means). This scale can cover 3 levels of severity (for example: low, medium, high) or 5 levels (for example: insignificant, minor, moderate, major, catastrophic) or otherwise. The EC Guidance suggests a 5 level scale to be used.

The consequences may generally relate to physical assets and operations, health and safety, environmental impacts, social impacts (including impacts on vulnerable populations), financial implications, etc.
Table *8* outlines a 5 levels scale for assessing severity of impacts. Other terms may be used in the scale e.g., terms such as slightly harmful (e.g., road connection interrupted for a few hours), harmful (few days), extremely harmful (several weeks or longer), etc. The meaning of the terms should reflect the specificities of the project.

Table 8 Example Scale for Assessing the Severity of Consequence

| Term | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Insignificant | Minor | Moderate | Major | Catastrophic |
| Meaning: | Minimal impact that can be mitigated through normal activity. | An event which effects the normal project operation, resulting in localised impacts of a temporary nature. | A serious event requiring additional actions to manage, resulting in moderate impacts. | A critical event requiring extraordinary action, resulting in significant, widespread or long term impacts. | Disaster with the potential to lead to shut down or collapse of the asset / network, causing significant harm and widespread long term impacts. |

Source: JASPERS (2017)

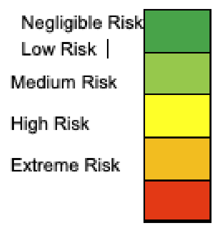
### *Risk assessment*

Having assessed the probability (likelihood) and severity of each hazard occurring, the significance level of each potential risk can be determined through a combination of the two factors. The risks can be categorized with the help of risk matrices that consider jointly the probability and severity of consequences. The matrices facilitate the identification of **the most significant risks that require targeted risk reduction (i.e. adaptation) measures**.

Table *9* presents one example of how such a risk matrix may look and to be tailored to the project/sector as per above.

Table 9 Example of risk assessment matrix

| | Probability | Rare | Unlikely | Probable | Likely | Almost Certain |
|---|---|---|---|---|---|---|
| Severity | | 1 | 2 | 3 | 4 | 5 |
| Insignificant | 1 | 1 | 2 | 3 | 4 | 5 |
| Minor | 2 | 2 | 4 | 6 | 8 | 10 |
| Moderate | 3 | 3 | 6 | 9 | 12 | 15 |
| Major | 4 | 4 | 8 | 12 | 16 | 20 |
| Catastrophic | 5 | 5 | 10 | 15 | 20 | 25 |




**NOTE:**
***If the risk assessment concludes that there are no significant risks to the project from climate change, and that conclusion has been duly justified, there may be no need to undertake further assessment or additional adaptation measures.***

## *Adaptation measures*

### <u>*Types of adaptation measures*</u>

If the risk assessment concludes that there are significant risks to the project, relevant and project-specific adaptation measures that reduce identified risks to an acceptable level need to be considered. For each significant risk identified, targeted adaptation measures should be considered, assessed, and where found justified, integrated into the proposed project's design and related interventions. Generally adaptation measures are divided in the following types:

- **Structural measures (hard measures)** – a physical change to the design of the project including its location. Amongst these the so-called low- or no-regret measures are very important, they consist of measures resulting from general technical development, part of construction costs therefore not generating additional costs, enhancing projects in climate adaptation terms (project in-built climate resilience). It is important to identify structural or hard measures when undertaking CCVRA.
- **Non-structural measures (soft measures)** – These include different ways to operate and maintain the project along climate hazards, plus relevant monitoring during the project operation. Non-

structural measures include early warning systems (and user information systems) and procedures in case of climate hazards occurrence. It might also include defining a responsible party to manage the project along climate risks – it could be defined as well as climate risk management. Those measures are important in case the project is not sufficiently adaptive to sustain climate risks and it can suffer from severe damages (including the interruption of delivery of project services) including vanishing the protective action from the structural measures (if those had been included in the project). Early warning and user information systems measures might be responsible to ensure the “acceptable” risks levels that the project promoter is aiming to achieve (e.g. accepting that a certain infrastructure will be flooded in certain situations since the relevant response measures will be in place to manage it in safe and adequate conditions). Finally, it is also highlighted the importance of measures related to monitoring and registering of climate hazards impacts (incidences), those represent evidence and data to inform further vulnerability and risk assessments and identify relevant adaptation measures/needs including measures as well on operation and management of existing infrastructure.

- **Risk management** – assessing whether and how the risks can be accepted and managed.

The potential use of nature-based solutions and/or blue or green infrastructure should also be considered to the extent possible.

It may also be appropriate for project promoters to consider flexible/adaptive measures such as setting up a monitoring system and only implementing physical measures when the situation reaches a critical threshold[15]. This option may be particularly useful when climate predictions show high levels of uncertainty. This approach is appropriate as long as the thresholds or trigger points are clearly set out and the future proposed measures can be proven to address the risks sufficiently. Monitoring should be integrated in the infrastructure management processes.

Adaptation will often involve a mix of response actions including soft measures, hard measures and risk management, as described above. It will be good to consider measures related to the different project cycle stages at the earliest possible (Annex 2 provides sectoral specific examples.

*Prioritisation of adaptation options*

The following groups can support the prioritisation of adaptation options:

- "**No-regret adaptation options**" measures that are worthwhile now (in that they would deliver net socio-economic benefits which exceed their costs) and continue to be worthwhile irrespective of the nature of future climate. Such measures will, as a rule, be cost neutral.;
- "**Low-regret adaptation options**" that are measures for which the associated costs are relatively low and for which, bearing in mind the uncertainties with future climate change, the benefits under future climate change may potentially be large.;
- "**Win-Win adaptation options**" are measures that have the desired results in terms of minimising the climate risks or exploiting potential opportunities, but also have other social, economic or environmental benefits. This can include measures that are introduced primarily for reasons other than climate change but also deliver desired adaptation benefits. For instance, this could be introduction of measures to improve water efficiency in agriculture, industry or buildings;

[15] This is also referred as adaptation pathway porspective, i.e. decisions that need to be taken now are identified and those that may be taken in future.

- "**Flexible or adaptive management options**" are those options that can be adjusted easily (and preferably with low cost), if circumstances change compared to the projections made initially;

The projects could initially consider win-win, flexible, or no-regret/low regret options that increase the project's resilience to the relevant hazards without entailing excessive costs. Once these win-win, flexible, or no-regret/low regret measures have been exhausted and in case significant vulnerabilities in the project design still remain, a further quantitative appraisal might be needed in order to identify the optimal solutions.

Please note that there are adaptation options that provide synergies with other goals such as mitigation, disaster risk reduction, environmental management or sustainability (e.g. ecosystem based approaches usually provide such multiple benefits). Focussing on options with multiple benefits can also facilitate the funding of the related actions by pooling resources and putting the emphasis on shared benefits that outweigh the costs.

It should be noted that beneficiaries should avoid maladaptive options (i.e. action taken to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups).

*Assessment of adaptation options*

Assessing the adaptation options can be done on a quantitative or qualitative basis, depending on the availability of information. In some circumstances, such as relatively low-value infrastructure with limited climate risks, a rapid expert assessment may be sufficient. In other circumstances, in particular for options with significant socioeconomic impact, it will be important to use more comprehensive information and assessment. The process described below would be more appropriate for the latter.

When the initial long list of possible adaptation options has been identified as relevant, the next step is to select a shortlist of targeted options for the project under preparation. A shortlist of preferred adaptation options that are environmentally, socially, technically, and legally feasible, could be identified through a screening and appraisal process by applying qualitative selection criteria. Criteria can be drawn from the lists in Box 3. The more of these criteria an option meets, the more suitable and acceptable it is likely to be.

**Box 3: Selection criteria for screening adaptation options**[16]

- **Effectiveness**: Does the option meet your overall adaptation target?
- **Robustness**: Will the option be robust under today's climate and also under a series of different and plausible climate change futures?
- **Equity**: the option should not negatively impact other areas or vulnerable groups
- **Timing**: Can the action realistically be implemented and within which timeframe?

[16] European Commission, Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient, 2011

- **Urgency**: how soon can it be implemented? • Flexibility: Is the option flexible enough also in the future?
- **Sustainability**: does it contribute to sustainability and resource efficiency objectives?
- **Efficiency**: Do the benefits of the actions exceed the costs?
- **Cost**: does it consider not only economic costs but also social and environmental costs?
- **Opportunities**: Are there windows of opportunities or synergies with other actions being planned that could promote further adaptation measures to be taken e.g. incorporating adaptation into the early steps of planning new construction or into infrastructure that is being upgraded anyway?
- **Synergies**: Will the adaptation option also decrease other risks than the intended climate risk, so that it help to achieve other objectives?
- **Other factors** which may be relevant in the specific context

Finally, the options should also be checked against the objectives for the project. This is to confirm that the actions will allow the objectives to continue to be met.

The following methods could be used for comparison of adaptation options, in a qualitative or quantitative way, if relevant:

- **Cost-Benefit Analysis (CBA)** - Compares the value of costs and benefits to the society for all options, and estimates the net benefits/costs in monetary options. The analysis can be used to decide the course of action.
- **Cost-Effectiveness Analysis (CEA)** - Determines the least costly way to achieve specific adaptation objective.
- **Multi-Criteria Analysis (MCA)** - Integrates various assessment criteria (financial and non-financial, monetised or expressed in other quantitative or qualitative terms) and priorities with respect to different criteria to arrive at scoring and relative ranking of the adaptation options.

Once the adaptation measures have been selected, the next step is to integrate the appraised adaptation options into the planning, design, implementation and planned operation of the project. It is important to demonstrate that they are not just suggested recommendations but that they will actually be included in the final project design and operation. Clear responsibilities for their implementation should be assigned and the costs of these measures should be incorporated in the project costs.

Annex 2 offers indicative examples of adaptation measures for various types of infrastructure. Additional adaptation options could be also inspired by the examples included in the EU Taxonomy Technical Expert Group (TEG) Technical Annex for the activities that contribute to adaptation.

The consideration of the adaptation measures aims to achieve an acceptable level of residual climate risks taking into account all legal, technical or other requirements. When doing so, the determination of "acceptable level" is dependent on the expert team undertaking the assessment and the risk that the project promoter is prepared to accept. For example, there may be elements of the project which are considered to be non-essential infrastructure where the costs of adaptation measures outweigh the benefits of avoiding the risks and the best option could be to allow the non-essential infrastructure to fail under certain circumstances. This is a form of risk management and part of adaptation measures assessment considerations.

### *Monitoring*

Since the risk assessment is a continual process, it is important to **determine** any critical assumptions and establish **monitoring and follow-up arrangements** in order to ensure that the adaptation measures are performing as envisaged and and implementing additional adaptation measures as and when needed. This is particularly important for projects relying on adaptive management.

### *Consistency with adaptation strategies and plans*

The final step of the climate resilience proofing process also is to ensure that:

- The project is aligned with the relevant EU and, as applicable, Polish national, regional and local strategies and plans on the adaptation to climate change, and disaster risk management plans[17]. The consistency of the project should be assessed against the Polish National Strategy for Adaptation to Climate Change with the perspective by 2030 (SPA 2020) and, as relevant, regional or local adaptation strategies such as the Urban Adaptation Plans for cities with more than 100,000 inhabitants in Poland; and

- The project does not adversely affect the adaptation efforts or the level of resilience to physical climate risks of other people, of nature, of cultural heritage, of assets and of other economic activities.

## 1.6 Climate change considerations in EIA and SEA processes

Currently, EIA Directive 2011/92/EU as amended through Directive 2014/52/EU explicitly includes many requirements for the assessment of climate change adaptation and mitigation concerns. The SEA Directive includes such requirements only implicitly, yet it offers an opportunity for specifying the relevant climate change mitigation and adaptation assessment requirements during the consultations on the determination of the scope of the strategic environmental assessment reports.

The European Commission has issued three guidance documents on EIA and SEA that encourage good practices in the consideration of climate change adaptation and mitigation issues. The documents include the European Commission Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment (EC, 2013a), the Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment (EC, 2013b) and the Guidance on the preparation of the Environmental Impact Assessment Reports (EC, 2017) that endorses the approach taken in the 2013 guidance documents and provides specific practical tips for application of this approach.

While many recommendations contained in these documents are similar to climate resilience proofing and climate neutrality proofing, there are important differences to bear in mind.

With regard to **climate change adaptation**, it is to be noted that all these documents underline that a proper adaptation process needs to consider both an adaption to the adverse impacts of climate change (e.g. when the infrastructure is at risk of such impacts – e.g. road in a flood-prone area) as well as its potential consequences on maladaptation when the proposed infrastructural solutions would increases

[17] Plans elaborated on the national level having transboundary dimensions should be closely alligned with the EU Strategy on Adaptation to Climate Change (COM/2021/82 final).

the risks for other assets, people, or nature (e.g. when building a dyke around a plot in a flood plain which results in shifting the damages to a neighbouring plot that is not protected[18]).

Within this context, the climate resilience proofing conducted in accordance with the EC climate proofing guidance (EC, 2021a) is primarily suitable for addressing adaptation concerns as it analyses the resilience of the proposed project to the impacts of the changing climatic conditions. Climate resilience proofing per se is not primarily designed to cover wider mal-adaptation issues. On the other hand, the EIA/SEA processes are well suited to analyse whether the proposed infrastructure can lead to maladaptation as they consider, amongst other factors, the implications of the proposed activity on the environment (that includes people, nature or assets that gradually become more vulnerable to changing climatic conditions). EIA/SEA processes are hence well suited to analyse whether the proposed development interventions increase an adverse impact of the current and future climate on people, nature or assets.

In this regard, the available guidance documents on SEA and EIA (EC, 203a, 2013b, and 2017) recommend that these assessment processes duly integrate climate change adaptation and maladaptation concerns by:

- Avoiding 'snapshot' analyses (i.e. at a single point in time) and consider trends, with and without the proposed project;
- Working with the notion of absorption capacity/environmental limits.
- Analysing the impact of proposed projects on key climate change and biodiversity trends and their drivers;
- Working with worst-case and best-case scenarios.
- Acknowledging assumptions and the limitations of current knowledge;
- Basing recommendations on the precautionary principle;
- Preparing proposed interventions for adaptive management.

When it comes to **climate change mitigation**, the mutual linkages between climate neutrality proofing and EIA/SEA process are straightforward. In its core, climate neutrality proofing should support - to the extent possible – the selection of low carbon options that are in line with EU decarbonisation objectives. It also helps to quantify and monetise GHG emissions which can support internal decision-making process by the project sponsors on the viability of proposed development options in the changing economic conditions that will increasingly - directly or indirectly – integrate the costs of GHG emissions. In other words, the GHG calculations can support internal investment decision-making process.

On the other hand, the EIA/SEA processes need to consider consistency of the proposed interventions with the relevant climate change mitigation objectives (for SEA) and provide information on GHG emissions associated with the proposed activities (both EIA and SEA). It therefore advisable to conduct these analyses jointly within the project cycle and identify development interventions that perform well on multiple environmental protection grounds. The EIA and SEA guidance documents also emphasize that the EIA and SEA processes need to duly consult stakeholders concerned with climate change mitigation matters. Lastly, the EIA/SEA processes need to explore various mitigation and enhancement measures and advise on their integration into the proposed plan (in case of the SEA) or proposed project (in case of EIA). They also need to provide recommendations for monitoring and follow-up of the proposed interventions.

[18] Adapted from the DNSH Guidance for the RRF

Table *10* offers a basic list of these generic tasks for the EIA/SEA process and related questions about the climate change that should be explored in the main stages of the EIA process.

Table 10 Generic questions about the climate change that should be explored throughout the EIA/SEA process

| SEA/EIA process | Key considerations |
|---|---|
| **Screening** | • Can the proposed interventions have significant effects on the GHG emissions, or be significantly affected by climate-related hazards? |
| **Scoping (as appropriate)** | • What are the current climatic conditions and how they are likely to change in the future?<br>• How will the expected changes in the climate affect the environmental baseline conditions in which the proposed interventions will operate?<br>• Who are the key stakeholders and environmental authorities with an interest in climate change and how will they be involved in the EIA/SEA? What do they think are the key issues?<br>• What are the key relevant climate change mitigation and adaptation policy objectives and targets that are relevant for the proposed intervention? |
| **EIA/SEA report** | • Are there any low-carbon and climate-resilient alternatives to the proposed intervention?<br>• How would implementing them affect climate change mitigation and adaptation concerns and the relevant environmental baseline trends?<br>• How can we avoid adverse effects on climate change? If we cannot, how can they be reduced or offset? How can the positive effects be maximised?<br>• How could wider factors climate change adaptation and maladaptation be integrated into the project?<br>• Have any major uncertainties and limitations of the current knowledge that may constrain the assessment been clearly explained? |
| **Decision making** | • How can climate change issues be integrated into the proposed plan (in case of SEA) or development consent for the proposed project (in case of EIA)? |
| **Monitoring** | • How will the proposed mitigation and enhancement measures and the effects of the project be monitored?<br>• How can the project adapt to the future changes in the climate? |

Given these linkages, it may be useful to integrate the outcomes of climate proofing, which should be done as an integral part of the planning/design tasks within the project cycle management, into the respective SEA/EIA processes that may be conducted by the external consultants and assess the wider environmental implications of the proposed activities. Ideally, SEA/EIA processes should be informed by the conclusions of climate proofing process and report/verify them within the assessment of the wider environmental implication of proposed infrastructure. Such coordination may reduce the time and costs associated with these analyses and help to prepare credible documentation for decision-making processes.

# 2 Part II: Integration of climate proofing into early project preparatory stages of the project cycle management

Project cycle management (PCM) is the process of planning, organizing, coordinating, and controlling a project effectively and efficiently throughout its phases, from planning through implementation and operation to decommissioning. The specific guidance for integrating climate proofing into the PCM is provided in Chapter 4 and Annex C of the EC Guidance.

The different phases of the project cycle are presented in Table 11 along with relevant tasks related to climate proofing. The integration of climate proofing into the PCM and particularly the earlier stages alongside other processes (e.g. strategy planning) will allow for synergies and potential time and cost efficiency gains. Part II focuses on earlier stages of project preparation providing practical guidance related to the integration of climate proofing.

Table 11: Integration of climate proofing into the Polish project cycle management

| Project cycle phase | Relevant tasks in the climate proofing |
|---|---|
| Strategy/Plan | • Integrating climate change mitigation and adaptation as part of strategy/plan objectives<br>• Climate change mitigation and adaptation as part of planning options comparison and assessment criteria<br>• Integration of strategic climate proofing into Strategic Environment Assessment (SEA) for the proposed strategy |
| Feasibility (STEs) | • Climate proofing of the project feasibility stage – comprising climate neutrality proofing and climate resilience proofing in the context of option analysis<br>• Reporting on the results of climate proofing as a part of the project feasibility studies documentation<br>• Integration of climate proofing into screening and scoping process for the Environment Impact Assessment (EIA) – if conducted during the feasibility studies |
| Design | • Climate proofing of the project design – comprising climate neutrality proofing and climate resilience proofing in design considerations<br>• Reporting on the results of climate proofing as a part of the project design documentation<br>• Integration of climate proofing into Environment Impact Assessment (EIA) for the proposed project |
| Procure / build | • Procurement process should ensure the implementation of climate change resilient solutions, at least as foreseen at design stage, and also promoting low-carbon approaches during implementation<br>• Implementing relevant climate change adaptation and mitigation measures as identified at the feasibility stage |

| Project cycle phase | Relevant tasks in the climate proofing |
|---|---|
| Operate/Maintain | • Monitoring of climate hazards impacts, and updating of the climate risk assessment (if the new hazards are identified), and implementing additional adaptation measures as needed<br>• Assessment of GHG emissions from the project (and or group of projects) in relation to foreseen impacts (or relevant targets when set, at the plan level for example) and implementing additional mitigation measures as when needed |
| Decommis-sion | • Decommission plan and its implementation should give due regard to climate change as well as net zero GHG emissions by 2050 and climate neutrality, and the principles of ‘energy efficiency first’ and ‘do no significant harm’ |

## 2.1 Climate resilience proofing and climate neutrality proofing at strategic levels of decision-making (strategies, programmes and plans)

**Introduction**

Strategic decision-making – used here as a broad term that encompasses sectoral and territorial development strategies, plans, programmes as well as land-use planning - plays a critical role in promoting low carbon development options and climate-resilient developments. Choices made at this ‘pre-project’ phase of project cycle management have often far-reaching influences as they lock the future development into long-term patterns having implications that cannot be easily changed through project level decisions.

In this regard, it is imperative to ensure that the course of the future development pursued through strategic decision-making properly integrate climate concerns and helps to consider various strategic options that are open at the given strategic decision-making level. In this spirit, undertaking vulnerability assessments at early stages (i.e., strategy/planning levels) might also inform the assessment at later project development stages.

Looking at transport sector for example, decisions and actions taken at the planning level are critical and are the main drivers to translating long-term climate mitigation strategies and goals into concrete measures to reduce GHG emissions from transport and enabling to achieve the full climate change mitigation potential of a transport system.
Additionally, in case of infrastructure networks (e.g. transport, energy, communication), undertaking climate change vulnerability assessment at the network level (as well as at strategy/plan level) can provide important and useful recommendations for integrating climate resilience into management and development of those networks. And, therefore, it constitutes an excellent basis for climate resilience proofing as it might inform detailed climate risks assessments at the project level. At the same time, it might also support identification of climate resilience needs of existing networks.

Obviously, not all options – i.e., demand management options, technological or process options, location options, or sequencing and prioritizing options - are always open for consideration in project level decision-making. Therefore, it is imperative to undertake climate proofing at strategic decision-making level that can consider much wider range of alternatives at all stages of the project cycle aiming at climate neutrality and resilience. Later on, feasibility studies for projects might build upon those assessments and climate considerations and still integrate them in the relevant areas (e.g. locations options). While the later on the project cycle the more limited power to influencing timing and sequencing options of proposed developments. In brief, integration of climate change mitigation and adaptation at strategic and planning stages would enable supporting low-carbon and resilient development in cost-effective manner.

To this end, the climate resilience proofing and climate neutrality proofing of strategic decisions should ideally involve the following overall tasks:

- Explore the links of the proposed strategy/plan with EU and national climate policy and GHG emission targets and ensure its consistency with the 2050 climate neutrality objective (or at least with the credible pathways to 2050 climate neutrality, if the strategic decision leads to interventions with a shorter lifespan)
- Setting climate change mitigation objectives (and targets) in the Plan (as per above) and defining and prioritising planning options that are aligned with those related targets
- Analyse and present climate change vulnerabilities of the strategy/plan scope that will be object of detailed assessment in later project preparatory stages
- Optional: Consider which (if any) interventions in the strategic decision may meet the requirements of the EU Taxonomy for sustainable activities.
- Advise on key concerns related to climate change that require attention during further development of proposed interventions and infrastructure projects and provides inputs to the TORs of these projects.
- Provide recommendations related to climate proofing for the later stages of the project preparation cycle.

Results of strategic climate proofing should be well documented. This section offers basic suggestions to support integrating climate change considerations at strategy/plan level based on good practices and aiming to represent the climate proofing [Paris Alignment] basis for resulting proposed interventions including, when relevant, infrastructure projects. For example, this is of particular importance for the transport sector that several interventions might be required in order to achieve the overall goal.

**Strategic climate resilience proofing**

Strategic climate resilience proofing should provide an understanding of the vulnerabilities of the relevant strategy/plan to the changing climatic conditions that may plausibly occur during their lifetime. Specifically, it should:

- Consider the changing climatic conditions that can be reasonably expected over the lifespan of the interventions proposed in the strategic decision.
- Conduct exposure analysis which considers the relevant climate variables and hazards in present and future climate for the area covered by the plan/strategy
- Provide understanding of sensitivity levels of the systems covered by the Plan to the climate variables and hazards irrespective of the project location.
- Integrate results of these two analyses into the concluding vulnerability analysis which shows the vulnerability of the proposed interventions to climate variabilities and hazards at the given location.

Such analyses might be undertaken under different forms while the logic described in chapter 1 is ensured. Table *12* below presents an example of the climate vulnerability assessment template that could be used at the level of a strategy/plan. This is just a one illustrative example – other templates may be used as well as long as they follow the logic of the climate resilience proofing described in Chapter 1.

Table 12 Example of a vulnerability analysis template at the level of a strategy/plan

| **Climatic variables and hazards** | Summarize key patterns under the current climate and their expected changes under the RCP 4.5 scenario until 2060. For infrastructure with lifespan beyond 2060 describe further the expected changes under the RCP 8,5 scenario. |
|---|---|
| Extreme rainfall events | |
| Average air temperature increase | |
| …….. | |
| Ground instability/ landslides/ avalanche | |

| **Exposure analysis** | Relevant climate variables for the selected location | | | |
|---|---|---|---|---|
| | Extreme rainfall events | Average air temperature increase | ……. | Ground instability/ landslides/ avalanche |
| Current climate | | | | |
| RCP 4.5 scenario | | | | |
| RCP 8,5 scenario | | | | |

| **Sensitivity analysis** | Sensitivity of the proposed infrastructure to the relevant climate variables and hazards irrespective of the project location | | | |
|---|---|---|---|---|
| | Extreme rainfall events | Average air temperature increase | …… | Ground instability/ landslides/ avalanche |
| Intervention 1 | | | | |
| Intervention 2 | | | | |
| Intervention 3 | | | | |
| ….. | | | | |
| Intervention Z | | | | |

The specific list of interventions might not be object of detailed screening; the aim being to understand main vulnerabilities of the plan scope to consider different set of adaptation options in later stages.

| **Vulnerability analysis** | Results of the sensitivity analysis | | |
|---|---|---|---|
| Results of the exposure analysis | High | Medium | Low |
| High | Intervention 1 (extreme rainfall events) | Intervention 3 (Average air temperature increase) | |
| Medium | Intervention Z (extreme rainfall events) | Intervention 2 (Average air temperature increase) | |
| Low | | | |

Key:

| | |
|---|---|
| High | |
| Medium | |
| Low | |

Irrespective of the approach used, the strategic climate resilience proofing should consider the most relevant climatic variables and hazards and the relevant infrastructure elements having a high and medium level exposure and sensitivity. At the end, it should unveil the most relevant hazards that require attention and further assessment

Consideration of climate-resilient development options

It is underlined that climate resilience and neutrality proofing should be integrated in the preparation process of strategies or plans. It means it should be jointly considered with other key objectives and priorities of the strategy/plan i.e. environmental, economic and social development. Other possibilities (optional) for consideration are again sustainable economic activities that contribute to climate change adaptation that are being defined within the framework of the EU Taxonomy[19]. Any consideration of alternatives again benefits from a close cooperation with the relevant SEA process to ensure that the proposed options don't harm other environmental concerns.

Provide recommendations for the preparatory stages of proposed interventions and their climate proofing

The final recommended step of the strategic climate resilience proofing is a wrap-up summary of key climate change adaptation concerns that require attention during further development of proposed interventions and infrastructure projects. To this end, strategic climate resilience proofing might provide

[19] The EU taxonomy for sustainable activities is a classification system, establishing a list of environmentally sustainable economic activities. It provides companies, investors and policymakers with appropriate definitions for which economic activities can be considered environmentally sustainable. It includes six environmental objectives (including climate change adaptation) and sets performance thresholds (called "technical screening criteria") for economic activities, which: 1. substantially contribute to at least one of the six environmental objectives; 2. do no significant harm (DNSH) to any of the other five environmental objectives; 3. comply with minimum social safeguards. A first delegated act on sustainable activities for climate change adaptation and mitigation objectives was published by the Commission on December 2021 and it includes the criteria that an economic activity should meet in order to have a substantial contribution to climate change adaptation. The EU Taxonomy Compass provides a visual representation of the contents of the EU Taxonomy, starting with the Delegated Act on the climate objectives (climate change mitigation and climate change adaptation).

clear recommendations for later project preparatory stages regarding aspects that might be integrated into the TORs of the proposed interventions for example. It might also provide recommendations for existing systems (e.g., in the case of transport systems possible operational measures to mitigate impacts of certain climate hazards on existing networks). It might ultimately remind on the need of climate resilience proofing during the upcoming preparation and advise on the scope of such proofing process.

**Strategic climate neutrality proofing**

Climate neutrality proofing at strategy/planning level aims at ensuring that the strategy/plan is aligned with the relevant targets, and ultimately with the 2030 emission reduction target and the 2050 climate neutrality objective (duly supported by GHG emission assessment of the strategy/plan). Specifically, the climate neutrality proofing conducted at the strategic levels of decision-making should:

- Clarify climate change mitigation context for the strategy/plan that will determine the specific climate change mitigation objectives/targets established at EU or national levels that need to be considered in the strategic decision. Such targets may come in different forms – some may specify the GHG emission reduction targets for the relevant sectors, others may formulate sector- or territory- specific targets that guide the transition of the given sector/territory towards low-carbon development pathway (that should ultimately be aligned with overall EU climate neutrality targets). The climate change mitigation context provides the basis to set the strategy/plan objective and targets on climate mitigation,
- Analyse whether the proposed planning options meet these objectives/targets. This might require: (i) analysing/assessing current GHG emission level (or reference year considered); (ii) assessing difference in GHG emissions between the planning option(s) at specific time horizon and current level in regard to objectives/targets set above; and (iii) prioritising and selecting the planning option(s) vis-à-vis the climate mitigation target(s) and other relevant targets in the strategy.

**Box 4: Example of set of indicators that might be used in urban mobility from the SUMP Topic Guide on Decarbonisation of Urban Mobility, EC, 2022**

| Strategic/general objective | Measurement / indicator calculation | Definition of target values and sources (other plans, Laws, Policies, etc. – EU/national/regional/ metropolitan/...) |
|---|---|---|
| 1. Climate change mitigation | 1.a. % of reduction of emissions of greenhouse gases, measured in tons of CO2 equivalent | |
| | 1.b. Reduction of energy consumption | |
| | 1.c. Use of renewable energy or share of renewable energy in transport | |
| 2. Climate change adaptation | 2.a. Climate risk reduction (qualitative assessment) | |
| 3. Compliance with the environmental thresholds | 3.a. Polluting emissions of NOx, CO, PM10 and PM2.5, etc. | |
| | 3.b. Noise and vibration | |
| | 3.c. Potential additional elements | |
| 4. Safety | 4.a. Fatalities | |
| | 4.b. Serious injuries | |
| 5. Metropolitan accessibility | 5.a. % travel time reduction between municipalities by PT | |
| 6. Financial sustainability | 6.a. % increase in ratio income from tariffs/ O&M costs for public transport services | |
| | 6 b. optional: Total transportation costs for citizens / commuters | |

Carbon neutrality proofing calculation conducted at strategic decision-making levels can involve assessment of GHG emissions based on the EIB carbon footprint methodology or other reliable guidance[20]. As previously referred, Polish Blue Books provide relevant guidance for transport sector assessments along with Polish specific emission factors.

The climate proofing at strategy level may also involve calculation of carbon externalities associated with the emissions generated through the planned interventions. These can use the relevant shadow carbon prices provided in chapter 1 and reflect these external costs/benefits das part of the economic analyses that may be performed during preparation of the proposed strategy/plan.

The preparation of strategies and plans should always involve identification and assessment of options vis-à-vis climate mitigation objectives (e.g. based on defined low-carbon pathways). It is understood that this needs to be duly integrated with other criteria and objectives of the strategy/plan and that this assessment might require an iterative process.

[20] For example, the most recent version of the Air pollutant emission inventory guidebook published by the European Monitoring and Evaluation Programme and the European Environment Agency in 2019 offers a comprehensive overview of default emission factors for various pollutants including key greenhouse gasses (i.e. carbon dioxide, methane, nitrous oxide) that are generated within various processes – e.g. during combustion of fossil fuels, in industrial processes and product use, in agriculture, and in waste management.

This should enable that the package of measures resulting from the selected planning option based on above considerations is aligned with the Plan objectives (i.e. including climate mitigation objectives). Therefore, it might constitute a relevant basis to support the related project(s) climate neutrality proofing i.e. alignment assessment of the project(s) to relevant climate mitigation objectives.

It might be considered (optional) assessing sustainable economic activities as per definitions within the framework of the EU Taxonomy. However, other approaches could be used to consider options that perform well climate-related concerns as well as on the wider environmental, economic, and social grounds.

Obviously, the analyses of alternatives to proposed interventions should ensure that options considered do not only support climate-related objectives but also support - or at least don't harm - other environmental objectives. This requires a close cooperation with the relevant SEA process that should be ideally closely coordinated with the elaboration of the proposed strategy/plan and its climate proofing.

Recommendations for later preparatory stages of proposed interventions and their climate proofing

The strategic climate neutrality proofing might highlight some climate change mitigation concerns that require attention during further development of proposed interventions and/or infrastructure projects. To this end, strategic climate neutrality proofing might formulate clear recommendations on options and issues that need to be integrated into the proposed implementation arrangements for the strategy/plan and/or development (e.g. as part of TORs) of the proposed interventions. The climate neutrality proofing should be integrated along the further project preparatory stages building upon the strategic climate neutrality proofing. It is underlined the importance of planning in achieving climate neutrality targets (e.g. in transport sector); since it will require an effective mix of different types of measures to be implemented to achieve the carbon reduction objectives (together with other main priorities that plan/strategies aim to tackle, e.g. transport safety) . As described above, strategic climate neutrality proofing (i.e. assessing GHG emissions levels and forecasts within those strategies/plans projects are part of and their alignment vis-à-vis the relevant targets and/or with the overall pathway to neutrality) might constitute the basis for related project climate neutrality proofing.

## 2.2 Considerations of climate change in strategic environmental assessments

The SEA Directive 2001/42/EC , and, and specifically, its Annex I, item (f) requires the SEA report to provide information on, amongst other issues, the likely significant effects on climatic factors and their interrelationship with other environmental factors. Good practice suggests that this includes climate change mitigation, adaptation, and maladaptation issues. This required information could be obtained through climate proofing of the proposed plan or programme when such proofing is conducted. In such case, the SEA process could be used to present or verify climate proofing and facilitate its review by the relevant authorities and the public.

Moreover, the SEA Directive Annex II (that defines the requirements for SEA screening) stipulates several considerations related to climate change adaptation and maladaptation including:

- environmental problems relevant to the plan or programme,

- the relevance of the plan or programme for the implementation of Community legislation on the environment[21],
- the risks to human health or the environment[22] (e.g., due to accidents), and
- the value and vulnerability of the area likely to be affected.

There are considerable benefits, not to mention cost-effectiveness, of considering climate change mitigation and adaptation, biodiversity, and other environmental issues together. The consideration of climate change will feed into the planning stage, which is the most relevant in particular for sectors like transport, where the main decisions especially for climate change mitigation are taken at this stage (e.g. favouring certain lower impact transport modes, policies, mobility patterns/habits). When doing so, the SEA process may ask questions about climate change mitigation and adaptation concerns and options considered.

Table 13 Examples of key questions that could be asked when identifying key climate change mitigation concerns (the topics marked in bold are additional to those addressed in a regular climate proofing process)

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the SEA | Examples of alternatives and/or mitigation measures at the assessment stage |
|---|---|---|
| **Energy demand in industry** | • Will the proposed PP increase or decrease demand for energy in industry?<br>• **Does the PP encourage or limit opportunities for low carbon businesses and technologies?** | • Reducing demand for energy (electricity or fuel) in industry<br>• Alternative low-carbon sources (onsite or through specific low carbon energy supplier)<br>• **Targeted support to businesses engaged in eco-innovations, low-carbon business and lowcarbon technologies** |
| **Energy demand in housing and construction** | • **Will the PP increase or decrease demand for construction of housing** and for energy use in housing? | • **Improve the energy performance of buildings**<br>• Alternative low carbon sources (onsite or through specific low carbon energy supplier)<br>• Potential synergies between adaptation and GHG reduction |
| **GHG emissions in agriculture** | • Will the PP increase or decrease generation of methane ($CH_4$) and nitrous oxide ($N_2O$) in agriculture?<br>• **Will the PP increase or decrease use of nitrogen in fertilising practices?**<br>• **Will the PP adversely affect or protect carbon rich soils?** | • Managing methane (enteric and manure)<br>• **Reducing the use of nitrogen in fertilising practices**<br>• **Protecting natural carbon sinks, such as peat soils**<br>• Potential synergies between adaptation and GHG reduction |

[21] Which includes various legislative documents addressing the climate change mitigation and adaptation – such as e.g. the European Climate Law published in form of the Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality. This regulaiton legally codified the goal for Europe's economy and society to become climate-neutral by 2050 and as such should be considered in the SEA screening processes.
[22] Which addresses also climate-related risks

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the SEA | Examples of alternatives and/or mitigation measures at the assessment stage |
|---|---|---|
| | | • Harvesting methane emissions for biogas production |
| **GHG emissions in waste management** | • **Will the PP increase waste generation?**<br>• **Will the proposed PP influence the waste management system?**<br>• How will these changes affect emissions of $CO_2$ and $CH_4$ from waste management? | • **Consider ways in which the PP can increase waste prevention, re-use and recycling, particularly to divert waste from landfill**<br>• Consider ways of producing producing biogas from wastewater and sludge<br>• Alternative low carbon sources (onsite or through specific low carbon energy supplier) |
| **Travel patterns and GHG emissions from transport** | • **Can the PP increase personal travel — the number and length of journeys and the mode of travel? Will it entail a shift from more-polluting to less-polluting modes of travel (e.g. from personal cars to public transport or from buses to electric trains)?**<br>• Can the PP significantly increase or decrease freight transport emissions?<br>• **How can the PP enhance or stimulate the provision of sustainable transport infrastructure or technologies — for instance electric vehicle charging points, LPG fuel, hydrogen fuel cells?** | • **Promote PP patterns that reduce the need to travel**<br>• **Support car-free PP**<br>• **Encourage walking and cycling**<br>• **Encourage public transport**<br>• **Provide transport choices to encourage a modal shift to cleaner modes (e.g. from cars to trains), such as an effective and integrated public transport system**<br>• **Transport demand management schemes**<br>• **Encourage car sharing**<br>• **Prioritise high density urban PPs (smaller housing at higher density) and reuse of brownfield land** |
| **GHG emissions from energy production** | • **Will the PP increase or decrease energy consumption?**<br>• **How will these changes in energy demand affect the energy supply mix?**<br>• What implications will this change in energy supply have on GHG emissions from energy production? | • Generic recommendations are intentionally not provided as these are context-specific, depending upon the energy production capacity and energy supply sources of the area in question |
| **Forestry and biodiversity** | • **What opportunities could the PP give for carbon sequestration via investment in forestry and biodiversity?** | • Promotion of carbon sequestration approaches in key ecosystems that have significant carbon sequestration potential |

Source: EC (2013a)

*Table 14* Examples of key questions for identifying climate change adaptation issues in SEA (the topics marked in bold are additional to those addressed in a regular climate proofing process)

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the SEA | Examples of alternatives and/or mitigation measures at the assessment stage |
|---|---|---|
| **Heat waves** | • What urban areas, population groups or economic activities are most vulnerable to heat waves? How will the PP impact on them?<br>• **Does the PP reduce or enhance the 'urban heat island' effect?** | • **Avoid development patterns that fragment habitat corridors or, for linear infrastructures, make sure that habitat continuity is restored in the most sensitive areas** |

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the SEA | Examples of alternatives and/or mitigation measures at the assessment stage |
|---|---|---|
| | • **Will the PP increase or reduce the resilience of landscape/forests to wildlife fires?** | • Improvements in urban structure — expansion of green areas, open water surfaces and wind paths (along rivers and waterfronts) in urban areas to reduce the possible heat island effect<br>• Heat wave early warning systems and response plans<br>• Encourage greater use of green roofs<br>• **Reduce man-made exhausts during heat waves (industries, and car traffic)**<br>• **Awareness-raising about risks associated with heat waves and action to reduce them** |
| **Droughts** | • **What are the key terrestrial habitats and migration corridors that may be significantly affected by droughts? How will the PP impact on them?**<br>• Will the PP increase water demand and to what extent?<br>• **Are there any significant risks associated with worsening water quality during droughts (increased pollution concentrations due to limited dilution, saline intrusion, etc.)?**<br>• **Which freshwater bodies will be exposed to excessive water pollution — especially during droughts when the pollution will become less diluted in reduced river volumes?** | • Encourage water efficiency measures<br>• Explore efficient use/re-use of rainwater and grey water<br>• Restrictions **on excessive/non-essential use water use during droughts (depending on their severity)**<br>• **Minimise low flow withdrawals**<br>• **Restrictions for effluent discharges into water bodies during droughts**<br>• **Maintain and improve the resilience of watersheds and aquatic ecosystems by implementing practices that protect, maintain, and restore watershed processes and services** |
| **Flood regimes and extreme rainfall events** | • **Will the proposed PP reduce or enhance the capacity of ecosystems and flood plains for natural flood management?**<br>• Will the proposed PP increase the exposure of the vulnerable (e.g. the elderly, unwell or young people) or sensitive receptors (e.g. critical infrastructure) to floods?<br>• What infrastructure (e.g. existing or planned road segments, water supply, energy, etc.) is at risk due to its location in extreme flood zones?<br>• Is the capacity of drainage networks sufficient to handle potential extreme rainfall?<br>• Does the design consider sustainable rainwater management including the reduction of flood risks for lower laying areas?<br>• | • **Avoid decreasing storage volumes in flood plains**<br>• Ensure that any existing or planned essential infrastructure is protected from future flood risk<br>• In high risk areas, consider arrangements for supply of goods/services that may be disturbed by floods<br>• Increase resilience to floods through use of sustainable drainage systems<br>• Enhance permeable surfaces and green spaces in new PPs |
| **Storms and high winds** | • What areas and critical infrastructure will be at risk because of storms and strong winds? | • Ensure new infrastructure considers the impacts of increased high winds and storms<br>• In high-risk areas, consider arrangements for supply of goods/services that may be disturbed by increased storm events |

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the SEA | Examples of alternatives and/or mitigation measures at the assessment stage |
|---|---|---|
| **Landslides** | • What property, persons or **environmental assets are at risk** because of landslides and their vulnerability? | • Avoid new developments in areas at risk from erosion<br>• In high-risk areas, consider arrangements for supply of goods/services that may be disturbed by landslides<br>• **Protect and expand native woodland cover** |
| **Sea level rise, storms surge, coastal erosion, hydrological regimes and saline intrusion** | • **What are the key aquatic, riverine and coastal habitats and migration corridors that may be significantly adversely affected by sea level rise, coastal erosion, changes in hydrological regimes and salinity levels? How will the proposed PP impact on them?**<br>• What are the key infrastructural assets (e.g. road segments and intersections, water supply infrastructure; energy infrastructure; industrial zones and major landfills) at risk due to their location in areas that may be inundated by sea level rise or subject to coastal erosion? Will the proposed PP reduce or increase these risks?<br>• What areas may be affected by saline intrusion? Will the proposed PP reduce or increase these risks? | • Avoid PPs that promote development in coastal areas at risk of rising sea levels, coastal erosion and flooding, except for projects for which this risk is taken into account, such as port development<br>• Move water intakes and any economic activities that depend on the supply of clean water or ground water (agriculture) away from areas that will be affected by saline intrusion |
| **Cold spells** | • What areas and critical infrastructure will be at risk because of short periods of unusually cold weather, blizzards or frost? | • Ensure that any existing or planned essential infrastructure is protected from cold spells |
| **Freeze-thaw damage** | • What key infrastructure (e.g. roads, water pipes, etc.) is at risk of freeze-thaw damage? | • Ensure that key infrastructure (e.g. roads, water pipes) is able to resist wind action and to prevent moisture from entering the structure by (e.g. different formulations of materials). |

Source: EC (2013a)

The consideration of CC mitigation and adaptation issues at the strategic decision-levels addressed at SEA stage will be inevitably constrained by the long-term and cumulative nature of effects; frequent complexity of the issues and their cause-effect relationships; and their uncertainty. The EC guidance on SEA (2013a) therefore recommends avoiding – where possible - 'snapshot' analyses that offer static picture at a single point in time and instead consider trends and environmental conditions with and without the proposed PP (and its alternatives). This is consistent especially with Annex I(b) to the SEA Directive, which requires the assessment of not only the current state of the environment, but also the 'likely evolution thereof without implementation of the plan or programme.' The baseline environment will be a moving baseline, particularly for PPs resulting in large infrastructure projects with a long planning or long-lasting effects (timescales exceeding 20 years).

It is essential to consider the following aspects when looking at the evolving baseline:

- Trends in key issues over time: e.g. water quality and availability during droughts, ecosystem deterioration, vulnerability of infrastructure to extreme climatic events, etc. Are these trends continuing, changing, or levelling out? Are there environmental outlooks or scenario studies available that have assessed the likely future direction of these trends? If data are unavailable for certain indicators, are proxy indicators available, e.g. if air quality monitoring data is not readily available for an urban area, are there data relating to trends in traffic flow/volumes over time?

- Drivers of change: e.g. major drivers such as demographic trends and the economic affluence of the society, the legal and policy framework, market forces and economic incentives, major projects that affect the issue, institutional powers and capacities to regulate and manage the issue.
- Thresholds/limits: e.g. have thresholds already been breached? Are there tipping points to be avoided in order to prevent serious deterioration or breakdown of relevant ecological and social systems?
- Key areas that may be particularly adversely affected by the worsening environmental trends?
- Critical interdependencies: e.g. water supply and sewage treatment systems, flood defences, energy/electricity supply and communication networks.

A good trend analysis can be also used for outlining the trends with the proposed PP under various assumptions and uncertainties. At times, this will require simplified models to give best estimates of emissions and impacts, for example, best-case and worst- case scenarios to illustrate different future states under various assumptions.

## 2.3 Climate resilience proofing and climate neutrality proofing during pre-feasibility and feasibility studies

**Introduction**

The 'pre-project' phases of project cycle management are often guided by standards and practices that may not yet fully reflect climate change considerations. The existing design norms[23] may not yet be adjusted to the forthcoming changes in the climatic conditions.

In order to ensure the long-term feasibility of proposed infrastructure in the changing climatic conditions and within the evolving economic premises in which the future infrastructure will operate, the climate resilience proofing and climate neutrality proofing should involve the following overall tasks:

- Analyse the consistency of the proposed infrastructure with the 2050 climate neutrality objective (or at least with the credible pathways to 2050 climate neutrality, if the infrastructure has a shorter lifespan) that might be based on the strategy/plan climate neutrality proofing
- Analyse resilience of the proposed infrastructure to the changing climatic conditions and explore detailed options that enhance its long-term climate resilience
- Explore low-carbon and climate-resilient options the proposed infrastructure that support - or at least do not harm - other environmental objectives and effectively coordinate these considerations with the EIA process for the proposed infrastructure.
- Optional: Consider if the proposed infrastructure meets the requirements of the EU Taxonomy for sustainable activities.

[23] It is also the case that some design standards had been adapted in last years to consider more extreme weather events (e.g. increased flooding return period for bridges in Poland desing standards after millenium floods).

- Advise on key concerns related to climate change that require attention during project implementation, operation and decommissioning[24].

The abovementioned tasks should consider any higher climate proofing studies conducted for strategies and plans that proceed preparation of projects when performed.

**Climate resilience proofing**

Bearing the above overall tasks in mind, the preparation of specific projects should fully integrate an efficient climate resilience proofing that involves, as described in Part 1 of this document:

- Screening
- Detailed analyses

Climate resilience screening

Climate resilience screening at the project level should determine the vulnerability of the various elements of the proposed infrastructure – covering on-site assets, inputs (such as water, etc.), outputs (products and services provided by the infrastructure) and wider links to the surrounding systems (e.g. transport links) to the changing climatic conditions that may plausibly occur during its lifetime. The screening should:

- Consider the changing climatic conditions that can be reasonably expected over the lifespan of the proposed infrastructure.
- Conduct exposure analysis which considers the relevant climate variables and hazards in present and future climate for the selected location
- Determine sensitivity of the proposed infrastructure to the relevant climate variables and hazards irrespective of the project location.
- Integrate results of these two analyses into the concluding vulnerability analysis which shows the vulnerability of the proposed infrastructure to climate variabilities and hazards at the given location.

As mentioned in section 1.4, such analyses might take different forms that enable identifying relevant climate hazards at the early project preparation stages.

In this sense, aspects such as project location (e.g. linear infrastructure running through a flood plain or elevated area) or different technological/technical solutions will present different vulnerability levels.

For infrastructure networks (as it is the case of transport), it is possible and recommended to undertake vulnerability assessments at the network level as basis to support integrating climate change resilience in management and development of those networks. This would constitute a sound basis to inform the climate neutrality proofing of a specific project.

If the climate resilience screening concludes that all vulnerabilities are deemed low or insignificant in a justified manner, no further (climate) risk assessment is needed. However, if it identified high or medium

[24] It is noted that for some types or projects this phase may result in often underestimated impacts to the climate and the environment (e.g. enormous amounts of harmful substances accumulate during operation phase).

vulnerabilities, the climate resilience screening needs to be followed up with detailed analysis that assesses the risks associated with the identified vulnerabilities and determines the relevant adaptation options that can reduce these risks to an acceptable level.

Detailed analyses (as and when needed)

Whenever climate resilience proofing experts determine that the hazards may lead to **critical events or disasters,** they should consult the relevant stakeholders (authorities, communities, businesses) and engage them in discussions on the potential adaptation measures that prevent, mitigate or transfer the risks to areas where it doesn't lead to unacceptable economic, social or environmental impacts.

The decision about which vulnerabilities to take forward to a detailed risk analysis will normally require consultation between the project designers and the climate assessment team and should engage the project promoter. To this end, it is imperative to directly engage the relevant personnel in charge of the proposed infrastructure in any climate risk assessment and involve them in the following deliberations on each specific risk that requires attention.

The climate change adaptation assessment should begin with **reflections on the expected future climatic variables and hazards and the project design parameters as well as in the planned operation**. It is important to recognize that the infrastructure is not designed in a vacuum as it is based on specific engineering approaches and standards that have evolved over decades and frequently reflect the historic climatic conditions. However, the existing norms may not sufficiently reflect the expected future climatic conditions. In such situations, it may be useful for the personnel in charge of the climate proofing and the personnel in charge of the given infrastructure to discuss the implications of the plausible climatic conditions under various scenarios and consider potential options for the adaptation of the infrastructure for these climatic conditions and variabilities.

The consideration of the **potential adaptation measures** can either involve changes in the project design and its operations that boost its resilience to plausible risks (e.g. amending the design parameters, adopting risk reduction procedures or planned measures at operation when the climate hazard would occur, preparing for flexible future amendments to the project through adaptive management) or flanking interventions in the surrounding environment (e.g. upstream interventions, nature-based solutions, etc.) that reduce the relevant hazards. Irrespective of the type, these measures should initially consider win-win, flexible, or no-regret/low regret options that increase the project's resilience to the relevant hazards without entailing excessive costs.

Once these win-win, flexible, or no-regret/low regret measures have been exhausted and significant vulnerabilities in the project design remain, a **risk assessment** is needed to explore the residual risks. Compared with vulnerability analysis, the risk assessment analyzes what could happen if a hazard occurs and considers the **likelihood and the potential consequences** of such risk event. Such information can be obtained through various methods - ranging from collective expert judgments (e.g., workshops and focus groups involving disaster risk management professionals/agencies) from qualitative to more quantitative analyses that assess the risk likelihood and express the potential consequences. The assessment might be done in the form of cost-benefit analyses (if data is available) or in a qualitative manner in form of multi-criteria analyses that consider different aspects of the proposed project and its alternatives – and they may also consider risks assessment. Quantitative risk assessment will require data inputs that may not be easily available. Therefore, use of semi-quantitative or qualitative approaches might be used to inform the project decision through advice on optimal alternative options.

Irrespective of whether the risks assessment is conducted through qualitative, semi-quantitative or quantitative approaches, it should be always discussed with the relevant authorities having specific mandates, data or expertise related to climate change resilience or disaster risk reduction.

This consultative process also needs to **consider potential** maladaptation and environmental effects. For this reason, it is imperative to closely coordinate the climate proofing with the relevant EIA process and ensure that the project and its adaptation solutions:

- not adversely affect the adaptation efforts or the level of resilience to physical climate risks of other people, of nature, of cultural heritage, of assets and of other economic activities;
- operate well within the broader planning framework of the relevant local, sectoral, regional or national adaptation strategies and plans; and
- consider the use of nature-based solutions or rely on blue or green infrastructure to the extent possible.

Last, since the risk assessment is a continual process, it is important to **determine** any critical assumptions and establish **monitoring and follow-up arrangements** for adaptive management of the project and implementing additional adaptation measures as and when needed.

**Climate neutrality proofing**

A climate neutrality proofing assessment should be conducted that involves:

- Screening
- Detailed analyses (as and when needed)

<u>Climate neutrality screening</u>

As mentioned in chapter 1, the EU climate neutrality target effectively requires the full alignment of all investments that may cause significant GHG emissions with the climate neutrality pathway.

The first step in preparation of any investment is therefore the determination whether the proposed project may cause potentially significant direct or indirect GHG emissions. Such determination can be arranged through a simple reference to climate neutrality screening list which can be found at

*Table 1*. In case of uncertainty as to whether the project emissions (absolute or relative) could exceed the recommended threshold of 20,000 tonnes of emitted or saved CO2e/year, a preliminary carbon footprint calculation should be performed to check the scale of the potential GHG emissions associated with the project.

Detailed climate neutrality proofing (as and when needed)

The detailed analysis in the climate neutrality proofing includes the consideration of low-carbon development options, quantification and monetisation of GHG emissions (and reductions), and the analysis of the consistency of the project options with the climate change mitigation targets for 2030 and 2050. While it is understood that each project is unique, the following principles should guide the detailed analysis.

### *Consideration of low-carbon development options*

The detailed analysis in the climate neutrality proofing should help to rank and select options with a view to promoting low-carbon choices and options as well as the energy efficiency first principle. Box 4 offers a basic general typology of options, some of which (e.g. technological options or location options) that could be considered in project-level decision-making while Table *15* provides examples of questions that can help to identify alternative lower carbon options. Another possibility (optional) is to consider alternative project options using the inspiration provided by the EU Taxonomy of sustainable activities.

**Box 5: Broad alternatives options that could be addressed during climate resilience proofing and climate neutrality proofing in strategic decision-making**

**Question 1: Is the proposed development necessary - generally and in the scale proposed?**
(Demand management options)
Can the need or demand be met without new infrastructure at all? Are there any realistic opportunities for managing demands for environmentally problematic developments (e.g., greenfield developments) - through e.g. better planning or regulatory, economic or administrative tools?
⇓
**Question 2: How should it be done?**
(Technological or process options)
Are there low-carbon or more climate-resilient technologies or processes that can meet the development demands?
⇓
**Question 3: Where should it go?**
(Location options)
Are there any more suitable locations of proposed interventions? Where should the proposed interventions go, and where should be avoided?
⇓
**Question 4: When should it be implemented?**
(Sequencing and prioritizing options)
When should the proposed interventions be conducted and what needs to follow them? Are there any better priorities than proposed interventions?

Table 15 Example of general considerations about alternative lower carbon options

| Alternatives that exist during the project preparation | Examples of guiding questions that can inspire thinking about project-level options having a lower GHG footprint |
|---|---|
| Realistic opportunities for managing development demand | • Does the project directly or indirectly create any new demands for:<br>o Use of energy?<br>o Personal travel and/or freight transport?<br>o Use of materials or products with high carbon footprint?<br><br>• What arrangements or options exist for reducing these demands? If not, can these demands be met through other means (i.e., without the project)? |
| Less GHG intensive technologies or processes | • Are there any technologies with lower GHG footprint – i.e. those that emit less carbon dioxide ($CO_2$), nitrous oxide ($N_2O$) or methane ($CH_4$) or any other greenhouse gasses? |
| More suitable locations? | • Does the proposed project entail any land-use change or forestry activities that may increase emissions or reduce current emission sinks? |
| Any better priorities? When should the intervention be conducted? | • Are there any interventions that need to be implemented before the project is put in place that reduce its GHG footprint? |
| Options meeting the energy efficiency first principle | • Does the project involve all economically feasible arrangements for reducing direct or indirect energy demands?<br>• |
| Options meeting the EU Taxonomy requirements[25] | • How does the EU Taxonomy treat the proposed project? Would it be eligible for potential inclusion into sustainable finance frameworks? Does the EU taxonomy include any similar activities that can be treated as potential options for consideration when it comes to the project design? |

### *The quantification of GHG emissions*

As described in Section 1.4, the quantification of GHG emissions (and reductions) is recommended to be based on the **Carbon Footprint Methodologies of the European Investment Bank**.

The quantification of GHG emissions should focus primarily on Scope 1 and 2 emissions which are currently used in the EIB methodologies. However, for certain sectors in which the scope 3 emissions associated with the projects are significant and can be estimated scope 3 emissions may need to be included (e.g. transport sector).

The GHG quantification is always subject to uncertainties and the limitations of the GHG emission calculation performed. There are many uncertainties due to inherently imperfect determination of the scope of the GHG emissions considered and the limited knowledge of the baseline GHG emission. Since the GHG calculations involve many limitations, it is advised to always base them on conservative

[25] The EU Taxonomy Compass provides a visual representation of the contents of the EU Taxonomy, starting with the Delegated Act on the climate objectives (climate change mitigation and climate change adaptation).

assumptions that are more likely to overestimate net increases in GHG emissions and underestimate net reductions of such emissions[26].

Since any analyses of alternatives should not harm other environmental objectives, the project developers and climate proofing experts should engage in a close cooperation with the relevant EIA process for the project.

### *Estimating the carbon externalities using shadow carbon prices and using them in the CBA*

The project promoters should use the GHG calculations to estimate the value of net carbon savings or emissions and use them in a cost-benefit analyses that represent the project's costs and benefits for the society.

When doing so, the project promoters should use EIB's shadow cost of carbon for GHG emissions and reduction presented in Table *2* of this document.

### *Verification of the project's compatibility with a credible GHG reduction pathway*

Verification of the project's compatibility with a credible GHG reduction pathway should analyse the project's compatibility with the objectives and targets as referred in Chapter 1. When climate neutrality proofing has been duly integrated in the preparation of the related project strategy/plan, this might support and be the basis for the project level verification.

### *Climate proofing reporting/statement*

At the end of the proofing process, climate proofing should be concluded with a relatively short summarising statement that is part of the proposed project documentation. The statement should explain how the climate proofing was conducted and its main findings. It should ideally include items stipulated in Box 6.

[26] It is often practice to use the scenarios (e.g.„with the project" and „without the project" options) used in the context of the CBA or economic assessment/appraisal as reference for relative GHG emissions assessment, if relevant for the sector.

**Box 6: Example of climate proofing statement contents**

**Climate-proofing process:**

Describe the climate-proofing process from initial planning to completion, including the integration into the project development cycle and coordination with environmental assessment processes (e.g. EIA).

**Mitigation of climate change (climate neutrality):**

Describe the screening and its outcome.

Where phase 2 (detailed analysis) is undertaken:

- Describe the project GHG emissions absolute and relative assessments. As applicable, describe its monetisation into the economic analysis with the use of the shadow cost of carbon as well as the preceding options analysis and the integration of the principle of 'energy efficiency first'.
- Describe the project's consistency with relevant EU and National Energy and Climate Plans, the EU target for emission reductions by 2030 and climate neutrality by 2050. How is the project contributing to the objectives of these plans and targets (it might be supported by relevant strategy/plan climate neutrality proofing when duly undertaken).

**Adaptation to climate change (climate resilience):**

Describe the screening and its outcome, including adequate details of the sensitivity, exposure and resulting vulnerability analysis.

Where phase 2 (detailed analysis) is undertaken, describe:

- the climate risk assessment including the likelihood and impact analysis, and identified climate risks.
- how the identified climate risks are addressed by relevant adaptation measures (considering in-built project climate resilience), including, as relevant, the identification, appraisal, planning and implementation of these measures.
- the assessment and outcome with regard to regular monitoring and follow-up for example of critical assumptions in relation to future climate change.
- the project's consistency with EU and, as applicable, national, regional and local strategies and plans on the adaptation to climate change, and national or regional disaster risk management plans.

**Any additional relevant information:**

Any other pertinent issues required by this guide and other applicable references.

This document should be used as summary to both internally record on analyses and recommendations performed within the climate proofing process as well as to inform the relevant authorities, investors, interlocutors, stakeholders and others on the same in a consistent and transparent manner. It is underlined that it is basically a summary/presentation of the climate proofing performed under project preparation process (e.g. as part of project feasibility studies) and it should not be seen as stand-alone/separated document.

The climate-proofing will be an essential component of decision-making on the proposed EU-funded projects.

## 2.4 Considerations of climate change in EIAs

The EIA Directive 2011/92/EU, as amended by Directive 2014/52/EU, requires the EIA screening to consider 'the risk of major accidents and/ or disasters which are relevant to the project concerned, including those caused by climate change' (Annex III of the EIA Directive, item 1 (f)) and also potentially significant 'effects of a project on climate' (Annex III of the EIA Directive, item 3). This means that the climate change mitigation and adaptation concerns need to be considered in the EIA screening process. To this end, it appears useful to closely coordinate EIA screening with the climate resilience screening. The Polish legal act implementing the Directive may be found at Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 7 kwietnia 2022 r. w sprawie ogłoszenia jednolitego tekstu ustawy o udostępnianiu informacji o środowisku i jego ochronie, udziale społeczeństwa w ochronie środowiska oraz o ocenach oddziaływania na środowisko and it should be noted that is currently under amendment.

In addition, the EIA Directive in its Article 3, para 1, item c) requires EIA to identify, describe and assess in an appropriate manner the direct and indirect significant effects of a project on climate. Article 3, para 2 further requires that this includes '*the expected effects deriving from the vulnerability of the project to risks of major accidents and/or disasters that are relevant to the project concerned'.* Article 5, read in conjunction with Annex IV of the EIA Directive, further stipulate that the EIA Report needs to include:

- item 4 with a description of the aspects of the environment factors that are likely to be significantly affected by the proposed project. These include environment factors related to climate – for example greenhouse gas emissions, impacts relevant to adaptation, etc.
- item 5.f. that requires information on *'the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change'.*

This makes it clear that the EIA process needs to properly consider climate change mitigation and adaptation concerns. This required information could be obtained through climate proofing of the proposed project if such proofing is conducted. In such case, the EIA process could be used to present or verify the climate proofing and facilitate its review by the relevant authorities and the public.

In addition, the European Commission's Guidance on the preparation of the EIA Report issued in 2017 (hereafter referred to as the 2017 EIA Guidance) confirms the approach outlined in the Commission's earlier Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment issued in 2013 (hereafter referred to as the 2013 EIA Guidance).

When it comes to climate change mitigation, the 2017 EIA Guidance notes that most Projects will have an impact on greenhouse gas emissions, compared to the baseline, through their construction and operation and through indirect activities that occur because of the Project. To this end, the EIA should include an assessment of the direct and indirect greenhouse gas emissions of the Project, where these impacts have been deemed significant. Such assessment should consider:

- Direct greenhouse gas emissions generated through the Project's construction and the operation of the Project over its lifetime (e.g. from on-site combustion of fossil fuels or energy use)

- Greenhouse gas emissions generated or avoided as a result of other activities encouraged by the Project (indirect impacts) e.g.
    - Transport infrastructure: increased or avoided carbon emissions associated with energy use for the operation of the Project ;
    - Commercial development: carbon emissions due to consumer trips to the commercial zone where the Project is located.

The EIA Guidance suggests that the assessment should take relevant greenhouse gas reduction targets at the national, regional, and local levels into account, where available. The EIA may also assess the extent to which Projects contribute to these targets through reductions, as well as identify opportunities to reduce emissions through alternative measures.

These recommendations fully reflect the practical tips for the consideration of climate change mitigation concerns provided through the earlier 2013 EIA Guidance (see Table *16* for a list of key guiding questions that could be asked when identifying key climate change mitigation concerns).

Table 16: Examples of key questions that could be asked when identifying key climate change mitigation concerns (complied from the 2013 EIA Guidance) – the topics marked in bold are additional to those that are likely to be addressed in a regular climate neutrality proofing process

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the EIA | Examples of alternatives and mitigation measures |
|---|---|---|
| **Direct GHG emissions** | • *Will the proposed project emit carbon dioxide ($CO_2$), nitrous oxide ($N_2O$) or methane ($CH_4$) or any other greenhouse gases part of the UNFCCC?*<br>• **Does the proposed project entail any land use, land-use change or forestry activities (e.g. deforestation) that may lead to increased emissions? Does it entail other activities (e.g. afforestation) that may act as emission sinks?** | • Consider different technologies, materials, supply modes, etc. to avoid or reduce emissions;<br>• **Protect natural carbon sinks that could be endangered by the project, such as peat soils, woodlands, wetland areas, forests**;<br>• **Plan possible carbon off-set measures, available through existing off-set schemes or incorporated into the project (e.g. planting trees).** |
| **Indirect GHG emissions due to an increased demand for energy** | • *Will the proposed project significantly influence demand for energy?* | • Use recycled/reclaimed and low-carbon construction materials;<br>• Build energy efficiency into the design of a project (e.g. include warmcel insulation, south facing windows for solar energy, passive ventilation and low-energy light bulbs);<br>• Use energy-efficient machinery;<br>• Make use of renewable energy sources. |
| **Indirect GHG caused by any supporting activities or infrastructure that is directly linked to the implementation of** | • **Will the proposed project significantly increase or decrease personal travel? Will the proposed project significantly increase or decrease freight transport?** | • **Choose a site that is linked to a public transport system or put in place transport arrangements;**<br>• **Provide low-emission infrastructure for transport (e.g. electric charging bays, cycling facilities).** |

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the EIA | Examples of alternatives and mitigation measures |
| --- | --- | --- |
| **the proposed project (e.g. transport)** | | |

When it comes to adaptation, the 2017 EIA Guidance again confirms the approach taken in the 2013 guidance. It emphasizes the need for dynamic baseline analyses that go beyond a static assessment of the current situation and reflect the future evolution of the potentially affected environment which can be influenced by the climate change and many other factors, such as the impacts of projects that have already been approved but not yet implemented as well as potential natural and man-made hazards. Since all these factors may cumulatively significantly influence the quality of the potentially affected environment (e.g., water quality, biodiversity, etc.), it is important to properly acknowledge them and outline uncertainties that need to be considered during the project design and its environmental assessment.

While the 2017 EIA Guidance does not provide many practical details on key CC adaptation issues to consider, but the EIA practitioners could refer to recommendations provided in the earlier 2013 EIA Guidance. Table 17 of the 2013 EIA Guidance offered a list of key guiding questions that could be asked when identifying key climate change adaptation concerns. The suggestions marked in bold are addition to usual CC adaptation concerns that would be typically investigated within the CC resilience proofing process.

Table 17: Examples of key questions that could be asked when identifying climate change adaptation concerns

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the EIA | Examples of alternatives and mitigation measures |
| --- | --- | --- |
| **Heat waves** (take into account that heat waves are usually associated with water scarcity — see also the suggestions for droughts) | • **Will the proposed project restrain air circulation or reduce open spaces?**<br>• *Will it absorb or generate heat?*<br>• **Will it emit volatile organic compounds (VOCs) and nitrogen oxides ($NO_x$) and contribute to tropospheric ozone formation during sunny and warm days?**<br>• **Can it be affected by heat waves?**<br>• **Will it increase energy and water demand for cooling?**<br>• *Can the materials used during construction withstand higher temperatures (or will they experience, for example, material fatigue or surface degradation)?* | • **Encourage design optimal for environmental performance and reduce the need for cooling;**<br>• *Ensure that the proposed project is protected from heat exhaustion;*<br>• *Reduce thermal storage in a proposed project (e.g. by using different materials and colouring).*<br>• *Consider green and blue infrastructure particularly in urban environments to mitigate the effects of heat waves to population.* |

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the EIA | Examples of alternatives and mitigation measures |
|---|---|---|
| **Droughts due to long-term changes in precipitation patterns** (also consider possible synergistic effects with flood management actions that enhance water retention capacity in the watershed) | • **Will the proposed project increase water demand?**<br>• **Will it adversely affect the aquifers?**<br>• **Is the proposed project vulnerable to low river flows or higher water temperatures?**<br>• **Will it worsen water pollution — especially during periods of drought with reduced dilution rates, increased temperatures and turbidity?**<br>• **Will it change the vulnerability of landscapes or woodlands to wild fires? Is the proposed project located in an area vulnerable to wildfires?**<br>• *Can the materials used during construction withstand higher temperatures?* | • *Ensure that the proposed project is protected from the effects of droughts (e.g. use water-efficient processes and materials that can withstand high temperatures);*<br>• *Introduce technologies and methods for capturing storm water;*<br>• **Put in place state-of-the-art wastewater treatment systems that make reusing water possible.**<br>• Use fire-resistant construction materials;<br>• Create a fire-adapted space around the project (e.g. use fire-resistant plants). |
| **Extreme rainfall, riverine flooding and flash floods** | • *Will the proposed project be at risk because it is located in a riverine flooding zone?*<br>• **Will it change the capacity of existing flood plains for natural flood management?**<br>• **Will it alter the water retention capacity in the watershed?**<br>• *Are embankments stable enough to withstand flooding?* | • Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.);<br>• Improve the project's drainage.<br>• Consider green infrastructure and nature-based solutions. |
| **Storms and winds** | • *Will the proposed project be at risk because of storms and strong winds?*<br>• *Can the project and its operation be affected by falling objects (e.g. trees) close to its location?*<br>• *Is the project's connectivity to energy, water, transport and ICT networks ensured during high storms?* | • Ensure a design that can withstand increased high winds and storms. |
| **Landslides** | • *Is the project located in an area that could be affected by extreme precipitation or landslides?* | • Protect surfaces and control surface erosion (e.g. quickly establishing vegetation — hydroseeding, turfing, trees);<br>• Put in place designs that control erosion (e.g. appropriate drainage channels and culverts).<br>• Consider green infrastructure and nature-based solutions. |

| Main concerns related to: | Key questions that could be asked at the screening and/or scoping stage of the EIA | Examples of alternatives and mitigation measures |
|---|---|---|
| **Rising sea levels and coastal erosion** | • *Is the proposed project located in areas that may be affected by rising sea levels?*<br>• *Can seawater surges caused by storms affect the project?*<br>• **Is the proposed project located in an area at risk of coastal erosion? Will it reduce or enhance the risk of coastal erosion?**<br>• *Is it located in areas that may be affected by saline intrusion?*<br>• **Can seawater intrusion lead to leakage of polluting substances (e.g. waste)?** | • Consider changes in construction design to allow for rising sea levels (e.g. building on pillars, etc.).<br>• Consider green and blue infrastructure and nature-based solutions. |
| **Cold spells and snow** | • *Can the proposed project be affected by short periods of unusually cold weather, blizzards or frost?*<br>• *Is the proposed project at risk of freeze-thaw damage (e.g. key infrastructure projects)?*<br>• *Can the materials used during construction withstand lower temperatures?*<br>• *Can ice affect the functioning/operation of the project? Is the project's connectivity to* energy, water, transport and ICT networks ensured during cold spells?<br>• Can high snow loads have an impact on the construction's stability? | • Ensure that the project is protected from cold spells and snow (e.g. use construction materials that can withstand low temperatures and make sure the design can resist |

The 2017 EIA Guidance reminds EIA practitioners that when addressing climate change adaptation concerns as part of EIA, they need to not only consider the historical data on climate, but also clearly identify and present the climate change scenario that should be considered in the assessment process. A clear description of the climate change scenario facilitates discussion on whether the expected climatic factors should be considered in the project design and how they may affect the project's environmental context. EIA practitioners should outline extreme climate situations to be considered as part of the environmental baseline analysis.

# 3 Part III: Documenting climate proofing in EU project applications

JASPERS has reviewed the climate considerations in the draft documents provided by the Ministry. The relevant ones were the Application Form manual and the draft Annex 4 - Compliance with environmental law (including climate considerations). JASPERS' proposals for Annex 4 related to climate change considerations had been provided in a separate document (in track changes) but also presented in the text below along with a couple of suggestions for the Application Form.

It should be noted that the proposal below can be used in every Operational Programme to address the climate proofing requirement in the Application Form.

## 3.1 Instructions for beneficiaries

To document compliance with the climate proofing requirement (if applicable), the beneficiary needs to provide the climate proofing report/statement as part of the project`s application package. The climate proofing report/statement should follow the structure stipulated in Box 6 of this guide.

Based on the climate proofing assessment the beneficiaries will also need to complete relevant point of the application form. More specifically:

**Climate proofing of project**

| Descriptive field — max. 4000 characters. |
|---|

**Instructions**

For infrastructure projects with a lifetime greater than 5 years, the applicant should perform a climate proofing assessment and provide a climate proofing report. The climate proofing assessment should be performed according to the EC Technical guidance on climate proofing of infrastructure in the period 2021-2027. The Polish guide on climate proofing for investment preparation in EU programming period 2021-2027 complements it as national guide for its application.

In this section, the capacity to respond and adapt to climate change should be described based on the results of the climate proofing assessment. The applicants should provide a brief summary of the climate proofing assessment documentation covering both climate neutrality (mitigation) and climate resilience (adaptation). It should cover:

- Climate proofing requirement for the project according to Common Provisions Regulation
- Climate change neutrality (mitigation) – If required:
    - Screening
    - Detailed analysis including compatibility with the overall GHG emission reduction targets for 2030 and 2050 (If required)
- Adaptation to climate change (resilience) – If required:
    - Screening
    - Detailed analysis including consistency with Polish, regional or local strategies and plans on adaptation to climate change (if required)
- Conclusion of climate proofing and alignment with the Paris Agreement

In the application form, at least for projects for which their main objective is the reduction of energy and GHG emissions (e.g. energy efficiency in buildings), the beneficiary should include an indicator on GHG emissions.

## Glossary

**Absolute (Ab) GHG emissions:** Annual emissions estimated for an average year of operation (EIB, 2022).

**Adaptation options (measures):** The array of strategies and measures that are available and appropriate for addressing adaptation. They include a wide range of actions that can be categorized as structural, institutional, ecological or behavioural (IPCC, 2021).

**Climate change:** Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. (EC, 2021a)

**Climate proofing:** A process to prevent infrastructure from being vulnerable to potential long-term climate
impacts whilst ensuring that the 'energy efficiency first' principle is respected and that the level of greenhouse gas emissions arising from the project is consistent with the climate neutrality objective in 2050 (European Parliament and Council,2021).

**Exposure:** The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (IPCC, 2021).

**Greenhouse gases (GHGs):** are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). (EC, 2021a).

**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, 2021).

**Low regret adaptation options:** measures for which the associated costs are relatively low and for which, bearing in mind the uncertainties with future climate change, the benefits under future climate change may potentially be large.

**Nature-based solutions:** Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

**No regret adaptation options:** measures that are worthwhile now (in that they would deliver net socio-economic benefits which exceed their costs) and continue to be worthwhile irrespective of the nature of future climate. Such measures will, as a rule, be cost neutral. It is important to understand why no regret options have not already been undertaken as an adaptation strategy could help address the existing constraints and barriers to implementation.

**Relative GHG emissions:** The difference (delta) between the absolute project emissions and the baseline scenario emissions (EIB, 2022).

**Residual risk:** The risk related to climate change impacts that remains following adaptation and mitigation efforts. Adaptation actions can redistribute risk and impacts, with increased risk and impacts in some areas or populations, and decreased risk and impacts in others. (https://apps.ipcc.ch/glossary/).

**Risk:**
The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence. (EC, 2021a).

In the instruction to the application for funding under OPI&E 2014-2020, climate risk was understood in two dimensions:
• as a risk of the lack (or insufficient level) of the project's resilience to climate change,
• as a risk of (significant) climate impact.
This understanding is consistent with the currently applicable concept of climate proofing.
Moreover, what is still valid, within the meaning of the Floods Directive, risk is defined as potential losses in the event of a specific natural phenomenon. Taking this risk into account is easier for projects in river valleys, for which the values of flood losses are indicated on flood risk maps.

**Risk assessment:** The qualitative and/or quantitative scientific estimation of risks (IPCC, 2021)[27].

**Typical year of operation**: In calculating the absolute or relative emissions of a project, a typical year of operation is used in which the project operates at normal capacity. This means excluding emissions from

[27] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection defines 'risk analysis' as the consideration of relevant threat scenarios, in order to assess the vulnerability and the potential impact of disruption or destruction of (critical) infrastructure. This is a broader definition than climate risk assessment.

construction or decommissioning and unexpected outages and maintenance activities. In many cases, it is the average year over the lifetime of the project (EIB, 2022).

**Vulnerability** [IPCC AR5[28]]**:** 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, 2021).

**Win-win adaptation options**: measures that have the desired results in terms of minimising the climate risks or exploiting potential opportunities, but also have other social, economic or environmental benefits. This can include measures that are introduced primarily for reasons other than climate change but also deliver desired adaptation benefits. For instance, this could be introduction of measures to improve water efficiency in agriculture, industry or buildings.

[28] PCC AR5 SYR, Synthesis Report, Annex II: Glossary, https://www.ipcc.ch/site/assets/uploads/2019/01/SYRAR5-Glossary_en.pdf

## References

European Commission (2013a). Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment.

European Commission (2013b). Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment.

European Commission (2013c) Green Infrastructure (GI) — Enhancing Europe's Natural Capital COM/2013/ 249

European Commission (2017). Environmental Impact Assessment of Projects. Guidance on the preparation of the Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU).

European Commission (2021a). Commission Notice: Technical guidance on the climate proofing of infrastructure in the period 2021-2027. C(2021) 5430 final. 29.7.2021

European Commission (2021b) Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. 9.12.2021

European Parliament and Council (2021c) Regulation (EU) 2021/1060 of the European Parliament and of the Council of 24 June 2021 laying down common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Just Transition Fund and the European Maritime, Fisheries and Aquaculture Fund and financial rules for those and for the Asylum, Migration and Integration Fund, the Internal Security Fund and the Instrument for Financial Support for Border Management and Visa Policy.

EIB (2023). EIB Project Carbon Footprint Methodologies – Methodologies for the assessment of project greenhouse gas emissions and emission variations.

IPCC (2021). IPCC Sixth Assessment Report Working Group 1: The Physical Science Basis

JASPERS (2017). JASPERS Guidance Note: The Basics of Climate Change Adaptation Vulnerability and Risk Assessment. Version 1. June 2017

SDC. Rapid Screening. Climate, Environment and Disaster Risk Reduction Integration Guidance (CEDRIG). Swiss Agency for Development and Cooperation. (Website accessed October 2022)

Guide to investment preparation respecting climate change mitigation and adaptation as well as resilience to natural disasters, Ministry of Climate and Environment, 2015.

# Annex 1: Key sources of climate change data

**Klimada 2.0**

**Description**

The project, implemented by the Institute of Environmental Protection in Poland, comprises numerous tasks, with the objective of raising knowledge on climate change and adapting to climate change impacts, together with knowledge dissemination channels, to strengthen economic, environmental and societal resilience as well as to support management of extraordinary risks associated with climate change. Among other objectives, the project deals with the establishment of a Central Emission Database, the development of climate scenarios with forecasts of a number of climate variables and, finally, the development of a Decision Making Support System (which includes the development of pollution and emission maps as well as financial analyses).

Klimada 2.0 is the main recommended source to be used for climate projections in the climate resilience proofing exercise in Poland.

**Reference information**

**Website:**

Klimada 2.0 – Baza wiedzy o zmianach klimatu (ios.gov.pl)

**Source:**

Klimada 2.0 website

**Blue Books for transport projects**

**Description**

Project preparation manuals called Blue Books for transport projects contain detailed methodologies on how to carry out Cost-Benefit Analyses within the scope of wider recommendations in preparing feasibility studies. They cover some of the main transport sectors and were produced with the support of JASPERS. While those guidelines are primarily referring to EU co-financed projects, Blue Books are also recommended as good practice in feasibility studies and CBA for all transport projects. Blue Books include the methodology for the calculation of GHG emissions of transport projects (including a set of national emission factors).

A table sheet with the most recent version of Blue Book unit costs, including the latest GHG emission factors is presented below.

**Reference information**

**Website:**

Methodologies:

Niebieskie Księgi 2021-2027 - Centrum Unijnych Projektów Transportowych. (cupt.gov.pl)

Datasheet: https://www.cupt.gov.pl/wp-content/uploads/2022/06/koszty-jednostkowe_v_14_20_105.xlsx

**Source:**

CUPT website

**National Energy and Climate Plan 2021-2030**

**Description**

The National Energy and Climate Plan 2021-2030 (NECP), submitted to the European Commission at the end of 2019, spells out the Polish Government objectives, policies, and activities in the areas of climate, energy and research and innovation. In its first part, the plan sets out concrete objectives for 2030 in terms of GHG reduction, share of RES in final energy consumption, increase in energy efficiency and reduction of coal consumption in electricity production. Meanwhile, the Annex presents the current situation and the forecasts of the Reference Scenario (using the current policies and measures) as well as the Climate and Energy Policy Scenario (the impact assessment of the policies and measures contained in the Plan).

**Reference information**

**Website:**

National Energy and Climate Plan 2021-2030 - Ministry of Climate and Environment - Portal Gov.pl (www.gov.pl)

**Source:**

Polish Government website

**Polish National Strategy for Adaptation to Climate Change with the perspective by 2030 (SPA 2020)**

**Description**

SPA 2020 indicates the goals and directions of adaptation actions to be taken in the most vulnerable sectors and areas within the perspective of 2030: water management, agriculture, forestry, biodiversity and protected areas, health, energy, building industry, transport, mountain areas, coastal zone, spatial development and urban areas. The vulnerability of those sectors has been identified on the basis of climate change scenarios adopted for SPA. The objectives, action lines and specific actions that correspond to strategy documents, have been proposed and other development strategies that are complementary in the context of adaptation.

**Reference information**

**Website:**

Strategiczny plan adaptacji dla sektorów i obszarów wrażliwych na zmiany klimatu do roku 2020 (mos.gov.pl)

**Source:**

Polish Government website

**The 2030 National Environmental Policy (PEP 2030)**

**Description**

On 16th July 2019, the Council of Ministers adopted the 2030 National Environmental Policy (PEP2030). PEP2030. The role of PEP2030 is to ensure Poland's ecological safety and high quality of life for all residents. In the system of strategic documents it specifies the mid-term Strategy for Responsible Development to 2020 with a perspective to 2030.

**Reference information**

**Website:**
[Polityka ekologiczna państwa 2030 - Archiwalna strona Ministerstwa Środowiska - Portal Gov.pl (www.gov.pl)]
[Monitor Polski 2019 r. poz. 794]

**Source:**
Polish Government website

**Urban climate adaptation plans**

**Description**
The project consists of the development of plans for adaptation to climate change in Polish cities with more than 100.000 inhabitants. The lifespan of the project was of two years, starting in 2017 and ending in 2019. 44 Urban Climate Adaptation Plans (MPAs) have been developed as a result of this project, which was supported by the European Union and organized by the Polish Ministry of the Environment.

**Reference information**
**Website:**
Urban | Adaptation Plans Let's feel the climate! (44mpa.pl)

**Source:**
ECMWF website

**National crisis management plan (KPZK)**

**Description**
The National Crisis Management Plan (KPZK) is a planning document prepared by the Government Centre for Security in based on the Act on Crisis Management. In KPZK, 19 threats have been identified including climate hazards and their impacts such as flood, disruption of telecommunications systems and services, disruption in energy, fuel and gas systems, severe frost, heavy snowfall, hurricane, large-scale fire, drought, heat, disruption in the functioning of the network and information systems and hybrid operations. Part A could be more relevant for the climate proofing exercise as it contains information about: 1. the characteristics of threats and the assessment of the risk of their occurrence, including those related to critical infrastructure; 2. Tasks and responsibilities of crisis management participants in the form of a safety net for phases: prevention and preparation.

**Reference information**
**Website:**
National Crisis Management Plan - Government Centre for Security - Portal Gov.pl (www.gov.pl)
National Crisis Management Plan – Part A
National Crisis Management Plan – Part B

**Source:**
gov.pl website

**Strategy for Responsible Development**

**Description**
The Strategy for Responsible Development until 2020 (with a perspective until 2030) – SRD – was adopted by the Council of Ministers on 14 February 2017. The Strategy contains recommendations for public policies. The strategy defines the basic conditions, goals and directions of the country's development in the social, economic, regional and spatial dimensions in the perspective of 2030. The SRD presents a new development model – responsible development and socially and territorially balanced. It is based on individual territorial potential, investments, innovations, development, export and highly processed products.

**Reference information**
**Website:**
https://www.gov.pl/documents/33377/436740/SOR.pdf

**Source:**
gov.pl website

**National Regional Development Strategy (CRS 2030)**

**Description**
The SRD (see above) adopted by the government indicates a new model of regional development Polish. The National Regional Development Strategy (CRS 2030) reflects the provisions of the SRD set out in the pillar of socially and territorially balanced development. The document presents the objectives of regional policy as well as the actions and tasks that should be undertaken by the government, provincial, district and municipal self-governments and other entities participating in the implementation of this policy in the perspective of 2030.

**Reference information**
**Website:**
https://www.gov.pl/attachment/38c54257-5b35-4b2d-b379-c897a31c85e7

**Source:**
gov.pl website

**National Urban policy 2030 (KPM 2030)**

**Description**
The National Urban Policy 2030 (KPM 2030) was adopted on 14 June 2022. The document diagnoses the most important development challenges of cities and their functional areas. The thematic scope of the challenges is at the same time in line with the European debate and trends in the development of urban areas, the current analysis of which allows for better planning of future activities. KPM 2030 formulates solutions and defines planned actions of government administration in the legal, financial and organizational field for the sustainable development of cities and functional urban areas. At the same time, the document is addressed to local authorities and local communities – it equips them with tools and opportunities for efficient action.

**Reference information**
**Website:**
https://www.gov.pl/attachment/01114756-5e93-4607-a616-44d59a24e9d5

**Source:**
gov.pl website

**Europe's changing climate hazards — an index-based interactive EEA report (Published Nov 2021 – Last modified Feb 2023)**

**Description**
The report groups climate hazards under 32 indices and they are presented in a highly visual way to help decision-makers understand the challenges they face and prepare for them. The features of the report include:

- an index-based overview of past and projected changes in major climate hazards affecting Europe.
- access to generalised or detailed information according to user needs in the European Climate Data Explorer.
- insight into how various climate hazards affect different sectors.
- the ability to zoom in on the data for a region or even a sub-region - for 15 of the 32 indices.
- interactive maps to better represent and communicate climate hazards to everyone affected.

**Reference information**
**Website:**
Europe's changing climate hazards — an index-based interactive EEA report — European Environment Agency (europa.eu)

**Source:**
EEA website

**European Centre for Medium-range Weather Forecast (ECMWF)**

**Description**
The ECMWF is an organization which provides detailed meteorological data in the form of forecasts, climate reanalyses, datasets and, most importantly, charts. Its Integrated Forecasting System (IFS) provides forecasts and associated verification at different resolutions and for multiple time ranges (with medium, extended, and long ranges available). ECMWF also produces and disseminates weather forecast data for the Meteorological and Hydrological Services of some Member States and other authorised users. Finally, it contributes to the Copernicus Emergency Management Service, providing air quality analysis, fire risk and hydrological predictions, and climate monitoring. The EIB has a cooperation agreement with the Centre.

**Reference information**
**Website:**
Forecasts | ECMWF

**Source:**
ECMWF website

**Climate Adapt Platform**

**Description**
The European Climate Adaptation Platform gathers data on climate change, on vulnerabilities of EU regions and sectors, on adaptation strategies, actions and case studies and on tools that support adaptation planning. Data on Poland, together with relevant links to the platforms, portals and plans are present at the link below.

**Reference information**
**Website:**
Poland — English (europa.eu)

**Source:**
Climate-ADAPT platform

# Annex 2: Climate proofing recommendations for key sectors

## Annex 2.1 Sectoral guidance on climate resilience proofing

This section provides sectoral guidance on climate resilience proofing with the aim to support: (i) the beneficiaries in performing the climate proofing assessment; and (ii) the Managing Authorities in appraising the quality and the adequacy of a climate-proofing report that will be submitted.

It is reminded that the sensitivity assessment is an integral part of the vulnerability assessment. This means that it only makes sense when it is accompanied by the exposure assessment, which is based on sound climate information (current and future) and takes into account the entire lifespan of the project. The project promoters should not only rely on the sensitivities mentioned in this document but they should assess all climate hazards in the screening phase, during the project preparation phase, to identify the ones that are relevant to their project.

The indicative list of adaptation measures should not be seen as an exhaustive catalogue and shall not be used as a checklist. The adaptation measures that should be implemented in a project would depend on the specificities of the project, expected climate risks, its location together with its lifespan, maintenance/major upgrade cycles and adaptive capacity. The level of the severity of the risks, their probability and the impacts in case of failure of the infrastructure, cost of the investments and willingness of the Beneficiary to accept certain risk will also be decisive for the adaptation measures that will be selected in each project.

It is crucial that at the earliest stage of the CCVRA (i.e., the vulnerability assessment) all project components and their interdependencies are included in the assessment.

### *Annex 2.1.1 Building projects*

The main guidance document for adaptation in buildings is the EU Technical guidance on adapting buildings to climate change[29] which was published by DG CLIMA in March 2023. The guidance collects and synthesises existing methods, specifications, best practices and guidance for climate-resilient buildings into a document that can provide practical advice for professionals and be referenced or used in different EU policy documents. The document is accompanied by a Best Practice guidance[30] that provides technical guidance on climate-adaptation measures at the building scale. These adaptation measures aim to be relevant for both new and existing buildings, across the different climatic zones of Europe.

The sections below provide an overview of the sector sensitivities and potential adaptation measures based on JASPERS experience with the building projects.

[29] European Commission, Directorate-General for Climate Action, EU-level technical guidance on adapting buildings to climate change, Publications Office of the European Union, 2023

[30] European Commission, Directorate-General for Climate Action, EU-level technical guidance on adapting buildings to climate change: best practice guidance, Publications Office of the European Union, 2023

*Sector sensitivities*

| Climate hazards | Sensitivities |
| --- | --- |
| Drought | Buildings can be vulnerable to public water supply/demand deficits. Higher temperatures can increase demand for water while dry periods can affect regional supply.<br>Climate change (increasing temperatures and changes in precipitation patterns) and population growth can also put pressure on water resources.<br>Water shortages can also impact buildings services and maintenance, including landscape management. |
| Extreme precipitation events (flooding) | Heavy and/or prolonged rainfall can produce large volumes of surface water that can overwhelm drainage and sewer infrastructure.<br>Surface water (pluvial) flooding can cause loss of life, injury and ill health, damage to buildings and structures, and disruption to critical infrastructure. The impacts of flooding can be felt for months and years after the event, in particular on health, wellbeing, livelihoods and social cohesion. |
| Extreme temperature events | Excessive outdoor temperatures can affect thermal comfort and building materials and design can also enhance or reduce this effect.<br>Public buildings (e.g. schools, hospitals) can be highly sensitive to this climate hazard as children and/or hospitalised people are a particularly at-risk group for heatwaves and extreme temperatures. Extreme weather can also cause brown/black outs. |
| Sea-level rise and storm surge | For buildings in coastal areas sea-level rise will increase the risk of coastal flooding from storm surges and high tides. Coastal flooding can damage the building envelope, as well building services, fixtures and fittings. |
| Solar radiation | Prolonged exposure to solar radiation and temperature extremes can cause damage to the building envelope, building services, fixtures and fittings due to the expansion, buckling and stresses of structures and surfaces and the failure of building services. |
| Storms and high winds | High winds and storms (including lightning and snow) can also cause damage to the building envelope, building services, fixtures and fittings. Extreme weather can cause brown/black outs. |
| Soil stability and subsidence | Drought and reductions in soil moisture content can cause soil shrinkage and subsidence.<br>Subsidence can cause localised but major damage to buildings and infrastructure. |
| Wildfire | Loss of life, high economic costs and health impacts from both the fire itself and the associated smoke. Extreme weather can also cause brown/black outs. |

*Indicative adaptation measures*

The text that follows provides example of adaptation measures for climate hazards that are typically relevant for buildings. It should be noted that not all measures may be applicable in the context of building *refurbishments* (for example in the context of projects to improve the energy efficiency of existing buildings), as some can only be implemented at the stage of planning and constructing *new* buildings. The eligibility for EU co-financing of the related expenditure should be verified in the context of the relevant call for projects.

| Climate hazards | Indicative adaptation measures |
|---|---|
| Drought | • Rainwater collection systems<br>• Water-efficient appliances<br>• Water meters<br>• Water leak detection and prevention systems<br>• Grey water recycling systems<br>• Organic sewerage treatment (e.g., reed bed) |
| Heavy precipitation and flooding<br><br>Sea level rise and storm surge | • Avoiding unsuitable cheaper land such as flood plains<br>• Perimeter drainage solution, including Sustainable Urban Drainage Systems, swales and other attenuation systems<br>• Permeable hard paving over landscaped areas and minimising non-permeable outside spaces, including the extensive use of green space<br>• Allowance for climate change in drainage network capacity<br>• Damp proofing membrane (walls and floors); the use of dense materials for ground floor walls and condensation resistant constructions above ground cover (e.g. subfloor of damp resistant materials); and enhancing structural capacity.<br>• Raising services to 1m above finished floor level (e.g. electrical socket outlets)<br>• Barrier construction, such as a wall or bank; or diversion of overflow<br>• Changes to door thresholds to accept barrier and/or sandbags.<br>• Water resistant construction to foundations and footings (e.g. concrete additives, dense brick/block work, etc) |
| Extreme/high temperature events | • Shading in landscape (including natural shading) and building aspect and geometry (e.g. brise soleil, deep window reveals, "second skin" type structures creating shade or overhanging eaves)<br>• Use of high-performance glass to minimise heat transfer, in either direction<br>• Increased thermal insulation to fabric and services<br>• Higher than usual air tightness to building envelope<br>• Use of low energy lights to reduce internal gains (e.g. LEDs)<br>• Higher duty chiller and/or increased efficiency<br>• Mechanical ventilation plant used instead of natural ventilation |
| Solar radiation | • Changes to building materials to withstand greater solar radiation |

| Climate hazards | Indicative adaptation measures |
|---|---|
| | • Changes to landscape materials (e.g. macadam) to withstand greater solar radiation<br>• Routing vulnerable components (e.g. plastic rainwater pipes) behind the façade<br>• |
| Storms and high winds | • Increase structural strength, such as wind posts, bracing & heavier frames<br>• Higher specification cladding to manage loading or decrease the spacing between the support structure.<br>• Additional roof deck holding down straps; and/or clips/nails to hold individual roof elements (e.g. tiles);<br>• Mechanical ventilation plant used instead of natural ventilation<br>• Siting, orientation, height, massing of buildings<br>• Wind breaks (natural/artificial) and avoiding narrow building access (i.e. high winds round tall buildings) |
| Changes in soil stability and subsidence | • Timber frame and/or structural insulated panels to lighten the load and allow the building to move<br>• Raft foundation to restrict building movement; or independent raft foundation to allow structure to 'float' and be re-levelled.<br>• Increased pile depth or extend piling down to rock level to make the structure independent of the soils |
| Wildfires | • Low or no flammability external cladding materials<br>• Arrange access roads to create a natural fire break |

Further detailed examples can be found in a Guide to adaptation measures for buildings prepared by the French Green Building Observatory and available (in French) at:
8691_OID21_Guide_des_actions_adaptatives_au_changement_climatique.pdf (taloen.fr).
Finally, the Global Alliance for Building and Constructions has published a report "Buildings and Climate Change Adaptation – A call for action which includes an annex (Technical Annex 1) providing information on how to implement adaptation in each building's life-cycle phase.

### *Annex 2.1.2 Transport*

***Linear transport infrastructure (railway, roads) and urban transport***

This section covers linear transport infrastructure projects such as roads and railway but also urban transport projects such as metro, light railway, tram.

**Roads**

*Sector sensitivities*

| Climate hazards | Sensitivities |
|---|---|
| Extreme temperature increase (including heat waves and droughts) | Damage to road pavements (e.g. softening, deformation, cracking, rutting, asphalt sweating, blow-up of concrete pavements, lifetime reduction); problems with bridges (stability, thermal expansion of bridge joints, paved surfaces, etc.); damage to horticultural assets |

| **Climate hazards** | **Sensitivities** |
|---|---|
| | (drying up) and increased need for watering; increased fire risk; increased health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion – potential demand changes; increased need for cooling (passenger and freight); increased construction and maintenance costs;… |
| Wildfires | Damage to all road infrastructure assets (pavement, equipment, structures, horticultural assets etc.); damage to adjacent land or other assets; reduced visibility; increased health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion;… |
| Cold spells | Damage to road pavement, concrete structures and electro-mechanical (E/M) equipment; increased winter maintenance costs; negative thermal expansion of bridges; increased safety risks to users and operators; traffic disturbance and congestion; slope instability and embankment failures;… |
| Freeze-thaw cycle | Increased slope instability and embankment failures; damage to road pavement and concrete structures; increased winter maintenance; increased users safety risks (e.g. hazardous pavement conditions due to ice); traffic disturbance and congestion;… |
| Change in average rainfall; change in extreme rainfall (storm surges) | Damage to road assets (pavements, earthworks, structures, drainage systems etc.); insufficient drainage and/or retention capacity - flooded pavements caused by reduced runoff especially in hollow sections and underpasses; dangerous pavement conditions and reduced visibility; increased runoff to/from adjacent land causing flooding; inundation from rivers; slope instability and landslides, mudslides and/or rockslides; scouring of roads and bridges and structures supports; deterioration of structural integrity of roads due to increased soil moisture levels; reduced safety including accidents and vehicle damage; hazardous pavement surface conditions (slippery) and reduced visibility; traffic disturbance and congestion;… |
| Flooding (coastal/ fluvial) | Damage to road assets, underground tunnels and bridges, inundation in coastal areas and coastal erosion; erosion of road base and bridge supports and abutments; scouring at bridge supports, damage to signs, lighting and E/M assets; increased risk of coastal erosion and submersion; increased risk to bridge decks stability; increased slope instability and landslides; temporarily or permanently inaccessible networks and assets; health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion;… |
| Snow/ avalanche | Changes to soil stability; reduced/increased need for snow clearing and winter maintenance; increased risk of ice/snow melting leading to increased runoff and/or flooding; damage to E/M equipment and |

| Climate hazards | Sensitivities |
| --- | --- |
| | other installations; changing nature and location of avalanche risk; increased health and safety risks to road users and road operators due to snow and ice; traffic disruption;… |
| Fog | Reduced visibility; increased health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion; increased smog;… |
| Maximum wind speed | Road obstructions: falling trees, falling infrastructure equipment (e.g. signs, lighting and CCTV columns etc.), flying and falling objects; increased health and safety risks to road users and road operators; operational constraints at exposed locations (e.g. high-sided vehicles); increased number of overturned vehicles due to increased wind speeds and storms; threat to stability of bridge decks; traffic disturbance and congestion;… |
| Soil erosion | Damage to embankments and cuttings; other road equipment damaged as a consequence of the above; increased risk of road subsidence and weakening of bridge supports; increased user and road operators health and safety risks including accidents and vehicle damage; traffic disturbance and congestion;… |
| Ground instability/ landslides/ avalanche | Damage to embankments and cuttings; user and road operators health and safety risks including accidents and vehicle damage; other road infrastructure (pavement, safety or E/M equipment); damaged due to landslides debris; traffic disturbance and congestion;… |

*Source: JASPERS work based notably on Climate Change Impacts and Adaptation for Transport Networks and Nodes, UNECE, 2020; CEDR Climate Change publications including RIMARROC.*

*<u>Indicative adaptation measures</u>*

| Climate hazards | Indicative adaptation measures |
| --- | --- |
| All hazards - General | **Planning**<br>- Considerations of implications for maintenance and operations through adequate Climate Change Vulnerability & Risk Assessment (CCVRA)<br>**Design and construction**<br>- Consider the implications of road design on maintenance & operation (e.g. when replacing old drainage systems, pavement rehabilitation, etc.)<br>- Analysis and identification of locations with climate change risks (through relevant CCVRA) followed by adequate design and improvement works<br>**Maintenance and operation**<br>- Use of asset management and traffic management systems (i) to record and monitor asset condition and climate hazards impacts and (ii) to provide timely information and warning to asset managers and users |

| Climate hazards | Indicative adaptation measures |
|---|---|
| | - Prepare and plan for rapid response during extreme situations (e.g. Disaster Risk Management Plan) and use adequate emergency warning systems |
| Extreme temperatures/ Heat waves/ Droughts/ Wildfires | **Design and construction**<br>- Design adequately robust pavements resistant to high temperatures (e.g. using more resilient materials and processes with increased heat-resistance properties)<br>- Adequate considerations for concrete pavements (e.g. proper dimensioning of expansion joints, etc.)<br>- Adequate considerations for bridges (e.g. thermal expansion impact on bridge joints)<br>- Adequate considerations for horticultural assets resistant to heatwaves and droughts<br>- Consider possible installation of fire hydrants at exposed locations and highway junctions<br>**Maintenance and operation**<br>- Forest management considerations and fire risks related to woody areas close to roads<br>- Review adequacy of pavement design during road reconstruction/ rehabilitation intervention<br>- Adequate fire-fighting planning, staffing and equipment |
| Extreme precipitation / Flooding | **Planning**<br>- Road alignment considerations (vertical and horizontal) when considering options<br>- Run-off water management analysis; River basin management plans<br>- Considerations of climate change in flooding maps (e.g. updates of flooding maps consider potential variations of the given return period flood)<br>**Design and construction**<br>- Adequate drainage system type and capacity including e.g. an allowance for future climate change and retention analysis (ensuring sufficient & efficient drainage and retention system is crucial for dealing with extreme precipitation hazards)<br>- Consideration of bridge supports and abutments erosion protection and robust foundations (e.g. avoid intermediate bridge supports in fast-flowing currents that could be vulnerable to scour)<br>- Possible review design standards and guidelines to incorporate climate considerations (review design rain intensity and frequency values or consider a climate change factor e.g. 10-20% increase in drainage capacity or increased clearance over 50-(100/200/300/500?) year flood levels under bridges);<br>- Other road design considerations: reducing slope gradients, slope consolidation & embankment protection measures, slope drainage, embankment elevation, stronger pavements etc.<br>**Maintenance and operation** |

| Climate hazards | Indicative adaptation measures |
|---|---|
| | - Review O&M practices for drainage systems and slopes (including regular routine maintenance and inspections)<br>- Review/update flood risks (e.g. embankment protection) and needs on the existing network |
| Landslides/ ground instability/ soil erosion | **Planning**<br>- Road alignment considerations (avoiding potential landslide risk areas) when considering alignment options<br>**Design and construction**<br>- Considerations of erosion protection<br>- Review earthworks design guidelines and/or practices (e.g. strengthen drainage, slopes, protection measures, use of berms, protective measures at the foot of embankments etc.)<br>- Development landslide risk assessment models<br>**Maintenance and operation**<br>**-** Ensure regular routine maintenance and inspections<br>- Review and update a list of landslides/ ground instability risk locations on the existing network with potential climate change considerations |
| Extreme wind | **Design and construction**<br>- Adequate consideration of future wind charges when designing vulnerable and exposed elements such as suspension bridges, supports and anchorages (e.g. noise screens, lighting and CCTV posts, signalling and E/M equipment, gantries and Variable Message Signs (VMS), etc.)<br>**Maintenance and operation**<br>- Tree condition monitoring and location assessment |
| Freeze-thaw cycle | **Design and construction**<br>- Consider resistant materials and technologies for pavements and concrete structures (e.g. higher-quality concrete and pavement materials, soil stabilization techniques to reduce frost action in subgrade soils) and structures<br>- Review design guidelines as regards freeze-thaw effect and salting<br>- Protection of slopes<br>**Maintenance and operation**<br>- Ensure adequate routine maintenance, repairs and inspections of pavements and exposed concrete structures to prevent water ingress and spalling |

*Source: own work based on several recognised publications (notably from CEDR Climate Change publications , PRIAC…).*

***Rail & Urban Transport***

<u>*Sector sensitivities*</u>

| Climate hazards | Sensitivities |
|---|---|
| Extreme temperature increase (including heat waves and droughts) | Track buckling; infrastructure and rolling stock overheating/failure; CCS component heating; slope failures; signalling problems; catenary dilatation; speed restrictions; asset lifetime reduction; demand changes; increased fire risk; occupational health and safety issues (e.g. extreme temperatures or increased accident risk); increased needs for cooling (passenger and/or freight); increased construction and maintenance costs, performance limitations for electrical systems (on-board batteries and related charging infrastructure – also due to increased need for colling stressing batteries); difficulty in accessibility and permanence in stops/stations in particular for vulnerable users |
| Cold spells | Rail track damages (e.g. buckling of rail tracks); slope instability and embankment failures; freight and/or passenger traffic disturbance, performance limitations for electrical systems (on-board batteries and related charging infrastructure, increased need for heating stressing batteries) |
| Change in average rainfall; change in extreme rainfall (flooding) | Flooding, damage and wash-outs of bridges; bridge scouring; problems with drainage systems and tunnels; flooding of below grade tunnels; slope instability and landslides, mudslides and rockslides; embankment and earthwork damages (including structural integrity due to increased soil moisture levels); short circuit of flooded substations, signalling and telecom components; operational problems (e.g. power-cut); restrictions and disruption of train operations, delays; changes in demand… |
| Snow | Changes to soil stability; reduced/increased need for snow clearing and winter maintenance; increased ice/snow melt leading to flooding; changing nature and location of avalanche risk; snowdrifts; track, catenary, substation, signalling and/or telecom damage; operational problems (e.g. switch malfunction, brake malfunction due to snow between disk and pad); components short-circuit; restrictions and disruption of transport operations, delays, access to fixed and mobile recharging and refuelling equipment (including Hydrogen Fuel Cell refuelling) |
| Maximum wind speed | Damages to installations and catenary; short-circuits due to trees or branches falling on the catenary contact wire; overvoltage; rail line obstructions (e.g. due to fallen power lines/trees); rail car blow-overs; slippery rails or locking of train wheels in case of fallen leaves; restrictions and disruption of train operations (e.g. progressive speed reduction), delays… |
| Freeze-thaw | Rail track damages (e.g. buckling of rail tracks); increased slope instability and embankment failures; switch malfunction; operational problems (e.g. catenary and components freezing, pantograph failure, |

| Climate hazards | Sensitivities |
|---|---|
| | brake malfunction, etc.); restrictions and disruption of train operations, delays … |
| Flooding (coastal/fluvial) | Damage to installation and catenary assets; damage and wash-outs of railway tracks and embankments, bridges and culverts; bridge scouring; flooding of below-grade tunnels; increased slope instability and landslides; temporarily or permanently inaccessible networks and assets; restrictions and disruption of train operations, delays, damage to roadside charging equipment … |
| Soil erosion | Damage to embankments and cuts; increased risk of embankment subsidence and weakening of bridge supports; damage to superstructure derived of previously mentioned damage; operational problems and safety risks; restrictions and disruption of train operations, delays … |
| Ground instability/ landslides/ avalanche | Embankment and earthwork damages; other infrastructure damages related to landslides debris (e.g. track destruction, catenary cut, substation damage, components of signalling and telecom broken, or cable cuts); operational problems and safety risks (e.g. derailment/overturning); restrictions and disruption of train operations, delays… |
| Wildfire | Damage to all rail infrastructure (embankments, catenary, structures…); damage to adjacent land or other assets; reduced visibility; operational problems and safety risks; restrictions and disruption of train operations, delays… |

*Source: Climate Change Impacts and Adaptation for Transport Networks and Nodes, UNECE, 2020; CEDR Climate Change publications including RIMARROC; UIC, and JASPERS own* work.

*Indicative adaptation measures*

| ***Climate hazards*** | ***Potential adaptation responses*** |
|---|---|
| All hazards - General | **Planning**<br>- Considerations of implications for maintenance and operations, corridors/areas to be avoided (including e.g. for sops positioning), general recommendations and data sources<br>**Design and construction**<br>- Consider the implications of rail design in maintenance (e.g. when replacing old drainage systems, tracks/ballast replacement/rehabilitation, etc.)<br>- Analysis and identification of locations at climate change risks and undertake improvement works<br>- Use of redundant installation to withstand basic performance and minimum services<br>- Consider system performance under full range of likely conditions (in particular e.g. for urban transport fleets and supporting infrastructure) |

| ***Climate hazards*** | ***Potential adaptation responses*** |
|---|---|
| | - Use naturally "resilient" solutions (e.g. green roofing for PT stops, green paths to access such stops – decreasing possible damages both from flooding and users vulnerability to heat waves, …)<br>**Maintenance and operation**<br>- Analysis of climate change risk of transport services and identify mitigation measures for operation including monitoring to avoid loss of lives and to preserve assets<br>- Use of asset management and traffic management systems (i) to record and monitor asset condition and climate hazards impacts and (ii) to provide timely information and warning to asset managers and users<br>- Prepare and plan for rapid response during extreme situations (e.g. Disaster Risk Management Plan) and use adequate emergency warning systems |
| Heat/ Fires | - Review existing power system arrangement (redundancy) to enhance supply reliability<br>- Carrying out trials to explore new technologies for improving ventilation and cooling of equipment and buildings<br>- Install expansion joints at especially critical points<br>- Avoid buckling of railway tracks, by means of increasing the rigidity and weight of the superstructure of the track, including ensuring their fixation with systems that increase their resistance to lateral displacement<br>- Additional inspection of equipment under extreme temperature to protect threshold<br>- Specific catenary maintenance to ensure its working tension (i.e. capacity to collect the length variations) and capacity of the brackets to rotate enough<br>- Heat/cool vehicles to ensure they are in operational condition<br>- Consider system performance under full range of likely conditions (including fleets)<br>- Use naturally "resilient" solutions (e.g. green roofing for PT stops, green paths to access such stops – decreasing possible damages both from flooding and users vulnerability to heat waves, …)- Forest management considerations and fire risks related to trees close to rail lines |
| Precipitation and flooding | **Planning**<br>- Rail/system (tram etc.) alignment considerations (elevation and horizontal) when considering options<br>- Run-off water management analysis; River basin management plans<br>**Design and construction**<br>- Drainage system type and capacity including retention analysis (ensuring sufficient & efficient drainage system is crucial for dealing with extreme precipitation hazards) |

| ***Climate hazards*** | ***Potential adaptation responses*** |
|---|---|
| | - Considerations to bridge erosion protection and robust foundations (e.g. avoid intermediate bridge supports in fast-flowing currents that could be vulnerable to scour)<br>- Possible review design standards and guidelines to incorporate climate considerations (review design intensity and frequency values or consider a climate change factor e.g. 10-20% increase in drainage capacity or increased clearance over 50-(100/200/300/500?) year flood levels under bridges)<br>- Other rail/system design considerations: reducing slope gradients, slope consolidation & embankment protection measures, slope drainage, embankment elevation, stronger pavements etc.<br>- Review existing power system arrangement (redundancy) to enhance supply reliability<br>- Incorporate flood gates and flood pumps<br>- Refrain from use of underground substations in lower points of the local topology<br>- Select a location on an upper site of the local topology to allow dry storage of equipment and rolling stock<br>- Identify equipment at low lying area, add flood proof features if it is possible and install sump pit and pumping system as well. Relocate the equipment present in an area with high flood potential<br>- Use naturally "resilient" solutions (e.g. green pavements) for overground PT infrastructures when possible, helping natural drainage.<br>**Maintenance and operation**<br>**-** Review O&M practices for drainage systems and slopes (including regular inspections)<br>- Review/update flood risks (e.g. embankment protection) needs on existing network<br>- Analysis of climate change risk of transport services and identify mitigation measures for operation including monitoring to avoid loss of lives and to preserve assets<br>- Set up automatic reporting mechanisms on water levels in tunnel installations to the control centre |
| Landslides | **Planning**<br>- Rail/system alignment considerations (avoiding potential landslide risk) when considering options<br>**Design and construction**<br>- Considerations of erosion protection<br>- Review earthworks design guidelines and/or practices (e.g. strengthen drainage, slopes, protection measures, use of berms, protective measures at the foot of embankments)<br>- Development of models for landslide risk assessment |
| Wind | **Design and construction** |

| *Climate hazards* | *Potential adaptation responses* |
|---|---|
| | - Considerations of wind charges when designing vulnerable elements such as suspension bridges or supports and anchorages (e.g. noise screens, signalling, etc.)<br>- Review existing power system arrangement (redundancy) to enhance supply reliability<br>- Considerations of rigid and latest design catenary use<br>- Review foundations design considerations<br>- Revise (and renew as relevant) the condition of roofs and canopies<br>**Maintenance and operation**<br>- Trees status monitoring and location assessments<br>- Keep tracks and areas close to tracks & catenaries free from hazardous objects and vegetation by enhancing vegetation management, preventing re-growth on embankments by setting out the responsibilities of both transport infrastructure owners and adjacent landowners<br>- Keep a regular check to trim tree branches near the power lines |
| Freezing and thawing/<br>Snow | **Design and construction**<br>- Consider resistant materials and technologies for pavements (e.g. concrete, soil stabilisation techniques to reduce frost action in subgrade soils) and structures<br>- Review design guidelines as regards freeze-thaw effect and salting<br>- Protection of slopes<br>- Review existing power system arrangement (redundancy) to enhance supply reliability<br>**Maintenance and operation**- Prevent drifting snow getting into ventilated, direct current, traction motors by storing trains under roofs.<br>- Check vehicles for overnight weather-related issues, such as frozen couplings, bogies and doors |

*Source: UITP and JASPERS own* work.

***Ports***

Very detailed guidance on climate adaption in ports can be found in the guidance document published in January 2020 by the World Association for Waterborne Transport Infrastructure on Climate Change Adaptation Planning for Ports and Inland Waterways (or PIANC's Working Group 178). The document provides guidance on how to ensure resilience of waterborne transport to climate change and to give examples and recommendation of good practice.

### *Annex 2.1.3 Urban regenaration*

The sections below refer to climate-proofing of urban regeneration projects, including public spaces such as s squares/open space, playgrounds, outdoor sport facilities, parks, green/blue infrastructure, and regeneration of brownfield sites. In case the broader project also includes buildings, users are advised to refer to JASPERS guidance note on buildings.

*Sector sensitivities*

| Climate hazards | Sensitivities |
|---|---|
| Drought | Urban regeneration projects can be vulnerable to public water supply/demand deficits. Higher temperatures can increase demand for water while dry periods can affect regional supply.<br>Water shortages will affect the maintenance of public spaces, including landscape management, irrigation of planted areas, periodic cleaning, operation of public fountains or lakes.<br>Droughts may degrade the quality of parks and public squares (e.g. due to weakening and destruction of trees and planted areas, drying-out of water ponds or waterfalls) thereby limiting their attractiveness to the public and increasing the demand for operation and maintenance funding, including replacement of plants and redesign of facilities. |
| Extreme heat | Extreme heat in public spaces can be discomforting to visitors[31] in case there is lack of shady areas and the air quality degrades. Materials such as marbles, concrete, steel (e.g. used for benches, paving, etc) can become very hot and reflect heat augmenting the heal island effect.<br>Some tree species may be attacked by insects or fungi while harmful algal blooms may be created in the water bodies located within parks.<br>Solar radiation could cause deterioration of materials.<br>Fire risk increases e.g., due to sparks (originating from power lines' overheating) being transmitted to dried tree branches.<br>Parks and squares may have to restrict visitor access during extreme heat waves to protect visitors' health and reduce the number of days during which specific recreational facilities (e.g., playgrounds, public markets, open-air expositions) are available to the public. |
| Extreme precipitation events (flooding) | Heavy and/or prolonged rainfall can produce large volumes of surface water that can overwhelm drainage infrastructure. Impermeable surfacing may increase surface runoffs creating serious safety concerns.<br>Pluvial flooding may wash out footways and paths within parks and public squares and may cause lower-elevation facilities (e.g playgrounds) to inundate.<br>Visitors' access to facilities (e.g., playgrounds or open-air courts) will be limited and may be prohibited.<br>Special features such as stone or wooden footbridges may be destroyed.<br>Facilities located in the vicinity of rivers may experience frequent inundation, while high water flow velocities may cause erosion or |

[31] Visitors of the space are all its users including residents in nearby areas as well as commuters from other regions.

| Climate hazards | Sensitivities |
|---|---|
| | scouring of riverbanks risking the integrity of neighbouring facilities and compromising the safety of their visitors.<br>Extreme rain could create slope instability issues or even land sliding, significantly threatening the overall stability and safety of projects located in the vicinity of slope crests. It could also create debris or mud flows that could cover or destroy the facilities. In case the project landscaping involves slopes, this will also be affected. |
| Extreme Cold and freeze-thaw cycle | Concrete and asphalt pavements and surface covering may experience cracking and be damaged while timber components may experience swelling or warping.<br>E/M equipment (e.g., pumps) may experience failures and require frequent parts' replacements.<br>Battery-operated utilities (e.g., solar lights) may deteriorate faster while their winter repairs and maintenance costs will increase.<br>Irrigation and water supply piping systems or sprinklers may freeze or burst.<br>Visitors may experience frost bites and hypothermia.<br>The overall costs for snow/ice clearing and winter maintenance will increase due to the increasing frequency of events and amount of ice/snow to be removed.<br>Freeze-thaw cycles cause increased risk of slope instability potentially impacting projects in the vicinity of slope crests.<br>Increased quantities of ice/snow melting could lead to increased runoff and/or flooding.<br>Shallow water ponds may freeze, affecting flora and fauna and potentially creating safety issues to visitors.<br>Snow accumulated in walkways and iced steps limit the accessibility of projects and create safety risks to visitors. |
| Sea-level rise and storm surge | Sea level rise will increase the risk of coastal flooding from storm surges and high tides causing frequent inundation of facilities especially when located closer to the waterfront. In extreme cases, inundation could become permanent.<br>Coastal parks may be significantly impacted as sea-level rise could harm nesting areas of marine animals.<br>Sea-water intrusion into the aquifer may threaten freshwater plants or animals in coastal parks, including landmark species.<br>It may also kill mangroves used for protection of coastal parks.<br>Increased salinity may provoke the withering of plants and accelerate the deterioration rate of structural materials. |
| Storms and high winds (including hurricanes) | High winds and storms may cause trees to fall which could create cascading effects including injuries to visitors or fatalities, power- |

| Climate hazards | Sensitivities |
|---|---|
| | line failures that could result in fire incidents, damage to features of the facility (e.g., playground equipment, lighting fixtures and columns, art installations).<br>Suspended features of the neighbouring urban environment (e.g., road signage, traffic lights, street lighting, CCTV columns) may be damaged or fall impacting the safety of visitors, and the integrity of the equipment within the project boundaries.<br>Cyclones, hurricanes, and gales may lift light constructions such as bus stops and advertising signs (or even overturn cars and light vehicles) and have them impact neighbouring squares and parks posing a very significant risk to visitors and equipment.<br>Timber or steel frames, kiosks and panels may be damaged, broken or collapse; in case they are lifted in the air, they may hit neighbouring structures or even impact people and vehicles.<br>Wind gusts could also severely damage or totally destroy tall installations including playground equipment such as ferry wheels present in recreational areas or carousels/roller coasters in amusement parks.<br>Blackouts due to failures of the power grid supplying the projects with electricity would pause the operation of electric-powered equipment including security and lighting.<br>In coastal areas, tall winds could generate high waves impacting the facilities.<br>Wind may pick up debris (i.e., wood, metal siding, toys, trash cans, tree branches, etc.) and transfer it to the facilities potentially impacting visitors, while it could also cause dust and sand debris storms. |
| Soil stability and subsidence | Massive rockfalls and rockslides may completely (or partially) cover parks shutting down operations, increasing the risk of serious injuries, destroying equipment etc.<br>Excessive landslides may drift away or vanish hillside parks that are built on or located adjacent to the landslide area.<br>Temporary closure of parks (and cancelation of hike and trail activities) to prevent accidents in case of increased landslide risk.<br>The park landscaping will be affected.<br>Smaller soil instabilities can wash-out footpaths, cut-off trails and cause damages to the park's facilities and equipment (e.g., facility houses, storages, pipelines etc). |
| Wildfires | Wildfires in the vicinity of urban regeneration projects pose the major risk of loss of life either as a direct impact or due to the smoke transferred to the urban regions, |

| Climate hazards | Sensitivities |
|---|---|
| | Urban regeneration projects may be totally destroyed or experience damage due to the extreme temperatures potentially causing melting of materials, trees being burnt, ash transfer etc.<br>Wildfires are responsible for the release of pollutants compromising air quality and creating health risks to visitors and die-offs of trees and any flora and fauna residing in the urban ecosystem (including migratory and non-migratory species, hedgehogs, squirrels, lizards etc) due to toxic compounds.<br>Burnt ecosystems will subsequently result in increased flooding events in neighbouring infrastructure due to increased runoffs.<br>Facilities may need to close to visitors to protect public health. |

*Indicative Adaptation Solutions*

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| Drought | **Planning and Design**<br>In coastal areas, consider using plants that are resistant to drought to avoid reliance on municipal water supply shortages.<br>Use efficient irrigation systems (e.g., drip irrigation) to minimize water needs and reduce evaporation losses.<br>Consider the possibility of using treated greywater connected to a drip irrigation system for grass, lawns, trees and ornamental greenery.<br>Install water tanks (ideally underlying squares or open spaces) to maintain water reserves, (including collection of rainwater through appropriate drainage design) and connect it to irrigation piping.<br><br>**Construction and O&M**<br>Use drought-tolerant native plants.<br>Use smooth-surface materials for ground surface covering so that routine cleaning can be performed consuming less water.<br>Where possible, prefer using permeable/porous materials that do not require frequent cleaning.<br>Consider re-using water for non-drinking purposes (e.g. irrigation) |
| Extreme heat | **Planning and Design**<br>Design landscaping for solar radiation protection.<br>Install renewables (e.g for night lights) to minimize grid dependence (i.e., avoid impacts of potential power failures) and increase energy efficiency. |

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| | Prefer cool pavements or cool-colored coatings for asphalt mixes that could reflect up to 50% of light.<br>Provide incentives for the construction of cool/green roofs and green facades in surrounding buildings to improve the microclimate conditions and reverse the heat island effect.<br>Convert grass-dominated parks to tree-dominated to maintain cooler temperatures. Trees, especially large trees, have high cooling benefits with more shade and transpiration. Select tree species with large canopy and leaf coverage, which will effectively reduce direct sunlight.<br><br>Apply high albedo (i.e., reflective) coating for paving and surfacing.<br>Install shading frames and kiosks made of -reflective materials.<br>Maximise shading by positioning shading structures and vegetation (e.g., trees) in a way to provide shade to the main outdoor functional areas (seating areas, playgrounds etc.) and main movement axes. Especially account for the sun's angle during the hottest part of the day.<br>Use thermoelectric cooling for outdoor kiosks.<br>Investigate using porous materials such as stabilized soil or dirt/earth mixes for pathways within the urban regeneration facility.<br>Provide urban equipment (e.g., benches, playground equipment) and other landscaped seating surfaces (e.g., bleachers) from materials of low thermal conductivity that don't become very hot in the summer.<br>Install blue-green spaces to increase humidification and air purification and enhance park cooling effects.<br>Identify and exploit existing ventilation corridors for natural cooling through the appropriate positioning of vegetation and other structural elements, and the three-dimensional landscaping of the terrain. |
| Extreme precipitation events (flooding) | **Planning and Design**<br>Perform a flood risk analysis also considering the potential changes in precipitation patterns due to climate change.<br>Investigate the applicability of Sustainable Drainage and Sewage System (SUDS) to prevent overflows.<br>Investigate whether the project, or part of it (e.g., a court within a park) could act as a flood retention pond by allowing it to become flooded thereby contributing to the resilience of the neighbouring area through the project. |

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| | Design and acquire flood defence equipment such as water diversion barriers, flood tubes, sand/aluminium barriers to protect critical parts of the facilities and divert water from sensitive areas.<br>Invest in early warning systems to be able to issue announcements and restrict visitor access to the projects when extreme events are forecasted.<br><br>**Construction and O&M**<br>Construct rain gardens, swells, constructed wetlands which are able to retain water and slowly release it to prevent uncontrolled runoff and overflows of combined sewage systems.<br>Avoid using impermeable paving materials to avoid uncontrolled runoff and prefer porous and green materials such as porous asphalt, pervious concrete, paving stones, gravel, woodchips, pine bark and manufactured "grass pavers" made of concrete or plastic. |
| Extreme Cold and freeze-thaw cycle | **Planning and Design**<br>Decide on the location of the facility to ensure it is not constructed in the vicinity (e.g., close to the crest) of an unstable slope.<br>Consider the weight of snow when designing light structures like kiosks etc.<br>Design drainage of the facility to be able to accommodate increased runoffs during snow melting.<br>Design designated spaces to pile snow during plowing.<br>Prepare a plan for snow management in cases of extreme snowfall including inventory of plowing vehicles and personnel based on an emergency response strategy.<br><br>**Construction and O&M**<br>Use cold-resisting, flexible materials to avoid cracking of paved/covered surfaces.<br>Do not leave sensitive E/M equipment (including batteries) exposed to extreme cold and ensure they are stored in appropriate protective casings.<br>Ensure insulation of irrigation and water supply piping systems or sprinklers to avoid freezing or bursting.<br>In extreme cases, consider installing heated pathways to accelerate snow melting and avoid ice formation. In the interest if energy efficiency, this should be done while taking advantage of existing networks such as municipal heating pipes etc. |

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| | Provide urban equipment (e.g., benches, playground equipment) from materials of low thermal conductivity that don’t become very cold in winter.<br>Investigate the possibility of setting up local teams of volunteers to assist in recovery following extreme events.<br>Limit the operation of the open spaces during extreme cold conditions.<br>Consider moving outdoors activities to indoor spaces during extremely cold days.<br>Set up an emergency response plan and order emergency supplies such as salt, sand, shovels, snow blowers and blankets for combatting cold weather. |
| Sea-level rise and storm surge | **Planning and Design**<br>Request data to inform future projections and adjust design if necessary.<br>In case of projected sea level rise in the future, consider relocating the facility possibly to a higher elevation location.<br>**Construction and O&M**<br>Stabilize and enhance shorelines (e.g., using plant marsh) to reduce erosion and protect from storm surges.<br>Use flood defences (e.g., sandbags, or aluminium barriers), revetments, or sills to protect from coastal flooding.<br>Apply solutions such as recharge wells and physical subsurface barriers to mitigate saltwater intrusion and protect the aquifers. |
| Storms and high winds (including hurricanes) | **Planning and Design**<br>Perform a risk analysis to identify hazards and potential impacts.<br>Replace movable furniture with fixed alternatives.<br>Design wind shelters (e.g., kiosks with embedded windbreaks or barriers) that can be used by people in need during extreme wind phenomena.<br>Design aerodynamic kiosks and canopies to limit stressing during wind loading. Use open-lattice roofs to prevent wind-uplift.<br>Consider setting up an early warning system to restrict access to visitors in periods of high risk.<br><br>**Construction and O&M phase**<br>Adjust trees landscaping to create wind barriers and protect visitors from wind gusts. |

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| | Ensure wind-proofing of sensitive parts and equipment using modern standards: design signage structures, CCTV and lighting columns, etc for increased wind speeds.<br>Anchor equipment and fixtures to ensure resistance to extreme winds.<br>Mitigate tree collapse hazards; ensure the height of trees is regularly controlled and trimming is applied when needed, do not plant tall trees next to power lines.<br>Inspect sensitive equipment and features -especially those intended for use in playgrounds or outdoor sports- for potential damages post event and only allow visitors' access following confirmation of safety levels by authorized personnel or experts.<br>Ensure backup power capacity if necessary (e.g., by means of generators or battery-backed renewables) to allow continuity of operations following grid failures or blackouts. |
| Soil stability and subsidence | **Planning and Design**<br>Perform slope stability analysis for facilities located in their vicinity of riverbanks or landslide prone areas.<br>Relocate facilities away from riverbanks.<br>Relocation of parks if in landslide prone areas<br>**Construction and O&M**<br>Cover topsoil with mulch, soil erosion blankets or turf reinforcement mats<br>Reinforce riverbanks with Coir logs, ripraps etc<br>Invest in automated avalanche monitoring systems (in case of skiing resorts)<br>Carry out local trimming and removal of loose blocks at the overhanging rocks.<br>Plant vegetation in unstable slopes to improve stability.<br>Construction of slope stabilization structures (e.g., gabion structures, crib walls etc.) at the toe zone |
| Wildfires | **Planning and Design**<br>Establish fire hazard severity zone maps and prepare action plans for different fire zones.<br>Depending on the size and expected use of the project, consider integrating in the site's layout safe public gathering areas and evacuation routes.<br>Collect and store rainwater that can be used for firefighting. Prepare/update fire management plans. |

| Climate hazards | Indicative Adaptation Measures |
|---|---|
| | Invest in fire extinguishing equipment and dedicated trained personnel.<br><br>**Construction and O&M**<br>Remove flammable vegetation (including the cleaning of fallen dry leaves) in fire-prone areas.<br>Apply fire prevention measures (e.g., restrict access to park areas, prohibit smoking)<br>Build partnerships, cooperate and exchange knowledge with fire management agencies.<br>Implement fire use bans (e.g., bbq) in case of increased fire risk or heatwaves.<br>Ensure adequacy of standby water for fire protection. |

### *Annex 2.1.4 Energy*

***Heat and Power generation***

*Sector sensitivities*

| Climate hazards | Sensitivities |
|---|---|
| Temperature related hazards (e.g. heat waves, cold waves / frost, temperature variability, wildfire) | Hazards related to rising and varying air temperature can have effect on total energy demand for heating and cooling. Expected changes in heating degree days (HDD) and cooling degree days (CDD) can be used to estimate the possible impact on required energy generation.<br><br>Peak electricity demand for cooling, which is almost exclusively provided by electricity, will increase.<br><br>Increasing temperatures, including extreme heat, are also affecting electricity generation as they lead to efficiency losses of thermal power plant. Increasing temperatures also affects evaporation from the water reservoir used for hydropower generation, therefore affecting the production / storage potential.<br><br>Solar PV is slightly affected by ambient temperature and wind speed changes, as both can have an impact on increasing cell temperature, which in turn can affect the generation efficiency.<br><br>Biomass availability from forestry can be negatively affected by increasing forest fire risk. Also, a decline in suitability for forest growth and decreasing crop yields can affect biomass availability as a result of increasing heat and water stress. |

| | |
|---|---|
| Water related hazards<br>(e.g. droughts, heavy precipitation, floods) | As regards water related hazards, the most relevant hydrological variables from the perspective of the energy system are annual river flow and river flow droughts (for thermal power plants and hydropower plants) and soil water availability (for bioenergy production).<br><br>Thermal power plants cooled with freshwater are vulnerable both to reductions in cooling water availability and to increases in its temperature.<br><br>The increase in precipitations (and in certain case snow accumulation) can lead to less solar irradiation and lower efficiency of solar panels.<br><br>Heavier and more frequent rainfall can also increase the moisture content of solid biomass feedstock and lower the average calorific value. |
| Wind related hazards<br>(e.g. storms) | Hail storms, can cause costly damage, in particular to solar panels – which can also be vulnerable to other extreme events (e.g., lighting strikes).<br><br>Wind, hail, ice and snow storms can adversely affect wind turbine operation. However, while the increase in maximum wind speeds may more frequently bring operational conditions above a certain cut-out speed, where no power is generated from the turbines, the increase in average wind conditions may favour an increase in average annual power generation. |
| Coastal and soil related hazards<br>(e.g. sea-level rise, landslides, coastal erosion, soil erosion) | Coastal hazards, such as erosion, storm surges and sea level rise can impact the physical integrity of generation plants or other energy infrastructure (e.g. LNG terminals) located on coastal areas. Maritime storms are a major hazard for offshore energy infrastructure.<br><br>As regards the consideration of climate change in the selection of the project sites, for solar photovoltaic power, it may be possible to select locations where expected changes in cloud cover, airborne grit, snowfall, and turbidity are relatively low. For wind power, sites should be selected also taking into account expected changes in wind speeds, storm surges, sea level rise, and river flooding during the lifetime of the turbines. |

*Indicative adaptation measures*

| **Climate Hazards** | **Indicative adaptation measures** |
|---|---|
| Temperature related hazards<br>(e.g., heat waves) | Pre-cooling of air used in combustion in thermal plants.<br><br>Adaptation options for thermal power plants during heat waves (or in water-stressed regions) include technological changes such as closed cooling and dry cooling systems.<br><br>For PV, consider solar modules with a higher temperature coefficient. The use of string or micro inverters allows more easy cooling. PV structures can be designed to improve passive airflow beneath mounting structures to reduce panel temperature and increasing power output. |

| Climate Hazards | Indicative adaptation measures |
|---|---|
| Water related hazards (e.g., flooding, high precipitation) | Shifts to power sources with low water use, in particular solar photovoltaics (PV).<br>Where cooling water is reduced with climate change, it may be possible to use air-cooled systems.<br><br>Additional seawater cooling for power plants located on coastal areas.<br><br>As regards flooding risks, adaptation measures include changing the operational regimes of reservoirs, dyke construction, component-based flood barriers and relocation.<br><br>Adaptation investments for hydro projects may include the oversizing of components at design stage, upgrade and/or expansion of the facilities and project components, expansion of storage reservoirs, change in facilities operation rules, cross sector integrated freshwater usage rules.<br><br>For geothermal projects, greater protection might be needed where floods are likely to increase.<br><br>Cabling and components of PV systems can be specified to resist to higher moisture content / flooding. |
| Wind related hazards (e.g., storms) | The design standard of wind turbines can be adapted to increase the robustness and resilience of different components (e.g. rotor blade). Taller towers can also be considered to harness stronger wind speeds at higher heights.<br><br>For PV, stronger mounting structures can be designed. |
| Coastal and soil related hazards (e.g. sea-level rise, landslides, coastal erosion, soil erosion) | Targeted retrofitting to increase resilience of thermal power plants in coastal areas / areas exposed to soil erosion or landslides (e.g., additional dikes or protective infrastructures to avoid damages from coastal flooding). |

As regards hydropower plants and the cooling of thermal units, additional information and case studies can be found on Climate ADAPT in the dedicated webpages on "Adaptation options for hydropower plants"[32] and on "Reducing water consumption for cooling of thermal generation plants".[33] In addition the EU Taxonomy: Final report of the Technical Expert Group (TEG) on Sustainable Finance includes examples of adaptation measures that can be implemented in hydropower projects to address climate risks:

[32] https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/adaptation-options-for-hydropower-plants

[33] https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/reducing-water-consumption-for-cooling-of-thermal-generation-plants

| Hazard | Sensitivities | Indicative adaptation measures |
|---|---|---|
| Cyclones<br>Hurricanes<br>Typhoons | Physical damage to hydropower facilities (e.g. dams, turbine houses, switchyards, ancillary infrastructure, etc.) | Adoption of structural strengthening of hydropower facilities (e.g. dams, spillways turbine houses, switchyards, ancillary infrastructure, etc.) |
| | | Adoption of hydro-meteorological monitoring and forecasting equipment |
| Changing precipitation patterns<br><br>Hydrological variability | Reduced water flows through turbines<br><br>Increased variability of water flows through turbines | Adoption of turbines capable of operating at low and/or variable flow conditions |
| | | Adoption of increased dam storage capacity |
| | | Adoption of hydrometeorological monitoring and forecasting equipment |
| Droughts | Insufficient water flowing through turbines | Adoption of turbines capable of operating at low and/or variable flow conditions |
| | | Adoption of increased dam storage capacity |
| | | Adoption of hydro-meteorological monitoring and forecasting equipment |
| Extreme precipitation events<br><br>Floods | Physical damage to hydropower facilities (e.g. dams, turbine houses, switchyards, ancillary infrastructure, etc.) | Adoption of structural strengthening of hydropower facilities (e.g. dams, spillways, turbine houses, switchyards, ancillary infrastructure, etc.) |
| | | Adoption of hydro-meteorological monitoring and forecasting equipment |
| Soil erosion | Loss of dam storage capacity | Adoption of sediment dredging and/or other sediment management measures |
| | Sediment damage to turbines | Adoption of sediment-resistant turbines |
| Avalanche<br><br>Landslide | Physical damage to hydropower facilities (e.g. dams, turbine houses, switchyards, ancillary infrastructure, etc.) | Adoption of structural strengthening of hydropower facilities (e.g. dams, spillways, turbine houses, switchyards, ancillary infrastructure, etc.) |
| | | Adoption of early warning monitoring equipment |
| | | Adoption of emergency response systems and equipment |

EU Taxonomy: Final report of the Technical Expert Group (TEG), 2020

***Electricity distribution / transmission networks***

*Sector sensitivities*

| Climate hazards | Sensitivities |
|---|---|
| Temperature related hazards (e.g. Increasing air temperature/heat waves, wildfire, temperature variability, frost) | Possible risks relate to the stability of electricity networks during heat waves, particularly when an increased peak electricity demand for cooling may coincide with limited cooling water supply for thermal power generation.<br>The rated capacity of power lines and transformers can be reduced during heat waves. Power losses can increase within substations and transformers.<br><br>Heat waves can cause overheating in electric transformers, in particular large power transformers, through reduced structural integrity and chemical reactions. This can in turn result in short circuits, power outages and costly repairs.<br><br>Wildfires can damage energy infrastructure, in particular wooden power poles at power distribution level.<br><br>Wet snow can cause icing to overhead cables. |
| Water related hazards (e.g. heavy precipitation, floods) | Heavy precipitation and inland floods can have significant impacts on energy infrastructure, such as electric substations. |
| Wind related hazards (e.g. storms, changing wind patterns)<br><br><br>Coastal and soil related hazards (e.g. sea-level rise, landslides, coastal erosion, soil erosion) | Storm-related events, such as wind, hail, ice and snow storms can adversely affect energy transformation and transport, transmission, distribution and storage infrastructure, resulting in blackouts and costly repairs.<br><br>Wind storms can affect overhead power lines either directly or indirectly, through vegetation coming into contact with or falling on to them.<br><br>Changing wind patterns can lead to downed transmission lines or gradual weakening of infrastructure leading to more frequent repairs.<br><br>Extreme weather and climate-related events, such as coastal and inland flooding, storms, hail and lightning, heat waves, droughts and wildfire events are among the most frequent causes of non-planned interruptions of power supply due to failures in the transmission / distribution network. |

*Indicative adaptation measures*

| Climate Hazards | Indicative adaptation measures |
|---|---|
| Temperature related hazard (e.g., increasing air temperature / heat waves, frost) | Designed network equipment for higher temperatures, including high-temperature transformers, high-temperature low-sag conductors and gas insulated lines or substations<br><br>More effective cooling of substations and transformers (e.g. external coolers).<br><br>Installation of additional storage facilities to adapt to higher volatility in load (and intermittent generation).<br><br>Consider increase in buildings' space cooling requirements when planning for expansion and refurbishments of transmission / distribution capacity.<br><br>Increase network digitalization to improve flexibility and enable demand-response mechanisms.<br><br>Establishment of early-warning systems to adapt consumer's behavior (demand)<br><br>Increase system capacity by increasing height of the poles or otherwise increasing tension on the line to reduce snag.<br><br>Consider underground cables to adapt to icing hazards. |
| Water related hazards (e.g., flooding, heavy precipitation, sea-level rise) | Increase in height of the pylons.<br><br>Relocation or replacement of overhead lines by underground cables.<br><br>Protection of grid assets against flooding e.g.:<br>Waterproof pipelines, substations, incorporate submergible transformers, switches, pumps, seal manhole covers.<br><br>Avoid the construction of power lines near dikes.<br><br>These are applied in locations with specific risks (coastal or riverside locations, forests). |
| Extreme weather events (e.g. storms), changing wind patterns | Adjust wind loading standards<br>Consider structural reinforcement of pylons and improved vegetation management.<br><br>Reroute power lines away from sensitive objects (e.g. trees) or plan / move them underground. |

| Climate Hazards | Indicative adaptation measures |
|---|---|
| | Adapted maintenance and damage response mechanisms. Create specially trained teams for the management / restore grid operations in extreme weather events.<br><br>Increase automation of the grid and remote reconfiguration of networks to minimise impact of faults. |
| Coastal and land-related hazards | Consider alternative routing options at investment planning stage.<br><br>Adopt underground cabling solutions in high vulnerability areas. |

More details and case studies can be found on Climate ADAPT in the webpage dedicated to "Adaptation options for electricity transmission and distribution networks and infrastructure"[34] and also in the TEG Final Report on EU Taxonomy[35].

### *Annex 2.1.5 Water and wastewater infrastructure*

JASPERS has developed a detailed Guidance Note on climate proofing in water and wastewater development. The Guidance Note covers all steps of climate proofing both for climate neutrality and climate resilience. It is also accompanied by a climate proofing document for an example water and wastewater project.

The sections below provide an overview of the sector sensitivities and potential adaptation measures based on the JASPERS Guidance Note.

#### ***Water infrastructure***

*Sector sensitivities*

The Sensitivity assessment in the JASPERS Guidance Note which is also presented further down is based on the following thresholds:

[34] https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/adaptation-options-for-electricity-transmission-and-distribution-networks-and-infrastructure

[35] https://finance.ec.europa.eu/system/files/2020-03/200309-sustainable-finance-teg-final-report-taxonomy-annexes_en.pdf

**High sensitivity (score 3)**

- the climate hazard may have a significant impact on assets and processes, inputs, outputs and transport links.
- as a result of climate hazard occurring WWTP or water supply network shutdown for more than 2 days,

**Medium sensitivity (score 2)**

- the climate hazard may have a slight impact on assets and processes, inputs, outputs and transport links.
- as a result of climate hazard occurring WWTP or water supply network shutdown for 1- 2 days, pollution incident which affects non-residential properties and has medium impact for water quality

**Low sensitivity (score 1)**

- the climate hazard has no (or insignificant) impact.
- as a result of climate hazard occurring WWTP or water supply network shutdown for up to 24 hours, minor pollution incident affecting collection system and minor impacts for water quality

**No sensitivity (score 0)**

- no possible impact of the climate hazard on any of the project components.
- no impact on the ability to manage the infrastructure - business as usual.

More information on how to assess the sensitivities and an indicative sensitivity matrix can be found in the JASPERS Guidance Note.

Sensitivity of water supply investments based on the above thresholds:

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | Ground Water Aquifer (Water Source) | Water Distribution Network (pipes) | Pumping stations | Water treatment plant and treatment processes | Quantity and quality of water supplied | |
| Heat and cold | Annual / seasonal / monthly average (air) temperature | 1<br>Possible degradation of raw water quality through increased turbidity. | 0<br>No impact | 0<br>No impact | 2<br>Impact on efficiency of treatment processes | 1<br>Possible impact on quality of treated water. | **2** |
| | Extreme temperature occurrences (including heat waves) | 0<br>no impact on groundwater sources (see drought for secondary effects of heat waves on water resources) | 0<br>no impact | 1<br>Difficult operating conditions which may affect pumping station efficiency and equipment | 2<br>Possible increase in the concentration of pollutants on the influence with effect on the treatment process, | 1<br>Additional demand for water during heatwaves. | **2** |
| | Cold spells | 1<br>Difficult conditions for managing / exploiting water resources due to frost, however groundwater sources are less sensitive than surface water sources. | 1<br>Difficult operating conditions due to frost | 1<br>Difficult operating conditions due to frost | 2<br>Decreased purification efficiency | 1<br>Potential for water to freeze | **2** |
| | Freeze-thaw damage | 0<br>Groundwater resources are isolated from the effect of freeze thaw cycles. | 1<br>Minor damage to concrete structures (underground infrastructure less vulnerable to temperature variations) | 2<br>Damage to concrete structures and electricity supply (above ground infrastructure more vulnerable to temperature variations) | 2<br>Damage to concrete structures and electricity supply (above ground infrastructure more vulnerable to temperature variations) | 2<br>Potential contamination from any pipe damage | **2** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | Ground Water Aquifer (Water Source) | Water Distribution Network (pipes) | Pumping stations | Water treatment plant and treatment processes | Quantity and quality of water supplied | |
| Wind | Average wind speed | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | **0** |
| | Maximum wind speed / Storms (tracks and intensity) | 0<br>No impact | 0<br>No impact | 1<br>Possible damage to structures | 3<br>Significant impact – can destroy the structure (Exceedance of design conditions could result in structural damage or collapse.) | 0<br>No impact | **3** |
| Other air and atmospheric | Air quality | 0<br>No impact | 0<br>No impact | 0<br>No impact | 1<br>Possible impact on some treatment processes | 1<br>Possible impact on drinking water quality. | **1** |
| Wet and dry | Annual / seasonal / monthly average rainfall | 2<br>Seasonal variation in rainfall could alter groundwater aquifer recharge | 0<br>Water supply network is sperate to stormwater drainage network so no possible interaction | 0<br>Water supply network is sperate to stormwater drainage network so no possible interaction | 1<br>Possible impact on water treatment process efficiency. | 1<br>Possible change in water demand and supply. | **2** |
| | Extreme rainfall (frequency and magnitude) | 3<br>Potential for rainfall to alter groundwater aquifer conditions | 2<br>Potential ingress of untreated rainfall into water distribution network. | 2<br>Potential for ingress into supply network with impact on pumping station efficiency. | 3<br>Potential to decreases the efficiency of the treatment process (influential dilution) or by-pass of treatment. | 2<br>Potential for flood water to contaminate treated water. | **3** |
| | River and groundwater flooding | 3<br>Groundwater flooding and links between surface, coastal and | 2<br>Potential ingress of untreated floodwater | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Potential for long duration | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | Ground Water Aquifer (Water Source) | Water Distribution Network (pipes) | Pumping stations | Water treatment plant and treatment processes | Quantity and quality of water supplied | |
| | | fluvial flooding with groundwater could contaminate or alter groundwater aquifer conditions. | into water distribution network. | | | contamination of treated water | |
| | Aridity | 0<br>Aridity has no direct impact on groundwater resources. | 0<br>No impact | 0<br>No impact | 0<br>No impact | 2<br>Increased water demand for irrigation reducing drinking water availability | **2** |
| | Drought / Water availability | 3<br>Significant impact on water resources | 0<br>No impact on the distribution network. | 0<br>No impact on pumping stations | 0<br>No impact on the treatment plant itself or treatment process. | 3<br>Insufficient water to meet demand | **3** |
| | Wildfire | 0<br>No impact | 0<br>No impact | 3<br>Infrastructure damage, danger of explosion | 3<br>Infrastructure damage, danger of explosion | 2<br>Potential increased demand for water for firefighting | **3** |
| Snow and ice | Avalanche | 0<br>No impact | 0<br>No impact | 3<br>Avalanche could significantly damage pumping stations | 3<br>Avalanche could significantly damage water treatment plants and impact on treatment processes | 0<br>No impact | **3** |
| | Melting permafrost | 3<br>Potential for change to groundwater recharge and quality | 3<br>Potential for changes to ground stability | 3<br>Potential for changes to ground stability | 3<br>Potential for changes to ground stability | 0<br>No impact | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | Ground Water Aquifer (Water Source) | Water Distribution Network (pipes) | Pumping stations | Water treatment plant and treatment processes | Quantity and quality of water supplied | |
| | Ice flows in rivers | 3 Potential change to groundwater recharge and quality which may last for a season. | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 3 |
| Coastal | Sea level rise | 0 No impact | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Possible saline incursion into drinking water supply. | 3 |
| | Flood (coastal) | 3 Groundwater flooding and links between surface, coastal and fluvial flooding with groundwater could contaminate or alter groundwater aquifer conditions. | 2 Potential ingress of untreated floodwater into water distribution network. | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Potential for contamination of treated water | 3 |
| | Coastal erosion | 3 Potential for change to groundwater recharge and quality | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 2 Potential for contamination of treated water | 3 |
| Oceanic | Sea water temperature | 0 no impact | 0 no impact | 0 no impact | 0 no impact | 0 no impact | 0 |
| | Ocean acidity | 1 Possible but unlikely effect on groundwater quality | 1 Possible effect in water quality which may affect piping of network | 0 No impact | 1 Possible effect in water quality which may affect treatment plant parts | 0 no impact | 1 |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | Ground Water Aquifer (Water Source) | Water Distribution Network (pipes) | Pumping stations | Water treatment plant and treatment processes | Quantity and quality of water supplied | |
| | Ocean oxygen level | 1<br>Possible but unlikely effect on groundwater quality | 1<br>Possible effect in water quality which may affect piping of network | 0<br>No impact | 1<br>Possible effect in water quality which may affect treatment plant processes | 0<br>No impact | **1** |
| | Ocean salinity | 1<br>Possible but unlikely effect on groundwater quality | 1<br>Possible effect in water quality which may affect piping of network | 0<br>No impact | 1<br>Possible effect in water quality which may affect treatment plant parts | 0<br>no impact | **1** |
| Other water | Fresh water temperature | 2<br>Changing the quality of groundwater sources, complicating the treatment process | 0<br>no impact | 1<br>Possible effect on pumping station flow and efficiency. | 2<br>Possible increase of the pollutant concentration on the influence with effect on the treatment process | 1<br>Possible slight impact on quality of supplied water | **2** |
| | Fresh water quality | 3<br>Potential for change to groundwater quality | 1<br>Possible effect in water quality which may affect piping of network | 0<br>No impact | 3<br>Increase level of water treatment required | 3<br>Lack of water fit for supply | **3** |
| Land, soil and geotechnical | Soil erosion | 0<br>no impact on groundwater sources | 0<br>no impact | 0<br>no impact | 0<br>no impact | 1<br>Possible slight impact on quality of supplied water | **1** |
| | Saline intrusion | 3<br>Saline intrusion into groundwater aquifers would significantly alter | 1<br>Possible effect in water quality which | 1<br>Possible corrosive impact on pumping station equipment | 3<br>Treatment process may not be able to deal with saline water | 3<br>Lack of water fit for supply | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | Global score |
|---|---|---|---|---|---|---|---|
| | | **Ground Water Aquifer (Water Source)** | **Water Distribution Network (pipes)** | **Pumping stations** | **Water treatment plant and treatment processes** | **Quantity and quality of water supplied** | |
| | | quality and availability of fresh water | may affect piping of network | | | | |
| | Ground Instability / landslides | 3<br>Potential change to groundwater recharge hydrology | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Potential incursion of untreated water into supply | **3** |
| | Dust storms | 0<br>no impact on groundwater sources | 0<br>no impact | 1<br>Difficult operating conditions, minor sand deposits on pumping station equipment | 1<br>Difficult operating conditions, minor sand deposits on the technological line | 1<br>Possible impact on water quality from dust settling | **1** |

Sensitivity of interdependencies for integrated water/wastewater projects based on the above thresholds:

| Hazard category | Climate Hazards | Interdependencies for water and wastewater aspects | | Global score |
|---|---|---|---|---|
| | | Power supply | Access roads | |
| Heat and cold | Annual / seasonal / monthly average (air) temperature | 2<br>Medium impact if metal used for wiring is sensitive | 0<br>No impact | **2** |
| | Extreme temperature occurrences (including heat waves) | 0<br>no impact | 0<br>no impact | **0** |
| | Cold spells | 2<br>Potential to increase demand for electricity. | 1<br>Possible difficult operating conditions due to icy road conditions | **2** |
| | Freeze-thaw damage | 0<br>no impact | 0<br>no impact | **0** |
| Wind | Average wind speed | 0<br>Average wind speeds will not have any impact on transmission network. | 0<br>No impact from average wind speeds. | **0** |
| | Maximum wind speed / Storms (tracks and intensity) | 2<br>Possible impact from high winds on overground power distribution networks to structures | 2<br>Some access routes may be temporarily cut off during and after storms. | **2** |
| Other air and atmospheric | Air quality | 0<br>No impact | 0<br>No impact | **0** |
| Wet and dry | Annual / seasonal / monthly average rainfall | 0<br>No impact | 1<br>Slight impact on road drainage may occur | **1** |
| | Extreme rainfall (frequency and magnitude) | 2<br>Medium impact (possible power outage from flooding to transmission network) | 2<br>Medium impact (possible flooding of access roads) | **2** |
| | River flooding | 2<br>Medium impact (possible power outage from flooding to transmission network) | 2<br>Medium impact (possible flooding of access roads) | **2** |
| | Aridity | 0<br>No impact | 0<br>No impact | **0** |

| Hazard category | Climate Hazards | Interdependencies for water and wastewater aspects | | Global score |
|---|---|---|---|---|
| | | Power supply | Access roads | |
| | Drought | 0<br>no impact | 0<br>no impact | **0** |
| | Wild Fire | 3<br>Infrastructure damage | 2<br>Access routes may be cut off for the duration of a wildfire. | **3** |
| Snow and ice | Avalanche | 3<br>Avalanche could significantly damage power supply networks | 3<br>Avalanche could cut off access or damage access roads | **3** |
| | Melting permafrost | 0<br>no impact | 0<br>no impact | **0** |
| | Ice flows in rivers | 0<br>no impact | 0<br>no impact | **0** |
| Coastal | Sea level rise | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | **3** |
| | Coastal flooding | 2<br>Medium impact (possible power outage from flooding to transmission network) | 2<br>Medium impact (possible flooding of access roads) | **2** |
| | Coastal erosion | 3<br>Significant impact on the integrity of the infrastructure | 2<br>Potential erosion of access roads in coastal environments. | **3** |
| Oceanic | Sea water temperature | 0<br>no impact | 0<br>no impact | **0** |
| | Ocean acidity | 0<br>No impact | 0<br>No impact | **0** |
| | Ocean oxygen level | 0<br>No impact | 0<br>No impact | **0** |
| | Ocean salinity | 0<br>No impact | 0<br>No impact | **0** |
| Other water | Fresh water temperature | 0 | 0 | **0** |

| **Hazard category** | **Climate Hazards** | **Interdependencies for water and wastewater aspects** | | **Global score** |
|---|---|---|---|---|
| | | **Power supply** | **Access roads** | |
| | | no impact | no impact | |
| | Fresh water quality | 0<br>no impact | 0<br>no impact | **0** |
| Land, soil and geotechnical | Soil erosion | 0<br>no impact | 0<br>no impact | **0** |
| | Saline intrusion | 0<br>no impact | 0<br>no impact | **0** |
| | Soil salinity | 0<br>no impact | 0<br>no impact | **0** |
| | Ground Instability / landslides | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on road networks. | **3** |
| | Dust storms | 0<br>no impact | 1<br>Impact on visibility | **1** |

*Indicative adaptation measures*

The adaptation measures listed below should not be seen as an exhaustive catalogue.

| **Climate hazards** | **Indicative adaptation measures** |
|---|---|
| Droughts<br><br>Water availability | • Consider alternative water sources;<br>• Consider back-up water sources;<br>• Regular monitoring of quantity and quality of raw water;<br>• Regular monitoring of the debits the surface water sources;<br>• Maintenance at optimal operation status of the abstraction with high capacities;<br>• Improving the treatment processes at the DWTP to cope with the variations and deterioration of raw water quality parameters;<br>• Reducing water losses on the networks (either through rehabilitation of networks/main trunks or through hydraulic optimization);<br>• Construction of an adequate DWTP and the provision of adequate storage capacities to cope with raw water quality variations (especially turbidity);<br>• Introducing new water supply boreholes at greater depths, where the hydrogeological conditions allows it; |

<table>
<tr><th>Climate hazards</th><th>Indicative adaptation measures</th></tr>
<tr><td></td><td><ul><li>The use of alternative sources for non-domestic consumption of non-potable water (e.g. small/medium depth boreholes);</li><li>Water metering of all categories of consumers;</li><li>The introduction of restrictions on the use of water for purposes other than drinking in periods with low flows of water supply sources;</li><li>Awareness campaigns regarding saving water for the final consumer.</li></ul></td></tr>
<tr><td>Temperatures increase/ temperature variations</td><td><ul><li>Ensure that the proposed project is protected from heat exhaustion (e.g. through shading);</li><li>Encourage design optimal for environmental performance and shading;</li><li>Reduce thermal storage in a proposed project (e.g. by using different materials and colouring);</li></ul></td></tr>
<tr><td>Extreme precipitations</td><td rowspan="2"><ul><li>Maintaining access roads in optimal condition;</li><li>The use of mobile electricity generators in case of breakdowns of electricity supply networks;</li><li>Designing the components of the water supply systems to withstand extreme rainfall;</li><li>Construction standards should ensure inbuilt resilience by default;</li><li>Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, anchoring of pipelines, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.).</li></ul></td></tr>
<tr><td>Storms</td></tr>
<tr><td>Winds</td><td><ul><li>Construction standards should ensure inbuilt resilience by default;</li></ul></td></tr>
<tr><td>Land instability/landslides/soil erosion</td><td><ul><li>Regular monitoring of the state of the infrastructure; Identification and marking of risk areas (identification of warning signs on the ground: changes in the landscape - water eddies on slopes, earth movements, leaning trees, cracks in the foundations of buildings, cracking of pipes, tilting of fences, etc.);</li><li>Reducing water losses on the networks (either through rehabilitation of networks/main trunks or through hydraulic optimization);</li><li>The planting of vegetation that favours the land stability in the vicinity of the locations at risk (e.g. by quickly establishing vegetation — hydroseeding, turfing, trees). Can include Nature-based Solutions and catchment management;</li></ul></td></tr>
</table>

| Climate hazards | Indicative adaptation measures |
|---|---|
| | • The use of mobile electricity generators in case of breakdowns of electricity supply networks;<br>• Maintaining access roads in optimal condition;<br>• Put in place designs that control erosion (e.g. appropriate drainage channels and culverts); |
| Floods | • Installation of the main components of the water supply system (e.g. catchments, DWTP) in areas not prone to floods;<br>• Regular monitoring of nearby rivers that may flood a DWTP;<br>• Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, anchoring of pipelines, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.);<br>• Flood resilient design of facilities, to withstand flood risk;<br>• Improve the project's drainage. Potentially through Sustainable Drainage Systems as a Nature-based Solution;<br>• Incorporate flood risk management measures and infrastructure into the project; |
| Wild fires | • Installation of the main components of the water supply system (e.g. catchments, DWTP) in areas less prone to wild fires;<br>• Provision of an adequate fire extinguishing system within the DWTP located in the vicinity of a forest area.<br>• Use fire-resistant construction materials;<br>• Create a fire-adapted space around the project (e.g. use fire-resistant plants); |
| Sea level rise | • Consider changes in construction design to be resilient to rising sea levels;<br>• Incorporate coastal flood and erosion protection measures and infrastructure into the project; |
| Cold spells and snow | • Ensure that the project is protected from cold spells and snow (e.g. deeper pipework); |
| Cold wave/frost | • Ensure that the project (e.g. key infrastructure) is able to prevent moisture from entering the structure (e.g. by using different materials or engineering practices). |

## ***Wastewater infrastructure***

### *Sector sensitivities*

Sensitivity of wastewater components based on the thresholds already presented in the water section:

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| Heat and cold | Annual / seasonal / monthly average (air) temperature | 1<br>Possible increase in concentration of pollutants in effluent | 0<br>No impact | 2<br>Impact on processes involved | 1<br>Impact on natural processes may alter effectiveness of tertiary treatment | 0<br>No impact | 1<br>Possible effect of land quality change on baseline which may result in air quality from sludge spreading exceeding tolerable thresholds | 1<br>Possible effect on soil and growing conditions and demand for irrigation water | **2** |
| | Extreme temperature occurrences (including heat waves) | 2<br>Possible decrease in wastewater flow which could increase concentration of pollutants | 2<br>Possible of difficult conditions from potential for clogged pipes and accumulation of gases resulting | 2<br>Possible increase in the concentration of pollutants on the influence with effect on the treatment process | 2<br>Decreases the efficiency of the treatment process | 2<br>Possible change to hydrological regime and temperature of water body | 1<br>Possible effect of soil temperature and conditions which could alter the available window for | 0<br>Possible increase in seasonal demand for irrigation (not likely to have a negative impact on | **2** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| | | | from fermentation | | | | sludge spreading | the project itself) | |
| | Cold spells | 0<br>No impact | 0<br>No impact | 2<br>Decreased purification efficiency due to the decrease of the influence temperature below the allowable limit | 1<br>Impact on functioning of wetland | 2<br>Possible change to hydrological regime and temperature of water body. | 1<br>Possible effect of soil temperature and conditions which could alter the available window for sludge spreading. | 2<br>Possible reduction in irrigation demand affecting storage capacity | **2** |
| | Freeze-thaw damage | 1<br>Potential increase in discharged flow from snow melt | 1<br>Minor damage to concrete structures (underground infrastructure less vulnerable to temperature variations) | 2<br>Damage to concrete structures and electricity supply (above ground infrastructure more vulnerable to temperature variations) | 0<br>No impact | 0<br>No impact | 1<br>Possible effect of soil temperature and conditions which could alter the available window for sludge spreading. | 0<br>No impact | **2** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| Wind | Average wind speed | 0<br>No impact | 0<br>No impact | 1<br>Possible secondary effect on air quality and odour through changes in wind speed and direction. | 0<br>No impact | 0<br>No impact | 1<br>Possible secondary effect on air quality and odour through changes in wind speed and direction. | 0<br>No impact | **1** |
| | Maximum wind speed / Storms (tracks and intensity) | 0<br>No impact | 0<br>No impact | 1<br>Possible damage to structures | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | **1** |
| Other air and atmospheric | Air quality | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 2<br>Possible effect of air quality change on baseline which may result in air quality from sludge spreading exceeding tolerable thresholds. | 0<br>No impact | **2** |
| Wet and dry | Annual / seasonal / monthly | 1<br>Possible change in the | 1<br>Possible change in the total | 1<br>Possible change to volume of | 2<br>Possible secondary | 2<br>Possible secondary | 2<br>Possible effect of soil | 2<br>Change in demand for | **2** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| | average rainfall | concentration of pollutants and total volume of discharge | volume of discharge in relation to pipe network capacity and frequency of combined sewer flows. | discharge and concentration of pollutants for treatment | effect on hydrological regime and treatment process. | effect on flow regime and assimilative capacity for sufficient dilution. | moisture and the number of wet days which could alter the available window for sludge spreading. | irrigation water and available storage capacity. | |
| | Extreme rainfall (frequency and magnitude) | 3<br>Increase in flow which could exceed inlet capacity to sewer networks | 3<br>Exceeding network capacity, urban flooding, uncontrolled discharges, bypass of treatment, and combined sewer discharge | 3<br>Difficult / impossible conditions for water resources management | 3<br>Severe impact on performance | 3<br>Erosion or scour of riverbanks at discharge outlets could alter local dilution of discharge. | 2<br>Possible effect of soil moisture and the number of wet days which could alter the available window for sludge spreading. | 2<br>Reduced demand for irrigation water and available storage capacity. | **3** |
| | River flooding | 3<br>Increase in flow which could exceed inlet capacity to sewer networks | 3<br>Exceeding network capacity, urban flooding, uncontrolled discharges, bypass of treatment, and | 3<br>Decreases the efficiency of the treatment process (influential dilution), by-pass, uncontrolled discharges | 2<br>Potential exceedance of water inputs into the wetland system that reduces tertiary | 3<br>Erosion or scour of riverbanks at discharge outlets could alter local dilution of discharge. | 3<br>Flooded land may be unavailable for spreading of sewage sludge. | 2<br>Reduced demand for irrigation water and available storage capacity. | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| | | | combined sewer discharge | | treatment capacity. | | | | |
| | Aridity | 2<br>Possible decrease in wastewater flow which could increase concentration of pollutants | 0<br>No impact | 0<br>No impact | 2<br>Possible effect on hydrological regime which could alter the effectiveness of the treatment process. | 1<br>Dry riverbanks may be more susceptible to erosion and increase turbidity of receiving water body | 2<br>Possible effect of soil moisture and the number of wet days which could alter the available window for sludge spreading. | 0<br>Increased demand for irrigation water (not likely to have a negative impact on the project itself) | **2** |
| | Drought / Water availability | 2<br>Possible decrease in wastewater flow which could increase concentration of pollutants | 0<br>No impact on the network itself | 0<br>No impact on the treatment plant itself or treatment process | 2<br>Possible effect on hydrological regime which could alter the effectiveness of the treatment process. | 3<br>Insufficient flow for dilution of discharged water. | 2<br>Possible effect of soil moisture and the number of wet days which could alter the available window for sludge spreading. | 0<br>Increased demand for irrigation water (not likely to have a negative impact on the project itself) | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| | Wildfire | 0<br>No impact | 0<br>No impact | 3<br>Infrastructure damage, danger of explosion | 0<br>No impact | 0<br>No impact | 2<br>Possible effect on soil conditions and suitability for sludge spreading. | 0<br>Increased demand for water (not likely to have a negative impact on the project itself) | **3** |
| Snow and ice | Avalanche | 2<br>Potential significant input to hydrological regime and concentration of pollutants | 3<br>Avalanche could significantly damage pumping stations | 3<br>Avalanche could significantly damage water treatment plants and impact on treatment processes | 2<br>Potential damage to wetland | 1<br>Possible effect of avalanche on river flow | 0<br>No impact | 0<br>No impact | **3** |
| | Melting permafrost | 3<br>Potential change to hydrological regime and concentration of pollutants | 3<br>Potential for changes to ground stability | 3<br>Potential for changes to ground stability | 0<br>No impact. Constructed wetlands would unlikely be constructed in permafrost soils. | 3<br>Potential change to hydrological regime and assimilative capacity of receiving water body | 0<br>No impact as permafrost soil is unsuitable for spreading of sewage sludge. | 0<br>No impact as permafrost soil is unsuitable for irrigation. | **3** |
| | Ice flows in rivers | 2<br>Potential change to | 0<br>No impact | 0<br>No impact | 2<br>Potential damage from | 3<br>Potential change to | 0<br>No impact | 0<br>No impact | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw effluent | Sewerage networks (new and existing) including pumping stations | Wastewater treatment plants and treatment processes (inc. filtration and disinfection) | Constructed wetland | Receiving river water body | Land used for spreading of sewage sludge | Reuse of treated water for irrigation and irrigation channels | |
| | | hydrological regime and concentration of pollutants | | | ice flows or rapid thaw to wetlands. | hydrological regime and assimilative capacity of receiving water body | | | |
| Coastal | Sea level rise | 3 Potential incursion of sea water during high tides. | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact – increase of water levels | 3 Could significantly alter land available for sewage sludge spreading | 3 Could significantly alter land available for irrigation and demand for irrigation | **3** |
| | Coastal flooding | 3 Increase in flow which could exceed inlet capacity to sewer networks | 3 Exceeding network capacity, uncontrolled discharges, bypass of treatment, and combined sewer discharge | 3 Decreases the efficiency of the treatment process (influential dilution), by-pass, uncontrolled discharges | 2 Potential exceedance of water inputs into the wetland system that reduces tertiary treatment capacity. | 3 Erosion or scour of riverbanks at discharge outlets could alter local dilution of discharge. | 3 Flooded land may be unavailable for spreading of sewage sludge. | 2 Change in demand for irrigation water and available storage capacity. | **3** |

| Hazard Category | Climate Hazards | Inputs | Assets and Processes | | | Outputs | | | Global score |
|---|---|---|---|---|---|---|---|---|---|
| | | **Raw effluent** | **Sewerage networks (new and existing) including pumping stations** | **Wastewater treatment plants and treatment processes (inc. filtration and disinfection)** | **Constructed wetland** | **Receiving river water body** | **Land used for spreading of sewage sludge** | **Reuse of treated water for irrigation and irrigation channels** | |
| | Coastal erosion | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | 3 Significant change in water body | 3 Loss of land suitable for sludge spreading. | 2 Change in demand for irrigation water and available storage capacity. | **3** |
| Oceanic | Sea water temperature | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | **0** |
| | Ocean acidity | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | **0** |
| | Ocean oxygen level | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | **0** |
| | Ocean salinity | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | 0 No impact | **0** |
| Other water | Fresh water temperature | 2 Increase in pollution concentration | 2 Difficult operating conditions due to low flow rates, accumulation of gases resulting from fermentation | 2 Possible increase of the pollutant concentration on the influence with effect on the treatment process | 2 Changing the quality of water sources, complicating the treatment process | 2 Possible variation in temperature of water body which could reduce assimilative capacity. | 1 Possible effect on soil conditions and suitability for sludge spreading. | 2 Water quality does not meet minimum standards for irrigation reuse | **2** |

| **Hazard Category** | **Climate Hazards** | **Inputs** | **Assets and Processes** | | | **Outputs** | | | **Global score** |
|---|---|---|---|---|---|---|---|---|---|
| | | **Raw effluent** | **Sewerage networks (new and existing) including pumping stations** | **Wastewater treatment plants and treatment processes (inc. filtration and disinfection)** | **Constructed wetland** | **Receiving river water body** | **Land used for spreading of sewage sludge** | **Reuse of treated water for irrigation and irrigation channels** | |
| | Fresh water quality | 2 Increase in pollution concentration | 2 Difficult operating conditions due to low flow rates, accumulation of gases resulting from fermentation | 2 Possible increase of the pollutant concentration on the influence with effect on the treatment process | 2 Changing the quality of water sources, complicating the treatment process | 3 Impact on assimilative capacity of receiving water body | 1 Possible effect on soil conditions and suitability for sludge spreading. | 3 Water quality does not meet minimum standards for irrigation reuse | **3** |
| Land, soil and geotechnical | Soil erosion | 0 No impact | 0 No impact | 0 No impact | 1 Could result in effect on the wetland structure | 2 Possible change is morphology and sediment regime of water body which could reduce assimilative capacity. | 2 Possible effect on soil conditions and suitability for sludge spreading. | 2 Change in demand for irrigation water. | **2** |
| | Saline intrusion | 2 Increase in salinity of effluent that requires treatment | 1 Possible network erosion | 1 Possible impairment of the treatment process. | 2 Decrease in quality of water sources, Difficult / impossible conditions for managing the | 2 Decrease in quality of water, and reduction in assimilative capacity of | 2 Possible effect on soil conditions and suitability for sludge spreading. | 2 Change in demand for irrigation water. | **2** |

| **Hazard Category** | **Climate Hazards** | **Inputs** | **Assets and Processes** | | | **Outputs** | | | **Global score** |
|---|---|---|---|---|---|---|---|---|---|
| | | **Raw effluent** | **Sewerage networks (new and existing) including pumping stations** | **Wastewater treatment plants and treatment processes (inc. filtration and disinfection)** | **Constructed wetland** | **Receiving river water body** | **Land used for spreading of sewage sludge** | **Reuse of treated water for irrigation and irrigation channels** | |
| | | | | | treatment process | receiving water body. | | | |
| | Ground Instability / landslides | 2<br>Potential change in pollutant concentration | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Natural functions within the wetland can adapt to ground instability, but landslide could fill the wetland. | 3<br>Significant impact – could cause morphological change to the water body | 3<br>Could significantly alter land available for sewage sludge spreading | 2<br>Change in demand for irrigation water. | **3** |
| | Dust storms | 1<br>Possible slight change in concentration of dust particles within effluent | 0<br>No impact | 1<br>Difficult operating conditions, minor sand deposits on the technological line | 0<br>No impact | 1<br>Could reduce water quality | 0<br>No impact | 2<br>Change in demand for irrigation water. | **2** |

Regarding the interdependencies, please see the relevant table presented under drinking water component.

*Indicative adaptation measures*

The adaptation measures listed below should not be seen as an exhaustive catalogue.

| Climate hazards | Indicative adaptation measures |
|---|---|
| Droughts | • Consider if alternative discharge points need to be considered for example reduced river or groundwater levels could alter discharge requirements (e.g. need for greater wastewater treatment due to reduced flow in receiving water bodies). |
| Temperatures increase/ temperature variations | • Ensure that the proposed project is protected from heat exhaustion (e.g. through shading);<br>• Encourage design optimal for environmental performance and shading;<br>• Reduce thermal storage in a proposed project (e.g. by using different materials and colouring); |
| Extreme precipitations<br>Storms | • Rehabilitation/replacement of existing sewerage networks to ensure adequate flow capacity of the pipes during extreme precipitation event, especially in areas that have already experienced problems;<br>• The provision of new pumping stations that can ensure the transport capacity of the sewage systems;<br>• The provision of retention basins to temporarily store water volumes during rainfall, to be returned later to the sewerage network;<br>• Building retention tanks at the WWTP to store the stormwater until it could be treated at the WWTP;<br>• Implementation of pilot projects for the collection of rainwater and its reuse for non-pure purposes (e.g. irrigation, fire reserve, etc.);<br>• Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, anchoring of pipelines, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.);<br>• Construction standards should ensure inbuilt resilience by default; |
| Winds | • Construction standards should ensure inbuilt resilience by default; |
| Floods | • Installation of the main components of the WWTP in area not prone to floods;<br>• Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, |

| Climate hazards | Indicative adaptation measures |
| --- | --- |
| | anchoring of pipelines, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.);<br>• Flood resilient design of facilities, to withstand flood risk;<br>• Improve the project's drainage. Potentially through Sustainable Drainage Systems as a Nature-based Solution;<br>• Incorporate flood risk management measures and infrastructure into the project; |
| Wildfire | • Installation of the main components of WWTP/ pumping stations in areas less prone to wild fires;<br>• Provision of an adequate fire extinguishing system within the WWTP/pumping stations located in the vicinity of a forest area;<br>• Use fire-resistant construction materials;<br>• Create a fire-adapted space around the project (e.g. use fire-resistant plants); |
| Land instability/landslides/soil erosion | • Regular monitoring of the state of the infrastructure; Identification and marking of risk areas (identification of warning signs on the ground: changes in the landscape - water eddies on slopes, earth movements, leaning trees, cracks in the foundations of buildings, cracking of pipes, tilting of fences, etc.);<br>• Reducing water losses on the networks (either through rehabilitation of networks/main trunks or through hydraulic optimization);<br>• The planting of vegetation that favours the land stability in the vicinity of the locations at risk (e.g. by quickly establishing vegetation — hydroseeding, turfing, trees). Can include Nature-based Solutions and catchment management;<br>• The use of mobile electricity generators in case of breakdowns of electricity supply networks;<br>• Maintaining access roads in optimal condition;<br>• Put in place designs that control erosion (e.g. appropriate drainage channels and culverts); |
| Sea level rise | • Consider changes in construction design to be resilient to rising sea levels;<br>• Incorporate coastal flood and erosion protection measures and infrastructure into the project; |
| Cold spells and snow | • Ensure that the project is protected from cold spells and snow (e.g. deeper pipework). |

| Climate hazards | Indicative adaptation measures |
|---|---|
| Cold wave/frost | • Ensure that the project (e.g. key infrastructure) is able to prevent moisture from entering the structure (e.g. by using different materials or engineering practices). |

### *Annex 2.1.6 Flood protection and disaster risk management infrastructure*

JASPERS has developed a detailed Guidance Note on climate proofing in flood and disaster risk management project development. The Guidance Note covers all steps of climate proofing both for climate neutrality and climate resilience. It is also accompanied by a climate proofing document for an example flood protection project.

The sections below provide an overview of the sector sensitivities and potential adaptation measures based on the JASPERS Guidance Note.

*Sector sensitivities*

Thresholds applied:

**High sensitivity (score 3)**

- the climate hazard may have a significant impact on assets and processes, inputs, outputs and transport links.
- as a result of climate hazard occurring there is a potential for instanteneous failure or exceedance of the flood risk management system which reuslts in the exceedence of design levels or capacity, breach of flood defences or can no longer perform to the required standard.

**Medium sensitivity (score 2)**

- the climate hazard may have a slight impact on assets and processes, inputs, outputs and transport links.
- as a result of climate hazard occurring there is a potential for gradual degredation of the flood risk management system which reuslts in the exceedence of design levels, breach of flood defences or can no longer perform to the required standard.

**Low sensitivity (score 1)**

- the climate hazard has no (or insignificant) impact.
- as a result of climate hazard occurring there is no (or very low) potential of failure or degredation of the flood risk management system which reuslts in the exceedence of design levels, breach of flood defences or can no longer perform to the required standard.

**No sensitivity (score 0)**

- no possible impact of the climate hazard on any of the project components.
- no impact on the ability to manage the infrastructure - business as usual.

Sensitivity of flood protection measures based on the above thresholds:

| Hazard Category | Climate Hazards | Assets | | | | |
|---|---|---|---|---|---|---|
| | | **Raised flood defences (levees and walls)** | **Changes to bridge structures** | **Pumping stations for surface water drainage** | **Flood storage areas and associated structures and features** | **Altered river channel form** |
| Heat and cold | Annual / seasonal / monthly average (air) temperature | 0<br>No impact | 0<br>No impact | 1<br>Slight impact on pump efficiency | 2<br>Potential for change in supporting conditions for wetland system. | 0<br>No impact |
| | Extreme temperature occurrences (including heat waves) | 1<br>Unlikely impact on raised flood defence structures, however depending upon the design and materials could be sensitive to cracking (e.g. clay embankments) | 1<br>Unlikely impact on bridge structures | 2<br>Possible overheating of pumps. | 2<br>Potential for change in supporting conditions for wetland system.<br>Unlikely impact on flood defence structures, however depending upon the design and materials could be sensitive to cracking of structures. | 0<br>No impact |
| | Cold spells | 1<br>Unlikely impact on defence structures | 1<br>Unlikely impact on bridge structures | 2<br>Prolonged freezing of the system – possible impact on functionality | 2<br>Prolonged freezing of the system – possible impact on functionality of moveable structures | 0<br>No impact |
| | Freeze-thaw damage | 1<br>Minor damage to concrete structures and earth embankments | 1<br>Minor damage to bridge structures | 2<br>Damage to concrete structures and electricity supply (above ground infrastructure more vulnerable to temperature variations) | 2<br>Damage to concrete structures and electricity supply (above ground infrastructure more vulnerable to temperature variations).<br>No damage to wetland. | 1<br>Minor damage to any concrete structures and culverts |
| Wind | Average wind speed | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact |

| Hazard Category | Climate Hazards | Assets | | | | |
|---|---|---|---|---|---|---|
| | | **Raised flood defences (levees and walls)** | **Changes to bridge structures** | **Pumping stations for surface water drainage** | **Flood storage areas and associated structures and features** | **Altered river channel form** |
| | Maximum wind speed / Storms (tracks and intensity) | 3<br>Significant impact if any trees on embankments fall and damage embankments or walls, which could result in a breach or failure.<br>Flood defence walls are constructed to withstand wind speeds and so no impact directly. | 0<br>No impact | 2<br>Possible damage to buildings. | 2<br>Possible damage to buildings. | 0<br>No impact |
| Other air and atmospheric | Air quality | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact |
| Wet and dry | Annual / seasonal / monthly average rainfall | 0<br>No impact (see aridity for effect of drier soils) | 0<br>No impact | 2<br>Possible impact on antecedent conditions prior to storm events. | 2<br>Possible impact on available storage capacity from wetter or drier conditions, especially if successive storms become more frequent. | 2<br>Possible impact on channel morphology and sediment regime may occur in response to change in rainfall patterns |
| | Extreme rainfall (frequency and magnitude) | 2<br>Possible impact with potential scour of raised embankments and walls. | 1<br>Potential flooding of road deck or effect on road drainage system | 3<br>Significant impact with potential exceedance of design capacity | 2<br>Potential for change in supporting conditions for wetland system. | 2<br>Potential for change in channel form and sediment deposition/erosion. |
| | River and groundwater flooding | 3<br>Exceedance of design conditions could result in failure or breach. | 3<br>Exceedance of design conditions could result in structural damage or collapse. | 3<br>Exceedance of pump capacity could result in overtopping of collection networks and hazardous flooding. | 3<br>Exceedance of design conditions could result in structural damage or collapse. | 3<br>Exceedance of design conditions could result in changes to channel form. |

| Hazard Category | Climate Hazards | Assets | | | | |
|---|---|---|---|---|---|---|
| | | Raised flood defences (levees and walls) | Changes to bridge structures | Pumping stations for surface water drainage | Flood storage areas and associated structures and features | Altered river channel form |
| | Aridity | 1<br>Possible effect on earth embankments from change in soil moisture. | 0<br>No impact | 0<br>No impact | 2<br>Potential effect on supporting conditions for wetland. | 2<br>Potential drying of river banks which could affect bank stability. |
| | Drought / Water availability | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact |
| | Wildfire | 3<br>Significant impact - fire can destroy the structure | 0<br>No impact | 3<br>Significant impact - fire can destroy the structure | 3<br>Significant impact - fire can destroy any operational structures | 2<br>Possible loss of riparian vegetation which could destabilise any earth banks. |
| Snow and ice | Avalanche | 3<br>Failure of the defence structures | 3<br>Blockage of bridge structures | 3<br>Significant impact – complete failure of stations and networks | 3<br>Damage to structures. Blockage of the structures, preventing the waters to enter/exit the storage | 2<br>Avalanche could increase upstream sediment supply which could alter channel form. |
| | Melting permafrost | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact could result in changes to channel form. |
| | Ice flows in rivers | 3<br>Potential damage to raised defence infrastructure. | 3<br>Potential blockage and damage to bridge structures | 0<br>No impact as ice flows are not likely in surface water drainage networks. | 3<br>Potential blockage and damage to inlet or outlet structures | 2<br>Potential change to channel from erosion of banks. |
| Coastal | Sea level rise | 2<br>Potential for gradual change in downstream water levels. Which may | 2<br>Potential for gradual change in downstream water levels. Which | 2<br>Potential for gradual change in downstream water levels. Which may | 2<br>Potential for gradual change in downstream water levels. Which may reduce flood | 2<br>Potential for gradual change in downstream water levels. Which |

| **Hazard Category** | **Climate Hazards** | **Assets** | | | | |
|---|---|---|---|---|---|---|
| | | **Raised flood defences (levees and walls)** | **Changes to bridge structures** | **Pumping stations for surface water drainage** | **Flood storage areas and associated structures and features** | **Altered river channel form** |
| | | reduce flood defence standard of protection. | may reduce flood defence standard of protection. | require adjustments to pumping regime and invert levels. | defence standard of protection. | may reduce flood defence standard of protection. |
| | Flood (coastal) | 3<br>Exceedance of design conditions could result in failure or breach. | 3<br>Exceedance of design conditions could result in structural damage or collapse. | 3<br>Exceedance of pump capacity could result in overtopping of collection networks and hazardous flooding. | 3<br>Exceedance of design conditions could result in structural damage or collapse. | 3<br>Exceedance of design conditions could result in changes to channel form. |
| | Coastal erosion | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure |
| Oceanic | Sea water temperature<br>Ocean acidity<br>Ocean oxygen level<br>Ocean salinity | 0<br>No pathway from coastal change to fluvial flood infrastructure | 0<br>No pathway from coastal change to fluvial flood infrastructure | 0<br>No pathway from coastal change to fluvial flood infrastructure | 0<br>No pathway from coastal change to fluvial flood infrastructure | 0<br>No pathway from coastal change to fluvial flood infrastructure |
| Other water | Fresh water temperature | 1<br>Unlikely impact on raised flood defence structures, however depending upon the design and materials could be sensitive to cracking (e.g. clay embankments) | 1<br>Unlikely impact on bridge structures | 2<br>Possible overheating/ freezing of pumps. | 2<br>Potential for change in supporting conditions for wetland system. | 0<br>No impact |
| | Fresh water quality | 0<br>No impact | 0<br>No impact | 0<br>No impact | 2<br>Possible change in wetland ecosystem conditions | 2<br>Possible effect from changes to water |

| Hazard Category | Climate Hazards | Assets | | | | |
|---|---|---|---|---|---|---|
| | | Raised flood defences (levees and walls) | Changes to bridge structures | Pumping stations for surface water drainage | Flood storage areas and associated structures and features | Altered river channel form |
| | | | | | | quality such as eutrophication or riparian vegetation. |
| Land, soil and geotechnical | Soil erosion | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 2<br>Potential reduction in channel capacity because of increased sediment input to river system. |
| | Saline intrusion | 0<br>No impact | 0<br>No impact | 0<br>No impact | 2<br>Possible change in supporting conditions for wetland ecosystem. | 0<br>No impact |
| | Ground Instability / landslides | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact could result in changes to channel form. |
| | Dust storms | 0<br>No impact | 0<br>No impact | 2<br>Possible impact - Blockage of the pumps, affecting system functionality. Impact on electrical components. | 2<br>Possible impact - Impact on electrical components. | 0<br>No impact |

Sensitivity assessment for the flood risk management project processes and interdependencies and Global Score based on the above thresholds:

| Hazard Category | Climate Hazards | Processes | | Interdependencies | | | Global score |
|---|---|---|---|---|---|---|---|
| | | Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure. | Maintenance of structures and channels including vegetation and sediment management. | Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A. | Power supply to all components. | Access roads for key facilities for maintenance and operations. | |
| Heat and cold | Annual / seasonal / monthly average (air) temperature | 0 No impact | 0 No impact | 0 No impact | 2 Medium impact if metal used for wiring is sensitive | 0 No impact | **2** |
| | Extreme temperature occurrences (including heat waves) | 0 No impact | 0 No impact | 0 No impact | 0 no impact | 0 no impact | **2** |
| | Cold spells | 0 No impact | 0 No impact | 0 No impact | 2 Potential to increase demand for electricity. | 1 Possible difficult operating conditions due to icy road conditions | **2** |
| | Freeze-thaw damage | 2 Potential damage to monitoring network gauges. | 1 Potential slight increase sediment sources that could be mobilised and increase the frequency of repeat sediment removal in dredged reaches of watercourses. | 0 No impact | 0 no impact | 0 no impact | **2** |
| Wind | Average wind speed | 0 No impact | 0 No impact | 0 No impact | 0 Average wind speeds will not have any | 0 No impact from average wind speeds. | **0** |

| Hazard Category | Climate Hazards | Processes | | Interdependencies | | | Global score |
|---|---|---|---|---|---|---|---|
| | | Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure. | Maintenance of structures and channels including vegetation and sediment management. | Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A. | Power supply to all components. | Access roads for key facilities for maintenance and operations. | |
| | | | | | impact on transmission network. | | |
| | Maximum wind speed / Storms (tracks and intensity) | 0<br>No impact | 0<br>No impact | 0<br>No impact | 2<br>Possible impact from high winds on overground power distribution networks to structures | 2<br>Some access routes may be temporarily cut off during and after storms. | **3** |
| Other air and atmospheric | Air quality | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | 0<br>No impact | **0** |
| Wet and dry | Annual / seasonal / monthly average rainfall | 0<br>No impact | 2<br>Change in rainfall patterns could alter mobilisation of sediment sources in the upper and lowland catchments and alter low-flow regime which could affect sediment regime. | 2<br>Change in rainfall patterns could alter mobilisation of sediment sources in the upper and lowland catchments and alter low-flow regime which could affect sediment regime. | 0<br>No impact | 1<br>Slight impact on road drainage may occur | **2** |
| | Extreme rainfall (frequency and magnitude) | 0<br>No impact | 3<br>Intense rainfall could increase upstream sediment supply which could necessitate more frequency repeat dredging of sediment. | 2<br>Intense rainfall could increase upstream sediment supply, transport and flow regime which could alter downstream flood risk. | 2<br>Medium impact (possible power outage from flooding to transmission network) | 2<br>Medium impact (possible flooding of access roads) | **3** |

| Hazard Category | Climate Hazards | Processes | | Interdependencies | | | Global score |
|---|---|---|---|---|---|---|---|
| | | Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure. | Maintenance of structures and channels including vegetation and sediment management. | Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A. | Power supply to all components. | Access roads for key facilities for maintenance and operations. | |
| | River and groundwater flooding | 0<br>No impact | 3<br>Mobilisation of in-channel sediments and changes to frequency of flood flows could alter sediment regime resulting in changes to the frequency of repeat sediment removal. | 3<br>Changes to frequency and magnitude of flood flows could alter downstream flood risk. | 2<br>Medium impact (possible power outage from flooding to transmission network) | 2<br>Medium impact (possible flooding of access roads) | **3** |
| | Aridity | 0<br>No impact | 1<br>Potential change in vegetation maintenance procedures in response to drier conditions. | 0<br>no impact | 0<br>No impact | 0<br>No impact | **2** |
| | Drought / Water availability | 0<br>No impact | 0<br>no impact | 0<br>no impact | 0<br>no impact | 0<br>no impact | **0** |
| | Wildfire | 3<br>Potential destruction of monitoring network gauges. | 0<br>no impact | 0<br>no impact | 3<br>Infrastructure damage | 2<br>Access routes may be cut off for the duration of a wildfire. | **3** |

| Hazard Category | Climate Hazards | Processes | | Interdependencies | | | Global score |
|---|---|---|---|---|---|---|---|
| | | Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure. | Maintenance of structures and channels including vegetation and sediment management. | Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A. | Power supply to all components. | Access roads for key facilities for maintenance and operations. | |
| Snow and ice | Avalanche | 3<br>Potential destruction of monitoring network gauges. | 2<br>Avalanche could increase upstream sediment supply which could necessitate more frequency repeat dredging of sediment. | 0<br>no impact | 3<br>Avalanche could significantly damage power supply networks | 3<br>Avalanche could cut off access or damage access roads | **3** |
| | Melting permafrost | 2<br>Potential alteration of monitoring network gauge datum. | 3<br>Mobilisation of in-channel sediments and changes to frequency of flood flows could alter sediment regime resulting in changes to the frequency of repeat sediment removal. | 3<br>Cahnge to flow and sediment regime could alter downstream flood risk. | 0<br>no impact | 0<br>no impact | **3** |
| | Ice flows in rivers | 3<br>Potential destruction of monitoring network gauges. | 2<br>Mobilisation of in-channel sediments and changes to frequency of flood flows could alter sediment regime resulting in changes to the frequency of repeat sediment removal. | 3<br>Change to flow and sediment regime could alter downstream flood risk. | 0<br>no impact | 0<br>no impact | **3** |

| **Hazard Category** | **Climate Hazards** | **Processes** | | **Interdependencies** | | | **Global score** |
|---|---|---|---|---|---|---|---|
| | | **Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure.** | **Maintenance of structures and channels including vegetation and sediment management.** | **Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A.** | **Power supply to all components.** | **Access roads for key facilities for maintenance and operations.** | |
| Coastal | Sea level rise | 1 Gradual change to monitoring network gauge datum. | 3 Potential for significant change to maintenance regime. | 3 Potential change in risk from coincident fluvial and coastal flooding. | 3 Significant impact on the integrity of the infrastructure | 3 Significant impact on the integrity of the infrastructure | **3** |
| | Flood (coastal) | 0 No impact | 3 Potential for significant change to maintenance regime. | 3 Potential change in risk from coincident fluvial and coastal flooding. | 2 Medium impact (possible power outage from flooding to transmission network) | 2 Medium impact (possible flooding of access roads) | **3** |
| | Coastal erosion | 3 Potential destruction of monitoring network gauges. | 3 Potential for significant change to maintenance regime. | 3 Potential change in risk from coincident fluvial and coastal flooding. | 3 Significant impact on the integrity of the infrastructure | 2 Potential erosion of access roads in coastal environments. | **3** |
| Oceanic | Sea water temperature | 0 No impact for terrestrial monitoring network | 0 no impact | 0 no impact | 0 no impact | 0 no impact | **0** |
| | Ocean acidity | | | | | | |
| | Ocean oxygen level | | | | | | |
| | Ocean salinity | | | | | | |
| Other water | Fresh water temperature | 2 Gradual change to monitoring network gauge calibration. | 1 Sediment regime not likely to be affected by temperature change, however water quality | 0 no impact | 0 no impact | 0 no impact | **2** |

| **Hazard Category** | **Climate Hazards** | **Processes** | | **Interdependencies** | | | **Global score** |
|---|---|---|---|---|---|---|---|
| | | **Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure.** | **Maintenance of structures and channels including vegetation and sediment management.** | **Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A.** | **Power supply to all components.** | **Access roads for key facilities for maintenance and operations.** | |
| | | | impacts on deposited material could result in concentration of pollutants in sediments. | | | | |
| | Fresh water quality | 1<br>Possible effect on monitoring network gauge calibration. | 1<br>Sediment regime not likely to be affected by temperature change, however water quality impacts on deposited material could result in concentration of pollutants in sediments. | 0<br>no impact | 0<br>no impact | 0<br>no impact | **2** |
| Land, soil and geotechnical | Soil erosion | 1<br>Possible effect on monitoring network gauge calibration. | 3<br>Soil erosion will result in upstream sediment supply which could necessitate more frequency repeat dredging of sediment. | 0<br>no impact | 0<br>no impact | 0<br>no impact | **3** |
| | Saline intrusion | 1<br>Possible effect on monitoring network gauge calibration. | 1<br>Sediment regime not likely to be affected by chemical impacts, however water quality impacts on deposited material could result in concentration of | 0<br>no impact | 0<br>no impact | 0<br>no impact | **1** |

| **Hazard Category** | **Climate Hazards** | **Processes** | | **Interdependencies** | | | **Global score** |
|---|---|---|---|---|---|---|---|
| | | **Flood forecasting and warning systems to mobilise and inform operation of storage area inlet and outlet structure.** | **Maintenance of structures and channels including vegetation and sediment management.** | **Downstream impacts on river flow regime and flood discharge and levels as a result of measures in Town A.** | **Power supply to all components.** | **Access roads for key facilities for maintenance and operations.** | |
| | | | pollutants in sediments. | | | | |
| | Ground Instability / landslides | 2<br>Abrupt change to monitoring network gauge calibration. | 3<br>Potential for mobilisation of sediments that could be deposited in dredged reaches of watercourses. | 0<br>no impact | 3<br>Significant impact on the integrity of the infrastructure | 3<br>Significant impact on road networks. | **3** |
| | Dust storms | 2<br>Potential damage to electrical components. | 2<br>Potential for dust to be mobilised and increase the frequency of repeat sediment removal in dredged reaches of watercourses. | 0<br>no impact | 0<br>no impact | 1<br>Impact on visibility | **2** |

*Indicative adaptation measures*

The adaptation measures listed below should not be seen as an exhaustive catalogue.

| Type of impact | Alternatives | Adaptation measures |
|---|---|---|
| **Heat waves** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk. | Ensure that the proposed project is protected from heat exhaustion.<br>Reduce thermal storage in a proposed project (e.g. by using different materials and colouring). |
| **Droughts** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk. | Ensure that the proposed project is protected from the effects of droughts (e.g. use water-efficient processes and materials that can withstand high temperatures). |
| **Wildfire / fires** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk. | Use fire-resistant construction materials.<br>Create a fire-adapted space around the project (e.g. use fire-resistant plants). |
| **Extreme rainfall, river flooding and flash floods, sea level rise** | Consider less exposed locations for sensitive project components. For example, operational facilities and stores for equipment and machinery can be located outside of flood hazard areas and where safe access can be guaranteed. | Consider changes in construction design that allow for rising water levels and ground water levels (e.g. build on pillars, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.).<br>Improve the project's drainage. Potentially through Sustainable Drainage Systems as a Nature-based Solution. |
| **Storms / high wind** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk.<br>Consider less exposed locations for sensitive project components (e.g. operational facilities, stores for equipment and machinery). | Construction standards should ensure inbuilt resilience by default. |
| **Landslides** | Consider less exposed locations for sensitive project components (e.g. | Protect surfaces and control surface erosion (e.g. by quickly establishing |

| | | |
|---|---|---|
| | operational facilities, stores for equipment and machinery). | vegetation — hydroseeding, turfing, trees). Can include Nature-based Solutions (NbS) and catchment management.<br>Put in place designs that control erosion (e.g. appropriate drainage channels and culverts). |
| **Cold spells and snow** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk. | Ensure that the project is protected from cold spells and snow (e.g. use construction materials that can withstand low temperatures and make sure the design can resist snow build-up). |
| **Freeze-thaw damage** | The location of a flood or disaster risk management project should not change in response to vulnerability to heat waves. The project location is dictated by the flood or disaster risk. | Ensure that the project (e.g. key infrastructure) is able to resist winds and prevent moisture from entering the structure (e.g. by using different materials or engineering practices). |

# Annex 2.2 Climate neutrality case studies – Carbon footprint

## *Annex 2.2.1 Carbon footortprint assessment for a large building*

Presenting a case-study addressing buildings is relevant as buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy-related greenhouse gas emissions. Therefore, buildings are the single largest energy consumer in Europe. At present, about 35% of the EU buildings are over 50 years old and almost 75% of the building stock is energy-inefficient, whilst only about 1% of the building stock is renovated every year.

*Presentation of the case-study*

The *Construction of the Wielkopolska Centre for Child Health (paediatric hospital) and its equipment* – located in *Poznań,* is the case-study illustrating how climate change mitigation methodologies and measures are implemented in a hospital (= large building) in Poland – new construction.

The hospital aims at improving the quality and efficiency of medical services for patients under acute emergency, requiring secondary and tertiary-level interventions. The hospital schedules 849 beds, of which 744 as acute inpatient beds plus 105 as intensive-care beds, and it will replace a total of 1,389 acute beds from four existing hospitals and a university clinic. Below a rendering image.

*The legislative framework*

This section elaborates briefly the main legislative requirements requiring increased energy efficiency and the reduction of energy demand, with consequent reduction of $CO_2$ emission and a contribution to climate change mitigation.

- **Directive 2010/31/EU** of the European Parliament and of The Council dated 19 May 2010, on the energy performance of buildings, represents the main Directive to be complied with, which promotes the improvement of the energy performance of buildings within the EU, taking into account outdoor climatic and local conditions, indoor climate requirements and cost-effectiveness.

The Directive lays down requirements addressing, amongst others, the methodology for calculating the integrated energy performance of buildings and building units, the application of minimum requirements to the energy performance of new/ existing buildings and new building units. The methodology shall reflect energy demand for heating and cooling and an energy performance indicator.

- **Directive 2018/844** of the European Parliament and of The Council dated 30 May 2018 amending Directive 2010/31/EU above. Article 2a Long-term renovation strategy requires that Member State establish a long-term renovation strategy to renovate the national stock of residential and non-residential buildings, both public and private, into a highly energy-efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-emission buildings.

- **Directive 2012/27/EU** of the European Parliament and of The Council of 25 October 2012, on energy efficiency. This Directive establishes a common framework of measures to promote energy efficiency within the Union to achieve the Union's 2020 20% headline target on energy efficiency, and to pave the way for further energy efficiency improvements beyond that date. In particular:

    - ✓ Article 4 and Article 14 elaborate building renovation and the promotion of efficiency in heating and cooling, requiring the Member States to establish a long-term strategy to renovate the national stock of residential and commercial buildings.
    - ✓ Article 7 requires that Member States set up an energy-efficiency obligation scheme, so energy sales companies achieve a cumulative energy target by 2020.

*The methodological framework*

Overall matters

The project underwent a full Environmental Impact Assessment (EIA) procedure, so the resulting EIA Decision covering the project incorporates the climate measures from the Feasibility Study. An option analysis as well considering climate change issues was not executed, even if an EIA procedure was executed. The available option analysis has included general environmental protection requirements, with no specific criteria. Nonetheless, thanks to the measures the EIA Decision requires, the project implements Directive 2010/31/EU on energy performance of buildings.

Which are the Greenhouse gases (GHG)

GHG are generally identified as a family of six gases, each reported together with its global warming potential (GWP) in respect to 1 molecule of $CO_2$. GWP measures how much energy (and heat, consequently) the emission of 1 ton of a gas will absorb over a given period of time, following to the emissions of 1 ton of carbon dioxide ($CO_2$).

| ***Greenhouse gas*** | ***Origin*** | ***Global Warming Potential*** |
|---|---|---|
| Carbon dioxide ($CO_2$) | Produced from burning fossil fuels | 1 |
| Methane ($CH_4$) | Mainly produced in waste management and animal husbandry<br>Extremely small amounts are also produced by burning fossil fuels | 28 |
| Nitrous oxide ($N_2O$) | Mainly produced by fertilisation in agriculture. Extremely small amounts are also produced by burning fossil fuels | 265 |
| Hydrofluorocarbons (HFCs) & Perfluorocarbons (PFCs) | Refrigerants in air conditioners and heat pumps of buildings. They are extremely powerful greenhouse gases | 116-12400 |
| Sulphur hexafluoride (SF6) | Generally it is not related to buildings | 23500 |

**Source:** Learn why EPA's U.S. Inventory of Greenhouse Gas Emissions and Sinks uses a different value

The Carbon Footprint methodology from the European Investment Bank

The EIB reference methodology is Version 11.3 released in January 2023, available at EIB Project Carbon Footprint Methodologies. Key features of the methodology:

- The GHG emissions are divided into:
  - Scope 1: Direct emissions, owned or operated by the economic activity on a direct basis.
  - Scope 2: Indirect emissions, related only to purchase heat and power.
  - Scope 3: All remaining indirect emissions, not included in Scope 1 or Scope 2 emissions - such as traffic generated by people going to/ coming from the hospital to visit patients and to deliver materials.

  The three Scopes allow identifying and calculating relevant emissions, and to identify the so-called "project boundaries" necessary to identify relevant emissions to be reduced.

- The decrease of future emissions is demonstrated through the negative value of the Relative emissions (Re), which is equal to:

Absolute emissions (Ab: emissions under the WITH-project scenario along a standard year of operation) – Baseline emissions (Be: emissions under the WITHOUT-project scenario along a standard year of operation).

Ab & Be = *Fuel energy use * fuel emissions factor*

The Re's positive value (= increase of future emissions) is allowed for projects expanding existing buildings, however in this case, to be approved & funded, the project shall comply with the maximum energy requirement/m$^2$/year, set in national legislation.

Table A1.1 of EIB Methodology (hereinafter) reports the default emission factors from liquid fossil fuels in $CO_2$-equivalent units, relevant to calculate the project's $CO_2$ emissions.

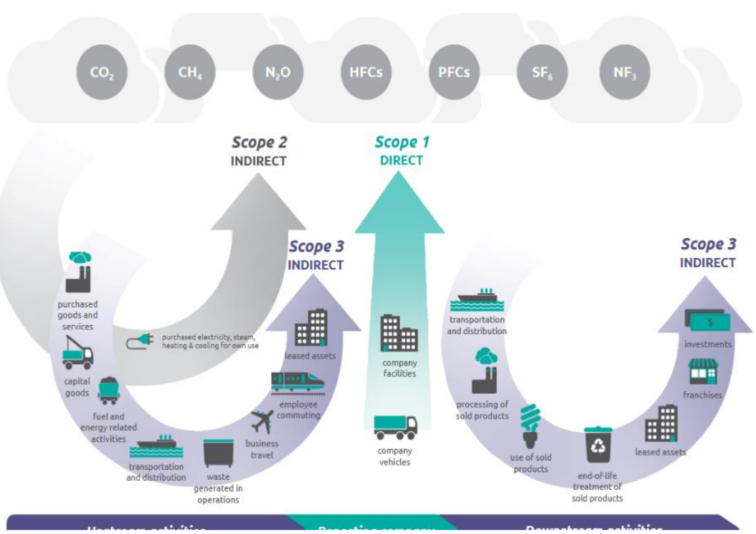
| Fuel name | Amount of fuel | Units | kg $CO_2$ | kg $CH_4$ | kg $N_2O$ | kg $CO_2e$ | kg $CO_2e$ incl. unoxidised carbon |
|---|---|---|---|---|---|---|---|
| Gas/diesel oil | 1 | litres (l) | 2.7 | 0.0 | 0.0 | 2.7 | 2.7 |
| Gas/diesel oil | 1 | TJ | 74 100 | 3.0 | 0.6 | 74 343 | 73 600 |
| Crude oil | 1 | litres (l) | 2.5 | 0.0 | 0.0 | 2.5 | 2.5 |
| Crude oil | 1 | TJ | 73 300 | 3.0 | 0.6 | 73 543 | 72 808 |
| Refinery feedstocks | 1 | metric tonne (t) | 3 152 | 0.1 | 0.0 | 3 155 | 3 123 |
| Refinery feedstocks | 1 | TJ | 73 300 | 3.0 | 0.6 | 73 543 | 72 808 |
| Motor gasoline | 1 | litres (l) | 2.3 | 0.0 | 0.0 | 2.3 | 2.3 |
| Motor gasoline | 1 | TJ | 69 300 | 3.0 | 0.6 | 69 543 | 68 848 |
| Aviation/jet gasoline | 1 | litres (l) | 2.2 | 0.0 | 0.0 | 2.2 | 2.2 |
| Aviation/jet gasoline | 1 | TJ | 700 000 | 3.0 | 0.6 | 700 243 | 693 241 |
| Aviation/jet gasoline | 1 | metric tonne (t) | 3 101 | 0.1 | 0.0 | 3 104 | 3 073 |
| Jet kerosene | 1 | TJ | 71 500 | 3.0 | 0.6 | 71 743 | 71 026 |
| Naphtha | 1 | litres (l) | 2.5 | 0.0 | 0.0 | 2.5 | 2.5 |
| Naphtha | 1 | TJ | 73 300 | 3.0 | 0.6 | 73 543 | 72 808 |
| Shale oil | 1 | litres (l) | 2.8 | 0.0 | 0.0 | 2.8 | 2.8 |
| Shale oil | 1 | TJ | 73 300 | 3.0 | 0.6 | 73 543 | 72 808 |
| Residual fuel oil/HFO | 1 | litres (l) | 2.9 | 0.0 | 0.0 | 2.9 | 2.9 |
| Residual fuel oil/HFO | 1 | TJ | 77 400 | 3.0 | 0.6 | 77 643 | 76 867 |
| Other kerosene | 1 | litres (l) | 2.5 | 0.0 | 0.0 | 2.5 | 2.5 |
| Other kerosene | 1 | TJ | 71 900 | 3.0 | 0.6 | 72 143 | 71 422 |

Emissions from electricity consumed as part of the project, or as part of the Be or Ab, should be calculated based on the country emissions factor, including grid losses of the connecting grid - Table A1.3 of EIB Methodology hereinafter - extract:

| **Emission factors in $gCO_2/kWh$ (The impact of non-$CO_2$ GHGs is negligible. For calculation purposes, the factors below can be considered as $CO_2e$)** | | | | | |
|---|---|---|---|---|---|
| **Country/territory/island** | Combined margin intermittent electricity generation | Combined margin firm electricity generation/ electricity consumption | Electricity consumption/ network losses HV grid +2% | Electricity consumption/ network losses MV grid +4% | Electricity consumption/ network losses LV grid +7% |
| **Afghanistan** | 331 | 193 | 197 | 201 | 207 |
| **Albania** | 0 | 0 | 0 | 0 | 0 |
| **Algeria** | 479 | 397 | 405 | 413 | 425 |

| Emission factors in $gCO_2/kWh$ (The impact of non-$CO_2$ GHGs is negligible. For calculation purposes, the factors below can be considered as $CO_{2}$-e) | | | | | |
|---|---|---|---|---|---|
| **Country/territory/island** | Combined margin intermittent electricity generation | Combined margin firm electricity generation/ electricity consumption | Electricity consumption/ network losses HV grid +2% | Electricity consumption/ network losses MV grid +4% | Electricity consumption/ network losses LV grid +7% |
| **American Samoa (US)** | 664 | 516 | 526 | 536 | 552 |
| **Andorra** | 144 | 70 | 71 | 72 | 75 |
| **Angola** | 1 203 | 748 | 763 | 778 | 800 |
| **Anguilla (UK)** | 647 | 472 | 481 | 490 | 505 |
| **Antigua and Barbuda** | 654 | 489 | 499 | 509 | 524 |
| **Argentina** | 407 | 288 | 294 | 300 | 308 |
| **Armenia** | 321 | 205 | 209 | 213 | 219 |
| **Australia** | 663 | 421 | 429 | 437 | 450 |
| **Austria** | 194 | 113 | 115 | 118 | 121 |
| **Azerbaijan** | 478 | 384 | 392 | 400 | 411 |
| **Azores (Portugal)** | 614 | 384 | 392 | 399 | 411 |
| **Bahamas** | 636 | 441 | 450 | 458 | 472 |
| **Bahrain** | 624 | 454 | 463 | 472 | 486 |
| **Bangladesh** | 484 | 412 | 420 | 428 | 441 |
| **Barbados** | 650 | 484 | 494 | 503 | 518 |
| **Belarus** | 359 | 292 | 297 | 303 | 312 |
| **Belgium** | 204 | 124 | 127 | 129 | 133 |
| ***Poland*** | ***717*** | ***532*** | ***543*** | ***553*** | ***569*** |

The following figure presents in graphical format Scope 1, Scope 2 and Scope 3 emissions, and the list of relevant GHG gases.




Source: [GHG Protocol Figure 1.1 of "Scope 3 Standard"]

Economic and financial considerations

Reducing future CO2 emissions generates economic and financial advantages, with an increasing impact upon the project's operational costs (OPEX) which will be reduced. If not OPEX are expected to rise considerably, following the increase of emitting CO2 into the atmosphere. Therefore, the Cost-benefit Analysis (CBA) reports the GHG emissions associated with the project which are monetised by using a standard shadow price of carbon, which is generally taken from the EIB Carbon footprint methodology. This case-study has used the Methodology's Version 11.3 dated January 2023, available when elaborating the case-study (available at EIB Project Carbon Footprint Methodologies).

The benefits from $CO_2$ emission reduction will apply to the business-as-usual (WITHOUT-project) and the WITH-project scenarios since they have an impact on the reduction of energy consumption, and will therefore reduce the emissions produced. The Economic Appraisal *Vademecum* 2021-2027 General Principles and Sector Application (available at Economic Appraisal *Vademecum* 2021-2027 - General Principles and Sector Applications.pdf (eib.org) elaborates in broader terms how to contextualise the price of each ton of $CO_2$ to be emitted. As an overall principle it is important to appreciate that it is convenient to invest in $CO_2$ reduction technologies, therefore to increase the project's capital costs - so-called CAPEX (paid for its majority by the EC co-financing rate), as this approach will allow reducing strongly the cost of future emissions as part of the project's operational costs - so-called OPEX. It shall be noted In fact that due to the climate mitigation policies the price of each ton of $CO_2$ to be emitted is expected to increase significantly. For instance, to give a general idea of price increase, according to the EIB Climate Bank Roadmap (Figure 4.4) the proposed average price of 1 t of $CO_2$ was 80€ in 2020, to be raised at- 800€ in 2050 – available at (CBR 2025 – Climate Bank Roadmap | Intranet (eib.org)).

*The measures adopted*

As a result of legislation and of the methodological framework elaborated above, the project's Feasibility Study schedules installing a number of climate change mitigation measures, covering energy efficiency and conservation, and the production of hot and cold water. The measures demonstrate that the project's operation, maintenance and eventual decommissioning are compatible with a credible pathway towards the Country's overall 2030 and 2050 GHG emission reduction targets and overall climate neutrality.

Overall and most important, according to the projections made the measures adopted allow keeping energy consumption below the maximum energy consumption (see Calculation of Greenhouse Gas (GHG) emission hereinafter), which is a key and overall project feature. Law dated 07/10/2022 {published in the Official Journal (Dz. U.) 2022, Item 2206} amending the Energy Performance of Buildings Act and the Construction Act constitutes national reference legislation, setting maximum energy consumption thresholds.

This is an important feature, as following the Covid-19 Pandemy many health infrastructures are in the course of being renovated & extended, new ones are under construction, so it may not be always possible to maintain the same surfaces as before the Pandemic.

The Project's integration with the network of public transports

The hospital is connected to the available network of bus lines, which helps preventing and reducing $CO_2$ emissions from private travel. Option 2 was selected for implementation as it is located in the immediate vicinity of Bus line No. 83, further at about 10-minute walking distance there is a tram stop for Line 9 and Line 11, and a cycle path connected to *Poznań's* bicycle network. Such location facilitates accessing the hospital by alternative transport modes, i.e. public transport and cycling. It can be assumed that both those who are customers of the hospital, especially the out-patient care, people visiting hospital's patients, and staff will benefit from the integration.

Technical measures covering climate change mitigation

- Lighting: using LED technologies for indoor and outdoor lighting.

- Heating:
  - ✓ Installing heat-exchanger ventilation units with high efficiency recovery from exhaust air.
  - ✓ Installing ventilation units with inverters to adjust ventilation to the current demand, thus reducing electricity consumption.
  - ✓ Recovering heat from compressors: heat separated during compressors makes possible to pre-heat hot water in order to reduce energy demand. Alternatively, the heat can be recovered with an air compressor station.

- Ventilation systems serving e.g. meeting rooms and teaching rooms: installing $CO_2$ sensors to adjust the air volume to the current demand.

- Operating blocks the extension of the relative humidity allowed to within the range 35-55 % and the 20-27 °C temperature limit is likely to lead to reduce energy consumption and energy costs.

- Heat exchangers to recovery of heat to be used to pre-heat warm water.

- Ice chillers have a free-cooling function.

- Adopting a draft Building Management System (BMS), integrating the cooling and the heating systems to generate comfort within premises. For individual or groups of rooms the BMS will indicate the temperature set and the heating mode in which the space is set (i.e. comfort/ transitional/ economic).

- Smart metering of refrigeration and heat installations to reduce electricity consumption.

- The Feasibility Study has evaluated the potential use of heat pumps, which were not installed as would have been too costly and paid back in an excessive number of years.

Calculation of Greenhouse Gas (GHG) emission

Overall, the building's design leads to a low demand of non-renewable primary energy for heating, ventilation, cooling, hot water and lighting. According to the Feasibility Study, the project is expected to require 256.3 kWh/m$^2$/year, which is below the threshold of 258.6 kWh/m$^2$/year set by the Regulation of the Minister of Infrastructure of 12 April 2002 on the technical conditions to be met by buildings and their location (published in the Journal of Laws of 2015, item 1422), implementing Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

Renewable energy sources (such as installing photo-voltaic panels, installing heat pumps, and accessing supply of green electricity) are expected to contribute to the annual total energy demand by 9.9%, which results from the energy measures briefly elaborated above.

The Ministry for Development and Technology on 15/04/2022 issued its Regulation on the conditions and technical requirements for buildings and their location - published in the Official Journal (Dz. U.) on 09/06/2022, Item 1225. Section X Energy saving and thermal insulation, paragraph 329.1. determines the maximum value of the annual non-renewable primary energy in buildings.

Carbon footprint is applied to quantify the impact of the project on greenhouse gas emissions. The project has made use of the methodology from the European Investment Bank (EIB), which results in an increased GHG footprint, for which this case-study makes the following notes:

- During operation the project is not expected to release Scope 1 direct emissions. The sole potential source of Scope 1 emissions is the use of emergency power generators, which is expected to occur occasionally in case of any power cut.
- The large majority of emissions will be Scope 2 indirect emissions, from purchasing heat and power.
- The Applicant has regarded Scope 3 indirect emissions as practically negligible, so they were not calculated. According to the Applicant's opinion project location in the centre of Poznan will not generate much travel for people and procurement of materials as the new hospital will have one site only, compared to several sites under the WITHOUT-project scenario. So in principle Scope 3 emissions are expected to be reduced. Even if JASPERS does not entirely agree with this stance this case-study remains relevant as it presents the methodology adopted.

To calculate the Baseline emissions (Be) the existing annual electricity and heat consumption (WITHOUT-project scenario) are considered. The Absolute emissions (Ab) are estimated via the expected annual electricity and heat consumption (WITH-project scenario). The Relative emissions (Re) are calculated as the difference between Ab and Be.

## Electricity consumption

The WITHOUT-project scenario under multiple sites requires the following quantity of electricity:

| location | electricity (kWh) | observations |
|---|---|---|
| Krysiewicz | 899,545 | network-powered facility, low-voltage |
| Nowyeñskie plus Sporna (taken together) | 224,567 | network-powered facility, low-voltage |
| Kierz | 272,000 | Medium-voltage |

Source: Hospital Wielkopolski Sp. z o.o.

According to the energy performance of the building the expected final electricity consumption (= WITH-project scenario) will be 2,423,709.3 kWh/year, to be powered by a medium-voltage network.

Table A.13 of the EIB Methodology (Version 11.3, January 2023) for Poland provides with the $CO_2$-equivalent emission factor per 1 kWh of electricity consumed, supplied by the national grid. The values are:

- 553 g - medium-voltage power supply
- 569 g - low-voltage supply

It should be noted that if it is the type of electricity is unknown (low, medium voltage) then the combined margin firm electricity generation/electricity consumption from Table A1.3 could be used.

Baseline emissions for electricity demand:

Be $_{EL}$ = (899,545 + 224,567 kWh consumed) * electricity emission factor for LV 569 + 272,000 consumed kWh * electricity emission factor for MV 553 = 790,035,728 g/year = 790.04 $tCO_2$/year

Absolute emissions for electricity demand:

AB $_{EL}$ = 2,423,709.3 kWh to be consumed * electricity emission factor for LV 569 = 1,379,090,592 $gCO_2$/year = 1,379.1 $tCO_2$/year

<u>Heat consumption</u>

The existing facilities (= WITHOUT-project scenario) at Ulica Krysiewicza, *Ulica Nowogrodzie*, and *Ulica Spornej* are supplied by the district heating network operated by Veolia Energy Poznań SA. In year 2017 thermal energy consumption amounted to:

- 6,496.60 GJ - site located at *Ulica Krysiewicza* 7/8
- 2,563.90 GJ - site located at *Ulica Nowogrodzie* 56/58, and *Ulica Spornej* 16

The aggregate thermal energy consumption is therefore 9,060.5 GJ.

The consumption of natural gas at the existing premises is 98,655 $m^3$ in 2017, without considering transmission losses. In accordance with the EIB Methodology the combustion of 1 $m^3$ of natural gas generates 1.9 kg of $CO_2$ (with 1 tonne = 1,000 kg).

The WITH-project scenario will be heated by the district heating network operated by Veolia Transport in *Poznań* SA. The estimated final heat consumption of this facility, according to the estimated project's energy performance characteristics, will be 2,879,850.6 kWh/year which would correspond to 10,367.38 GJ (1GJ = 277.78 kWh). The energy sources on this network are the cogeneration units operated by Veolia Energy *Poznań* ZEC SA. According to its website, the company produced its energy content of more than 86% on the basis of coal burning.

In accordance with the EIB Methodology carbon (anthracite) emission factor - Table A1.4, the $CO_2$ emission factor is 312 tonnes/GWh (where 1 GWh = 1,000,000 kWh). As well, energy losses along the network should be considered. According to the information provided by the Energy Regulatory Office the average transmission efficiency in Polish district heating networks in 2016 was 86.7%.

The calculation of Baseline and Absolute emissions (heat) is therefore:

Baseline emissions (heat):

Be $_{TH}$ = 9,060.5 (GJ of heat consumed in 2017 * 100/88 (considering 12% network losses) * 100/86.7 (efficiency of heat generation) * 98.7 ($kgCO_2$/GJ emission factor for coal[36]) / 1000 (conversion factor to obtain ton $CO_2$) + 98,655 $m^3$ (gas consumed in 2017) * (1.9/1.000 (conversion factor, $m^3$ to t) = 1,359.6 $tCO_2$/year

[36] Anthracite is considered in the example. If another type of coal is used then the relevant emission factor from Table A1.4 should be used

Absolute emissions (heat):

$AB_{TH}$ = 10,367.38 (estimated GJ of heat to be consumed/year) * 100/88 (considering 12% network losses) * (100/86,7 Efficiency of heat generation) * 98.7 ($kgCO_{2/GJ}$ emission factor for coal) / 1000 (conversion factor to obtain ton $CO_2$) = 1,341.17 $tCO_2$/year

The total Baseline and Absolute emissions are (heat + electricity consumption – Scope 2 emissions only):

Be = $BE_{EL}$ + $BE_{TH}$ = 790.03 $tCO_2$/year + 1,359.6 $tCO_2$/year = 2,149.6 $tCO_2$/year
Ab = $AB_{EL}$ + $AB_{TH}$ = 1,379.1 $tCO_2$/year + 1,341.17 $tCO_2$/year = 2,720.26 $tCO_2$/year

The Relative emissions are:

Re = Ab - Be = 2,720.26 $tCO_2$/year – 2,149.6 $tCO_2$/year = 570.66 $tCO_2$/year

The project's Relative emissions have a positive value, however it should be noted that the new hospital will be much larger than the existing facilities, which is 35,923 $m^2$ against 16,616 $m^2$. The average proportion $CO_2$/surface/year is:

- WITHOUT-project alternative: 2,149.6 $tCO_2$/y/ 16,616 $m^2$ = 0,1294 ($tCO_2/m^2$ * year)
- WITH-project alternative: 2,720.26 ($tCO_2$/y)/ 35.923 $m^2$ = 0,0757 ($tCO_2/m^2$ * year)

The WITH-project alternative coefficient for greenhouse gas emissions is about 41% lower than the same coefficient under the WITHOUT-project alternative.

**<u>Conclusions, the lessons learnt</u>**

The case-study demonstrates that nowadays the market makes available a series of technical measures which have become of current use, effective to reduce future $CO_2$ emissions. Therefore, reducing future emissions shall be regarded mostly a matter of adequate architectural planning of large buildings. As several large buildings such as hospitals, universities or research centres will be expanded as a recurrent case it is possible that their future Relative emissions will be positive, which is accepted only at the condition to maintain energy consumption/$m^2$/year within the maximum values set by national legislation, and in any case to reduce the future $CO_2$ quantity/surface in respect to the WITHOUT-project alternative.

### *Annex 2.2.2 Carbon footprint assessment for a portfolio of onshore wind farms*

The project comprises the design, construction and operation of 11 small to medium sized wind farms geographically dispersed across Poland, with a total nominal capacity of ~380 MW. The project comprises of 156 turbines of two different suppliers with several different unit sizes ranging from 2 MW up to 4.2 MW. Unit size, hub heights and rotor diameter of the turbine types are selected and adapted to the conditions of each wind farm site. These wind farms (average nominal capacity ~35 MW) are geographically dispersed throughout the west (wider region of Poznan) and north (region around Gdansk) of the country, with one windfarm located in the south (between Lodz and Krakow). The annual electricity generation of the project is expected to be 1130 GWh/year.

According to Table 1 of this guide, renewable energy projects will typically require a carbon footprint assessment since they displace electricity from the National grid and lead to significant amounts of GHG savings.

The estimation of the carbon footprint will be performed according to the EIB Carbon footprint methodology (January 2023 version) and both the absolute and relative GHG emissions for a typical year of the project operation will need to be estimated. Key features of the methodology:

The GHG emissions are divided into:

- **Scope 1**: Direct emissions, by emission sources owned or operated by the project.
- **Scope 2**: Indirect emissions, related to purchase of heat and power.
- **Scope 3**: All other indirect emissions that can be considered a consequence of the activities of the project - such as emissions from the extraction or transportation of raw materials or feedstock (e.g., fugitive emissions from gas transportation).

**ABSOLUTE GHG EMISSIONS: Project's emissions estimated for an average year of operation.**

**RELATIVE GHG EMISSIONS: The difference (delta) between the absolute project emissions and the baseline scenario emissions (for an average year of operation).**

The absolute emissions of this onshore wind farms project are zero since the project involves energy generation from wind power and no GHG emissions are expected during the operation phase:

**Absolute emissions (Ab)** = 0 kt CO2e/year

The electricity produced by the wind farms will displace the same amount of electricity from the Polish grid produced by various power plants. This will be the baseline for the project and the estimation of emissions for the baseline will be done by using the grid emission factors for Poland in Table A1.3 of the EIB Carbon footprint Methodology (see the table in Annex 2.2.1 above). The value that will be used for the grid emission factor is the combined margin for intermittent electricity generation which is 717 g CO2e/kWh = 717 t CO2e/GWh

**Baseline emissions (Be)** = Electricity produced * Grid emissions factor = 1130 GWh/yr * 717 t CO2e/GWh /1000 (conversion of tonnes to kt) = 810 kt CO2e/year

**Relative emissions (Re)** = Absolute emissions (Ab) – Baseline emissions (Be)

$$= 0 \text{ kt } CO_2e/\text{year} – 810 \text{ kt } CO_2e/\text{year} = – 810 \text{ kt } CO_2e/\text{year}$$

The negative value of relative emissions shows that the project leads to GHG savings compared to the baseline.

## Annex 2.3 Climate resilience case studies

### *Annex 2.3.1 Climate resilience assessment for a highway project*

***The Climate Change Vulnerability and Risk Assessment (CCVRA) results and corresponding proposed adaptation measures presented below are for the purposes of the present case study. Those are also object of explanatory context and wider suggestions. The level of detail for some assessments is limited by the theoretical context of the case study and, in practice, additional specific assessments are often required. Therefore, the present case might be considered as a reference, but a CCVRA needs to be performed for the specific project in question.***

*Project Description*

The project consists of construction of a dual carriageway expressway section (S class road, 2x2) of 30 km long. The project is part of the TEN-T core network located in the North-Eastern part of Poland. The project's main objectives are to improve traffic and safety conditions within the TEN-T corridor, to facilitate long distance and regional traffic, and to improve transport accessibility and interregional connections to the TEN-T network with a climate resilient road section. The project is part of the measures included in the national transport sustainable strategy.

It will connect two junctions, running mainly through rural and agricultural land, forest, meadows, and crossing some small urban areas as well. The road section also crosses a river and its floodplain. The road cross-section consists of double carriageway with two-lanes, central reserve, and safety lane.

According to the project traffic forecasts, the average annual daily traffic (AADT) for the section is 14,000 veh/day in 2026 and increasing to 21,000 veh/day in 2048, with an overall average share of 30% of heavy goods vehicles.

*Note: The preparatory phases for the present project are advanced, and the project design is being performed. The CCVRA assessments, adaptation measures and resilience aspects identified are considered within this context. As general good practice, climate change considerations should be developed and incorporated at the earliest possible project preparatory stages.*

*Project's Climate Chnage Vulnerability and Risk Assessment: introduction*

The climate resilience assessment presented below is based on the 2021 EC Technical guidelines for climate proofing, and recommendations included in the present guidelines. Climate resilience proofing aims to ensure an adequate level of resilience of the infrastructure to the impacts of climate change over its lifetime. A climate resilience proofing assessment helps identify the significant climate risks for the project. It is the basis for identifying, appraising and implementing targeted adaptation measures which will help reduce the residual risk to an acceptable level.
The Climate Change Vulnerability and Risk Assessment (CCRVA) presented below refers to the climate hazards considered of relevance for this road project in Poland. Those are based on the list of climate hazards presented in "Wytyczne JASPERS Podstawy adaptacji do zmian klimatu, ocena podatności i ryzyka" and relevant to this road project. Alternatively, the list of climate hazards from the EU Taxonomy Climate Delegated Act could be used, as per below.

Table A2.1: List of climate hazards considered

| Climate Hazard | Description |
|---|---|
| Extreme temperature occurrences (including heat waves) | Changes in the frequency and intensity of periods of high temperatures, including heat waves (periods of extremely high maximum and minimum temperatures) |
| Cold spells | Prolonged periods of extremely cold temperatures |
| Freeze-thaw damage | Repeated freezing and thawing cycles may cause stress damage to structural elements made of concrete or pavements |
| Average rainfall change | Trends over time of either more or less precipitation |
| Extreme rainfall events | Changes in the frequency and intensity of periods of intense precipitation |
| Snow | Changes in the frequency and intensity of periods of snow precipitation |
| Flooding (fluvial) | Flooding from rivers |
| Fog | Water droplets suspended in air reducing visibility |
| Maximum wind speed | Increases in the maximum force of gusts of wind |
| Storms (tracks & intensity) | Changes in the location of storms, their frequency and intensity |
| Wildfire | Unwanted, unplanned and damaging fires such as forest fires and fires of shrub and grasslands |
| Ground instability/ landslides/ avalanche | Ground instability: movement of the ground; Landslide: movement of a mass of rock, debris or earth down a slope under the direct influence of gravity, often with other contributing causes such as rainfall, snowmelt, changes in ground water, human disturbance, among others; Avalanche: a rapid flow of snow down a sloping surface |

Table A2.2: List of climate hazards associated (according to the EU Taxonomy Climate Delegated Act)

| | Water-related | Temperature-related | Wind-related | Solid-mass related |
|---|---|---|---|---|
| Chronic | Changing precipitation patterns and types (rain, hail, snow/ice) | Changing temperature (air, freshwater, marine water) | Changing wind patterns | |
| Chronic | | Heat stress | | |
| Chronic | | Temperature variability | | |
| Chronic | | Permafrost thawing (Not relevant for Poland) | | |
| Acute | Heavy precipitation (rain, hail, snow/ice) | Heat wave | Cyclone, hurricane, typhoon | Avalanche |
| Acute | Flood (fluvial, pluvial) | Cold wave/frost | Storm (including blizzards, dust and sandstorms) | Landslide |
| Acute | | Wildfire | Tornado | Subsidence |

*Phase 1 – Screening: Sensitivity, exposure and vulnerability assessment*

The first phase in the climate resilience proofing is a screening that aims to identify the most relevant climate hazards for the project at the planned location. It comprises of three steps:

1. **Sensitivity analysis** – which aims at identifying the climate hazards that are relevant to the specific type of infrastructure irrespective of its location.
2. **Exposure analysis** – which aims at identifying the climate hazards the infrastructure is going to be exposed to at present and in the future in the given specific location, irrespective of the infrastructure type being assessed.
3. **Vulnerability analysis** – which combines the outcomes of the previous two steps (sensitivity and exposure) and determines the climate hazards that are relevant for the project being assessed, based on the type of infrastructure and its location. Where a high or medium level of vulnerability is identified, a more detailed risk analysis will be required in the detailed analysis phase that would also help in identifying the required adaptation measures.

The final aim is to ensure the project (infrastructure and its operation/service) is resilient to climate change. Therefore, it is strongly recommended to that experts should take a precautionary approach when scoring. This will enable to duly assess vulnerabilities and identify all those relevant hazards for detailed risk assessment, as basis to reflect on resilience aspects and adaptation measures that will mitigate those risks.

Sensitivity analysis

The scale used to assess sensitivity to climate hazards is presented below. It refers to typical components of a road project:

| **Level** | | **Description** |
|---|---|---|
| 0 | *No / Negligible Sensitivity* | No infrastructure service disruption or damage – business as usual |
| 1 | *Low Sensitivity* | Localised infrastructure service disruption. No permanent damage, some minor restoration work required |
| 2 | *Medium Sensitivity* | Widespread infrastructure damage and service disruption requiring moderate repairs. Partial damage to local infrastructure |
| 3 | *High Sensitivity* | Permanent or extensive damage requiring extensive repair |

For the sensitivity assessment of the road project, the following areas are considered[37]:

- Damage and destruction of infrastructure (material losses);
- Infrastructure operation/functionality and related economic impacts (including O&M impacts as well as on road users with related economic impacts).

The sensitivity of the road project was assessed[38] as presented in the table below.

[37] Those are considered as main relevant ones for a road project. The project assessment might consider different ones but it is important that it cover as well as infrastructure as well as users impacts.

[38] The assessment is conducted by relevant experts and might consider available assessments for road projects from benchmarking and recognised sources (e.g. sectoral international sources: climate change adaptation publications and projects from CEDR, PIARC, UNECE…) as well as KLIMADA 2.0 project.

Table A2.3: Sensitivity matrix for a road project

| Climate Hazard | Damage and destruction of infrastructure (material losses) | Infrastructure operation/functionality and related economic impacts (incl. O&M and road users with related economic impacts) | Overall |
|---|---|---|---|
| Extreme temperature occurrences (including heat waves) | **Medium**<br>Damage to road pavements; problems with bridges; damage to horticultural assets (drying up) and increased need for watering; increased fire risk | **Medium**<br>Traffic disturbance and congestion, increased health and safety risks, increased maintenance costs | **Medium** |
| Cold spells | **Medium**<br>Damage to road pavement, concrete structures and electro-mechanical (E/M) equipment; slope instability and embankment failures | **Low**<br>Increased winter maintenance costs; increased safety risks to users and operators (e.g., hazardous pavement conditions due to ice); traffic disturbance and congestion | **Medium** |
| Freeze-thaw damage | **Medium**<br>Increased slope instability and embankment failures; damage to road pavement and concrete structures | **Low**<br>Increased winter maintenance (i.e. potholes, bridge joints replacements, bridge parapet replacements); related traffic congestion and lane availability; increased users safety risks | **Medium** |
| Average rainfall change | **Medium**<br>Possible damages to pavement and other assets, damages to horticultural assets (grass slopes, trees, bushes etc.) | **Low**<br>Increased/decreased maintenance costs for drainage systems and horticultural assets, traffic disruption | **Medium** |
| Extreme rainfall events | **High**<br>Damage to pavement and other road assets (earthworks, drainage systems, structures…), insufficient drainage and/or retention capacity, increased slope instability/landslides, mudslides and/or rockslides, scouring of roads and structures supports, flooding of pavement surface, inundation from rivers | **Medium**<br>Dangerous pavement conditions, traffic disturbance and congestion including blocking road for long periods, increased health and safety risks to users and operators, hazardous pavement surface conditions (slippery) and reduced visibility | **High** |
| Snow | **Medium**<br>Changes to soil stability; reduced/increased need for snow clearing and winter maintenance; increased risk of ice/snow melting leading to increased runoff and/or flooding; damage to E/M equipment and other | **Medium**<br>Increased health and safety risks to road users and road operators due to snow and ice; traffic disruption | **Medium** |

| Climate Hazard | Damage and destruction of infrastructure (material losses) | Infrastructure operation/functionality and related economic impacts (incl. O&M and road users with related economic impacts) | Overall |
|---|---|---|---|
| | installations; changing nature and location of avalanche risk | | |
| Flooding (fluvial) | **High**<br>Damage to road assets, bridges, erosion of road base and bridge supports and abutments; scouring at bridge supports, damage to signs, lighting, and E/M assets; increased risk to bridge decks stability; increased slope instability and landslides | **High**<br>Temporarily or permanently inaccessible networks and assets; health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion | **High** |
| Fog | **Low**<br>Damage resulting from accidents | **Medium**<br>Reduced visibility; increased health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion; increased smog | **Medium** |
| Maximum wind speed | **Medium**<br>Damage to infrastructure equipment (lights, signs, etc), threat to bridge stability | **Medium**<br>Road obstructions through falling objects, operational constraints at exposed locations, increased health and safety risks, falling and flying objects; traffic disturbance and congestion | **Medium** |
| Storms (tracks & intensity) | **Medium**<br>Damage to infrastructure equipment (lights, signs, etc), threat to bridge stability, damage to pavement and other road assets (earthworks, drainage systems, structures…) | **Medium**<br>Road obstructions through falling objects, operational constraints at exposed locations, increased health and safety risks, falling and flying objects; traffic disturbance and congestion | **Medium** |
| Wildfire | **Medium**<br>Damage to all road infrastructure assets (pavement, equipment, structures, horticultural assets etc.); damage to adjacent land or other assets | **Medium**<br>Reduced visibility; increased health and safety risks to road users and road operators including accidents and vehicle damage; traffic disturbance and congestion | **Medium** |

| Climate Hazard | Damage and destruction of infrastructure (material losses) | Infrastructure operation/functionality and related economic impacts (incl. O&M and road users with related economic impacts) | Overall |
|---|---|---|---|
| Ground instability/ landslides | **High**<br>Damage to embankments and cuttings; other road equipment damaged as a consequence of the above; increased risk of road subsidence and weakening of bridge supports; | **Medium**<br>Increased user and road operators' health and safety risks including accidents and vehicle damage; traffic disturbance and congestion | **High** |

Exposure analysis

Exposure assessment should consider current and future climate at the project's location. Future climate needs to look at project design life; therefore, for the present road infrastructure project 50-75 years is recommended as the timescale. The reference horizon of 2075-2100 will be considered in assessing future climate exposure.

It is important to undertake the assessment based on sound and reliable data: observed trends for current climate and forecasts/projections for future climate. The use of local knowledge and evidence of recent climate incidents are of high value (see below the Polish national roads network climate resilience assessment).

Polish national climate data and forecasts are the basis for this assessment. For the purposes of the present case study, only a brief summary of the current climate, recent trends and forecasts for Poland is presented, including references to relevant sources. Information is to be project location specific (e.g., region).

***Current climate***

The main information source used on Polish current climate is the Polish National Meteorological Institute (IMGW).

Poland has mostly temperate climate, in transition between oceanic climate dominating in the north and west of the country, and continental climate in the south and east. Air masses may come to Poland from all directions. Hence the climatology of Poland can be perceived as a mix of maritime, continental, polar and tropical influences. Oceanic currents are an important factor driving the climate of Poland. The inter-year variability of seasonal or monthly mean temperature can be very high. Depending on the frequency of atmospheric circulation types, monthly temperatures can largely vary between years, particularly in winter.

According to the latest available climate report, the area average air temperature in Poland in 2021 reached 8.7°C and was equal to the average annual long-term temperature value for the climatological normal period 1991-2020. And this was also the case for the project's region. The warmest regions of Poland were the Coast and the Southern-Baltic Coastlands belt, and the coldest region was the Sudetes. June and July, and all autumn months, were particularly warm. Conversely, the coldest month was February, characterized by an average air temperature of 1.5°C below normal. The highest temperature (36.1°C) was recorded on 20 June in Słubice. In turn, the lowest temperature at 2 m above ground (–26.4°C) was recorded on 18 January in Suwałki and the lowest air temperature at the ground, i.e., at 5 cm height, was recorded on 18 January at the Białystok station (–32.9°C). The summer of 2021 was the fourth warmest summer in Poland since the mid-20th century. The strong upward trend in air temperature in Poland, occurring for many years, continued in 2021. Since 1951, the total annual temperature increase has been estimated at 2.0°C. The value of the trend coefficient differs in the individual climatic regions of the country.

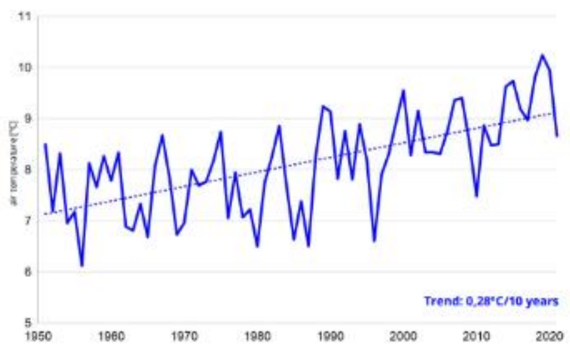
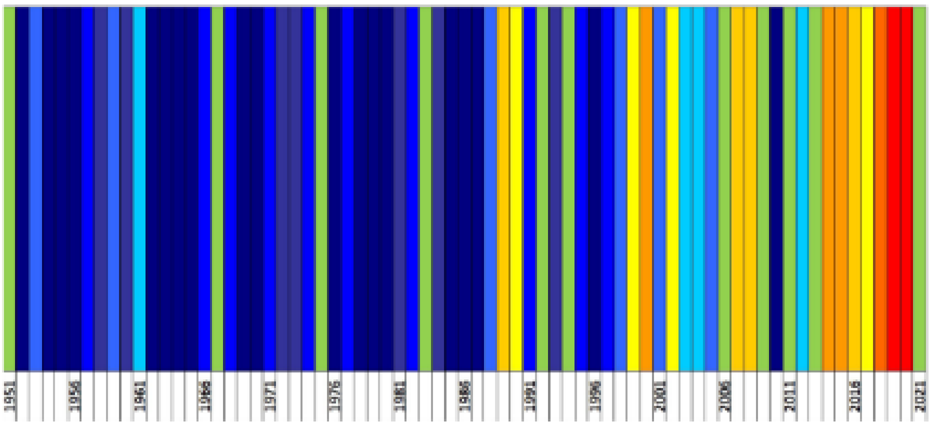



Figure A2.1: Annual average temperature 1950-2020. Source: Climate of Poland 2021, IMGW.




| quantiles | thermal conditions of the month | quantiles | thermal conditions of the month |
|---|---|---|---|
| > 0,95 | extremely warm | 0,30-0,40 | slightly cold |
| 0,90-0,95 | anomalously warm | 0,20-0,30 | cold |
| 0,80-0,90 | very warm | 0,10-0,20 | very cold |
| 0,70-0,80 | warm | 0,05-0,10 | anomalously cold |
| 0,60-0,70 | slightly warm | < 0,05 | extremely cold |
| 0,40-0,60 | normal | | |

Figure A2.2: Illustration of relative thermal conditions change in Poland (1951-2021). Until mid-1980s, those were classified as cold, and from that time, there is a clear steady increase of temperature with the last decade presenting conditions that range from very warm to extremely warm. Source: Climate of Poland 2021, IMGW.

The strongest temperature increase occurs in the lake districts, where it exceeds 2.1°C, the weakest in the Sudety Mountains, reaching almost 1.8°C. It should be emphasized that the rate of temperature increase in large urban agglomerations has increased significantly over the last 40 years.

Extreme events have the greatest impact on climate conditions, with noticeable changes observed[39]. The occurrence of severe heat waves (days with maximum daily air temperature ≥ 30 °C lasting at least 3 days) and very hot days (with a maximum temperature of ≥ 30 °C) are more common in the south-western part of Poland, least common in the coastal area and in the mountains.

In most areas of Poland, there are decreasing trends in the number of cold and frost days. Small increases in the number of frost days are marked only in mountainous areas and in the south-western part of Poland. The length of freezing periods in majority of the country shows a slight upward trend. The longest very frosty periods occurred in the north-east and eastern parts of the country (10-20 such episodes over 40 years), in the rest of the area there were several very frosty periods, with the exception of coastal areas where no such temperatures were recorded.

The area-averaged precipitation total in Poland in 2021 was 627.4 mm, which was almost 103% of the so-called normal value determined on the basis of 30 years measurements (1991-2020). In 2021, precipitation was characterized by a strong spatial variability (from over 450 mm to nearly 1,050 mm). The highest annual precipitation was recorded in the Tatra Mountains.

[39] It is noted that the yearly climate report from IMGW provides a summary of the year extreme weather and climate events.

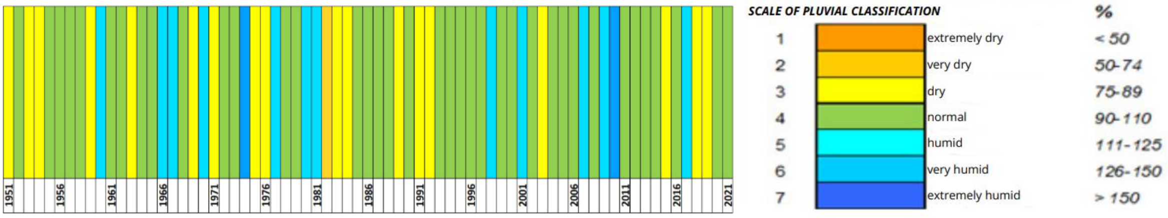



Figure A2.3: Comparative classification of yearly pluvial conditions. Source: Climate of Poland 2021, IMGW.

In the warm season of the year, numerous cases of violent and extremely heavy rainfalls causing local flooding occurred. Such phenomena struck several agglomerations and resulted in urban flash floods. Szczecin and Słubice (June 30: 96.3 mm and 71.3 mm, respectively) and Poznań (June 22: 79.4 mm) were particularly affected by heavy rainfalls. The highest daily precipitation total of 104.4 mm occurred on August 23 at Śnieżka.

In the central part of the Coast and Pomerania, there was a rainfall deficit of up to 20% of the long-term normal, while in Eastern Poland, annual rainfall was higher by 10 to 30% compared to the 1991-2020 normal. In the entire western and central part of eastern Poland, in 2021, evapotranspiration outweighed precipitation. The moisture loss in the mentioned area reached 220 mm, i.e., about 1/3 of the precipitation totals.

The annual value of sunshine duration ranged from just over 1,458 hours in Śnieżka and 1,564 hours in Mława to 2,127 hours in Łeba.

Some more specific characteristics of the project area's recent climate are the following: between 2000 and 2018, the project area has a recorded yearly average temperature of 8.3°C, slightly lower than the national average. The average number of hot days per year (when the 24-hour average temperature is above 25°C) was 1.9 for the period 2000-2018, with a strong increase from the 20$^{th}$ century of an average of 0.2 days per year. At the same time, freezing days (24-hour average temperature below -1°C) decreased to 53.4 days per year on average for 2000-2018, down from an average of 68 days per year during the 20$^{th}$ century. The highest temperatures are recorded in July, with an average maximum temperature of 24.3°C for the recent climatological period, while the lowest temperatures are recorded in January with an average minimum temperature of -4.6°C.

Average monthly precipitation in the project area is highest in July at 88 mm. The summer months from May – September further have high average precipitation, ranging between 65 mm and 78 mm. February has the lowest average precipitation at 44 mm. July furthermore has the highest average number of rainy days at 10 days, with February and October having the lowest average at 7. Average snowfall is highest in January with 75 mm for the month. The months from October to April are the windiest with averages of 15 km/h, while the months May – September are slightly less windy.

***Future climate***

Relevant information on climate forecasts for Poland is available from the KLIMADA 2.0 project. The EC technical guidance on climate proofing recommends using the RCP 6.0 or RCP 8.5 for the initial screening under the climate proofing assessment (RCP 6.0 projections are not currently available for Poland as part of KLIMADA 2.0). For projects with a lifespan longer than 2060, as the present road project, it is recommended to consider the expected changes in the climatic variables based on the RCP 8.5 scenario.

The description below provides a summary of climate change projections for Poland for the relevant climate hazards complemented with project location specifics (based on KLIMADA 2.0 project, for RCP8.5 and climate variables considered relevant as per available data):

- **Temperature:** all forecasts consistently predict an increase in average temperature, annually and seasonally. As regards extremes:
  - **Heatwaves** (at least 3 days with a maximum daily air temperature of ≥30 °C) might be more frequent as well as the number of days with Tmax>25°C and the number of those type of periods.
  - **Cold spells**: a decreasing trend on the number of days of Tmin<0°C, and on the number of yearly days with a minimum temperature ≤-10 °C and ≤-20 °C is expected

The project is located in a region where the number of days with T>25°C is expected to increase by 5 days by 2050 and by more than 20 days by the end of the century compared to this last decade (see Figure A2.4). For the days with T>30°C, the increase is expected to be around 3 days by 2050 and growing to 9 by 2100. The average number of frosty days (with a lowest temperature <0°C) per year is forecast to decrease by 26 days by 2050 and by 59 days by 2100. The average length of cold spells is expected to decrease by 1.5 days by 2100. The average number of days per year that the temperature passes through 0°C is forecasted to decrease by 14 days by 2050 and by 32 days by 2100.

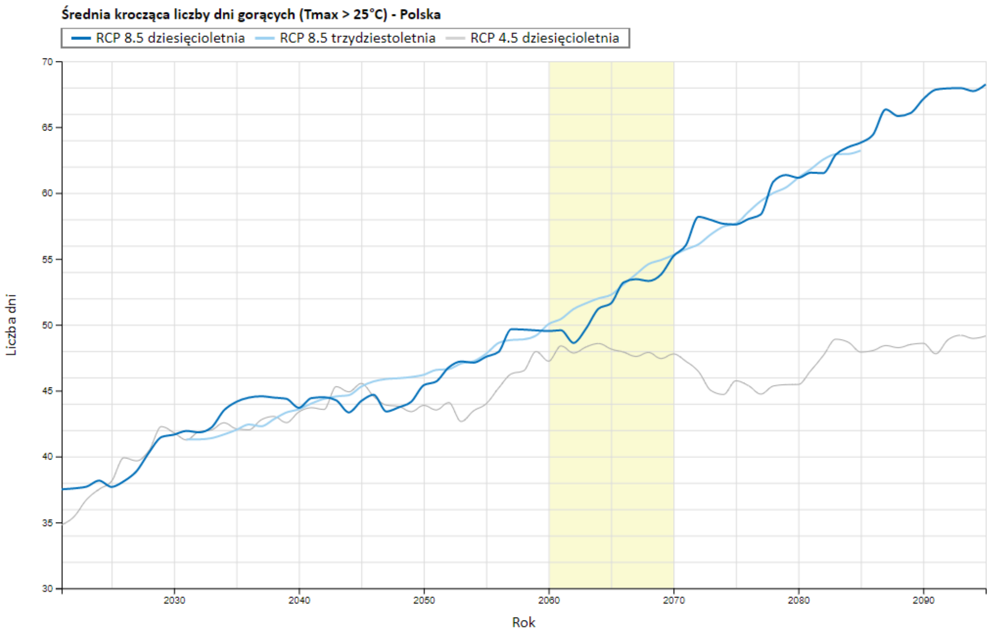



Figure A2.4: Number of hot days per year (Tmax > 25°C; RCP 8.5). Source: KLIMADA 2.0

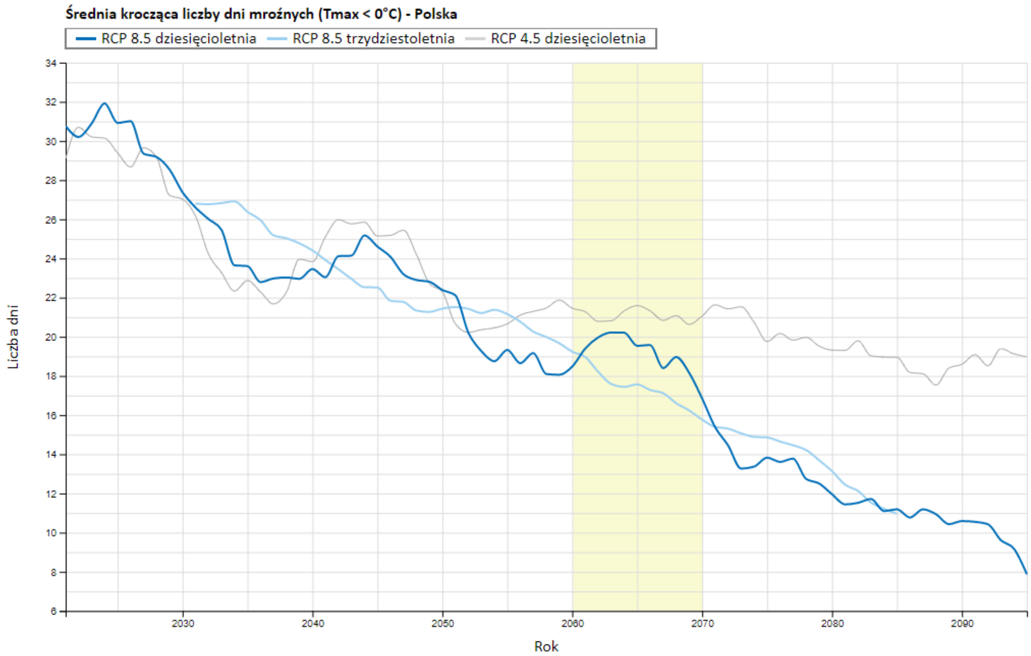



Figure A2.5: Number of frosty days per year (Tmax < 0°C; RCP 8.5). Source: KLIMADA 2.0

- **Precipitation:** forecasts are differing with regards to the expected changes in precipitation; nevertheless, all suggest rainfall will likely increase in future (as annual average) with differences across regions and seasons, notably in winter. As regards extremes:
    - **Heavy rainfall:** it is expected that more frequent heavy rainfalls will be registered in Poland; including the number of days with heavy precipitation (>20 mm/day), in the southern and eastern parts of Poland particularly (see Figure A2.6).
    - **Flooding:** considering the above presented tendencies, it is expected that the frequency of this type of event would also increase.

According to climate forecasts, the average number of days in a year with precipitation >20mm/day will increase by approximately 0.6 days by 2050 and by 1.5 days by 2100 (see Figure A2.6). Total yearly rainfall is projected to increase by 50 mm by 2050 and by 133 mm by 2100 in the project area.

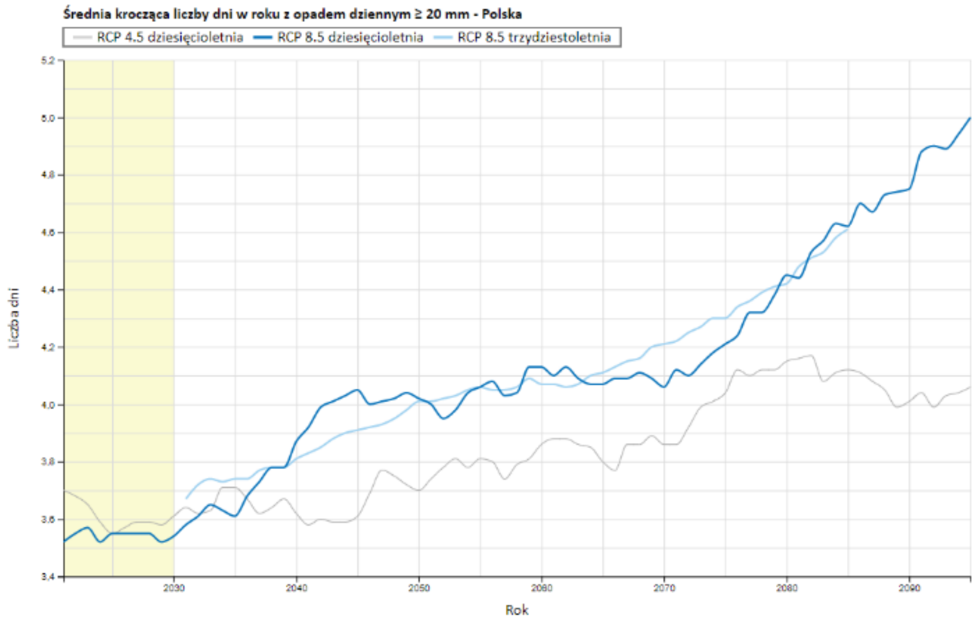



Figure A2.6: Number of days per year with daily precipitation ≥20 mm (RCP 8.5). Source: KLIMADA 2.0

- **Snow:** a continuous decrease in the number of days with snow cover is expected and the presented model results show a clear decrease in the average of snow cover thickness.

The project area will see, compared to this past decade, a decrease in the average days with snow cover per year of around 32 days by 2050 and of 59 days by 2100 (Figure A2.7). Similarly, average snow cover thickness will decrease by approximately 1 cm by 2050 and by 1.5 cm by 2100.

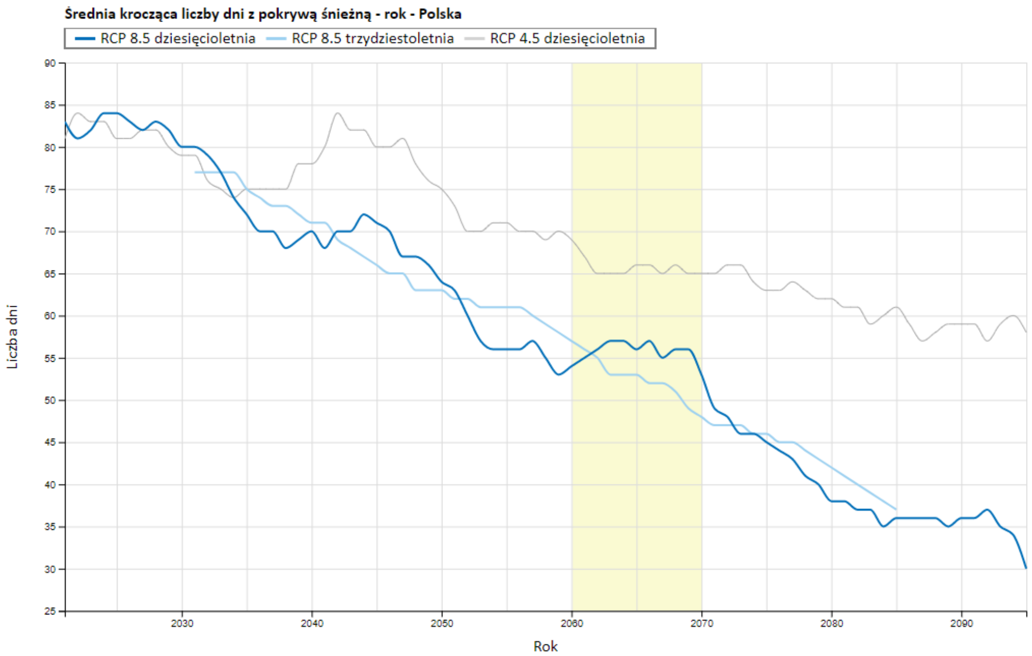



Figure A2.7: Average number of days with snow cover per year (RCP 8.5). Source: KLIMADA 2.0

- **Wind:** the forecasts do not show a significant change on the average wind speeds; nevertheless, there will be changes in the share of high-speed winds with a slight increase of those extreme events in the coming decades.

Forecasts for the project area show, compared to this past decade, a doubling of the share of strong and very strong winds in the last two decades of this century.
Exposure assessment considers three categories: low, medium and high exposure. Furthermore, the exposure to climate impacts is assessed for both current climate conditions and for future climate conditions (see table below).

Table A2.4: Exposure to climate impacts for current and future climate conditions

| Exposure assessment | | | |
|---|---|---|---|
| | **Current** | **Future** | **Overall** |
| Extreme temperature occurrences (including heat waves) | Low | Medium | Medium |
| Cold spells | Medium | Low | Medium |
| Freeze-thaw damage | Medium | Low | Medium |
| Average rainfall change | Low | Medium | Medium |
| Extreme rainfall events | Medium | High | High |
| Snow | Medium | Low | Medium |
| Flooding (fluvial) | Medium | Medium | Medium |
| Fog | Low | Low | Low |
| Maximum wind speed | Medium | Medium | Medium |
| Storms (tracks & intensity) | Low | Medium | Medium |
| Wildfire | Low | Low | Low |
| Ground instability[40] | Low | Low | Low |

The highest exposure score from either the current or future climate determines the overall exposure of the project. The project presents high exposure level to extreme rain and medium exposure to flooding and average rainfall change, as per the climate forecasts and data described above. The exposure to cold-spells, freeze-thaw damage and snow is currently medium and would decrease in the future as climate forecasts show in terms of the number of days with low temperatures, the number of days with temperature crossing through 0°C as well as the number of days with snow cover (or even snow cover thickness). In the case of heat, the current project exposure is rated as low considering Polish average climate in the region; while forecasts show a continuous increase of average temperature and, in particular, of more extreme events (e.g., number of days with Tmax>25°C or also of Tmax>30°C), future exposure rate is therefore increased to medium[41]. For wildfires, the current low exposure is considered to remain relatively low in the future. For extreme winds, as described, the region is currently exposed to this phenomena and forecasts show an expected increase of those extremes. Additionally, it is expected that storms will also be more frequent in the future. As regards fog, this is not considered to be of concern currently

[40] Based on information from project feasibility studies and/or early available design documentation.
[41] It is noted that Poland, compared to other countries in Europe, is not highly exposed to this climate hazard; nevertheless, for the purpose of the assessment and considering the local recent trends and expected increases, it is signalled for consideration in further assessment.

nor in the future. For the case of landslides, the project location is assessed as having low exposure which remains unchanged in the future. Some land stability issues could occur as a result of some extreme rain events on the project embankments.

### Vulnerability analysis

Vulnerability results from multiplying sensitivity and exposure, such that a vulnerability matrix is prepared for the project:

Table A2.5: Vulnerability matrix

| | | **Exposure** | | |
|---|---|---|---|---|
| **Sensitivity** | | **Low** | **Medium** | **High** |
| | **Low** | | | |
| | **Medium** | • Fog<br>• Wildfire | • Average rainfall change<br>• Extreme temperature occurrences (including heat waves)<br>• Cold spells<br>• Freeze-thaw damage<br>• Snow<br>• Maximum wind speed<br>• Storms (tracks & intensity) | • Extreme rainfall events |
| | **High** | • Ground instability | • Flooding (fluvial) | |

The vulnerability matrix shows that the project is most vulnerable to extreme rainfall events and flooding (fluvial); while having medium vulnerability to average rainfall change, extreme temperature occurrences (including heat waves), cold spells, freeze-thaw damage, snow, maximum wind speed, storms (tracks & intensity) and ground instability.

To help with *Phase 1 – vulnerability assessment*, it is worth referring to the GDDKiA and JASPERS supported project on climate change adaptation of Polish national road network. The project started with the climate change vulnerability assessment and mapping of the Polish national road network based on registered extreme climate incidences. The incidences register was built on the basis of a GDDKiA internal survey which collected over 3,300 climate related incidents (i.e., requiring road service team intervention) on the national road network for the period 2004 – 2016. The analysis of survey results concluded that the majority of incidents were caused by mainly three climate related hazards: heavy rain, strong winds and heavy snowfall (see figure below).

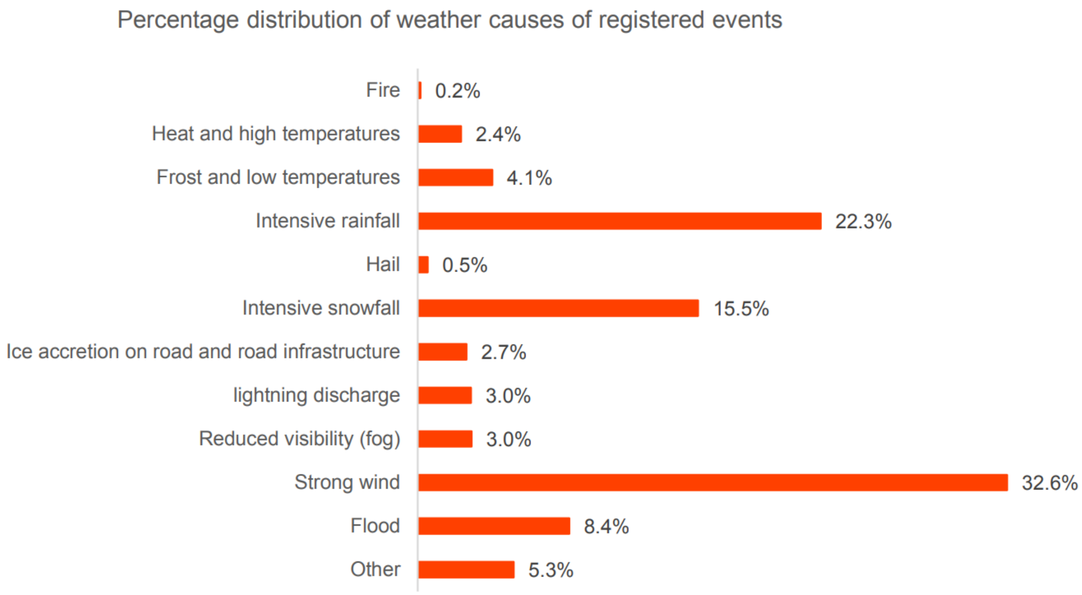



Figure A2.8: Climate related incidents on the national road network based on internal GDDKiA survey (2004 – 2016). Source: GDDKiA.

The survey results also showed that national roads, as opposed to motorways and expressways, presented higher rates of weather-related incidents, which may be explained due to differences in their design and maintenance standards.

It was observed that the majority of incidents were registered during the summer months, as well as in the months of January and December. The climate vulnerability of the network was assessed as the result of combining sensitivity (i.e. level of events impacts on infrastructure and users) and exposure assessment (i.e. frequency of occurrence). Registered data enabled the mapping of network vulnerabilities and potential climate risks, GIS support is key for this type of analyses.

When considering the future exposure of the road network on the basis of national climate forecasts, an overall increased vulnerability to extreme rain and wind related hazards and a decreased vulnerability to snow were noted.

To complement the results of the network vulnerability assessment, a survey was conducted on damage costs and impacts of registered climate incidents. The results provided some references on (i) infrastructure damage costs and (ii) impacts on infrastructure operation and service (i.e., in terms of traffic disruption time that might be considered to estimate users' economic impacts). A pilot case for economic justification of adaptation measures was carried out and concluded as a sound basis to support further assessments on the area of adaptation needs and, particularly, providing a robust economic justification for adaptation of the roads network.

In brief, the climate resilience assessment of the Polish national road network might be used to inform the assessment of climate vulnerabilities at the project level. In this sense, the main climate

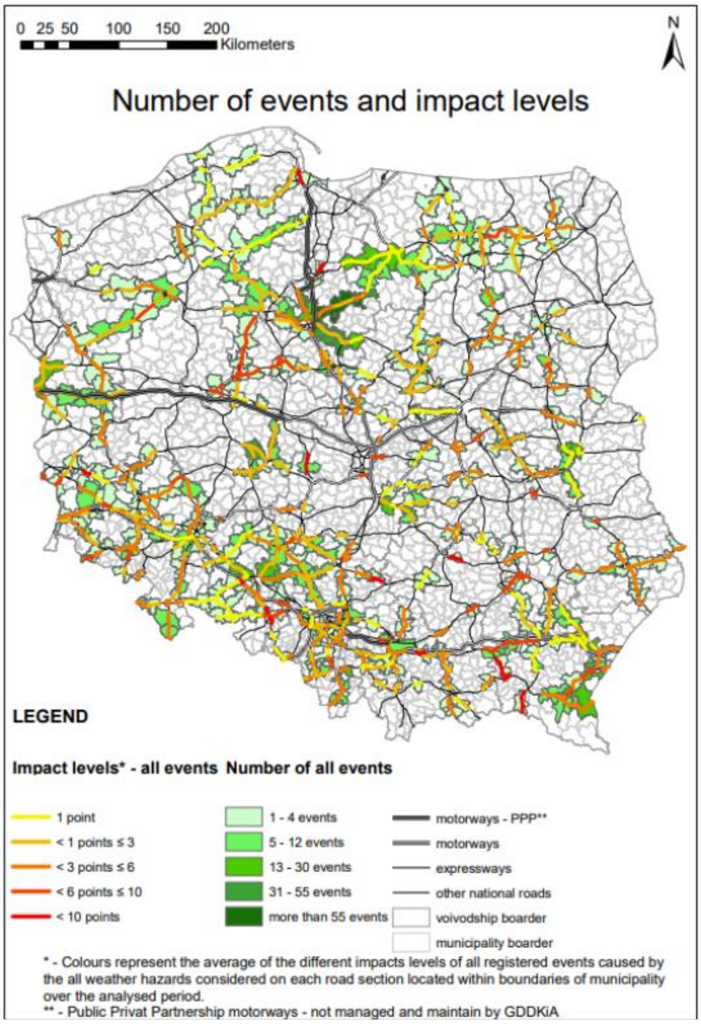



Figure A2.9: Climate vulnerability map of the national roads based on climate related incidents registered (2004-2016). Source: *GDDKiA & JASPERS*

hazards responsible for the national road network vulnerabilities confirm the ones identified in the vulnerability analysis above (particularly heavy rain, strong winds and heavy snowfall).

The survey results on climate incidents in the project area, for the period 2004-2016, registered a number of events caused by heavy rainfall, few events caused by heavy snowfall, while a considerable amount were registered as caused by strong wind, distributed throughout the project area.

*Phase 2 – Detailed Analysis: Likelihood, impacts and risk assessment*

The risk analysis is built on the basis of the vulnerability assessment. It focuses on the hazards identified as relevant through the vulnerability analysis. For the hazards where there was no vulnerability or it was low, the detailed analysis is not required. The risk analysis is undertaken for hazards with medium or high vulnerability.

The risk assessment considers likelihood (i.e., probability) and impact if the relevant hazard occurs (i.e., potential consequences). This assessment facilitates the process of cause-effect study between the climate threat and project performance. The risk analysis might be qualitative, semi-quantitative and/or quantitative depending on the availability and representativeness of data.
It is important to define the assessment scale for likelihood and impacts to ensure transparency and consistency throughout the assessment process (table A2.6).

Table A2.6: Scales used to assess likelihood and impact

| Probability | | | Impact on the project (effect) | | |
|---|---|---|---|---|---|
| **Scale** | **Range of probabilities** | **Point value** | **Scale** | **Meaning** | **Point value** |
| Very low | Highly unlikely to occur; 0-10 % | 1 | No impact | No impact on social well-being and functioning, even without remedial action | I |
| Low | Given current practices and procedures, unlikely to occur; 10-33 % | 2 | Small impact | Little impact on social well-being, functioning, small impact on the financial results of the project, remedial and corrective actions are needed. | II |
| Medium | Has occurred in a similar setting; 33-66 % | 3 | Mode-rate impact | Moderate impact on social well-being and functioning, mainly negative financial effects even in the medium or long term | III |
| High | Likely to occur; 66-90 % | 4 | Critical impact | High loss to social well-being, the occurrence of an event results in the impossibility of achieving the basic objective of the project, very intensive remedial actions may not lead to the avoidance of high losses | IV |
| Very high | Very likely to occur, possibly several times; 90-100 % | 5 | Cata-strophic impact | Failure of the project, the event may cause a complete failure to achieve the project objective, the main effects of the project will not be achieved in the medium and long term | V |

For roads projects, the risk analysis will focus on the operational phase considering the relevant timeframe for this assessment[42]. The risk assessment will consider impacts which may occur during the lifetime of the project.

The results for each climate hazard assessment build upon information sources and data referred to for exposure and sensitivity, carried out in a more in-depth manner as regards the present project specifics (i.e., its design, planned operation and maintenance measures).

## Likelihood analysis

The likelihood analyses are performed based on expert opinion which refers to the available information as regards the possibilities of occurrence of relevant climate hazards (notably based on information presented for the exposure assessment for the project region in climate projections).

| Climate hazard | Probability |
|---|---|
| Extreme temperature occurrences (including heat waves) | **Medium**<br>Constant increase of temperature over the century, and projected increase of heatwaves |
| Cold spells | **Medium**<br>Decreasing probability over the century |
| Average Rainfall Change | **Medium**<br>Constant increase of total yearly rainfall over the century |
| Freeze-thaw damage | **Medium**<br>Decreasing probability but still a common hazard for the project region |
| Extreme rainfall events | **High**<br>Steady increase of probability of days with heavy rainfall |
| Snow | **Medium**<br>Though probability of snowfall will decrease, snowfall remains as of relevant probability in the project region |
| Flooding (fluvial) | **High**<br>The project crosses river and streams, the probability of flooding is relevant and increased by climate forecasts |
| Maximum wind speed | **Medium**<br>Increasing probability of strong winds in a region where it is already currently a common hazard |
| Storms (tracks & intensity) | **Medium**<br>Increasing probability of strong winds and related storms |
| Ground instability | **Low**<br>Project location is at low risk for ground instability |

## Impact analysis

For each climate hazard, the following areas are considered for assessment:

- cost to operators of road infrastructure assets (e.g., costs of repairs, emergency response, loss of profit, etc.);
- road users' and operators' health and safety;
- costs to road users due to disruption of services (e.g., cost of lost time, increased vehicle operating costs, etc.);

[42] Only if some specific cases would deem it relevant, it might also analyse climate risks during construction.

- wider social and environmental impacts (e.g., access to social services, isolation of communities, nearby environmentally sensitive areas affected, etc.)

The referred CCVRA guidelines[43] also included reputational risk as it could also be of relevance in certain areas/countries where, for example, tourism plays a significant role.

[43] E.g., Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient, EC 2009

Table A2.7: Assessment of impacts for relevant climate hazards

| *Risk areas/Impacts* | Extreme temperature occurrences (including heat waves) | Cold spells | Freeze-thaw damage | Snow | Maximum wind speed | Storms (tracks & intensity) | Ground instability | Flooding (fluvial) | Extreme rainfall events | Average rainfall change |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost to operators of road infrastructure assets (e.g., costs of repairs, emergency response, loss of profit, etc.) | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Critical | Critical | Critical | Moderate |
| Road users and operators' health and safety | Critical | Small | Small | Small | Moderate | Moderate (*) | Moderate | Critical | Moderate (*) | Small |
| Costs to road users due to disruption of services (e.g., cost of lost time, increased vehicle operating costs, etc.) | Moderate | Moderate | Moderate | Moderate | Critical | Critical | Critical | Critical | Critical | Small |
| Wider social and environmental impacts (e.g., access to social services, isolation of communities, nearby environmentally sensitive areas affected, etc.) | Moderate | Small | Small | Moderate | Moderate | Moderate | Moderate | Critical | Critical | Small |
| **Overall** | **Critical** | **Moderate** | **Moderate** | **Moderate** | **Critical** | **Critical** | **Critical** | **Critical** | **Critical** | **Moderate** |

(*) it is noted that the risk of accidents is not considered to be higher since according to the analysis undertaken under the project on climate resilience assessment for the Polish national road network, statistics show that the rate of accidents in Poland increases under good weather conditions.

## Risk assessment

The level of risk, as determined by the multiplication of probability and impact, is expressed as a matrix below (table A2.8).

Table A2.8: Risk matrix

| Risk Level | | Likelihood | | | | |
|---|---|---|---|---|---|---|
| | | Very low | Low | Medium | High | Very high |
| Impact | No impact | | | | | |
| | Small impact | | | | | |
| | Moderate Impact | | | • Average rainfall change<br>• Freeze-thaw damage<br>• Cold spells<br>• Snow | | |
| | Critical Impact | | • Ground instability | • Extreme temperature occurrences (including heat waves)<br>• Maximum wind speed<br>• Storms (tracks & intensity) | • Extreme rainfall events<br>• Flooding (fluvial) | |
| | Catastrophic Impact | | | | | |

| Risk Level Legend | Low | Medium | High | Very High |
|---|---|---|---|---|

The highest level of risk identified through the risk assessment is very high for extreme rainfall events and flooding (fluvial) and high for extreme temperature occurrences (including heat waves), maximum wind speed and storms (tracks & intensity). For the other climate hazards assessed (, cold spells, snow, average rainfall change and ground instability), the level of risk is medium.

## Risk assessment conclusions and adaptation measures

All risks with a medium, high or extreme risk score need to be managed to an acceptable level through climate adaptation measures and/or identifying those measures/aspects that are part of the planned project in-built resilience. Those are described in the following tables.

| | |
|---|---|
| **Climate hazard** | Maximum wind speed, storms (tracks and intensity) |
| **Vulnerability** | Medium |
| **Probability** | Medium |
| **Impact (Consequences)** | Critical<br>Damage to infrastructure equipment (e.g., lighting posts, CCTV masts,, signs), road obstructions, health and safety risks due to falling debris, operational constraints |
| **Risk Score** | High |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• Design of sensitive infrastructure elements (e.g., signalling and noise screens supports, lighting posts and CCTV masts as well as O&M centre buildings and service areas) to withstand very high strong winds, especially if located at exposed locations[44]<br>Additionally, some measures will be at the project operation stage and, therefore, those should be part of the measures and requirements included in the operation and maintenance contract/procedures of the road:<br>• maintenance standards for this road class should ensure regular monitoring of condition of assets and repairing and/or replacement of damaged elements (e.g., signalling) in short time<br>• management of greenery (including trees) in the right of way, with adequate maintenance procedures including regular monitoring and assessment of trees and plants conditions<br>• for lower class roads (not applicable to the project itself), the road operation could be restricted for HGV in particular if certain extreme conditions (e.g., certain wind speeds) are forecasted by weather services<br>• implement adequate road management systems that will provide user warning and response systems[45] (i.e., appropriate signalling and/or other information systems in place to inform on planned restrictions), e.g. in case of trees/objects falling on the road pavement |
| **Residual risk** | Medium.<br>It is considered to be an acceptable level as per the measures in place during project operation.<br>The risk will be object of monitoring to assess if measures in place need to be reconsidered. |

[44] Design standards (inc. Eurocodes) specify that supporting structures are designed for wind loads based on the designated wind zone, taking into account relevant loads including weight and dimensions of devices mounted on them. The analysis will look at considered extreme wind loads and related climate projectios, as available.

[45] Early warning systems include the relevant procedures when certain hazards / risks are forecasted (very short-term forecasting of high precision). It might include measures to reduce the impact of the hazard, or modification of the operation, including geo-referencing systems that enable swift responses and analysis *a posteriori*. Those response systems require coordination among different stakeholders/parties and administration levels in the decision-making and response interventions. It also includes coordination of different potential affected operators and/or infrastructure managers.

| | |
|---|---|
| **Climate hazard** | Snow |
| **Vulnerability** | Medium |
| **Probability** | Medium |
| **Impact (Consequences)** | Moderate<br>Damage to electronic equipment, changes to soil stability, traffic disruptions due to required maintenance operations, health and safety risks to users and maintenance teams due to snow and ice |
| **Risk Score** | Medium |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• considerations for slopes embankment stability and/or protection<br>• providing snow blowing barriers if/when relevant<br>• avoiding deep cuttings at exposed locations to minimise occurrence of snow drifts<br>• adequate winter O&M facilities to be planned and designed<br>The following measures for the related project resilience refer to the operation stage and, therefore, those will need to be implemented and/or part of the relevant operation and maintenance contracts/procedures of the road:<br>• high standards for operation and maintenance for this class of road (e.g., snow is cleared from the road within 4 hours) including planning for adequate O&M facilities (depot, soil silo, winter maintenance vehicles and staff etc.)<br>• monitoring system which allows pre-emptive salting of the road under certain climatic conditions<br>• road management systems providing user warning and response systems (i.e., appropriate signalling and/or other information systems to inform on planned restrictions and/or rerouting), e.g. when the road is covered by snow before ploughing |
| **Residual risk** | Low |

| | |
|---|---|
| **Climate hazard** | Extreme temperature occurrences (including heat waves) |
| **Vulnerability** | Medium |
| **Probability** | Medium |
| **Impact (Consequences)** | Critical<br>Damage to pavement (e.g., softening, deformation, rutting, …), problems with bridges (e.g., stability, thermal expansion at joints, etc), increased O&M costs, increased risk of wildfires, increased health and safety risks to users and road operators |
| **Risk Score** | High |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• road pavement designed to be resilient to very high temperatures and load axel overloading enforcement[46]<br>• high temperature considerations for bridges (e.g., thermal expansion impact on bridge joints)<br>• adequate considerations for horticultural assets resistant to heatwaves and droughts (e.g., type and origin of species planted, time of the year for planting)<br>The following measures for the related project resilience refer to the operation stage and, therefore, those will need to be implemented and/or |

[46] Those requirements are duly part of the relevant tenders and contracts technical specifications.

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| | part of the relevant operation and maintenance contracts/procedures of the road:<br>• review adequacy of pavement design during road reconstruction/ rehabilitation intervention<br>• forest management considerations and fire risks related to woody areas close to roads including relevant coordination and response systems<br>• road management systems providing user warning and response systems (i.e., appropriate signalling and/or other information systems to inform on planned restrictions and/or rerouting), e.g. in case of pavement damages or repairs |
| **Residual risk** | Low |

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| **Climate hazard** | Cold spells |
| **Vulnerability** | Medium |
| **Probability** | Medium |
| **Impact (Consequences)** | Moderate<br>Damage to road pavement, concrete structures and electro-mechanical (E/M) equipment; increased winter maintenance costs; increased safety risks to users and operators (e.g., hazardous pavement conditions due to ice); traffic disturbance and congestion |
| **Risk Score** | Medium |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• considerations of resistant materials and technologies for pavements and concrete structures<br>The following measures for the related project resilience refer to the operation stage and, therefore, those will need to be implemented and/or part of the relevant operation and maintenance contracts/procedures of the road:<br>• ensure adequate routine maintenance, repairs and inspections of pavements conditions<br>•<br>• road management systems providing user warning and response systems (i.e., appropriate signalling and/or other information systems to inform on planned restrictions and/or rerouting), e.g. in case of hazardous pavement conditions due to ice |
| **Residual risk** | Low |

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| **Climate hazard** | Freeze-thaw cycle |
| **Vulnerability** | Medium |
| **Probability** | Medium |
| **Impact (Consequences)** | Moderate<br>Increased slope instability and embankment failures; damage to road pavement and concrete structures; increased winter maintenance (i.e. potholes, bridge joints replacements, bridge parapet replacements); related traffic congestion and lane availability; increased users safety risks |
| **Risk Score** | Medium |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• considerations of resistant materials and technologies for pavements and concrete structures (to be duly included in relevant tender and contracts technical specifications) |

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| | • considerations for slopes protection<br>The following measures for the related project resilience refer to the operation stage and, therefore, those will need to be implemented and/or part of the relevant operation and maintenance contracts/procedures of the road:<br>• ensure adequate routine maintenance, repairs and inspections of pavements and exposed concrete structures to prevent water ingress and spalling<br>• adequate and regular monitoring of slopes condition and maintenance<br>• road management systems providing user warning and response systems (i.e., appropriate signalling and/or other information systems to inform on planned restrictions and/or rerouting), e.g. in case of related pavement repairing |
| **Residual risk** | Low |

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| **Climate hazard** | Extreme rainfall events, Flooding (fluvial), Average rainfall change |
| **Vulnerability** | High (Extreme rainfall events/Flooding), Medium (Average rainfall change) |
| **Probability** | High (Extreme rainfall events/Flooding)/ Medium (Average rainfall change) |
| **Impact (Consequences)** | Critical (Extreme rainfall events/Flooding), Moderate (Average rainfall change)<br>Damage to pavement and other road infrastructure, slope instability and landslides, risk of flooding, blocking of the road, traffic disruption, health and safety risks, inaccessibility for maintenance teams |
| **Risk Score** | Very High (Extreme rainfall events/ Flooding)/ Medium (Average rainfall change) |
| **Description of in-built resilience & proposed adaptation measures** | The following design aspects will provide project in-built resilience:<br>• design standards for bridges to withstand 200-year flood[47]<br>• consider if applying a climate factor for bridges and culverts (e.g. 10-20% increase of rainfall and/or increased clearance over 200-300-year flood levels under bridges);<br>• design standards for road drainage system to withstand 10-year rainfall events<br>• consider if applying a climate factor for drainage systems (e.g. 10-20% increase of drainage capacity)<br>• design of relevant retention systems along road drainage systems<br>• adequate design of intermediate bridge supports and abutments, incl. avoidance of intermediate bridge supports in fast-flowing streams prone to flooding, erosion protection<br>• adequate design of road embankments at exposed locations and protections of river banks |

[47] It refers to „WR-M-12 Wytycznymi obliczania świateł drogowych mostów i przepustów hydraulicznych"from September 2022 which replaced Regulation of the Minister of Transport and Maritime Economy of May 30, 2000 for which high class roads (A, S, GP), the desing of bridges should consider 300-years return period flood and adjustment of the minimum bridge clearance, ensuring free flow. It is also noted that this regulation from 2000 was a modification after the occurrence of the so-called Millennium floods in Poland. In this sense, it is strongly encourage that (and aligned wiht Regulations) the design process duly considers its appropriateness (including use of updated hydrological data in design as per requirements) and the possible need of a climate factor to consider climate change projections (as per previous guidance). The ultimate aim is that the infrastructure can peform its functions which is in alignment wiht initially referred Regulation.

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| | • use of adequate greenery that is adapted to increased average rainfall<br>The following measures for the related project resilience refer to the operation stage and, therefore, those will need to be implemented and/or part of the relevant operation and maintenance contracts/procedures of the road:<br>• adequate routine maintenance of drainage and retentions systems and slopes including monitoring (and inspections) of drainage, bridge, culverts…<br>• conditions to ensure drainage efficiency and capacity<br>• adapt maintenance regime of roadside greenery to increased precipitation<br>• continuous monitoring of flood risk according to which additional measures can be initiated<br>• road management systems providing user warning and response systems (i.e., appropriate signalling and/or other information systems to inform on planned restrictions and/or rerouting), e.g. in case of certain road section being flooded or land stability issues affecting the road traffic<br>• analysis of scouring risks for bridges including providing/justifying resilience measures to protect bridge supports and structures (to be undertaken as relevant for the planned bridges)<br>• in case of relevant landslides risks, considerations related to increased heavy precipitation, that might conclude on need of monitoring, or specific technical studies |
| **Residual risk** | Medium<br>It is considered to be an acceptable level as per the measures in place including relevant response measures when those hazards occur. The risk will be object of monitoring to assess if measures in place need to be reconsidered. |

It is noted that the present assessment refers to the specific project focus of the case study; nevertheless, there are a number of aspects that need to be addressed in a horizontal manner for the sector and therefore are worth to be also referred to, as per above.

The importance of a systematic register of climate incidents is underlined as a fundamental adaptation measure. Continuous monitoring and registering incidents are key to (i) feed into future climate resilience assessments in projects; (ii) adapting operation, maintenance and user warning and response procedures; and (iii) identify whether additional adaptation measures are needed (e.g. in case of achieving certain thresholds identified in the risk assessment).

Since a number of measures relate to the project infrastructure operation stage (i.e., operation and maintenance measures, monitoring and registering, user warning and response systems), it is important that the relevant resources and financing are ensured and incorporated in the project's budget (continued importance of adequate maintenance and operation budgets that also account for adaptation).

The importance of undertaking further review of different considerations related to planning and design of road projects in parallel is also underlined. This could also build upon recent studies, knowledge, under-going assessments at the project level and acquired experience. It would benefit from establishing a dedicated exchange of relevant stakeholders in the road sector (universities, technical associations, relevant ministries, etc.).

While generally technical specifications and design standards do not currently consider climate change per se, those are addressing it in a number of related aspects. While changes on standards or technical legislation might take a long time to adapt (see above), internal instructions to the infrastructure manager could lead to a faster implementation. Technical standards and regulations do not limit in this regard and they aim for an appropriate functioning of infrastructure (see reference above). In this regard, some measures could already be implemented in the short-term. In planning and project preparation, the practice of a CCVRA could be implemented to any new investment from its very early preparatory stages (i.e., early feasibility studies). For design, in view of changes in recent regulations, it could also be contemplated if a safety factor is to be applied when calculating water flows for drainage systems (e.g., 20-25% increase of rainfall from the currently applied return period) for certain road classes or specific elements.

Additionally, for other aspects of importance such as flood risk management plans that are under responsibility of other institutions, it will be relevant to understand how those account for climate change related impacts. Cooperation between different institutional actors and stakeholders is therefore of key importance.

Compliance with climate change adaptation strategies

The CCVRA results and conclusions with related proposals on adaptation measures are in alignment with the Polish National Strategy for Adaptation to Climate Change with the perspective by 2030 (SPA 2020).

In particular, SPA 2020 refers to general vulnerabilities of transport sector (for example, signalling the particular risks related to strong winds and heavy rainfall for roads). The strategy also indicates objectives and directions of adaptation actions for the sector. For transport, it points out the need of climate change considerations in the design and construction processes of transport infrastructure and particularly with monitoring of climate vulnerabilities of transport and providing user warning systems. It also refers to the importance of ensuring efficient functioning of transport systems through the review and/or creation of action plans related to operation and maintenance of transport infrastructure in case of climate hazard impacts. Therefore, the present project assessment conclusions and measures are aligned with those action lines.

It is also noted that an update of this strategy is currently planned by the Ministry of Climate.

In addition, it is worth referring to the approach initiated by GDDKiA with the network assessment of climate change vulnerabilities. It aims at integrating climate change adaptation in the Polish national roads system. In this sense, this is also aligned with EU Adaptation strategy ("Forging a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change, EC 2021" ) and, particularly, one of its key objectives that refers to systemic adaptation.

### *Annex 2.3.2 Water supply and wastewater project*

A detailed example prepared by JASPERS (document in English) is provided in this link.

### *Annex 2.3.3 Flood protection project*

A detailed example prepared by JASPERS (document in English) is provided in this link.