RESIST

Needs assessment for large-scale demonstrator regions

Deliverable 1.1

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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other
[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

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Abbreviations

AIGP.....Integrated Areas of Landscape Management
C2C CC.....Coast to Coast Climate Challlenge
C40.....C40 Cities Leadership Group
CCA.....Climate Change Adaptation
CDR.....Central Denmark Region
CIM.....Commissions for Coordination, Regional Development and Inter-Municipal Council
CRA.....Climate Risk Assessment
ENAAC.....Estratégia Nacional de Adaptação às Alterações Climáticas
ESCACC30.....Marc estratègic de referència d'adaptació al canvi climàtic per a l'horitzó 2030 (Strategic Reference Framework for Adaptation to Climate Change for the Horizon 2030)
ESCAT20.....Servei Meteorològic de Catalunya 2020
ESPON.....European Observation Network for Territorial Development and Cohesion
EWS.....Early Warning System
FCCP.....Finnish Climate Change Panel
GVA.....Gross Value Added
IoT.....Internet of Things
IPCC.....Intergovernmental Panel on Climate Change
LSD.....Large-scale Demonstrator
MH-EWA.....Multi-Hazard Early Warning Systems
ML.....Machine Learning
NAP.....National Adaptation Plan
NbS.....Nature-based Solutions
OCCC.....Oficina Catalana del Canvi Climàtic
PIAAC.....Intermunicipal Climate Change Adaptation Plan
PROCICAT.....Catalan Territorial Civil Protection Plan
RCP.....Representative Concentration Pathway
SECAP.....Sustainable Energy and Climate Action Plans
SLR.....Sea Level Rise
SSW.....Site-specific Warning
SW.....South-West
UNFCCC.....United Nations Framework Convention on Climate Change
WP.....Working Package
XR.....Extended Reality

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1 Introduction

1.1 Purpose of the needs assessment

Task 1.1, which this needs assessment is part of, aims to support the regions in the RESIST project in their climate adaptation actions. In order to develop a plan of action for this support as well as a basis for designing innovative adaptation solutions, it is first necessary to understand the status quo in each of these regions. This includes an analysis of the challenges they are facing and the needs they have, regarding both the immediate project activities that will be implemented as part of Work Package 3, as well as in the wider regional adaptation context. Examining the baseline from which the regions are starting from in the project is, therefore, a core component of this analysis.
The needs assessments form the first step in the climate change adaptation framework of Task 1.1. As described in the proposal, this framework follows several overarching principles, which are integrated into the analytical approach of this needs assessment:

1. Following a **flexible and context-specific approach** in which the developed solutions are tailored to the needs and vulnerabilities of each individual region. To implement this approach, it is essential to have detailed insights into the context in which climate adaptation takes place in each region. This is a prerequisite for solutions being designed to fit the needs of the region.
2. The design of adaptation solutions and decision-making process is based on a **participatory approach**, considering the most vulnerable population groups and accounting for the gender-specific impact of climate change. Contributing to just resilience is, therefore, a central principle of this framework. Examining how far these considerations are already integrated into adaptation activities is a core component of the needs assessment.
3. The facilitation of **nature-based solutions**, in line with the new EU Adaptation Strategy. Understanding whether nature-based solutions already play a role in regional adaptation plans and measures or if they could be integrated into future adaptation activities.
4. Following, where possible, a **transformative adaptation** approach (see section 2.1.2) which enables large-scale and long-lasting impacts. The results of the needs assessment can in subsequent steps point towards possible paths of upscaling solutions, using currently planned activities as a basis for designing more transformative options.

Identifying starting points for possible support to regional partners allows adelphi and other partners to tailor their next steps to the most important needs and challenges. It also gives an indication of ways in which the effectiveness or scale of adaptation activities could be increased in order to achieve large-scale impacts.
It is crucial to understand that the purpose of the needs assessment is not to evaluate the regions' work on climate change adaptation. On the contrary, it is to find ways in which to most effectively support their work and understand the context in which regional partners operate, and to learn from each other as will be further detailed in task 1.3 in which an approach for documenting and

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benchmarking practices will be developed. Another goal of the needs assessment is to identify questions that remain open but will be answered as soon as the necessary information is available to support regional climate change adaptation in the most effective way.

1.2 Overview of this document

This deliverable contains the individual needs assessment for each of the four large-scale demonstrator regions that are part of RESIST.

Chapter 2 details the methodological approach applied to these assessments and outlines the different parts of the analysis. It also describes the information sources that were included in the analysis and how these were utilized. Limitations in some of the data used, specifically the ESPON dataset, are pointed out.

Chapter 3 contains the four needs assessments of the large-scale demonstrator regions. Each of these assessments follows the same structure: The first part looks at the region's climate risks and the already existing climate risk assessments (either at local, regional or national level). The second part examines existing and planned adaptation measures and points to ways in which these might be improved or their implementation might be supported by the partners in the project. The two subsequent sections of each needs assessment examine the stakeholder engagement as well as capacity constraints the region is facing. The final chapter summarises the results and gives an overview of the identified regional needs and challenges. The description also contains initial ideas of how activities that go beyond those already planned in the regions as part of RESIST could support climate adaptation.

Chapter 4 provides an overview of the most important results of the assessment, identifies common themes in the four regions and discusses some of the experiences made during the needs assessment process. Finally, this chapter looks ahead at the next steps and discusses what the update process of the needs assessment for Deliverable 1.11 "Needs Assessment for Leading and Twinning Regions updated and finalised" will involve.

Annex A and Annex B contain documents that formed part of the needs assessment process. Annex C and Annex D describe details about a dataset (European Observation Network for Territorial Development and Cohesion, ESPON) that was used as part of this assessment.

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2 Methodological approach

2.1 Analytical concept for the needs assessments

The needs assessment collects information on currently existing climate risk assessments, adaptation policies and measures as well as information about stakeholder involvement and different capacities. It identifies any gaps, challenges or needs for support in each region. For the first two components (climate risk assessments and adaptation measures), which constitute the main focus of this analysis, we applied a list of “best practice”-criteria. These criteria are framed as guiding questions for the analysis and constitute characteristics of adaptation that, when fulfilled, lead to effective, just and sustainable adaptation actions.
Following this structured approach allows for identification of any areas of potential improvement or further development of adaptation measures as well as determining more general challenges the regions are facing in the context of climate adaptation. The results will indicate possible angles for support from horizontal partners. For each region, the structure or focus of the assessment may be changed slightly to accommodate the individual circumstances, available information and adaptation dimensions of the respective region.

Many of the questions and analytical components outlined in the following sections may not be answered fully at this moment since the information available regarding planned adaptation measures is not sufficiently detailed and will be updated throughout the project life time and presented in next iterations of this deliverable. However, this lack of detail is in no way to the detriment of this needs assessment.
Each section of the regions’ needs assessment summarises information about the status quo, existing climate risk information and adaptation measures as well as the stakeholder community and institutional and financial capacities. It then examines whether criteria of good practice are met, where gaps exist and how the existing information or plans can be improved. This assessment of information, institutional capacity and resource needs, on the one hand, points to further development potential and possible avenues for support by the project partners of measures planned within RESIST. On the other hand, it indicates ways in which the overall goal of the project can be achieved, i.e. developing and upscaling innovative solutions and supporting systemic adaptation.

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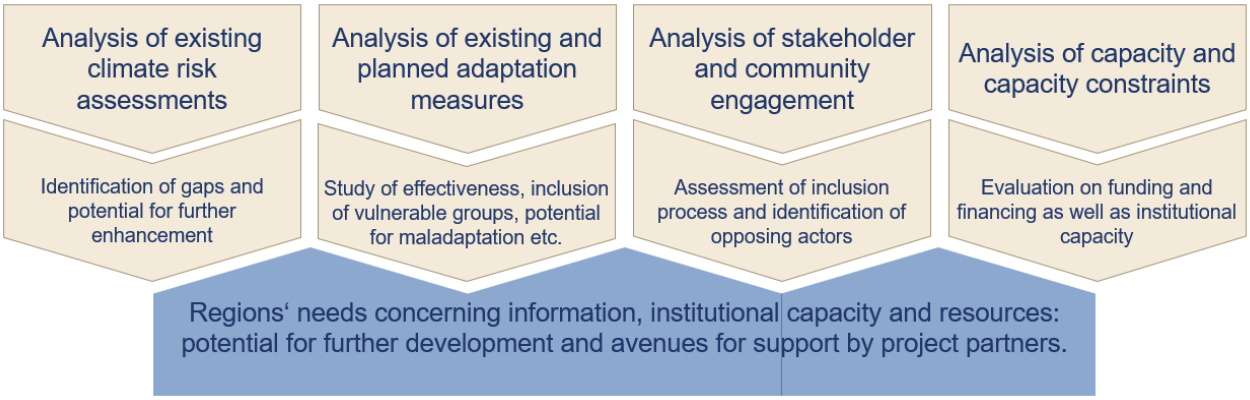

Figure 1: Schematic illustration of applied methodology to needs assessment.

2.1.1 Analysis of climate risk assessments

Not all regions that are part of RESIST have their own climate risk assessment. What we refer to here as climate risk assessments are any documents that contain an analysis of or information about climate hazards, exposure or vulnerability to the impacts of climate change that cover the region or parts of the region. The information provided in these documents is analysed by adelphi to identify how far certain good quality characteristics for climate risk assessments are fulfilled.

Following the international standard EN ISO 14091 Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment (ISO 14091:2021) and the requirements of the EU Taxonomy for climate risk assessments (see EU Delegated Act 2021/2178 (European Commission 2021) and corresponding interpretation) a number of key steps for climate risk assessments (CRA) can be identified. As part of the needs assessment, the project team checked whether the past climate risk assessments in the target regions have included these steps. This is beneficial for putting the findings of past assessments into context and determining possible needs and approaches with respect to future risk assessments. The key steps or criteria are as follows:

1. The analysis covers at least two RCP scenarios. Preferably, scenarios should be used that conform to current emission pathways, i.e. RCP 8.5[3].
2. The analysis looks at medium- and long-term changes, e.g. mid-century and end of century.
3. The analysis touches on a wide range of climate-related hazards, not only changes in temperature and rainfall.

[3] The Representative Concentration Pathways (RCPs) specify different scenarios of the development of greenhouse gas concentrations until the end of the century. Based on the RCPs, climate models simulate future climate trends. RCP8.5 is a high-emission scenario where greenhouse gas emissions continuously rise during this century.

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4. The analysis considers both extreme events (such as flooding or heat waves) as well as slow onset changes (such as sea level rise).
5. The analysis includes examination of the main risk components and is not simply looking at hazards or only operating with aggregated factors like risk or vulnerability. The main risk components are:
    - sensitivity, defined as “the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change” (IPCC 2022),
    - exposure, defined as “the presence of […] assets in places and settings that could be adversely affected” (IPCC 2022), and
    - adaptive capacity, defined as “the ability of systems […] to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (IPCC 2022).
6. When looking at exposure, sensitivity and adaptive capacity, temporal aspects are taken into account, e.g. it is considered how these factors are likely to change over time. For example, sensitivity might change due to changes in the population structure.
7. The analysis outlines impact chains in a transparent way. Impact chains are a tool to better understand, visualize, systemize and prioritize the factors that drive climate risk (ISO 14091:2021).
8. Uncertainties and data sources used are highlighted.
9. The results of the analysis have a spatial component, e.g. indications where certain risks are most prevalent.

It is not expected that an analysis of climate risks in the LSD-regions comply with all of these features. The list provides a framework for assessing the information already covered in existing analysis to identify potential gaps. Climate risk assessment containing information on all the aspects listed above provide a meaningful basis for the design and prioritization of adaptation measures. For example, pointing out particular spatial “risk hotspots” or areas with a population particularly sensitive to the impacts of heat waves allows policy makers to design adaptation measures specifically targeted to these areas and vulnerabilities.

2.1.2 Analysis of adaptation measures

A similar approach is applied to the analysis of the existing and planned adaptation measures in each region. The project team defined a number of characteristics that these measures should exhibit. Many of these are process-based, meaning that the process of designing and implementing adaptation measures should include certain steps and considerations and the analysis looked at whether these were integrated in steps already taken in the regions. As already mentioned, the aim of this approach is not to point out deficiencies in past or ongoing work in the regions, but to allow the partners within RESIST to tailor their support services in the most effective way. Any gaps or needs pointed out in this analysis provide the partners with crucial information on how to design their activities in this project. This includes the design and use of Graphical Digital Twins for each region as well as the support for innovative adaptation solutions.

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Are measures effective in addressing identified climate risks?
For adaptation measures that are already implemented in the regions, any information available on their effectiveness, such as evaluations of adaptation action plans, is collected and analysed.
The effectiveness of adaptation measures in reducing climate risks is a central criterion for their quality. Effectiveness of adaptation measures refers to the impact they have on one or more climate change risks in the area where they are applied. Common indicators for effectiveness are their wide-ranging impact (reducing risk not just in one specific location), their long-term impact, the extent to which they reduce one or more climate risks, or the number of people they benefit.
Estimating the effectiveness of measures that are not yet implemented involves an ex-ante perspective on the anticipated effects these will have and whether they are deemed suitable to address relevant climate risks.

Are measures designed in a gender-sensitive way and explicitly consider the implications on different genders?
This question is also part of the gender framework being developed in Task 1.4. A person's gender is one attribute that can contribute to their vulnerability. Gender is a cross-cutting dimension in climate adaptation. Integrating a gender-sensitive perspective in adaptation means considering gender differences in access to information and training, access to resources, position in society or differences in risk perception (Lager et al. 2023).

Are measures designed in a way that considers the needs of particularly vulnerable population groups?
Vulnerability is defined as "the propensity or predisposition to be adversely affected due to the inequalities in the socio-economic system" comprising "sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC 2022). As mentioned in the previous paragraph, a person's vulnerability is determined by a number of attributes. Groups that are potentially particularly vulnerable include, amongst others, older people, people with disabilities, marginalised groups, minorities, lower-income groups and certain genders (Lager et al. 2023).
There is growing evidence on how the most vulnerable people are disproportionately at risk from the impacts of climate change (Lager et al. 2023). Vulnerable population groups have fewer capacities to adapt to these impacts and are less likely to be heard in the adaptation process. It is, therefore, essential to ensure adaptation actions benefit vulnerable groups. Where these aspects have not yet been specifically considered, this can be a useful indication for support to be provided by adelphi in the future in order to promote just resilience through adaptation.

Do the measures avoid the risk of maladaptation?
Maladaptation means that planned or implemented adaptation measures have negative side-effects such as increasing vulnerability, impairing wellbeing or otherwise undermining sustainable development. These negative consequences can occur in the same or in other locations, systems

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or population groups than those initially concerned by the adaptation action (Institute for European Energy and Climate Policy (IEECP) et al.). When designing an adaptation action, possible unintended negative impacts on climate mitigation, ecosystems, resources, other geographical areas, the same or other sectors than the one addressed by the adaptation action should always be considered at an early stage.
The newly developed self-assessment tool to spot risks of maladaptation from the EU-funded REGILIENCE project provides detailed support in identifying possible risks of maladaptation. It contains a checklist of 17 questions to which the user can respond to by selecting either “yes”, “no”, or “partially”. The tool is designed for actors responsible for planning and implementing regional adaptation actions. The questions are divided into different sections. Some of these comprise questions that are already listed in section **Error! Reference source not found.** and other parts of this methodological chapter. Many questions look at the information that was considered for the identification and design of adaptation options (Institute for European Energy and Climate Policy (IEECP) et al.).
Within our analysis, we first check whether a consideration of possible negative side-effects is already integrated in the planning and design process of adaptation measures. Where this is not the case, the next step involves, wherever suitable and sufficient information is available, applying this list to the planned adaptation activities of RESIST regions.

Do the adaptation measures have social equity impacts?
This question can be seen as a sub-component of addressing the avoidance of maladaptation. One way in which maladaptation can occur is when an adaptation measure has negative social equity impacts. Thus, it should be checked whether any dimension of social equity could be impacted by the planned activities. In many cases these potential impacts can be difficult to predict, particularly at an early stage of the design and planning process. However, it is important to include this dimension of possible side-effects in the analysis before implementing climate adaptation measures.

Is a preference for or prioritisation of nature-based solutions discernible?
One of the priorities of the EU’s new adaptation strategy is the support for nature-based solutions for climate change adaptation. The term nature-based solutions (NbS) refers to “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 must therefore benefit biodiversity and support the delivery of a range of ecosystem services (European Commission 2023).
Within this analysis, we therefore also consider the integration of NbS. If NbS are not part of the planned activities within the RESIST project, further steps will include a closer look at whether or how adaptation measures that go beyond the immediate scope of RESIST can include NbS. Of

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course, it will be taken into consideration that some adaptation activities are more suitable to including NbS than others.

Are measures designed in a transformative instead of an incremental way?
The RESIST project aims at innovative and large-scale solutions. Therefore, one of the aspects to analyse is whether adaptation measures are designed in a way that supports transformative, large-scale adaptation and goes beyond incremental adaptation. Incremental adaptation refers to adaptation that maintains the essence and integrity of a system or process (Pelling 2011). Transformative adaptation, on the other hand, refers to actions aiming at adaptation to climate change resulting in significant changes in structure or function which go beyond existing practices (Pelling 2011). In other words, incremental adaptation aims at maintaining the status quo in spite of changes in the climate. Transformative adaptation aims at a new way of doing things that can be adopted at a large scale or by a large number of people, can lead to new strategies in a region, transform places or potentially shift locations.

These guiding questions do not only provide a framework for this first needs assessment. They will be applied throughout the project in the process of designing and implementing adaptation measures. They provide useful guidance for all involved partners regarding what steps should be taken and what aspects should be considered in order to design best possible adaptation solutions. This approach of checking for good quality adaptation constitutes one core component of the climate adaptation framework that will be applied throughout the project and will guide the framing of adaptation activities.

2.1.3 Analysis of stakeholder involvement and capacities

The involvement of relevant stakeholders should form an integral part of planning and implementing climate adaptation. Analysing who these stakeholders are, how they are being included in the adaptation process and what interests they represent is therefore a further component of this needs assessment.
Opposing interests can be a significant barrier to the success of climate adaptation. At the same time, to avoid unintended effects that could lead to maladaptation, the involvement of and discussion with relevant stakeholders is crucial. In this way, previously neglected information can be brought to the attention of those responsible for adaptation measures.
This part of the analysis will provide indications of where there might be a necessity to expand stakeholder involvement or what activities might be helpful in convincing relevant actors to participate in and support the projects' actions.
The main guiding questions for this component of the assessment are:

1. Who are the main regional stakeholders involved in climate adaptation? Who are the main opposing interests?
2. How are stakeholders being involved in the planning and implementation process?

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Lastly, the needs assessment analyses the existing institutional and financial capacities in the four regions and identifies the main capacity constraints. This step involves the consideration of current funding opportunities for adaptation and possible financial capacity constraints as well as institutional or other relevant capacity constraints.

2.2 Sources of data and information

2.2.1 Desk research

For this deliverable, an extensive desk research was conducted by adelphi. The most important sources consulted include

- Country profiles on the Climate-ADAPT platform,
- The 7th National Communications under the UNFCC,
- Information provided as part of the reporting under EU Governance Regulation 2018/1999
- Country fiches from the European Commission Adaptation Preparedness Scoreboard.

These documents provide information on national level adaptation policies, climate risks and institutional contexts. Further detailed information was collected from national adaptation strategies, action plans and, where possible, evaluations of adaptation policies. In some cases, these documents also look at the challenges and climate risks in specific regions, identifying hotspots for certain risks or particular regional challenges. They are therefore an important source for this analysis.

Another starting point for the desk research were documents mentioned in the RESIST proposal that provided crucial insights into the political, social and institutional context of the adaptation activities that are planned by the regional partners. Where available, regional climate plans and similar policy documents were consulted for the analysis. In addition, relevant scientific literature was included in the research wherever suitable.

2.2.2 Information provided by regional partners

Given the focus on the regional level, a crucial source of information were the regional partners themselves. To elicit the necessary information, a two-track approach was followed: First, a questionnaire was sent to the regional partners asking for important documents and information.
This questionnaire was designed in close cooperation with other partners from WP 1 and included information requests necessary for other tasks in this work package. To provide regional partners with one consolidated information request, questions by WP 1 partners were collected and aligned before finalizing the questionnaire. The full questionnaire that was designed as part of the needs assessment is included in Annex A: Questionnaire.

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To support the regional partners in responding to this information request, a virtual meeting was conducted with each LSD region to explain the process behind the questionnaire, its purpose and how the information collected from this questionnaire will be used. All LSD regions filled in the questionnaire and provided adelphi with valuable information and links to relevant resources.

Second, in order to collect supplementary information from the regional partners, virtual interview sessions were conducted by adelphi and KU Leuven in cooperation with WP 1 partners. These sessions were scheduled between May 26th and June 2nd and lasted for two hours. Participants in the meeting were sent a pre-read document with information about the purpose and agenda of the sessions as well as guiding questions that would structure the discussion between WP 1 partners and LSD regions. This pre-read document is included in Annex B: Information about virtual interview sessions.

2.2.3 ESPON Data

ESPON-CLIMATE is a project that aims to enhance the understanding of climate change impacts and vulnerability in European regions, including E27 countries (Switzerland, Iceland, Liechtenstein, Norway, and the United Kingdom) at NUTS 3 level[4]. The assessment was recently updated in 2022 based on the latest IPCC reports (AR5 and AR6), utilizing data from diverse sources such as satellite and census data. The ESPON-CLIMATE dataset is thus a comprehensive source of aggregated data that offers information on climate risks based on impact chains. The primary purpose of the ESPON-CLIMATE dataset is to assist policymakers, researchers, and stakeholders in comprehending the challenges and opportunities posed by climate change in Europe (Navarro et al. 2022).
The following list outlines the impact chains/ risk scenarios identified by the ESPON-CLIMATE Update 2022 based on the causal model of risk which were developed based on expert consultations and data assessments:

- Heat stress on population
- Coastal flood on infrastructure, industry and service sectors
- River flood on population
- River flood on infrastructure, industry and service sectors
- Flash floods on cultural sector
- Wildfire on environment
- Droughts on primary sector

[4] NUTS is the abbreviation for *Nomenclature of Territorial Units for Statistics* and was created by EUROSTAT do define the economic areas of the EU in specific territorial units based on population size of the regions (NUTS0: member states, NUTS1: major socio-economic regions (7 Mio.-3 Mio. inhabitants), NUTS2: basic regions (3 Mio.-800.000 inhabitants), NUTS3: small regions (800.000-150.000 inhabitants)). This serves the purpose of harmonizing the gathering of regional data and for creating and comparing statistics and analysis of socio-economic situations (https://ec.europa.eu/eurostat/documents/3859598/15193590/KS-GQ-22-010-EN-N.pdf/82e738dc-fe63-6594-8b2c-1b131ab3f877?t=1666687530717).

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Each impact chain in the assessment consists of hazard, exposure, and vulnerability (sensitivity and adaptive capacity) indicators. These are comprised of aggregated proxy variables. The selection of these proxy variables was based on scientific frameworks, normative decision on what is to be included and assessed and data availability. The data sources varied, depending on the type of indicators, including i.a. the Copernicus Climate Data Store, Risk Data hub, EUROSTAT GISCO, UNESCO, ESPON-TITAN and others, see Annex D: ESPON-CLIMATE: Data sources for more information (Navarro et al. 2022). Important to note is that only hazard indicators are projected for different emissions scenarios (RCP2.6, RCP4.5, and RCP8.5) for the time period of 2070-2100, not for vulnerability and exposure.

The ESPON-CLIMATE dataset can be a valuable resource for the RESIST project regions, providing additional information on climate risks. It allows for comparisons with regional climate risk assessments and offers insights into key hazards, exposure, and vulnerability for regions without regional-specific assessments. The indicators used in the dataset, described in Annex E: ESPON-CLIMATE: Framework of Impact Chains, contribute to a better understanding of the factors influencing climate risks. For each LSD region, the climate impact chains were extracted and analyzed. The results are presented within the chapters describing climate risks which are prevalent in the region and can assist in determining the priority areas that require specific attention due to the identified risks (Navarro et al. 2022). However further detailed, more context-specific analysis in the region is necessary to thoroughly examine and validate the results. In addition, the following limitations have to be considered. As mentioned above, projections based on the three RCP scenarios are only simulated for hazard indicators. Exposure, sensitivity and adaptive capacity are solely based on historical data. This can particularly lead to incorrect assumptions and interpretations when it comes to the aggregated risk indicator. Furthermore, uncertainty has to be taken into account for future scenarios regarding the hazard indicators (Navarro et al. 2022). The ESPON-dataset is thus used as a supplementary source of information about regional climate risk and vulnerability factors.

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3 Needs assessments for large-scale demonstrator regions

3.1 LSD 1: Southwest Finland

3.1.1 Introduction

Figure 2: Location of LSD 1 Southwest Finland.

With a population of 479,000, the region of Southwest Finland (SW Finland) is one of the most densely populated areas in Finland, in which a larger urban area is surrounded by a relatively dense but rural hinterland. The region comprises 27 municipalities, of which the largest city and administrative seat is Turku. Its landscape is characterised by a unique archipelago and fertile agricultural land. SW Finland is a high-income developed region with strong and diverse economic activities, i.a. in the field of pharmaceutical production, bioimaging and food production.

Located at the coast of the vulnerable Archipelago Sea, rising temperatures and changing precipitation patterns threaten marine ecosystems, urban agglomerations and rural, agricultural lands. Flooding, erosion, drought and heat stress are critical climate change related risks in SW Finland. Within RESIST, planned activities focus on nature-based solutions in the context of stormwater and sustainable water management. The measures will be designed and implemented in collaboration with local stakeholders and subsequent cost-benefit analysis will improve knowledge on the effectiveness and co-benefits of NbS.

3.1.2 Climate risks

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3.1.2.1 Regional climate risk assessments and identified risks

The central documents analysing climate change related risks in SW Finland are the "Suomen ilmastopaneeli Raportti 2/2021" (The Finnish Climate Change Panel Report; Gregow et al. 2021) for the regional level, and the Turku Climate Plan 2029 (Turku City Council 2018) for the City of Turku.

The report of the Finnish Climate Change Panel (hereafter abbreviated as FCCP) collected information on the temporal and local impacts of climate change and compiled tables on changes in weather, climate and marine factors for each of Finland's regions (see extract in **Error! Reference source not found.**). These include meteorological parameters of temperature and precipitation as well as marine factors such as sea surface temperature, salinity and medium water level. Special focus is laid on flood risks, comprising inland watercourse floods, flash floods and seawater floods. The impacts of the latter are assessed for all five Finnish sea and coastal areas, including the Archipelago Sea. The aim of the report is to illustrate what is already known about climate change impacts and adaptation, what calls for particular attention and where knowledge gaps exist.

Table 1: Extract of the table in the FCCP report
Extract of the table in the FCCP report of the table in the FCCP report evaluating changes in weather and climate factors in SW Finland towards the 2050s (Gregow et al. 2021). The symbols have the following meaning: '++' increasing/increasing at an alarming rate, '+' increasing/growing, '/' no significant change, '()' change uncertain, '—' decreasing significantly, '-' decreasing, and '' not known or insignificant.*

Variable	Winter	Spring	Summer	Autumn	Year
Average temperature	++	++	+	++	++
Precipitation	+	+	/	+	+
Thermal season length	--	+	+	+	*
Maximum daily temperature	++	++	+	++	++
Number of frosty days	-	--	-	--	--
Snow	--	--	*	--	--
Intensity of heavy rainfall	+	+	+	+	+
Wind speed	+	+	/	/	/
Amount of debris flow	--	--	*	*	--

Concerning weather and climate events, the report finds the past warming to continue, with a projected rise in average temperature of +1.8-3.0 °C by mid-century. Daily maximum temperatures will increase in all seasons while the number of frost days and average snow depth will decrease. Annual precipitation is expected to increase by 6-10 % until 2050 and heavy rainfall is expected to intensify.
The assessment of flood risks differentiates between inland watercourse, heavy rainfall associated and seawater flooding. The current risk of inland watercourse flooding is moderate and climate change is not projected to cause a major change in the region by 2050. However, the impact may vary by river basin, from a reduction in flood risk due to a decrease in spring floods to an increase in

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heavy rainfall and winter floods. Main risk areas in the region are Salo on the Uskelanjoki, Eura on the Eurajoki and Perniö along the Perniönjoki branch of the Kiskojoki. Flooding in these highly populated areas can jeopardize road transport links. Flash floods already pose a relatively high risk in SW Finland due to the high population density, the high number of paved surfaces and the topography. With increasing frequency and intensity of heavy rainfall, the risk of flash floods is expected to increase further in the future. The Turku coastal area is the central major seawater flood risk area in the region. Flooding events are rare but affect five hard-to-evacuate sites, as well as food and medical industry locations and sites subject to environmental permits. Climate change is not expected to change the likelihood of high sea levels in the Archipelago Sea substantially by 2050 and thus seawater flood risk is assumed to remain significant but not aggravating. Towards the end of the century, sea levels are projected to increase but these estimates are subject to considerable uncertainty.
According to the FCCP report, the Archipelago Sea is very vulnerable to climate change impacts caused by slow onset trends in marine temperature and salinity parameters as well as anthropogenic pollutant entry due to flooding. Rising sea surface temperatures and decreasing salinity threaten the Archipelago ecosystem, worsening the poor oxygen status of seabeds and causing stress to marine flora and fauna. Additionally, increased nutrient pollution from agriculture deteriorates the surface water status which, in combination with rising temperatures and decreasing salinity, i.a. leads to increased blue-green algae blooms.

Zooming further in on the region's largest city and administrative seat, the Turku Climate Plan 2029 (Turku City Council 2018) carried out an extensive analysis of climate change risks and vulnerabilities. It follows the SECAP guidelines (European Commission. Joint Research Centre. 2018) providing signatories of the Covenant of Mayors for Climate and Energy with a set of methodological principles, procedures and best practices. Concerning risk and vulnerability assessments, the guidelines recommend two different methodological approaches based on city size. For small to mid-size cities the indicator-based assessment consists of five steps: 1. exploratory analysis, 2. identification of climate hazards, 3. selection of indicators, 4. data gathering and processing and 5. assessment of vulnerability score. In Turku, the exploratory analysis was based on pertinent publications on city, regional and national level. Subsequently, risks posing a threat to the city were identified and evaluated with the help of expert interviews.
The Turku Climate Plan identifies two major sets of climate change related risks: risks related to water bodies and water management, and risks caused by changes in ecosystems. The future precipitation shift from summer to winter months is expected to increase nutrient pollution and consequently eutrophication of water bodies, river erosion and river bank failure potentially damaging urban infrastructure, and the need for irrigation during dry summer periods. In combination with a lack of green areas and absorption surfaces in the city, runoff water additionally poses a significant risk. Finally, an increase in intensity and frequency of storms together with rising sea levels was considered to increase the risk of flooding in Turku. Concerning ecosystems, climate change poses a significant threat to biodiversity, severely challenging green and blue infrastructure planning. The

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spreading of invasive species and diseases does not only affect ecosystems but also the urban population, especially vulnerable groups.
Building on the 2018 vulnerability assessment, the 2022 update of the Turku Climate Plan (Turku City Council 2022) revises and amends the identified climate risks based on recent national material, local explanations and expert assessments. The update expands the underlying methodology providing definitions of the key concepts according to the IPCC (2014) and listing identified city-level vulnerability and exposure factors in risk maps.
In addition to the two sets of risks already identified in the 2018 assessment – risks related to the water cycle and water management, and risks from ecosystem change – the update also includes risks related to heat and drought. The most significant climate change related threats in these clusters are heavy rainfall, flash and seawater flooding, and changes in the freeze-thaw cycle; biodiversity loss, forest diseases and pests; prolonged periods of heat and drought and the heat island effect.

In addition to these two main sources on climate change risks in SW Finland, the FCCP report and the Turku Climate Plan, the ESPON climate dataset (see 2.2.3) provides information on regional climate risks and the underlying components of hazards, exposure, vulnerability, sensitivity and adaptive capacity. For the baseline scenario (1981-2010), ESPON identifies the effects of droughts on agriculture and forestry to be the most significant risk, followed by impacts of flash and river flooding on cultural heritage and population, and environmental consequences from wildfires. Applying the high emission scenario (RCP8.5, 2070-2100) to the hazard component, droughts remain highly relevant but otherwise the ranking shifts: The impacts of coastal flooding on infrastructure and heat stress on population increase distinctly in relevance and become key risks while river and flash flooding as well as wildfires do not gain significance. This analysis of future risks must be viewed with caution, as the other underlying factors (i.e. exposure, vulnerability and adaptive capacity) are only considered in their baseline version though they will change significantly until the end of the century. However, the scenario analysis shows which hazards result in high risks if exposure and vulnerability are not reduced and thus indicates where adaptation measures gain relevance under a future changing climate.
The high significance of droughts on the primary sector stems from both high hazard indication and exposure. In the baseline scenario, the high ranking of flash floods is due to the hazard indicator; river floods on the contrary pose a material risk due to their high exposure. Shifting relevance under the RCP8.5 scenario results from shifting significance of the underlying hazards: until the end of the century coastal flooding and heat stress are expected to increase considerably.

Despite substantially different methodological approaches and setting aside diverging or unclear definitions of hazards and risks, the results of the analyses performed on the regional level and the ESPON project point in the same direction. All assessments identify flooding as a major climate change risk in the region. The analysis of the most pertinent form of flooding varies slightly but both flash and coastal floods are seen as key risks now and in the future. Heat stress, drought and

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ecosystem deterioration are identified as major future risks in two of the three sources. The FCCP report however falls short of including heat and drought in its analysis and thus runs behind the current assessment. Only the recent update of the Turku Climate Plan includes heat and drought as major risks (Turku City Council 2022). The focus of regional adaptation policies on flooding as the central climate change risk is also reflected in the measures planned within RESIST. However, both the development in regional documents as well as the expert interviews with regional partners reveal an increasing awareness for the topics of heat and drought.

3.1.2.2 Qualitative assessment of the regional CRA

Methodologically, the FCCP report does not follow a standard CRA scheme but collects and compiles existing information on climate change impacts and risks on the national and regional level. Most shortcomings thus stem from the lack of a clear climate risk analysis framework. Already concerning the definition of physical climate risk, the report does not refer to the common understanding of these risks as a function of a. hazards, b. exposure and c. vulnerability (IPCC 2022). Hence, it is not clearly indicated where the term 'risk' is used interchangeably for climate events and in how far exposure and vulnerability are considered in risk statements. Nevertheless, the report fulfils several requirements of a sound CRA by covering multiple scenarios (RCP2.6, 4.5 and 8.5), by considering both slow onset trends in temperature and rainfall as well as extreme events such as heavy rainfall and especially flooding, and by highlighting uncertainties and knowledge gaps. The report however does not systematically consider a wide variety of possible hazards and does not outline impact chains. For a comprehensive analysis, the assessment should rely on a clear risk framework integrating further climate and weather events and systematically analysing factors of exposure and vulnerability. The FCCP report serves as a good starting point for a further detailed assessment of both climate change risks and adaptation needs as it highlights major impacts and identifies knowledge gaps.

The climate change risk and vulnerability analysis in the 2018 version of the Turku Climate Plan 2029 (Turku City Council 2018) also does not apply a clear risk framework and does not perform all of the SECAP proposed steps. Comprehensive expert knowledge is not consolidated with further municipal (spatial) data and factors of exposure and vulnerability remain unclear. On the other hand, the report touches on a wide range of climate-related hazards, considers different time frames and includes a rating of the reliability of the assessment. The analysis partially outlines impact chains and, for some risks, points out more or most affected regions in the city.
Most of the shortcomings of the first initial assessment are addressed in the 2022 update of the Climate Plan (Turku City Council 2022), underlining that a climate risk assessment is an on-going and recurring process. The 2022 update provides a clear risk framework and points out city-level vulnerability and exposure factors for each of the major climate hazards. The list of considered hazards is expanded significantly and the most vulnerable city sectors are identified. The terms 'hazard' and 'risk' are still sometimes used interchangeably and thus the level of aggregation is not always clear. This might be resolved in the further development of the assessment: The City of Turku

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already plans its next steps, including work on the definition of monitoring indicators and further analysis of vulnerabilities.

The largest needs to performing a comprehensive climate risk assessment in LSD1 lie in a clear definition of the underlying risk framework which differentiates between hazards/climate events and risks. This would also facilitate a broader analysis of vulnerable groups and the identification of cause-effect-relationships and impact chains. The update of the Turku Climate Plan already integrates a wide range of climate-related hazards, which would similarly be desirable for the assessment on the regional level.

3.1.3 Adaptation measures

3.1.3.1 Existing plans and measures

Finland's first National Strategy for Adaptation to Climate Change was adopted in 2005. Besides describing possible future climate change scenarios and its impacts on 15 sectors, it outlines actions and measures to improve the capacity to adapt to future climate change (Ministry of Agriculture and Forestry of Finland 2005). It was superseded by the National Adaptation Plan 2022 (NAP) in 2014, implementing the EU Strategy on Adaptation in Finland. The NAP formulates three key objectives in the field of social and institutional climate adaptation: integrating climate adaptation into planning, providing access to climate change assessments and management methods, and enhancing adaptive capacity through capacity building. Corresponding measures to reach the goals thus focus on soft actions such as mainstreaming climate adaptation into national and international strategies, supporting research and development as well as intensifying communication, education and training (Ministry of Agriculture and Forestry of Finland 2014). As the time period covered by the NAP expired, a new Adaptation Plan was adopted on 15 December 2022, guiding the adaptation actions until 2030 (Suomen valtioneuvosto 2022). The so-called KISS 2030 (from "Kansallinen ilmastonmuutokseen sopeutumissuunnitelma") sets out a vision and three goals towards which adaptation work will be taken in the long term. Two chapters are devoted to the analysis of vulnerable population groups as well as institutional vulnerability.
Long-term prosperity and security in a changing climate are meant to be ensured by 1. building a strong will among society's actors to adapt, 2. establishing effective means to assess, prevent and manage climate change risks, and 3. increasing adaptive capacity. These goals are backed by 24 climate change adaptation objectives and corresponding actions, ranging from strategic planning and anticipation to protecting and promoting health. All measures include a description of responsible parties, time frame and funding. The new target structure in KISS 2030 shows the advancement of the national adaptation strategy from a rough description of possible measures in relevant sectors in 2005 to a clear vision and objective-based actions in 2022. In addition to this advancement in terms of strategy and target setting, the FCCP report also points to a shifting baseline in climate adaptation as successful actions in the past already reduced the threat of certain hazards, especially flooding, in former high-risk areas (Gregow et al. 2021).

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In the current National Adaptation Plan, objectives 16-18 “Managing climate risks at regional and local level” are particularly relevant for regional adaptation in SW Finland. In this context, KISS 2030 diagnoses two major gaps in adaptation planning: the substantially larger role of mitigation and the focus on very few sectors, mainly technical rainwater and stormwater management. On the other hand, central actors and levers for regional and municipal adaptation are identified including the key role of the Centres for Economic Development, Transport and the Environment (ELY Centres) as well as regional forums for cooperation and coordination on preparedness and safety. Proposed measures focus on developing guidance for regions and municipalities on risk assessments and implementation of adaptation, mainstreaming climate adaptation into national and regional policies and strengthening vertical cooperation (Suomen valtioneuvosto 2022).

Regional climate strategies and programmes were developed in the early 2010s but focused mainly on climate change mitigation (Gregow et al. 2021). This trend continues in the most recent climate policy documents in SW Finland. The Climate Roadmap states the need for climate adaptation in the region but out of 21 key topics with several corresponding actions, only three measures concern climate adaptation: improving water management of agricultural land, increasing research and pilots in climate adaptive construction, and identifying the climate change impacts and opportunities for stakeholders in river basins (Varsinais-Suomen liitto et al. 2023). Similarly, the SW Finland Regional Strategy 2040+ identifies threats of climate change to the water cycle, the built environment, flood risk management and the food sector but only marginally includes adaptation measures in its Regional Programme (Varsinais-Suomen liitto 2021). However, sector-specific strategies such as the Regional Forest Programme (Suomen metsäkeskus 2020), the Water Management Strategy for Western Finland 2050 (Etelä-Savon ELY-keskus 2021) and the Regional Stormwater management plan for the municipalities Turku, Kaarina, Lieto, Raisio and Rusko (City of Turku et al. 2014) develop adaptation measures to selected hazards. This fact points to the largest gap in existing regional climate change adaptation: the need for consolidation of existing measures and integration into a cross-sectoral strategy.

Consolidating the overall view of adaptation measures and continuous functioning of regional collaboration are also identified as the main challenges concerning climate adaptation in the Turku Climate Plan 2029 (Turku City Council 2018). Building on the measures formulated in 2018, the 2022 update of the Turku Climate Plan largely extends the scope and systemizes proposed measures. The plan contains actions for the risks identified as most relevant for the City of Turku, i.e. water and water management, ecosystem change as well as heat and drought (also see 3.1.2.1). The majority of the measures are of general nature, presenting more of a goal to be achieved and lacking detailed and concrete elaboration. However, the advancement of the Turku Climate Plan in terms of risk analysis (see 3.1.2.1) and adaptation action planning is already moving towards a more systematic adaptation management. Formulating specific objectives, establishing – as planned – a related monitoring and specifying concrete measures will promote climate adaptation in Turku further. This will also allow for a systematic consideration of gender-sensitive approaches and the needs of

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vulnerable communities. The focus on nature-based solutions should be maintained and strengthened further.

3.1.3.2 Planned adaptation measures within RESIST

Planned adaptation measures within RESIST focus on nature-based solutions for stormwater and sustainable water management in three demonstration sites. The sites were chosen to cover a variety of land use groups (urban residential, urban industrial, rural), main stakeholders (citizens, local companies, farmers) and water management challenges (water quantity, water quality).
In the Rauvolanlahti residential area, implementing nature-based stormwater solutions shall support ecosystem services in the drainage basin which discharges to a nature conservation area. The activities include drafting of the drainage-basin based stormwater plan in co-creation with local citizens and restauration of main ditches using NbS. Additionally, the ecosystem services of stormwater retention, biodiversity and recreation will be assessed in a cost-benefit analysis (CBA) to improve knowledge on the effectiveness of NbS and increase motivation of multiple rural and urban stakeholders to design and invest in NbS.
The stormwater system in the Oriketo industrial area shall be renovated and redesigned based on innovative technical solutions and collaboration with the local businesses. While precising the technical renovation plans, the suitability of NbS will also be assessed. The aim is to negotiate and plan a joint stormwater treatment solution reducing hazardous pollution in the area.
In the rural small-scale drainage basin of Savijoki river, NbS shall be implemented in the sub-catchment to restore the hydrological balance, abate effects of floods and droughts and reduce nutrient releases to the vulnerable Archipelago Sea. Activities include engaging in a dialogue with stakeholders, establishing a drainage-basin specific multi-beneficial water retention plan and assessing the cost-benefit-effectiveness of NbS.

The regional partners pointed out that planning is still in its early stages and will be further developed during the project. On the one hand, this limits the ability to conduct a profound analysis of the measures in terms of effectiveness, inclusion of vulnerable groups and transformational potential (see 2.1.2). On the other hand, determining main questions and considerations at this early stage allows for their integration in the primal planning phase.
Flooding was identified as a major climate change risk in SW Finland, along with heat stress, drought and ecosystem deterioration (see 3.1.2.1). Addressing stormwater floods in combination with drought and ecosystem degradation focuses on these key risks and enables co-benefits, especially as NbS are prioritised at the demonstration sites. Performing an ex post cost-benefit analysis allows to evaluate the effectiveness of the measures.
Concerning gender-sensitivity, vulnerable groups and social equity impacts, the current planning does not point to an explicit consideration of vulnerability factors such as race, class, sexual orientation and identification, national origin, and income inequality. Nevertheless, planned dialogue and co-creation activities provide an excellent basis to include the needs of particularly vulnerable population groups and design the measures accordingly. The analysis of vulnerable groups in

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KISS2030 could be a starting point. Similarly, the matter of maladaptation can be addressed in the further process, with the self-assessment checklist developed within the project REGILIENCE as a great tool to evaluate the maladaptation potential of planned adaptation actions (Institute for European Energy and Climate Policy (IEECP) et al.; see 2.1.2).
Currently, the planned measures classify as incremental adaptation as they focus on local sites, are based on NbS that have already been established as solutions in similar contexts and do not alter the original land use. However, transformative potential lies in the design of the co-creation process and the results of the cost-benefit analysis. Building on these impulses alongside institutional and policy innovations could allow for more profound transformations.

The main need for successful implementation of the activities at present is to develop further details about implementation of measures while integrating potential impacts for most vulnerable groups, including the gender dimension. According to the regional partners, it might prove a challenge to convince essential stakeholders and the wider community of the adaptation necessity and accompanying benefits. When plans have evolved further, a detailed ex-ante assessment of planned measures is necessary to anticipate possible side effects and avoid maladaptation. Finally, the above-mentioned potential for innovative and transformative adaptation should be taken into account in the further design of these and additional measures.

3.1.4 Stakeholders and community engagement

The necessity of stakeholder and community engagement to support successful implementation and future up-scaling of the adaptation measures is uncontested. In the context of capacity building and transferability, it is well designed that all three demonstration sites concern different groups of actors. In Rauvolanlahti key stakeholders besides the city of Turku are the 4,500 inhabitants of the area. The concerned actors in Oriketo are local companies and the regional ELY centre which is responsible for a wide range of tasks relevant to climate change adaptation, especially in the area of business and industry as well as environment and natural resources. In the rural catchment of the Savijoki river, main stakeholders are farmers and forest owners, but also citizens and the ELY centre.

As already stated, planning is still in its early stage. The regional partners have identified key stakeholders but have not yet established a structured engagement format. Currently, there is no indication of major opposing interests and the hope is that any such challenges can be met by creating a win-win situation through well-designed adaptation measures.
In Rauvolanlahti, residents, recreational users, a club for small-scale farming, and potentially residential clubs and birdwatchers will be involved in the process. The first step is to conduct on-site surveys on recreational use of the site including questions on the personal background, i.e. gender, age, professional background and education which also holds potential for considering needs of vulnerable groups. Additionally, the regional partners plan focus group discussions with vulnerable groups that cannot access surveys such as small children and elderly people. The Oriketo pilot site will involve collaboration with local businesses to discuss innovative measures for the open area.

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According to the regional partners, the companies are already marginally managing stormwater on their own but the measures planned within RESIST have not been presented to them yet. Consequently, without knowledge of their reaction to the propositions, no strategy yet exists on how to convince the businesses to expand their activities and support implementation. Similarly, the main stakeholders in the Savijoki area, the private landowners who are mainly farmers, are not yet actively involved in the activities. In order to convince and engage them in the creation of NbS, field days and excursions to good practice NbS pilot sites are planned. Currently, no plans exist on how to involve vulnerable groups with the main focus group being private landowners.
At this stage, two main questions should be addressed concerning stakeholder engagement: How can vulnerable groups be included adequately in the process? And how can the process truly enable co-creation of adaptation actions?

Beyond the three pilot sites, the regional partners expressed the need for more regional coordination. They plan to have meetings and workshops with national ministries of e.g. agriculture, forestry, environment etc. to build on national experience and knowledge on a regional level, but also with regional stakeholders such as associations of farmers or the Finnish Forest Center. Furthermore, other municipalities in the region were identified as additional potential stakeholders as they have previously expressed interest in Turku's plans. However, stakeholder involvement and community engagement is not planned to become a more formalized commitment in the area. Without this institutionalization, it will prove difficult to establish long-term collaboration beyond current measures and pilot sites.

3.1.5 Capacity and capacity constraints

Financial capacity is generally identified as one of the most pertinent constraints on climate change adaptation. Lack of funding also plays a vital role for LSD1, especially as the envisaged NbS are perceived as more expensive than traditional grey infrastructure. In Oriketo, financial contribution of local businesses is hoped for but insufficient understanding of the multiple benefits and value of ecosystem services that NbS can provide impedes private investment. All regional partners agree that both more public funding is needed for climate change adaptation as well as incentivising private sector funding. Planned changes in legislation concerning water quality might already provide such an incentive in the context of sustainable industrial and agricultural water management. Cost-benefit analysis in Rauvolanlahti and the Savijoki catchment shall build the basis to overcome general reservations about NbS and help promote the wider uptake of these solutions.

As far as organizational or institutional capability is concerned, several challenges were identified at regional workshops and municipal surveys in the context of the Government analysis of adaptation in Finland (Hildén et al. 2022):

- **Unclear responsibilities and roles:** The unclear division of work between regional adaptation actors, underdeveloped cooperation between regions, sectors and relevant

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stakeholders as well as different perceptions of the role of regional councils and ELY centres impede effective adaptation policy.

- **Lack of political regulation**: An absence of legislative obligation, gaps in policies and regulation, and the voluntary nature of guidance hinder broad and concordant adaptation work.
- **Dominance of short-term projects**: As adaptation work is often project-based, implementation, continuity, monitoring, learning and knowledge sharing is not secured, and own funding and resources are required.
- **Lack of detailed information and guidelines**: In terms of available information, there is a lack of high-resolution regional and local data, and only incomplete or superficial knowledge on costs and benefits of climate change impacts and adaptation action, especially in the context of innovative NbS.
- **Fragmentation of monitoring and evaluation of effectiveness**: No comprehensive, common monitoring framework exists and assessments of the effectiveness of adaptation measures follow different approaches.

The regional partners confirmed that all of the above-mentioned challenges were areas of concern within their work, several of which they are hoping to address within the project. Additionally, they found a lack of awareness for climate change impacts and the necessity to adapt, insufficient know-how on NbS as well as fragmented ownership of land and poor capacity of local water protection associations/private landowners to apply for national funding to hamper regional climate change adaptation.

Based on this analysis of constraints, LSD1 has put an explicit focus on addressing several of these challenges within RESIST. Stakeholder engagement, cost-benefit analysis and the general promotion of NbS can help increase adaptive capacity regarding awareness raising and knowledge building. At the same time, certain policy and governance constraints can only be removed in a coordinated effort on the regional and national level.

3.1.6 Going beyond RESIST

RESIST aims at developing innovative solutions that can be scaled up beyond individual measures planned in the regions and assist systemic adaptation beyond the project context. For LSD1, RESIST is both an opportunity to explore co-created nature-based sustainable water management solutions in different land use and stakeholder contexts as well as the chance for capacity building feeding into further advancement of climate adaptation in SW Finland. How can stakeholder engagement be organised and managed to enable an inclusive, collaborative process? How can measures be designed to promote the positive impacts that NbS can create for vulnerable groups? How can the results of the cost-benefit analysis be generalized and communicated beyond the pilot projects?

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Integrating these questions at the current planning status can help to overcome several of the above-mentioned constraints, such as lack of awareness, limited knowledge and hesitation for financing. Furthermore, building and institutionalising collaborative platforms are an important resource to enhance regional actors' abilities to formulate, implement, and monitor adaptation actions.

In order to exploit the full potential, it is also vital to understand how climate change adaptation can be integrated within existing frameworks or where policy reforms are necessary. The new Finnish Climate Change Act (Ministry of the Environment of Finland 2022) was supplemented with an obligation for municipalities to draw up climate plans that set mitigation targets and corresponding measures. It is a notable development that municipal climate policy is now included in the national act, but as climate adaptation remains unaddressed in these obligations, incorporating adaptation targets and actions is solely voluntary.
Similarly, the revision of the Land Use and Building Act (Ministry of the Environment of Finland 2025) focused on bringing climate change mitigation comprehensively into construction legislation but neglected climate change adaptation. However, regional and local land use planning are powerful levers to systematically integrate and scale up nature-based solutions. Mainstreaming climate adaptation into Regional Plans and Local Master Plans is a prerequisite for systemic adaptation. Generally, regional and local development strategies such as the Regional Programmes should integrate climate change adaptation thoroughly. The overall goal should be to look beyond individual adaptation measures and aim for a comprehensive approach that encourages progress in governance as well as access to finance, analytics and technology.

3.1.7 Results

Current climate risk assessments on the regional level could be improved by clearly defining the underlying risk framework and considering a wide range of weather and climate events, both slow onset trends and hazards. Additionally, special focus should be laid on the analysis of vulnerable groups and the identification of cause-effect-relationships and impact chains.
At the current planning status, the largest need is to integrate dimensions of vulnerability, such as gender and socio-economic status, in the layout of the measures at the three demonstration sites, and to design the stakeholder engagement processes in an inclusive and collaborative way. When plans have evolved further, the measures should be checked for possible negative side effects and the potential of maladaptation. Simultaneously, later up-scaling can be supported if questions like "How can the results of the cost-benefit analysis be generalized and communicated beyond the pilot projects?" or "How can learnings from the inclusion of vulnerable groups and experiences with stakeholder engagement help other regions?" are kept in mind during design and implementation of measures.
The greatest challenge to creating more systemic solutions is bridging the gap between existing individual measures and establishing a long-term cross-sectoral adaptation strategy. Impulses from the co-creation processes and the results of the cost-benefit analysis can provide a momentum for upscaling solutions but institutional and policy innovations are needed to allow for more profound

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transformations: profit from the growing regional coordination and collaboration within RESIST to institutionalize vertical exchange and local stakeholder and community engagement, use results of the cost-benefit analysis to convince central actors of creating financial framework conditions of public and private investment for nature-based solutions, and finally advocate for the further integration of climate change adaptation into climate legislation, regional and local development strategies and land use planning.

adelphi can offer support in integrating the consideration of gender aspects and the needs of particularly vulnerable population groups in the design of the adaptation measures. The development and application of the ethics and gender framework by ESF can provide additional guidance. Furthermore, adelphi can assist in communicating with and convincing stakeholders that might be opposed, and give advice on how to ensure the design of solutions avoids maladaptation. The regional partners pointed out that they are also very interested in the adaptation action platform that the KU Leuven is currently establishing to help regions access relevant information on adaptation measures, data and tools through an easy to use interface. In this context, KU Leuven will identify similar practices and initiatives in other regions of Europe and provide a mechanism to compare different adaptation projects. The immersive Graphical Digital Twin developed by AugmentCity was also met with great interest. Visualizing planned adaptation solutions can help convince stakeholders to support the measures and enable vivid exchange and co-creation. Additionally, FASTTRACK can help map and endorse private investment opportunities, especially in the industrial area of Oriketo. Through transformative social innovation and reflexive regional change processes guided by ZSI, the regional partners can be supported in exploiting the transformative potential that lies within RESIST.

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3.2 LSD 2: Central Denmark

3.2.1 Introduction

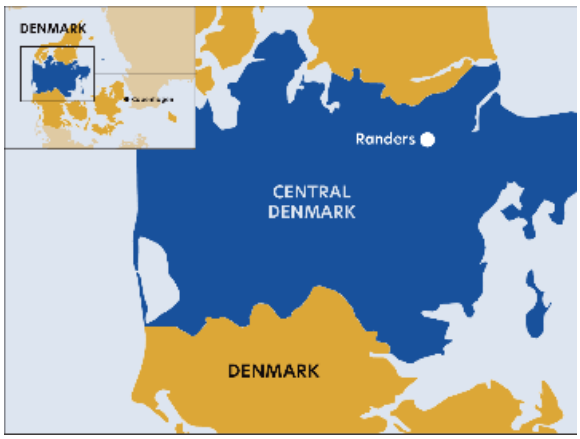

Figure 3: Location of LSD 2 Central Denmark.

As stated in the RESIST proposal, Denmark is a high-income country and is administratively divided into five regions of which Central Denmark Region (CDR) administers the central part of the Jutland peninsula with 1,300,000 inhabitants (23% of Denmark's population). The CDR encompasses a variety of landscapes, including coastal areas, forests, and agricultural lands. The region is home to Denmark's second-largest city, Aarhus, as well as numerous smaller towns and rural communities. This geographical diversity poses various climate risks, including flooding along the coastal areas and potential drought or heat-related issues in the more inland-oriented agricultural zones. The region's urban centres, such as Aarhus and Randers, might also face unique climate challenges related to heat islands and stormwater management.

As for climate, the Central Denmark Region experiences a temperate oceanic climate, characterized by moderate temperatures, with cool summers and mild winters, and relatively high precipitation throughout the year. Given the region's proximity to the sea, it's particularly susceptible to sea level rise and coastal flooding, which are expected to be exacerbated by climate change. Changes in precipitation patterns could also impact agricultural productivity and water management in the region. Furthermore, the presence of culturally significant sites and infrastructure in areas at risk of flooding, such as Randers, adds another layer of complexity to the region's climate risks.

The Central Denmark demonstration activities focus on four main areas, implemented across four municipalities (Lemvig Municipality, Hedensted Municipality, Horsens Municipality, and Randers Municipality):

1. The first area involves the construction of a dense network of IoT data loggers for groundwater level measurement in coastal towns and urban areas, and the construction of

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demonstration buildings that can resist flooding. This includes the introduction of three multi-functional infrastructures for flood prevention.
2. The second focus is on decision-support systems, including the creation of local XR visualizations and a warning system app developed through machine learning and IoT data.
3. In order to further develop the "BEST Adapt" tool, which supports prioritization of climate change adaptation (CCA) investments, data from three additional flood sources will be added, along with a recreational value of these investments.
4. The final component includes the transfer of best practices. This will entail assessing the governance system, analysing the regulatory framework, and identifying mechanisms that accelerate CCA implementation. A handbook for CCA officials will be developed to accelerate local CCA in the EU, with plans to upscale results across the region.

3.2.2 Climate risks

Notably, no climate risk assessment exists on the regional level for Central Denmark. Denmark's national level strategies and policy papers related to climate adaptation, e.g. "Danish strategy for adaptation to a changing climate" 2008 (The Danish Government 2008) or the "Mapping climate change" – background report (Danish Nature Agency 2012) do identify climate risks, but also lack regional specifications on climate risks, making it hard to apply findings directly to the Central Denmark Region. Therefore, the focus of climate risk assessment and management falls on municipalities, which are required to develop their own plans.

3.2.2.1 Municipal CRA

In 2013, all municipalities in Denmark were mandated to produce municipal climate adaptation action plans. These plans were meant to specifically include risk mapping for flooding, as it presents a hazard of significant concern due to Denmark's geographical location, mostly flat topography and climate conditions. This municipal obligation has been supported in 2020 by a nationwide risk assessment in the form of the "Kystplanlægger"-webportal (Kystdirektoratet), which was published by the Danish Coastal Authority. It presents mapping of risks from floods and coastal erosion along the entire coastline for the years 2020, 2070 and 2120 and provides recommendations for municipal planning authorities on risk reduction and coastal protection for every coastal unit (see **Error! Reference source not found.**). In general, municipal risk assessments mainly – or even exclusively – focus on flood risk management, but not on assessing a broader range of climate risks. This strong focus on flooding and sea level rise is a common theme throughout Denmark's climate adaptation related strategies and policy papers on different political levels (see chapter 3.2.3.1). There is less emphasis on other climate hazards such as heat and drought, leading to a potential information gap for some municipalities. Although expert interviews with regional partners revealed an increasing awareness of heat and drought as new and emerging challenges, the existing lack of data for such risks may limit risk assessments to simply mapping areas at risks from heat and drought.

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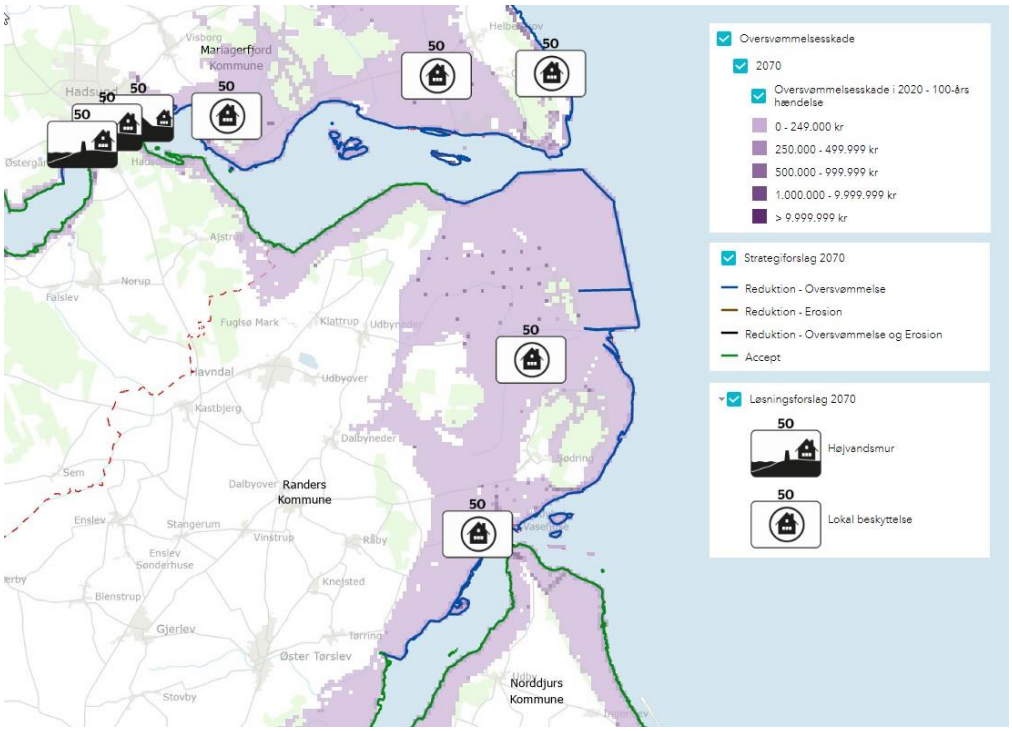

Figure 4: "Kystplanlægger" webportal mapping risk from flood and erosion and providing recommendations

In the Central Denmark Region, municipal climate risk assessments for three RESIST pilot areas are pertinent. Each of these assessments focuses on specific areas within the region, addressing local climate risks and providing strategies for mitigation and adaptation.

The RESIST pilot municipality "Randers City" developed a flood risk assessment for the period 2021-2027 (Oversvømmelsesdirektivet 2021) based on two different climate scenarios: a 100-year flood event in 2019, and a 100-year flood event projected for the year 2115. The assessment showed that the city centre of Randers City is most vulnerable to flooding, with an estimated 200 properties significantly impacted. Critical points include environmentally harmful companies and cultural heritage sites. Based on these findings, the municipality has developed plans to reduce flood impacts, avoid damage to properties, and prevent future floods.

Another RESIST pilot municipality "Norddjurs" developed a risk management plan for the whole Randers Fjord risk area (Norddjurs Kommune) for the same period 2021-2027 and used another three scenarios: a 100-year storm surge event in 2019, another one in year 2065 with a water level of 1.97m and third one in year 2115 with a water level of 2.40m (both under the RCP 8.5 scenario). It provides hazards maps on potentially flooded areas, damage maps on the calculated costs of floods and risk maps on the annual costs of floods. Most severe risks are related to damaging of infrastructure and buildings, traffic networks being affected and dyke stability remaining unclear, with

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implications or securing homes in dammed areas. Based on these findings, the plan formulates measures of prevention (e.g. preventive planning, new land use), protection (e.g. dykes, high water walls, buffer areas, citizen dialogue) and preparedness (e.g. coordinated warning and emergency response).

The third RESIST pilot area "Juelsminde" published a "Reassessment and update of the flood risk assessment plan" (Oversvømmelsesdirektivet 2021b) for the same period 2021-2017, also referring to 100-year storm surge events in 2019, 2065 and 2115 as well as low, medium and high probability scenarios of flooding, as used in the initial plan. The reassessment showed that the pre-developed plan has met its goals of protecting the city against flood events, but recommends to implement measures that secure the city's safeguarding up to higher water levels than is currently the case: instead of protection up until water levels of 1.80 m (currently), future measures should ensure protection against water levels of up to 2.50 m, and on a more long-term perspective even be prepared for water levels up to 2.88m/3.05m. Accordingly, the Juelsminde reassessment plan clearly refers to the increasing threat of sea level rise in Central Denmark.

It becomes clear that none of these municipal risk assessments address climate risks on a broader scale and also do not recommend to do so in future reassessments, but continue to follow the dominant focus on flood risks. However, some municipalities have extended, at least, their climate adaptation plans to include other climate-related issues such as heat and drought, e.g. Hedensted Municipality's "Climate Plan 2050" from 2022 (Hedensted Kommune 2022). These climate adaptation plans are part of the Climate Adaptation Planning (CAP) Framework developed by C40. Nevertheless, there is limited data available for heat and droughts (i.e. not enough high-quality data for a comprehensive cost-benefit analysis for heat risks). Therefore, municipal risk assessments continue to focus on mapping areas at risk from heat or drought.

3.2.2.2 Comparison with risks according to the ESPON-CLIMATE dataset

Since no climate risk assessment exists for Central Denmark Region, the ESPON-CLIMATE dataset is a valuable supplementary source of information on regional climate risks (see chapter 2.2.3). For the baseline scenario (1981-2010), ESPON identifies the effects of drought risks in the primary sector to be the most significant risk. These drought-related risks occur on a medium risk level and are expected to stay at that same level under the RCP8.5 scenario (2070-2100). This risk impact chain appears widely unconsidered among the existing climate risk assessments in Denmark and thus may represent a considerable information gap that needs specific attention as an additional priority area in future risk assessments, especially on the municipal level.

Furthermore, the ESPON dataset reveals several flood-related risk impact chains for Central Denmark. The highest flood-risks in the baseline scenario (1981-2010) come from river floods affecting the population and from flash floods affecting the cultural sector, followed by risks from river floods affecting infrastructure, industry and the service sector. All these flood-related risks are expected to increase to a medium or slightly higher risk level under the RCP8.5 scenario. An outstanding role is played by coastal floods and their impacts on infrastructure, industry and service

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sectors. Coastal floods show the strongest increase in risk between the baseline scenario and the RCP8.5 scenario. Coastal floods are currently on a comparatively low risk level (baseline scenario), but are expected to escalate to an extent in the future (RCP 8.5 scenario, 2070-2100) so that they exceed the medium risk level and even surpass all other impact chains. The currently dominant focus on flood-related risks throughout Denmark's national policy papers and municipal action plans and risk assessments well reflects the increasing climate risks that have also been identified in this area by ESPON. However, one should highlight again that risks related to drought (on the primary sector) and heat stress (on the population) will exceed medium risk levels as well and need to be considered accordingly in Denmark's landscape of risk assessments.

While referring to ESPON data, one should note that the aggregated risk indicators used only partly contain projected data for the future, but mostly rely on historical data (see chapter 2.2.3) and thus might contain incorrect assumptions.

Summarizing the different perspectives on assessing climate risks in the Central Denmark Region, one can note that the municipal risk assessments (as described in chapter 3.2.2.1) are mostly in alignment with the ESPON dataset. ESPON expects increasing risks from all types of floods in the Central Denmark Region and Danish municipalities put great effort into getting prepared for these scenarios and assessing flood risks accordingly. But where ESPON data and the current way of undertaking municipal risk assessments diverge strongly, is the aspect of drought stress (on the primary sector) and heat stress (on the population). These climate risks are expected to become significant – or even the most pressing – regional risks in the future. However, current risk assessments approach in Denmark and its municipalities fall short of integrating these climate risks. Interviews revealed an increasing awareness about this information gap.

3.2.3 Adaptation measures

3.2.3.1 Existing plans and measures

Denmark does not have a National Climate Adaptation Plan currently, but various stakeholders expect such a guiding policy paper to be formulated by the Danish government in the near future. Currently, no political dialogue seems to be ongoing to push the process forward. However, a "Danish Strategy for Adaptation to Changing Climate" (The Danish Government 2008) has been formulated, which identifies various climate hazards under three different climate scenarios (A2, B2 and EU2C) nationwide until mid-century and end of century and respective vulnerabilities and possible measures in 11 significantly affected key sectors (coastal management, buildings and infrastructure, water supply, energy supply, agriculture and forestry, fisheries, nature management, land use planning, health, rescue preparedness and insurance aspects). The strategy sets three main objectives which represent rather soft measures: 1) an information campaign including a web portal (for climate change integration into planning and development), 2) a (climate) research

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strategy as well as 3) an organizational framework including horizontal coordination among public authorities.

The national assessment report “Mapping Climate Change – Barriers and Opportunities for Action” (Danish Nature Agency 2012) presents the most important positive and negative impacts of climate change in Denmark for 14 different areas (housing and infrastructure, coasts and ports, transport, water, agriculture, forestry, fisheries, energy, tourism, nature, human health, emergency preparedness, insurance, spatial planning). For all mentioned areas, it provides an overview of adaptation possibilities, bodies of responsibilities, ongoing and completed initiatives as well as barriers and opportunities for adaptation. It also puts emphasis on the importance of a socio-economic analysis on climate adaptation that reveals its cost-benefit-dynamics.

Based on these policy papers, the “Action Plan for a climate proof Denmark” (The Danish Government 2012) presents 64 concrete initiatives that should support implementation of Denmark’s climate adaptation efforts. These initiatives are grounded in five general areas: 1) improving the climate adaptation framework; 2) expanding consultation and developing a new knowledge base; 3) strengthening collaboration and coordination; 4) advancing the green transition and 5) adapting to climate change at the international level. In this national action plan, Denmark’s municipalities are mandated to prepare both municipal climate change adaptation plans (including municipal wastewater utilities’ flood risk assessments under A1B climate scenario) and to carry out risk assessments, which must assess flood risks specifically (based on nationwide blue-spot maps (i.e. road infrastructure vulnerable to flooding) provided by the Ministry of Environment). So here it becomes clear again that Denmark’s landscape of policy documents sets a clear focus on flood risks in the country’s strategic climate adaptation efforts.

Regional level climate policies and strategies have been published under the project C2C CC (“Coast to Coast Climate Challenge”), which lasted for a duration of 6 years between 2017 and 2022 and has been managed by the Central Denmark Region. The “Common Strategy & After LIFE plan” (Coast to Coast Climate Challenge (C2CCC) 2022) is a publication on behalf of all 31 project partners, including 18 municipalities, 3 knowledge institutions and several private organisations, that collected regional experiences related to climate adaptation and formulates 1) main principles for guiding future efforts in climate adaptation, 2) a reflection of the future adaptation agenda with a collection of themes that are expected to characterize future adaptation, 3) next steps for 24 sub-projects (mainly in the Central Denmark Region) spanning the whole water cycle, as well as 4) an action plan called “After LIFE”, which comprises a selection of projects stemming from the C2C CC project on an international, national, regional and local level and further details on e.g. time planning and the status of initiation. The C2C CC sub-projects are further detailed in the so-called “Layman’s report” (Coast to Coast Climate Challenge (C2CCC) 2022), including tool development for municipalities, groundwater management, innovation rainwater usage, dialogue between local stakeholders, joint municipal risk assessment and management etc.

Additional projects which plan or implement adaptation measures in the Central Denmark Region – and are directly connected to the C2C CC project mostly – include the following: “BioScape”

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(improving Biodiversity in the landScape) is a project that aims improving the government's pilot programme for multifunctional land consolidation, which includes Horsens, Lemvig and Hedensted as municipal partners among others, and which includes adaptation measures e.g. delaying water in the hinterland, re-meandering streams and reducing flooding, combined with strengthening biodiversity. "Blue Transition" is another project in the region and in parts focuses on holistic water management, protection of groundwater resources, on salt water intrusion and the interaction between sea level rise and shallow groundwater. "ENCORE" (Environmental Conference of the Regions of Europe) is a project that focuses on the outstanding role of regions and focuses on creating a dialogue among EU regions and with relevant EU directorates on environmental and sustainability issues and climate action. Another very relevant project has not yet started and remains in the proposal phase until 2024: "LIFE SIP" aims at elevating and promoting the actual implementation of all Danish municipalities' DK2020 Climate Plans on both mitigation and adaptation and to create a broad network for knowledge exchange.

Looking at this set of policy documents as well as existing projects and their respectively formulated adaptation measures, one can note a few important aspects that are worth being considered while conceptualizing climate adaptation efforts and measures, are actually missing. A gender-sensitive or vulnerable groups-sensitive approach to climate adaptation is currently not present in Denmark's adaptation efforts. Social equity topics in general seem rather unaddressed in the identified documents. Also, projects and the integration and consideration of Nature-based Solutions (NbS) appears selective rather than across the board. Potential maladaptation cannot be excluded e.g. due to the rather narrow focus of Denmark's adaptation efforts on flood-related risks, instead of a broader spectrum of climate risks.

3.2.3.2 Planned adaptation measures within RESIST

The measures within RESIST in Central Denmark are set to take part in several locations, including Lemvig Municipality, Hedensted Municipality, Horsens Municipality, and Randers Municipality. The final pilot locations and activities in each of these municipalities are currently in the process to be clarified. The project's main focus is on water-related risks such as sea level rise, saltwater intrusion, and interaction between shallow groundwater and rising sea levels.

A key part of the RESIST project is to build demonstration houses close to the water. The goal here is to explore different construction techniques that result in flood-resistant infrastructures and to advocate for such building techniques amongst the construction sector and individual owners. Two types of houses will be demonstrated: houses that are placed "on water" and houses that are close to water.

The project also plans to use machine learning (ML) in order to track shallow groundwater logging. This system could serve as an early warning mechanism against the impacts of rising sea levels on groundwater (i.e. rising groundwater levels as an additional flood source and saltwater intrusion). The Danish municipalities of Horsens and Lemvig have already implemented the IoT technology for logging groundwater levels. The primary focus in Horsens has been on monitoring the intrusion of

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saltwater into the freshwater supply, a significant concern with the rising sea levels due to climate change. In Lemvig, continuous logging of groundwater levels has also been carried out, with an existing project set to be continued and expanded. A phenomenon of particular interest is the response time between rising seawater levels and corresponding groundwater levels in unidentified inland areas. Detailed analysis of this data could help in predicting potential impacts of seawater level fluctuations and plan appropriate responses. In the coastal municipality Hedensted, there are plans to set up new loggers in an area protected by a dike. The primary goal here is to monitor how sea level rise (SLR) affects the area behind the dike, providing invaluable data for future coastal management strategies and climate change adaptation measures.

Additionally, the RESIST project plans to have a test site for the “BEST Adapt” tool that was developed prior to the RESIST project and initially focused on pluvial flooding only. Recognizing the need for a more comprehensive tool, it was subsequently expanded to also account for other flood sources including rivers, the sea, and rising groundwater. The tool is capable of calculating damage costs and defining needed services - essentially determining the most economically beneficial level of protection against flooding. This earlier version of the tool was developed in accordance with Danish regulations and primarily used available data based on housing prices. However, it did not account for the recreational value of areas. With the RESIST project, plans are underway to integrate these additional factors into the tool, for instance, to account for the positive impacts of a park on local house prices. Additionally, RESIST aims at determining what data is crucial for the tool to function optimally. However, it's important to note that the tool is proprietary software and its transferability to other regions or countries might be challenging due to differences in economic factors such as housing prices. Furthermore, the effectiveness of the tool may be dependent on the availability of high-quality, freely accessible data in other regions.

Finally, the implementation of Extended Reality (XR) technology for educational purposes is planned, providing an immersive and interactive method for visually interpreting the threats of rising sea levels and other water-related hazards. The utilization of XR is to ensure that CCA plans and benefits are better understood by everyone, including politicians and citizens. This tool promises to be instrumental in persuading a variety of stakeholders to respond proactively to climate change consequences. It is still uncertain as to the specific areas where this XR simulation would be primarily used, whether in infrastructural development or in Nature-based Solutions (NbS). However, it is clear that the XR system will establish a nexus with other Work Packages (WPs), for instance, the governance WP. The focus of planned visualisations will be defined in dialogue with municipalities in the upcoming month. Regional partners have also highlighted the importance for exploring synergies and linking the efforts with Augment City on the Digital Twin approach.

As stated earlier, Nature-based Solutions (NbS) are not widely featured in adaptation plans. While they have potential to provide resilient and sustainable solutions, it is crucial to ensure that they respond to climate justice criteria, maintaining fairness and equity in adaptation efforts. Showcasing NbS in RESIST’s XR activities without this validation could propagate a misleading narrative, potentially leading to misplaced resources and efforts, increasing the risk of maladaptation. It

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therefore might be important to consider these aspects when choosing specific NbS for XR demonstrations in RESIST and ensure that adaptation efforts consider a comprehensive range of climate risks, that data gaps are addressed, and that the fairness of solutions such as NbS is proven before they are widely promoted or implemented.

Some municipalities have begun to address vulnerable groups in their Climate Change Adaptation (CCA) plans, particularly in relation to heat. Due to the comprehensive data in Denmark, it has been quite successful in mitigating risks and reducing the relevance of the demographic composition of specific areas. Nevertheless, the question of how to effectively communicate and inform different populations, such as elderly people or non-Danish speakers, remains a significant consideration and a topic of ongoing discussion.

As part of the demonstrator, the RESIST partners plan to conduct interviews to understand what it's like to live in a vulnerable area. Specifically, they want to know how different groups respond when they experience threats from climate change. They anticipate diverse responses based on various factors like age, language proficiency, socio-economic status, etc.

3.2.4 Stakeholders and community engagement

3.2.4.1 Main stakeholders

A needs assessment has been conducted for the RESIST project, identifying both the primary partners involved and the potential stakeholders who could contribute in various capacities. The main partners of the project are municipalities, which participate to varying degrees at different levels. However, their specific involvement in each of the four main activity areas of the project needs further clarification. So does the potential for their involvement in workshops and other co-creation and capacity-building activities if they are not directly part of the project.

Five distinct stakeholder groups have been identified, each contributing in different capacities:

- **Media, Cultural NGOs, and Civil Society**, including Klimatorium (directly involved in demonstration houses), CONCITO, DNNK: National Network for Climate Adaptation, and the network of stakeholders from the EU-LIFE project C2CCC. These stakeholders play a crucial role in data collection, as well as in increasing the visibility of the project. Therefore, the stakeholders that are not directly involved in the project are the ones that the project partners have established contacts to through previous collaborations.
- **Governance and Policy-Makers**, like the CDEU (Central Denmark EU Office), KL (Local Government Denmark), and the Danish Regions. These stakeholders are not directly involved into the project and according to regional partners might need to be convinced to

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participate in some activities. Therefore, one of the project activities directly addresses governance aspects.

- **Research and Academic institutions**, featuring Aarhus University, VIA University College, and the Danish Technological Institute.
- **Municipal Stakeholders** include Lemving Municipality, Norddjurs Municipality, Randers Municipality, Hedensted Municipality, and Horsens Municipality.
- **The Private Sector** primarily includes water tech and utility service companies. The project is also considering involving small tech companies in the demo houses. These stakeholders will become more concrete in the upcoming month of the project.

Currently, the strategy to engage these stakeholders and to ensure their commitment is still in the ideation phase. However, it should be noted that a positive dialogue with many of these stakeholders has already been established. This is primarily due to existing relationships forged through prior projects and contact, leading to a foundation of mutual trust which could be leveraged in the current project.

No stakeholders with conflicting interests have been identified during the needs assessment. While the project has a varied assortment of partners, regional stakeholders have highlighted the necessity for national and regional decision-making bodies to be involved in strategic alignment and planning for CCA. At present, this doesn't represent an urgent requirement but is projected to gain significance with time.

A potential challenge lies in securing buy-in from decision-makers, a critical factor for successful governance dialogue. It is essential not only to ensure their participation in specific project activities but also to ensure broad outreach at the national and regional level. Encouragingly, groundwork has been laid at the national level, and a critical mass of stakeholders with aligned interests is currently applying pressure on the governmental structures. Despite these positive steps, ambiguity persists regarding the timeline for the development of a national CCA plan, as political negotiations have not started yet.

Furthermore, a notable gap exists in the current project structure: vulnerable and gender groups have not been factored in, a shortcoming attributed to the absence of a suitable mechanism for this in Denmark. As the project proceeds, developing a strategy for considering and involving these stakeholders will be important.

Among stakeholder groups, many are not directly involved in the project but share common interests and objectives. Their motivation is apparent, yet it's imperative to confirm their commitment to specific activities and pilots. This foundational trust will be instrumental in the successful implementation of the current project.

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3.2.5 Capacity and capacity constraints

Regional partners emphasized that funding of adaptation measures is among the biggest constraints at the moment. Channelling funds into projects is therefore considered a challenge. For the moment, the following resources and programmes have been identified as accessible.

Table 2: Accessible financing options

Resources / programmes	Financed projects include
EU level	
LIFE LIFE (S)IP Horizon Europe Interreg	https://www.c2ccc.eu/ http://www.life-bioscape.eu/ https://www.interregnorthsea.eu/blue-transition https://northsearegion.eu/c5a/about/ https://northsearegion.eu/topsoil/ https://resist-project.eu/
Danish Board of Business Development European Regional Development Fund European Social Fund	https://lighthousewatertech.dk/
European Investment Bank	Currently, there is a dialogue on loans for municipalities to implement large-scale solutions
National foundations	
Innovation Fund Denmark Aage V Jensens Charity Foundation	https://redoco2.net/ Cascading funds for http://www.life-bioscape.eu/ on nature and recreational actions

There is a need for increased public financing to address climate change adaptation, alongside incentivizing investment from the private sector. The cost-benefit analysis tool “BEST adapt” should form the basis for overcoming general reservations about adaptation measures by also including their recreational value and promoting the wider uptake of these solutions. However, more incentives for innovative methods of finance should be explored.

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The matters of organisational and institutional capacities will in part be addressed by the regional partners in the forthcoming municipal surveys and RESIST workshops. It must be noted that some of the planned activities, like getting stakeholders involved, further developing the costs-benefit analysis, and using visualisation tools to spread the word about Nature-based Solutions (NbS) can help improve the ability to adapt by raising awareness and expanding knowledge.

Regional partners perceive coordination as a challenge. The absence of a regional CCA plan makes it harder to align strategies, creating a disconnect between the regional and national level. However, this situation also provides municipalities with a certain degree of autonomy, which they may perceive as a positive aspect. At the same time, in regions with large catchment areas, municipalities are taking the initiative to collaborate and coordinate. They are, for instance, setting up shared secretariats to manage the water catchment area, where CCA is part of a wider complex approach.

3.2.6 Going beyond RESIST

Although we are still at an initial phase of the project, this needs assessment is exploring initial needs and opportunities to effectively broaden and systematically incorporate the solutions intended for LSD 2. Of course, a successful, well-documented demonstration of these innovative solutions would be crucial for scaling up.

One of the biggest hurdles in developing more systemic solutions is bridging the gap between existing individual measures in municipalities and formulating a National Climate Change Adaptation Plan. The formulation of such a national plan could strengthen regional actors' ability to formulate, implement, and monitor adaptation action. The visualisation of NbS, consultations and co-creation with project stakeholders and results from the cost-benefit analysis (“BEST Adapt Tool”) can provide the momentum that is needed to scale up solutions. However, institutional and policy coordination and innovation are needed to enable deeper transformations. This could include taking advantage of the growing regional coordination and collaboration within RESIST in order to a) institutionalize vertical exchange and local stakeholder engagement, b) utilize the results of the cost-benefit analysis to persuade key actors to establish improved financial conditions for public and private investment, and c) advocate for a more comprehensive integration of climate change adaptation into national and regional climate policy and planning.

3.2.7 Results

It's crucial to consider the views of vulnerable population groups in adaptation measures planned within the RESIST project. RESIST can help incorporate this perspective by identifying potential vulnerable groups in the proposed pilot areas and developing measures to meet their needs. In this process, adelphi can help in incorporating considerations of gender aspects and the needs of particularly vulnerable population groups into the design of adaptation measures. Additional guidance can be provided by the development of the ethics and gender framework by ESF.

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Other considerations include how to organize and manage stakeholder engagement for an inclusive, collaborative process, especially on different levels of governance and how to communicate the results of the cost-benefit analysis beyond the pilot projects. By integrating these questions into the current planning stage, several constraints such as the need to convince decision-makers at various levels of governance, limited knowledge, and reluctance towards financing can be addressed.

adelphi can provide additional support, such as determining suitable workshop formats, enhancing community engagement, engaging and convincing stakeholders from different sectors. This could involve getting support from private sector actors to boost and potentially expand the project's activities. Another possibility is to evaluate the pilot measures to avoid any potential maladaptation.

Finally, to ensure effective climate change adaptation beyond RESIST, the following points should be considered.

Regional CRA: Risk assessments should not be limited to municipal levels but should also be conducted at a regional scale. This ensures a broader understanding of climate risks across interconnected ecosystems and communities, and could help design regional adaptation strategies that are more holistic and effective.

Broader Scope of CRA: Risk assessments should include a broader spectrum of climate hazards, such as droughts and heatwaves, and should not be solely water-related. Climate risks are multifaceted and interconnected; focusing primarily on water-related risks could neglect other equally significant vulnerabilities and hazards. Such a broadened scope should not only be applied on the national and regional level, but also in risk assessments on the municipal level, so that a better understanding of resulting climate risks can guide targeted, context-specific adaptation strategies in each municipality.

Inclusive Framework in Climate Adaptation: An approach that considers both gender differences and the needs of vulnerable groups should be employed. Climate change impacts are not uniform; they vary based on gender, socio-economic status, age, disability, and other factors. Consequently, adaptation strategies should consider these differentiated impacts. Perspectives based on gender and vulnerability should be integrated into CRAs, adaptation planning, and the design and implementation of NbS. This ensures that the needs, vulnerabilities, and capacities of all demographic groups, including men, women, and vulnerable populations, are considered and addressed effectively.

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3.3 LSD 3: Catalonia

3.3.1 Introduction

Figure 5: Location of LSD 3 Catalonia.

Catalonia is located in north-eastern Spain and encompasses an approximate area of 32,000 km^2. Situated in a predominantly subtropical Mediterranean climatic zone, it is known for its prevalent hot and arid summers. The region is further characterized by mild and relatively rainy winters. However, due to the diverse geographical and orographic features, the climate within the region exhibits variations associated with local continental, oceanic, and alpine influences (Servei Meteorològic de Catalunya 2022).

The region is home to approximately 7.6 mio. people (roughly 236 inhabitants per km^2), with the majority living in Barcelona and its surrounding satellite towns. Barcelona is Catalonia's economic and political centre, encompassing a population of 5 mio. inhabitants in the metropolitan area. Due to a shortage in economic opportunities, Catalonia's hinterland and rural regions are experiencing depopulation and outward migration to urban centres and coastal areas (OECD; Generalitat de Catalunya 2022b).

Catalonia is Spain's wealthiest and most industrialized region. It functions as Spain's economic powerhouse, with a thriving tourism sector. However, the manufacturing industry takes precedence, with a substantial transition from traditional textile production to sectors such as chemicals, pharmaceuticals, food processing, and metalworks. The automobile industry also holds a key position within Catalonia's industrial landscape. Overall, agricultural activities in Catalonia now constitute only a small fraction of the GDP (Generalitat de Catalunya 2022a).

Climate change has resulted in a rise in climate-induced emergencies, causing casualties, infrastructure damage, and impacting natural systems and socio-economic sectors. Measures within RESIST focus on the civil protection sector with the aim to improve and extend Early Warning Systems (EWS) and raise awareness for climate-related risks. The measures address the heightened risks of extreme events such as flash floods, wildfires, heat waves, and strong winds.

The adaptation measures include four key areas. As a first area, IT developments will focus on facilitating regional-local coordination in emergency management, as well as on improving and expanding EWS. The second key area focuses on raising awareness and effectively communicating risks to communities, including the design of EWS messages and giving special attention to the

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needs of most disadvantaged or marginalized groups. The third area of adaptation measures focuses on local-regional demonstration. The goals include identifying vulnerable areas and communities susceptible to specific or multiple hazards and implementing better EWS, starting with the municipalities of Terrassa and Blanes. The last area of adaptation measures focuses on transferring best practices (and potentially developed EWS solutions) to the twinning regions Puglia and Baixo Alentejo and making use of the digital twin developed in Work Package 1.2 of the RESIST project.

3.3.2 Climate risks

3.3.2.1 Regional climate risk assessment, focussing on the civil protection sector

The central document analysing climate change risks for the Catalonia region is the Strategic Reference Framework for Adaptation to Climate Change for the Horizon 2030 (Generalitat de Catalunya 2021) (in Catalan: Marc estratègic de referència d'adaptació al canvi climàtic per a l'horitzó 2030), hereafter abbreviated as ESCACC30. The ESCACC30 investigates climate change risks in natural systems, socio-economic sectors and different territories (hereafter referred to as investigated "systems") and covers many relevant aspects of a full climate risk assessment. A full list is provided in Table 3.

Table 3: Natural systems, sectors and territories as defined in ESCACC30, for which risks from climate change were assessed.

Natural systems	**Sectors**	**Territories**
Biodiversity	Agriculture and livestock	Inland
Water	Insurance and financial sector	Coastal
Forests and forestry	Energy	Mountain areas
Marine ecosystems	Industry	
Fisheries	Services and trade	
	Mobility infrastructure	
	Natural risks and civil protection	
	Research and training	
	Health	
	Tourism	
	Urban planning and housing	

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Each is analysed in detail (ESCACC Annex 2), mostly based on a literature review of existing studies. Based on the findings, key climate risks are identified and tabularised for each system, differentiating between hazards, potential impacts, vulnerability, and exposure. Due to the somewhat overlapping systems, certain risks are mentioned several times with a slightly different framing (e.g. “risk of forest fires” in the territory “mountain”, and “risk of forest fires” in the natural system “forest”). Two summary tables are shown as examples below.

Table 4: Summary table for identified climate risks in the sector “Insurance and financial sector”(Generalitat de Catalunya 2021).

Scope / sector	Climatic hazards	Impacts	Exposure	Vulnerability	Risk
Insurance and financial sector	Extreme climatic events	Personal damage Property damage Damage in the agricultural sector (crop losses)	High exposure of population, goods and services in coastal region; high exposure of nearly one-third of the region’s agricultural land	High vulnerability of the agricultural sector and the coastline	Increase in the cost of coverage and risk premiums for insurance

Table 5: Summary table for identified climate risks in the sector “Natural risks and public protection”(Generalitat de Catalunya 2021).

Scope / sector	Climatic hazards	Impacts	Exposure	Vulnerability	Risk
Natural risks and civil protection	• Floods • Droughts • Forest fires • Land slides	Damage to people, goods, services and ecosystems	Elevated in densely populated areas and in areas of high economic activity	Dependant on the magnitude of the climate hazard Catalonia has numerous civil protection plans in place to deal with	• Loss of lives and money • Increased costs of repairing major infrastructure • Increase in energy prices

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				natural and climate risks	

The detailed analysis for the sector “Natural risks and civil protection” – which is also the focus of LSD 3 in RESIST – differs from the other analyses included in ESCACC30. For this sector, the analysis is divided into three risk categories:

1. Meteorological risks (such as heat waves, cold, snow, frost, extreme rainfall)
2. Socio-natural risks (floods, droughts and forest fires)
3. Geological risks (landslides and snow avalanches)

Risks from heat are not included in the sector “Natural risks and civil protection” but are covered in the sector “health”.

Meteorological risks

Annex 1 of the ESCACC30 investigates past and future changes in temperature and precipitation for Catalonia, which form the base for the meteorological risks assessed for the sector. Observed changes in climate are thoroughly assessed, looking at temperature, precipitation (and various related climate indices) for the period 1950-2020, as well as at sea-water temperature and sea level (for Estartit, since 1974). It further includes analyses of the snow thickness in the Pyrenees and state of the glaciers, phenological observations in the Serra D’Almos (i.e. relationships between climatic factors and the seasonal or periodic manifestations of species such as the flowering of plants, migration of birds, etc.), and episodes of strong wind and storms.

The future climate is analysed based on the results of the study "Regionalized climate scenarios in Catalonia: regionalized statistical projections at 1 km spatial resolution (1971-2050)" (Servei Meteorològic de Catalunya 2020), performed by the Meteorological Service of Catalonia and abbreviated as ESCAT20. This study assesses future climate (for 2030 and 2050) in Catalonia at a 1km spatial resolution, using regionalised climate scenarios. Both a moderate emission scenario (RCP4.5) and a high emission scenario (RCP8.5) are considered. Average, maximum and minimum temperature, accumulated precipitation (both on an annual and seasonal scale), and temperature- and precipitation-related climate indices are derived. The main conclusion of ESCAT2020 is that in 2050, the region of Catalonia will be, on average, warmer and drier (compared to the period 1971-2000). The average annual temperature will continue to increase across the region across all scenarios. For a high emission scenario, the average temperature may increase by up to 3ºC by 2050. Maximum temperature is projected to increase by up to 4 ºC, minimum temperature by up to 3 ºC. Geographically, the largest increases are projected for the Pyrenees. Projected precipitation presents a large interannual variability. Despite the uncertainty, the trend seems to point towards a general decrease in average annual precipitation, particularly during summer.

Socio-natural risks

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For each municipality in Catalonia, a level of risk for fluvial (riverine) flooding has been established in the Special Flood Emergencies Plan of Catalonia (INUNCAT) (Comissió de Protecció Civil 2017). This was done based on existing flood hazard zones (under current climate conditions) and using monetary damages, number of people located in the flood zone and total length of circulation routes within the flood zones as indicators to assess vulnerability. Table 6 shows the number of municipalities falling into different pluvial flood risk categories. Pluvial (precipitation-driven) flood risks are not explicitly discussed.

Table 6: Number of municipalities in Catalonia falling into different fluvial flood risk categories (Generalitat de Catalunya 2021). [5]

Very high risk	High risk	Medium risk	Moderate risk	Low risk
200	180	108	260	198

Future risks from fluvial flooding in Catalonia are assessed by the Catalan Water Agency within the risk management plan for river basin district of Catalonia for the period 2022 - 2027 (Agència Catalana de l'Aigua 2022). This assessment is again discussed in the ESCACC30. Fluvial flood risk is assessed for two emission scenarios (RCP4.5 and RCP8.5) for different flood return periods (10, 100 and 500 years). Results indicate that areas with significant increases in fluvial flood risk correspond to the large river basins of the region, affecting important urban centers such as Barcelona, Girona, Tarragona or Manresa.

Droughts are discussed and analysed in the ESCACC30 based on the ESCAT20 projections. According to the results, precipitation anomalies (annual and seasonal), both positive and negative, are projected to increase, leading to years with very significant increases but also years with significant reductions in precipitation. The dry streak length index is generally increasing throughout the territory.

Forest fire risk in Catalonia is analysed in a special emergency plan for forest fires (INFOCAT) (Generalitat de Catalunya 2014). It assesses vulnerability of areas based on five indicators: population, particularly dangerous elements, infrastructure, protected natural spaces and potential for fuel. A map of municipal vulnerability to forest fires is available.

Geological risks

[5] Catalonia consists of 947 municipalities. The riverine flood risk is only reported for 946 municipalities in the ESCACC30 – the riverine flood risk for one municipality is therefore missing.

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Risks from landslide are only assessed based on the results of a study which investigates the damages produced by the storm Glòria in 2020 (ICGC 2020). Future risks from landslides are not assessed.

Risks from avalanches are discussed based on the study investigating the effects of climate change in the Pyrenees (OPCC & CTP 2018). It considers three emission scenarios (RCP 8.5, RCP 6.0 and RCP 4.5) and medium-term as well as long-term changes (until 2100). Results of the study suggest that the frequency of avalanches and their impact will probably decrease in the future due to an increase in winter temperature. However, the impact of climate change on avalanche risk remains fairly uncertain.

3.3.2.2 Comparison with risks according to the ESPON-CLIMATE dataset

The ESPON project has identified several prevalent risks for the region of Catalonia under current climate conditions. These include flash floods posing a risk to the cultural sector, droughts affecting the primary sector, and wildfires impacting the environment. Additionally, risks from heat stress on the population are projected to become increasingly prevalent during the time period 2070-2100 (under a high emission scenario – RCP8.5), while the previously mentioned risks remain high.
It is important to note that the ESCACC30 does not assess risks from flash floods, which represents a significant gap in the analysis. However, expert interviews conducted with regional partners indicate a high level of awareness regarding flash flood risks among local authorities and research institutes. Furthermore, risks from droughts in the primary sector are not adequately addressed in the main risk summaries for the sectors of "agriculture and livestock" or "water" of the ESCACC30. Instead, they are only mentioned in the risk summaries for the sectors "energy," "industry, trade, and services," and "natural risks and civil protection". Nevertheless, droughts play a crucial role in the adaptation measures outlined for the agricultural sector in the second part of the ESCACC30. It is essential to rectify this discrepancy in future adaptation strategies and plans to ensure comprehensive coverage of risks from droughts in the primary sector. While the ESCACC30 discusses risks from wildfire, it only considers current climate conditions and fails to account for future developments. Additionally, since risks are not prioritized in the ESCACC30, it remains unclear whether certain risks have been identified as particularly relevant.

3.3.2.3 Qualitative assessment of the regional CRA

Methodologically, no unified approach is applied to analyse the risks from climate changes across the various systems, and the analyses performed vary in depth. Many shortcomings thus stem from the lack of a clear climate risk analysis framework. The time horizons considered differ substantially, future climate scenarios are only sometimes explicitly taken into account. For certain systems, only past changes are assessed, such as for the “forest and forestry”: here, only the development of ecosystem services over time is analysed, given changes in forest extent, quality and management practices between 1990 and 2014. The risk analysis for marine ecosystems and fisheries, on the other hand, considers different climate scenarios (RCP4.5 and RCP8.5) as well as medium- and

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long-term changes (2050 and 2100). Furthermore, the structure of ESCACC30 results in a very high number of risks identified for Catalonia, without prioritizing some of them. The results of the analysis are therefore not easily transferrable to concrete adaptation action.
The ESCACC30 explicitly uses the terminology based on the definition of risk from the IPCC Fifth Assessment report, which defines risk as emerging from the interaction of hazards, exposure and vulnerability (IPCC 2014). These terms, however, are not always used consistently. For the vulnerability assessment of certain systems, potential impacts are discussed rather than vulnerability. When investigating vulnerability, a distinction is sometimes made between adaptive capacity and sensitivity, but this is not done consistently. Furthermore, a clear differentiation between risk, impact, hazard and exposure is not uphold across all components of the analyses.

Nevertheless, the report fulfils several requirements of a sound CRA. The ESCACC30 touches on a wide range of climate-related hazards. Both slow onset trends in temperature and rainfall as well as extreme events are considered. Data sources, uncertainties and knowledge gaps are clearly communicated. Furthermore, for most risks, the ESCACC30 outlines where in Catalonia these risks are most prevalent, thereby providing important spatially differentiated information.

3.3.3 Adaptation measures

3.3.3.1 Existing regional plans and measures, focusing on the civil protection sector

ESCACC30

The ESCACC30 (Generalitat de Catalunya 2021) contains the region's adaptation framework and is also the most important and extensive document with regard to the region's adaptation strategy. It is regulated by Law 16/2017 of 1 August on climate change[6], which establishes climate change mitigation and adaptation objectives and prescribes the production of a Strategic Reference Framework for Adaptation. Furthermore, the law specifies that the objectives and measures presented in the framework shall be integrated into the sectoral strategies and the planning of the responsible ministries of the Generalitat (region) of Catalonia. The ESCACC30 was officially approved by the Catalan government in January 2023 (Generalitat de Catalunya 2023).

The ESCACC30 contains operational objectives for each natural system, sector and territory as defined in Table 2. Several adaptation measures are defined for each operational objective, resulting in a total of total of 312 measures for the period 2021-2030. The ESCACC30 includes an inexhaustive list of sectoral plans and programmes which have to integrate these objectives and measures. The operational objectives and measures for the sector "Natural risks and civil protection" focus on the following key areas:

[6] Available at: https://portaljuridic.gencat.cat/eli/es-ct/l/2017/08/01/16

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- Promotion of the assessment of natural risks under consideration of climate change (using climate scenarios)
- Consideration of how natural risks will develop under climate change in planning documents
- Expansion and strengthening of existing systems for climate observation, early warning, communication and education
- Revision of regulations related to natural risks (e.g. urban planning regulations, establishment of fire prevention strip, etc.) in accordance with climate change scenarios

This shows that the region is aware of certain gaps in assessing climate risks (as identified in Section 3.2.2) and is already taking action to remedy some of these gaps. Overall, although the ESCACC30 is a very comprehensive adaptation framework targeting various sectors, the majority of measures included are of rather general nature, not providing detailed and concrete activities for implementation. This, however, can partly be explained by the process of implementation for the ESCACC30 measures, which have to be taken up by and implemented through the plans and programmes of the various sectors. Nevertheless, the general nature of the measures leaves room for interpretation and might render the monitoring and evaluation of the implementation more difficult. Furthermore, the objectives and measures in the ESCACC30 are rather strictly divided between different natural systems, sectors and territories. This has the potential to create adaptation actions designed in “sectoral silos” instead of using synergies with other sectors (or natural systems / territories). Droughts and heat waves, for example, are not targeted in the sector “natural risks and civil protection”, although these climate hazards can have severe impacts on the population and targeting these hazards could benefit from solutions developed within the civil protection sector.

Civil Protection Map

The Civil Protection Map is an online interactive mapping tool which allows the user to choose from various layers, which are consequently mapped for Catalonia (Generalitat de Catalunya). These include layers showing the level of risk of an area, available for various climatic and non-climatic risks. Layers for climate-related risks are available for the following hazards:

- Forest fire
- Impediments through snow events
- Flooding
- Avalanche

The risk maps only exist for current climate conditions, risks under future climate conditions are not considered. As previously mentioned, however, the measures of the ESCACC30 aim at further promoting the inclusion of climate change scenarios.

Additionally, the mapping tool also includes layers showing the municipalities for which a territorial civil protection plan (Catalan Territorial Civil Protection Plan, PROCICAT) and/or a municipal emergency plan for a certain risk is recommended or obligatory. These plans aim at establishing organizational structures and procedures for intervening in emergencies, providing coordination

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mechanisms with the State Protection Plan, and establishing a coordination system with organisations in each territory. Furthermore, they include the creation of a Municipal Action Plan and require the establishment of basic risk maps for the communities. PROCICAT is mandatory for municipalities of a certain size and covers (in a more general manner) risks not included in special emergency plans. Climate-related risks covered by the PROCICAT include the following hazards:

- Heat waves
- Droughts
- Frost with serious impact on the supply of basic services
- Storm surges

Special emergency plans exist for various risks, referring to the following hazards:

- Forest fire
- Impediments through snow events
- Flooding
- Avalanches
- Strong wind and storms

Whether it is recommended or required (or none of the former) for a municipality to implement a special emergency plan is determined by a set of risk-specific indicators. These, however, are based on current climate conditions. The consideration of risk development under climate change scenarios is missing so far and would represent a very valuable addition.

Global indicator of climate change adaptation in Catalonia

A global indicator of adaptation was first introduced in 2014 and reviewed in 2018, with the aim to measure Catalonia's progress in adapting to climate change over time (Oficina Catalana del Canvi Climàtic (OCCC) 2019). The global indicator is currently composed of 42 sectorial sub-indicators.[7] Assessments of how the indicator's value has changed show that it has increased by 8.74% between 2005 and 2014, suggesting successes in Catalonia's overall climate adaptation strategy (Oficina Catalana del Canvi Climàtic (OCCC) 2019). [8]

3.3.3.2 Planned adaptation measures

Adaptation measures planned within RESIST focus on the civil protection sector, aiming at improving and expanding Early Warning Systems (EWS) as well as at raising awareness for climate-related

[7] The sectors include: agriculture and livestock; biodiversity; water management; forest management; industry, services and trade; mobility and transport infrastructure; health; energy sector; tourism; urban planning and housing.
[8] The increase is measured against the indicator baseline value of 100 in 2005. In 2014, the indicator value had increased to 108.74.

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risks. The measures address the heightened risks of extreme events such as flash floods, wildfires, heat waves, and strong winds. The adaptation measures include four key areas, shortly described in this section and summarized in Figure 6.

Figure 6: Overview of key activities planned within RESIST for LSD3, adapted from the LSD3 kick-off meeting.

The focus of the first key area lies on facilitating regional-local coordination in emergency management, as well as on improving and expanding EWSs. This will include expanding the scope of site-specific warnings (SSWs) to trigger self-protection protocols tailored to different hazards and areas. These SSWs target high priority locations from a civil protection perspective (for example a school or a roundabout that is known to always flood). Additional sensors useful for EWS are sometimes already available at these locations or are currently being installed. In the future, SSWs should be available in an easy-to-use app, which directly issues site-specific warnings to affected users and potentially include recommendations for action. For certain locations, SSWs could be connected to automated reactions, for example the lowering of a barrier that closes off a flooded road. This is, however, currently still in the pilot phase.

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Furthermore, the development of tools for the systematic application of Multi-Hazard Early Warning Systems (MH-EWA) at the local (municipal) level will be supported to monitor complex emergencies. To this purpose, the web-based early warning system “Argos” will be further developed and implemented in additional municipalities. Additionally, systems will be implemented to collect local data to enhance emergency management processes. This may involve utilizing crowd-sourced data, training, and e-learning materials that draw on historical cases for improved preparedness and response.

The second key area focuses on raising awareness and effectively communicating risks to communities. It involves designing warning messages for SSWs and developing an inclusive framework for prevention and emergency management at the local level to incorporate the needs, knowledge, and capacities of the most disadvantaged or marginalized groups, ensuring their voices are heard and accounted for in decision-making processes. Further, surveys will be conducted to evaluate IT developments and assess community awareness. Other participatory activities will also be conducted, such as dedicated end-user community workshops and sessions. The overarching goal is to engage the vulnerable communities, understand their risk response, and prioritize their needs. Establishing an ecosystem of urban stakeholders will support effective communication and collaboration.

The third area of adaptation measures focuses on local-regional demonstration. The goals include identifying vulnerable areas and communities susceptible to specific or multiple hazards and implementing better EWSs, starting with the municipalities of Terrassa and Blanes. The initial focus will be on areas prone to floods, specifically identifying suitable locations for installing new sensors for SSWs. It further involves evaluating the performance of implemented MH-EWS tools (Argos) during significant weather events and evaluate changes in communication and awareness using surveys. Additionally, there are plans to replicate successful demonstrations in more municipalities within Catalonia and the twinning regions to build a community of practice.

The last area of adaptation measures includes transferring best practices (and potentially developed EWS solutions) to the twinning regions Puglia and Baixo Alentejo, and making use of the digital twin developed and implemented in Task 1.2 of the RESIST project. This will be done through visits, working groups, and dissemination materials. However, there are ongoing discussions on how to export the experiences and knowledge gained in Catalonia to other regions.

The adaptation measures planned within RESIST focus on the civil protection sector, mainly addressing emergency response. In the planned measures, the main focus so far lies on flood risks and risks from forest fires. The inclusion of risks from heat waves and further hazards are being considered for the MH-EWS tool Argos, potentially on a needs basis for participating municipalities. The suggested EWS solutions have the potential to increase the outreach of early warnings and make them more readily available for different target groups (directly affected population as main target group of the SSW solutions, civil protection staff as main target group of the MH-EWS Argos). Special attention is given to identify and reach vulnerable and marginalised groups, thereby potentially helping civil protection services to prioritize action and redirect efforts where they are most

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needed. Targeted early warning messages can further help trigger appropriate action by the affected people themselves.

Currently planned measures prominently include activities to identify and consider the needs and capacities of vulnerable and marginalised groups and how to better reach them in the context of EWS. The progressive approach of addressing the topic of social vulnerability holistically – integrating aspects of socio-economic capacities, gender, demography as well as mental and physical health – while aiming at developing evidence-based solutions needs to be emphasised and can be used as positive example for other regions.

The measures planned for RESIST are partly of incremental and partly of more transformative nature. LSD3 aims to achieve some actionable change going beyond existing practices, aiming at increasing risk awareness and sharpening risk perception by citizens as well as improving civil protection coordination between the local and regional level. Many activities in LSD3, however, are deeply integrated into the existing Catalan civil protection project landscape. This ensures that synergies with other projects are used and solutions are developed in a way compatible with established processes. Further consideration should also be paid to how the developed solutions could be further extended (or results used) to contribute to long term risk mitigation, i.e., decrease exposure or increase adaptive capacity.

A key challenge for successful project implementation identified by the regional partners is to establish a good connection between the civil protection sector and the region's citizens. This should ideally be supported by the early warning tools used within the project. The challenge consists in making sure that people most at risk are reached, but also to ensure a high credibility of the warnings and targeted, useful warning messages. Additionally, the above-mentioned potential for innovative and transformative adaptation should be taken into account in the further design of these and additional measures.

3.3.4 Stakeholders and community engagement

Stakeholders explicitly identified as important by the regional partners in LSD3 include stakeholders to be engaged in local-regional demonstration activities, regional stakeholders, and municipal stakeholders. The most important ones are listed below:

Stakeholders to be engaged in local-regional demonstration

- ACCIÓ (Agència per la Competitivitat de l'Empresa) – Agency for Business Competitiveness
- OCCC (l'Oficina Catalana del Canvi Climàtic) - Catalan Office for Climate Change
- Project EDERA (Early warning Demonstration of pan-European rainfall-induced impact forecasts)
- Project CLIMAAX (CLIMAte risk and vulnerability Assessment framework and toolbox)

These stakeholders will be engaged in the local-regional demonstration activities planned in Terrassa and Blanes, and potentially additional municipalities in Catalonia. The EDERA project is a

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European Commission Civil Protection Preparedness project focusing on an improved strategy for compound flood impact forecasts (combining convective hazards, flash floods and river floods). The CLIMAAX project is another Horizon Europe project aiming at supporting European regions in improving their regional climate and emergency risk management plans, including comprehensive multi-hazard Climate Risk Assessment (CRA). Catalonia is involved in both projects. More specifically, both CRAHI-UPC and INT are involved in the CLIMAAX project, CRAHI-UPC is additionally involved in the EDERA project; good contacts as well as good project overviews, including possible synergies with the RESIST project, are therefore already established.

Regional stakeholders

- Departament de Drets socials (Social Rights Department)
- Red Cross Catalonia

Both the Social Rights Department and the Red Cross Catalonia have been identified as important regional stakeholders, especially for identifying vulnerable and marginalized groups, assessing their needs and capacities and discussing EWS options to reach those groups.

Municipal stakeholders

So far, municipalities strongly involved in the local-regional demonstration activities are Terrassa and Blanes. Further municipal stakeholders will need to be identified and contacted when the EWSs will be expanded to other municipalities in Catalonia. Potential stakeholders could include the Federation of Municipalities of Catalonia (Federació de Municipis de Catalunya) as well as regional councils (consells comarcals).

Community engagement

As previously mentioned, a key challenge identified by the regional project partners is establishing effective communication between the civil protection sector and the region's residents, which should ideally be supported by the EWS tools deployed through the project. The challenge lies in ensuring that the individuals who are most vulnerable receive the necessary information while also maintaining the credibility of the warnings and delivering targeted, useful warning messages. Community engagement will therefore be key. The evaluation of improved communication and awareness will be assessed with the use of surveys. Additionally, workshops are envisaged to further engage regional and local stakeholders. These activities, however, are still in the planning phase, and key stakeholders for community engagement have not been identified yet.

3.3.5 Capacity and capacity constraints

3.3.5.1 Funding and financing

Catalonia's climate adaptation financing can be divided into three main pillars: European funding, state financing (Spain) and regional financing. European funding plays an important role for

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Catalonia's overall climate adaptation finance. According to the ESCACC30, the following EU funding mechanisms / EU funded projects are especially relevant for Catalonia (Generalitat de Catalunya 2021):

- Next Generation EU: Recovery and Resilience Mechanism and REACT-EU
- European Green Deal: EU Horizon projects
- European Social Fund Plus (ESF+)
- European Regional Development Fund (ERDF): For the period 2021-2027, Catalonia will receive around 840.5 mio. EUR from the EU (40%), the contribution of the Generalitat's budget in investments will be 1,260 mio. EUR (60%).
- European territorial cooperation (Interreg) 2021-2027, financed by the European Regional Development Fund (ERDF)
- European Agricultural Fund for Rural Development (EAFRD)
- European Maritime, Fisheries and Aquaculture Fund (FEMPA)
- RIS3CAT 2030, Research and innovation strategy for the intelligent specialization of Catalonia 2030: financing of actions will come from the cohesion funds (from FEDER and from the from the REACT-EU mechanism of the Next Generation funds)

Additionally, the EU LIFE program and the European Investment Bank (EIB) (especially its increased support for climate adaptation based on its Adaptation plan) are mentioned as potential future funding sources.

With regard to Spanish financing, the ESCACC30 highlights the Spanish Law 7/2021 of 20 May on climate change and energy transition.[9] This law establishes financing mechanisms for several climate change adaptation policies, including:

- Financing plan for climate change adaptation related to the water sector and hydrology
- Financing mechanisms for fair transition agreements for vulnerable workers

Furthermore, the PIMA Adapta Plan, launched in 2015, provides a dedicated financing line for adaptation projects across various sectors within the framework of the Spanish National Climate Change Adaptation Plan (Plan Nacional de Adaptación al Cambio Climático - PNACC). Additionally, through the Biodiversity Foundation (Fundación Biodiversidad), public calls for financing climate change adaptation projects are carried out (Generalitat de Catalunya 2021).

With regard to funding from the region itself, the Catalan Climate Fund plays an important role. It was established through the Law 16/2017. The fund is financed by taxes on economic activities that generate GHG emissions as well as from a tax on port emissions from large ships. Additionally, part of the revenue from income taxes flows into the Climate Fund. Available funds are estimated at 50 mio. EUR per year (Generalitat de Catalunya 2021).

[9] Available at: https://www.boe.es/diario_boe/txt.php?id=BOE-A-2021-8447

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An evaluation of the financing opportunities for climate adaptation in Catalonia – and the civil protection sector more specifically – as well as the identification of funding gaps is still outstanding and needs to be provided by the regional partners. Results will be included in the final report.

3.3.5.2 Institutional capacity (personnel, governance)

The regional partners highlighted the current “emergency focused” approach of the civil protection sector. Long-term adaptation processes to increase climate resilience are not integrated in the civil protection sector yet. To initiate this shift, a need for trainings and improved skills was mentioned by the partners.

This also touches upon another institutional constraint, namely the attribution of different natural and climatic risks to different sectors and institutional entities. Increased cooperation across sectors could therefore be highly beneficial, such as between the civil protection sector, the Catalan water agency (Agència Catalana de l'Aigua – ACA) which is responsible for drought management, and the health sector, which is responsible for measures to reduce impacts from heat waves.

3.3.6 Going beyond RESIST

RESIST aims at developing innovative solutions with the potential for transformative change, scaling up piloted project measures beyond participating lead regions. The LSD3 measures planned for RESIST are deeply integrated into the existing Catalan civil protection project landscape. Further efforts should therefore be invested in investigating which project parts have the potential to be scaled up for and beyond the twinning regions – and under which pre-conditions. Additionally, further consideration should be paid to how the developed solutions could go beyond supporting emergency response and contribute to or be integrated into long term risk mitigation. Furthermore, cooperation with other sectors – especially the health sector – should be further strengthened to identify and use synergies with regard to the tools being developed and implemented within the RESIST project. Where useful, the expansion of the MH-EWS tool could be considered for other climate-sensitive sectors beyond civil protection, such as the health or agricultural sector. This is well beyond the scope of the current project, but could be taken up by other projects in the future.

3.3.7 Results

In the ESCACC30, the analysis of climate risks lacks a unified approach and varies in depth across different systems. Furthermore, there is a need for more comprehensive consideration of risk developments under future climate scenarios. However, the adaptation strategy demonstrates awareness of this issue and includes measures to incorporate climate projections into future plans and products in the civil protection sector.

The region's approach prominently includes activities that aim to identify and address the needs and capacities of vulnerable and marginalized groups, particularly in the context of Early Warning Systems (EWS). This serves as a positive example that can be applied to other projects or regions.

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The measures focussing on Early Warning Systems (EWS) and digital solutions are deeply integrated into the existing Catalan civil protection project landscape. It is crucial to invest further efforts in identifying project components with the potential to be scaled up not only within the twinning regions but also beyond, while considering the necessary pre-conditions. Additionally, it is important to give due consideration to how the developed solutions can extend beyond supporting emergency response and contribute to long-term risk mitigation. Currently, the civil protection sector primarily adopts an emergency-focused approach, lacking integration of long-term adaptation measures to enhance climate resilience. The regional partners mentioned that new skills might be needed to facilitate this shift towards a more long-term perspective.

One of the key challenges identified by the project partners is to ensure that the developed solutions not only suit the civil protection sector but also enhance the usefulness and credibility of EWS for citizens. Therefore, community engagement becomes crucial. However, community engagement activities are still in the planning stage and require further refinement.

As previously emphasized, the Catalan adaptation strategy assigns different natural and climatic risks to specific sectors and institutional entities. Enhanced cooperation across sectors, such as between the civil protection sector, the Catalan Water Agency (Agència Catalana de l'Aigua - ACA), responsible for drought management, and the health sector, responsible for measures to mitigate the impacts of heatwaves, would be highly beneficial. For future projects that extend beyond RESIST, it would be worth considering the potential for expanding the MH-EWS tool to other climate-sensitive sectors, including health and agriculture. This expansion would enable the project to go beyond the scope of RESIST.

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3.4 LSD 4: Centro Portugal

3.4.1 Introduction

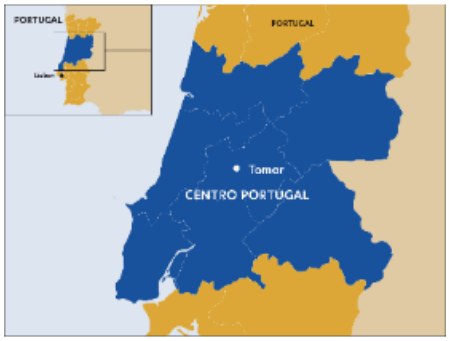

Figure 7: Location of LSD4 Centro Portugal.

Médio Tejo and Coimbra are both NUTS 3 regions situated in Central Portugal (consisting of in total eight NUTS3 regions). According to the Koeppen Climate Classification, they fall within the CsA and CsB climate groups, indicating a temperate climate with either hot (a) or warm (b) summers (Loureiro et al. 2017; CIM-MT 2019). The Central region (PT16) has approximately 2.3 Mio inhabitants and is strategically well located with proximity to Lisbon and the Spanish border. With a geographical position that boasts a central location in mainland Portugal, the Médio Tejo (NUTS3) spans an area of 3.344 km^2 and accommodates a population of nearly 250.000 people (CIM-MT 2019). Coimbra region (NUTS3) covers a total area of 4.336 km^2 with 460.000 inhabitants (Loureiro et al. 2017). Both regions face similar demographic challenges, such as low birth rates and a growing age dependency rate as well as emigration from rural areas. In addition, the fragmented land structure was named as a major challenge in the region during the interviews. In the following, the most important frameworks, laws and strategies regarding climate change adaptation are presented for Portugal on a national level (Loureiro et al. 2017; CIM-MT 2019).

The **Climate Law** of 31 December 2021 (n.º 98/2021) establishes the right to a balanced climate and sets ambitious targets for various sectors regarding mitigation and adaptation. It introduces novel concepts like climate refugee, climate justice, and environmental health into the country's legal framework. The primary aim of the law is to achieve carbon neutrality by 2050, with provisions for the government to explore the possibility of attaining this goal even earlier, by 2045. In addition, a significant part is dedicated to climate adaptation (Assembleia da República 2021).

The first Portuguese Climate Risk Assessment was conducted in 2002 with the name SIAM. The deliverable at hand does not go into details of this assessment as currently a new climate risk assessment for Portugal is being carried out, the so called **National Roadmap for Adaptation 2100** (RNA 2100). It will contain information on current and future vulnerabilities of Portugal and an assessment of investment needs for adaptation until 2100, including an analysis of the costs of inaction (Agencia Portuguesa Do Ambiente 2023).

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The **National Adaptation Strategy** (Estratégia Nacional de Adaptação às Alterações Climáticas (ENAAC), is the foundation for national climate adaptation and is valid until 2025 (Presidência do Conselho de Ministros 2015). The strategy aims at integrating adaptation measures into sectorial policies and territorial planning. The priority sectors for ENAAC include agriculture, biodiversity, economy, energy and energy security, forests, human health, safety of people and goods, transport, communications and coastal areas. It additionally provides support to central, regional, and local authorities in identifying effective methods and resources for implementing adaptation strategies (Agencia Portuguesa Do Ambiente 2015). Within the strategy, climate change impacts were identified for Portugal and sectorial working groups were established to achieve a better understanding of climate risks and to develop sectoral adaptation plans. The programme **POSEUR**, a program created by the European Commission in 2016 as part of the Portugal 2020 Strategy supports the implementation of adaptation measures and focuses on promoting sustainable growth and addressing the challenges of transitioning to a low-carbon economy. The programme aims to achieve this by encouraging the efficient use of resources and enhancing resilience to climate risks and disasters (Portugal 2020 & European Commission 2023).

Based on the ENAAC, a **National Adaptation Plan (P-3AC)** was developed with the goal of implementing adaptation measures, based on planning exercises at national, regional and municipal level. The strategy comprises eight lines of action. It emphasizes the importance of preventing rural fires through structural interventions in agricultural and forestry sectors. The strategy also focuses on minimizing flood risks, increasing coastal protection, and developing decision support tools, capacity building initiatives, and awareness-raising actions (UNFCCC 2021; Agencia Portuguesa Do Ambiente 2023).

PIAAC-MT and PIAAC-RC

As mentioned in the ENAAC, its goal is to develop and implement adaptation strategies on a regional level. As Portugal does not have an established regional government level, it relies on Commissions for Coordination, Regional Development and Inter-Municipal Councils (CIM) and Metropolitan Areas to address aspects that concern the NUTS2 and NUTS3 level (OECD 2023). To further promote the integration of climate adaptation strategies and plans at the intermunicipal level, the ClimAdapt.PT project was initiated. This project specifically focused on supporting intermunicipal associations in the development of local adaptation plans, thereby fostering a bottom-up approach. Through trainings for local officers, the project aimed to build capacity and empower municipalities to effectively address climate change challenges. By developing guidance documents developed by the project, municipalities were equipped with the necessary tools and resources to formulate their own tailored adaptation strategies. Thus, many CIM's developed Intermunicipal Climate Change Adaptation Plans (PIAAC). The PIAACs usually asses climate risks and select suitable adaptation measures in the region and on municipal level. Both the PIAAC for the Coimbra region (PIAAC-RC) and the PIAAC for Médio Tejo (PIAAC-MT) have a full list of climate adaptation measures with a focus on sectors identified in the ENAAC and P-3AC. This approach facilitates a decentralized and context-specific response to climate change, ensuring that local communities could actively engage

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in climate adaptation efforts (adapt.local - Rede de Municípios para a Adaptação Local às Alterações Climáticas 2023).

3.4.2 Climate risks

Within this section, the results of the ESPON-CLIMATE assessment and results of the PIAAC's climate risk assessments are described.

Coimbra Region

The PIAAC-RC summarizes information on meteorological parameters, including temperature and precipitation as well as historical data for wind, relative humidity and cloud cover. Changes in temperature and precipitation are depicted in **Error! Reference source not found.**7, including projections for short- and medium-term changes with RCP4.5 and RCP8.5. Annual precipitation is projected to decrease while temperature is projected to rise further up to 2°C with RCP8.5. In addition, climate risks such as flood, heavy rainfall, forest fires, sea level rise and periods with extreme heat (>32°C) are projected to have negative impacts on the region (Loureiro et al. 2017).

Table 7: Projections for temperature and precipitation for the Region Coimbra

Variable	**Historical (modeled; 1971-2000)**	**RCP4.5 (2011-2040) (2041-2070)**	**RCP8.5 (2011-2040) (2041-2070)**
Average monthly temperature "anomalies" (in °C)	13	+1.0 +1.8	+0.6 +2.0
Average monthly precipitation (RCP scenarios: "anomalies") (in mm)	1290.22	-167	-103.4

Similarly, the ESPON-CLIMATE database identified flash floods, heat and wildfires as the main climate hazards for the Coimbra Region in both the baseline and high emissions scenario. In the high emissions scenario, coastal flooding is added as an additional important hazard. Population is found to be specifically exposed to heat, whereas agricultural, forested, protected and mixed areas are specifically exposed to droughts and wildfires. Population, specifically old-aged and young population groups are specifically sensitive to heat and river floods. Additionally, sensitivity to floods is based on employment in the industry and the overall gross value added of industry located in coastal areas and river basins. Overall, the main climate risks identified for the region are heat, flash floods, wildfires and droughts (Navarro et al. 2022). Within the PIAAC-RC, identical climate hazards

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are identified, however not for all hazards, vulnerabilities and exposures to these hazards are identified and clearly outlined.

Médio Tejo

In the PIAAC-MT, meteorological parameters are assessed, namely temperature, precipitation and wind speed. As identified in the PIAAC-RC, temperature is projected to increase together with an increase in heat waves with very hot days (>35°C) and a decrease in cold spells. The number of hot days will increase by the end of the century to up to 25 days under RCP4.5 and 59 days in RCP8.5 by the end of the century. Forest fires are accounted as a major risk to the region, based on past events, however no projections are included in the assessment. Precipitation and wind speed are both projected to decrease in both scenarios, with precipitation significantly decreasing in summer months (up to 28%) and increasing in winter months (up to 16%) with PCP8.5 as depicted in table 8. However heavy and very heavy precipitation events are likely to increase in the future (CIM-MT 2019).

Table 8: Projections for temperature, precipitation and wind speed for Médio Tejo

Variable	**Historical (modeled; 1971-2000)**	**RCP4.5 (2041-2070) (2071-2100)**	**RCP8.5 (2041-2070) (2071-2100)**
Average monthly temperature “anomalies” (in °C)	13.1	+1.6 +1.6	+2.1 +3.8
Average monthly precipitation “anomalies” (in mm)	895	-64 -31	-42 -47
Average annual wind speed “anomalies” (in km/h)	12.6	-0.1 -0.1	0.0 -0.1

Similarly, in the ESPON dataset, heat, flash floods and wildfire are accounted as the major climate hazards in the region in the baseline scenario with additionally the risk of droughts in the high emissions scenario. Population is specifically highly exposed during heat spells while agricultural, forested, protected and mixed areas are having a high exposure level to droughts and wildfires. Regarding sensitivity, heat and river floods are the aspects to which the population is most susceptible to. Additionally, employment in the industry and the overall gross value added of industry within prone flood zones in river basins are sensitive to floods. Overall, the major climate risks, composed of hazard, exposure, sensitivity and adaptive capacity indicators, are thus heat stress, flash floods, wildfires and droughts (Navarro et al. 2022). The hazards identified by the ESPON dataset are in line with the ones identified in the PIAAC-MT, however the additional dimensions of

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exposure, sensitivity and adaptive capacity indicators have not yet been taken up in the PIAAC-MT and it'd thus be interesting to additionally include these in further updates to the plan.

The forest sector and its climate risks in Coimbra and Médio Tejo

Within RESIST, a specific focus is laid on forest fires. In the CRA of both regions, forest fires are accounted as one major risk. 23% of the intermunicipal area in Coimbra was affected by fires at least twice between 1990-2013. With climate change, the meteorological fire risk is on the rise, as evidenced by the data from the CIM-RC. Within the forest sector, forest fires represent the most important risk. The meteorological fire risk is predicted to increase for up to 5.2 days of extreme fire risk and 41.3 days of high fire risk under RCP8.5. In addition, water deficit will decrease with differing spatial distribution will increase from west to east in the Coimbra region in future scenarios, leaving municipalities in the east with higher water deficit levels which would lead to 46.6% of Region Coimbra's territory area being affected by very high and extreme water deficit in RCP8.5. Within the needs assessment interview with the regions, the pulp and paper industry were highlighted as an important economic sector. This is confirmed in the risk assessment of both regions, Coimbra and Médio Tejo, as 33% of gross value added (GVA) of the national turnover of the paper industry is concentrated in the Coimbra region (Loureiro et al. 2017). In Coimbra, 12% of the total GVA is accounted for by the pulp and paper industry. Indicated in the assessment, the forest industry in the region is heavily reliant on a small number of species, namely maritime pine and eucalyptus, for its raw materials. This narrow focus leaves both the wood industry and, to a lesser extent, the paper and pulp industry more vulnerable to the impacts of climate change. A total of 216 forest fires were recorded in 2016 in the Médio Tejo region, resulting in a burnt area of 2,607 hectares. Within many municipalities, forest fire danger is listed as high and very high (CIM-MT 2019).

3.4.2.1 Brief description of existing CRA

PIAAC-RC

The plan was conducted by the CIM of the region of Coimbra with support from researchers of different disciplines from Coimbra University and several external researchers. In the first section of the strategy, a general analysis was conducted to assess current changes in climate variables, including temperature, precipitation, relative humidity, wind speed, insulation variation, and cloud cover across each municipality (Loureiro et al. 2017). Temperature and precipitation were then modelled for both Representative Concentration Pathways (RCPs) 4.5 and 8.5. The plan assesses the main impacts and vulnerabilities in the sectors of agriculture, food, forests, natural areas and biodiversity, water resources, estuaries and coastal zones, infrastructure and energy, tourism, and health. Within each sectoral chapter, a different methodology, models, data etc. were used and analysed by the researchers. Additionally, two workshops were conducted to integrate perspectives of municipal officers. In a last section, the plan describes the adaptation measures identified. Additionally, a survey among different population groups was conducted to integrate the

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perspectives in the development of the adaptation measures (Loureiro et al. 2017). The strategy is in line with ENAAC 2020 and POSEUR (see Chapter 3.4.1) proposed approach. This targeted approach ensures that the plan effectively addresses the unique vulnerabilities present in the CIMRC.

PIAAC-MT

The PIAAC-MT was developed in 2017 and is an integrated intermunicipal climate change adaptation strategy. The overall methodology used in the PIAAC-MT draws from the Guidebook of the ClimAdapt-Local project mentioned earlier. It follows a series of steps, including the identification of current and future climate vulnerabilities, and of adaptation options. To gain a comprehensive understanding of past so-called climate events and their impacts on the municipalities and the region, a survey was conducted involving economic agents, associations, media, and other stakeholders. Based on that, projections of climate drivers were developed (CIM-MT 2019). In a second part, options for adaptation are elaborated as well as an implementation and monitoring plan. For each municipality in Médio Tejo, a “Profile of Local Climate Impacts” was developed outlining the main climate hazards (so-called occurrences and climate events), such as number of floods in the municipalities (incl. a brief description of the event and if available, pictures, precipitation data and flow velocity). The information enables the analysis of relevant factors, including the prevalence of specific so-called weather events, the actors involved in response and their planning efforts, past actions and responses implemented. In addition, thematic sections based on nine sectors, including forestry, were developed that include adaptation measures. (CIM-MT 2019).

3.4.2.2 Describe results of applying checklist for good quality CRA

Coimbra

The PIAAC-RC is a very thorough analysis of effects of climate change in the region and the corresponding municipalities. It does not specifically follow a common standard like ISO 14091, however it integrates many best practices following the IPCC AR5 in the PIAAC-RC (Loureiro et al. 2017). However, within the plan, the depth of analysis and methodology varies between sectors that are analysed. It is therefore not possible to directly compare the thematic chapters in their setup and methodology used. This assessment thus considers the overall structure with some specificities of thematic areas. The PIAAC-RC incorporates two climate projections using the IPCC AR5 based emission scenarios RCP4.5 and RCP8.5. It PIAAC-RC focuses both on historical data and on climate change projections and thus considers both short-term (2011-2040) and medium-term (2041-2070) changes, with a baseline period of 1971-2000. Within the first part of the assessment a general analysis of current changes in climate variables, such as temperature, precipitation, relative humidity, wind speed and cloud cover was conducted per municipality. Regarding future projections, temperature and precipitation were considered. In the sectoral assessments of the report, different hazards are taken into account, depending on their relevance for the sector.

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The assessment covers both extreme events and slow onset events in the respective thematic chapters. However, in some chapters, such as the Human Health thematic area, not all relevant extreme events and their impacts were thoroughly analysed due to a lack of specific data, such as the effects of floods on human health. The assessment incorporates a comprehensive analysis of the socio-economic structure in the region, considering factors such as employment per sector, education levels, housing structures, and the overall economic fabric, all of which are indicators of sensitivity. Due to the diverse authors responsible for writing the sector chapters, there is variation in the analysis and terminology employed throughout the chapters. In certain chapters, a vulnerability framework was developed, focusing on sensitivity and adaptive capacity, and incorporating specific indicators for the analysis. In addition, exposure parameters are included in the assessment, however they are not always clearly named as such. Within the chapter on physical, socio-economic and demographic characterisation of Coimbra Region population changes in the region are modelled, considering current trends in mortality, birth rates, and assumptions about fertility levels and life expectancy. The scenarios are disaggregated by sex and age structure to understand future sensitivity, including age dependency rates. However, the integration of modelled changes is not integrated consistently in the analysis. Within some of the sector chapters, impact chains are defined and analysed, such as Health, Agriculture, Food and Infrastructure, while other sectors like Forest, Biodiversity, Tourism or Energy lack a clear description of impact chains.

The assessment acknowledges uncertainties at the beginning but lacks further elaboration on them. While data sources are provided, uncertainties are occasionally mentioned without a further detailed explanation. Regarding the spatial component of the CRA, there is a specific municipal-level analysis conducted for each thematic area. The spatial component varies depending on the sector and parameters being examined, but overall the analysis incorporates a spatial element to identify areas within the municipalities where certain risks are most prevalent (Loureiro et al. 2017). The fact that there is a municipality-specific analysis in almost all chapters eases the development of adaptation options that are tailored to the very local needs and increase integration of local stakeholders (Ramalho et al. 2022).

Recommendations

In the needs-assessment of the PIAAC-RC some minor gaps and needs can be identified, highlighting the areas where improvements might be necessary for a more comprehensive understanding of climate risks. Firstly, there is a need for streamlining the development of impact chains, making it easier to comprehend the causal relationships between hazards, exposure and vulnerabilities. Additionally, adopting a consistent approach for identifying sensitivity and adaptive capacity per sector would enable a systematic evaluation of each sector's vulnerability, as it was done e.g. in the thematic area of health. In addition, a stronger focus on cross-sectoral interrelations would be beneficial, by considering multiple sectors simultaneously and examining their interrelations, synergies and trade-offs for adaptation measures.

During the analysis it was observed that vulnerable population groups and gender were not always considered. To address this, a clearer focus on vulnerable population groups and gender could be

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emphasized throughout the analysis. By ensuring their consistent integration in the risk assessments, a more comprehensive understanding of the unique challenges and risks faced by these groups can be achieved. Lastly, a need for an action plan on communication and more citizen engagement was identified, both from the PIAAC-RC and the interview with regional stakeholders. The survey results demonstrated the importance of engaging with the population and municipal technicians on the topic of climate change and adaptation. Only 2.5% of respondents of the population survey ranked climate change as the most important problem. Therefore, developing a strategic communication plan would ensure effective dissemination of the assessment's findings and enhance public awareness and understanding of climate risks. It is also important to decrease resistance of stakeholders from various sectors to changes in the "business as usual" of resource management, as it was mentioned in the stakeholder interview (Loureiro et al. 2017).

Médio Tejo

The PIACC-MT encompasses two Representative Concentration Pathway (RCP) scenarios, namely 4.5 and 8.5, providing a comprehensive assessment of potential climate outcomes. It also examines medium and long-term changes by integrating historical (1971-2000), mid-century (2041-2070), and end-of-century (2071-2100) time horizons. PIAAC-MT encompasses a range of extreme hazards, including heat spells, cold spells, and floods and forest fires, among others, initially identified with surveys among municipal officers. Slow onset changes are only considered to a certain extent, such as changes in precipitation patterns and temperature (CIM-MT 2019). Changes like land loss, degradation and erosion are not considered in the assessment (IPCC 2014). Extreme events were based on temperature-related factors, such as the number of tropical nights and the number of summer days. Precipitation was also assessed, specifically the number of rainy days. Projections were conducted exclusively for precipitation, temperature, and wind, focusing on how these variables are expected to change in the future (CIM-MT 2019).

Regarding the definition of risk, within the PIAAC-MT, it is defined as the probability of harmful consequences or losses resulting from the interaction between climate, human-induced hazards, and the vulnerability of systems. This definition is adapted from ISO 31010 (2009[10]) – Risk assessment techniques - and encompasses a range of potential impacts, including death, injuries, damage to property, disruption of economic activities, and environmental impacts (CIM-MT 2019). Consequently, there are variations in the definitions of vulnerabilities and risks, sometimes leading to confusion. It seems that the terms vulnerability and risk are occasionally used interchangeably, however errors in translation cannot be ruled out. Additionally, the terminology used in the assessment is not always clear, as the distinction between hazards and exposure (referred to as impact) and consequences (referred to as sensitivity) becomes blurred. While adaptive capacity is not explicitly mentioned on a regional level, it is addressed in some municipal plans under the concept of response capacity, which is interpreted differently in various contexts. Within the study a

[10] A newer version is available, ISO 31010:2019.

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table identifies climate hazards (so called climate events), impacts and so called consequences. Consequences identified include both exposure and sensitivity factors, such as “damages to health” or the ”increase in the number of deaths and respiratory diseases” (CIM-MT 2019).

It has to be pointed out that the definition of climate risks differs in the report from the current internationally accepted definition according to the IPCC 2014. It is thus important to acknowledge the differences in the terminology and definitions used in this assessment, as it may influence the interpretation and understanding of climate risks. Impacts in the assessment are understood as hazards (floods, fires) mixed with exposure and sensitivity (damage to production chains; diseases related to heat; damage to vegetation). These so-called impacts are then coupled with so-called consequences which include the loss of agricultural crops, closure of public spaces or loss of vegetation. The assessment thus does not have clear impact chains that are disaggregated by hazards, exposure and vulnerability. Instead, the plan identified the most important climatic events in the region and links them to consequences and affected sectors. The analysis of adaptive capacity is not directly based on impact chains but describes it on a more general level, including the identification of agencies and institutions that were and will be active in the response to past or future events. Data sources are detailed. However, a clear referral to the matter of uncertainties is missing in the report (CIM-MT 2019). Incomplete knowledge, disagreements or the lack of information should be transparently reflected in the PIAAC-MT, based on the robustness of evidences of findings (IPCC 2014).

Recommendations:

The assessment of climate risks both in present and future could be enhanced in future updates when including an explicit consideration of exposure, sensitivity, and adaptive capacity within the analysis. Currently, these aspects are indirectly mentioned, however clearly pointing out which population groups are most at risk and which infrastructure is most exposed and sensitive to climatic changes would enhance the clarity of the assessment. Furthermore, climate risks such as floods should be modeled based on the two RCPs used in the analysis to get a more thorough risk analysis. Another aspect is the development of clear impact chains and the integration of models specifically designed for assessing further climate hazards. Using impact chains would also support the development of adaptation options based on a comprehensive understanding of all climate risk components. Using a standardized terminology ensures a common understanding among stakeholders, enabling effective communication and collaboration in addressing climate risks. Furthermore, there is a need to show the link between adaptation options developed and the hazard, exposure and vulnerability of a respective sector. This allows for a more targeted and efficient allocation of resources and enables decision-makers to prioritize actions based on their potential for effective risk reduction.

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3.4.3 Adaptation measures

3.4.3.1 Existing plans and measures

PIAAC Coimbra Region

The PIAAC-RC incorporates specific lines of action based on relevant thematic areas identified for the region. Through detailed sector descriptions and assessments, a total of 39 adaptation measures, consisting of 68 individual actions, are proposed for implementation (Loureiro et al. 2017). Each adaptation measure was developed upon a clear so-called *diagnosis*, which is based on the respective sectoral risk assessment (Loureiro et al. 2017). The identified adaptation measures were classified into four types: acceptance of impacts/losses, prevention measures and risk reduction, compensation of losses and risk sharing, and new opportunities. The actions were further categorized based on their urgency for implementation, estimated effectiveness, no-regret actions, and win-win actions. The integration of no-regret actions and win-win actions as a category for adaptation measure can be seen as a first indication that the avoidance of maladaptation was considered (Loureiro et al. 2017). Furthermore, sector-specific action sheets were developed, providing an elaboration on the adaptation measures for each sector, including their objectives, typology, costs, effectiveness, and monitoring indicators. Moreover, for each action, other sectors that are touched upon, alignment with European, national and regional strategies and programmes of financing are outlined. However, no ex-ante cost-benefit analysis or similar assessment was done so far to get a clearer picture on the overall effectiveness of the measure. While reviewing the adaptation measures, it is evident that the majority of measures lack a specific focus on gender and vulnerable groups. However, some measures do address specifically vulnerable groups, such as the Action I XII.3.1, which involves the creation of an intersectoral team to intervene in the community during crises. This measure specifically targets vulnerable populations, including the elderly, children, pregnant women, and chronically ill individuals. Vulnerable groups are particularly addressed in the sector human health and the “Measure I XII.3 Improving knowledge and support for the most vulnerable social groups“ (Loureiro et al. 2017). Nature-based solution are discernible in the outlined actions, such as in measures that entail the creation of green infrastructures or conservation of biodiversity in urban areas (Loureiro et al. 2017). Nonetheless, based on this first assessment of the adaptation plans, a prioritisation of nature-based solution cannot be ascertained. When looking **at the forest sector**, most adaptation measures are aimed at boosting the forestry industry. One example is Action | VI.4.2 Support for innovative projects in the forestry sector. Here the aim is to support and stimulate the revitalization of less competitive sub-sectors of the forestry industry, such as cork, and hence support a diversification of income sources. The adaptation measure includes an ideation competition for innovative ideas on products (Loureiro et al. 2017).

PIAAC Médio Tejo

In a first step, adaptation options were identified. Based on that first selection, 21 core adaptation options for Médio Tejo were chosen in the first round, clustered according to the thematic areas/

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sectors. The measures were additionally grouped by type of measure (grey infrastructure, green infrastructure, non-structural options) as well as scope (improve adaptive capacity, reduce vulnerability and/or seize opportunities). More general measures are consolidated into an action guide that focuses on four overarching measures: "risk and impact assessment," "planning and preparation," "communication and awareness-raising," and "civic participation". Within the municipality-specific measures, 187 specific measures were evaluated. The 21 core adaptation measures for Médio Tejo are further described including objectives, planned activities, barriers, estimated costs, indicators for monitoring and involved agencies and financing options. Adaptation options are allocated into the categories of no-regrets, low-/limited-regret, always win-win and flexible/adaptive management and hence the risk of maladaptation is reduced (CIM-MT 2019). Furthermore, each option is assessed according to their additional impacts in the different sectors and hereby, the intersectionality of options highlighted. Regarding transformational adaptation actions, some can be classified as such, such as the action of promotion and dissemination of innovative techniques and good behavioural practices on circular economy (water, waste, forest biomass). Out of the 21 priority actions, 14 actions include at least some aspects of green infrastructure. Vulnerable groups and gender are only partially addressed in the adaption guide, for example in measure No. 16 “Development of a contingency plan to cope with extreme temperatures-heat waved and cold spells in Mèdio Tejo” (CIM-MT 2019). Even though the specific vulnerability of particular groups is highlighted in the sector of human health, the corresponding adaptation measures do not exhibit a specific consideration of these groups. In addition, gender is not taken up as a distinct dimension in adaptation measures, thus gender-sensitive planning does not seem to have been a priority for adaptation planning. In total, PIAAC-MT has five adaptation measures that are directed towards the forestry sector, all with the goal of reducing the risk of forest fires and increasing resilience (CIM-MT 2019). The measures include trainings and mechanisms on good practices in forest management. Regarding forest fires, there is one specific measure dedicated to this climate risk. The main objectives are to reduce the biomass fuel and thus reduce the risk of forest fires in the region. This is intended to be achieved by increasing the use of best practices and creating a working group at inter-municipal level for steering the process on updating municipal plans on forest fire fighting. Economic valorisation of biomass should additionally be enabled through the collection and intermediate storage of biomass left over from forestry and agricultural activities in rural areas (CIM-MT 2019). Important barriers are characterized by institutional complexity and the intricate task of liaising with multiple stakeholders, which was reiterated in the interview conducted with regional stakeholders (CIM-MT 2019).

Summary

The assessment of the two PIAAC adaptation measures revealed certain aspects that could be enhanced in future updates. One notable aspect identified was the rather low presence of a gender and vulnerable groups dimension in the formulation of adaptation measures, highlighting the need for their integration. Additionally, a thorough examination of potential maladaptation risks was found to be crucial in ensuring effective adaptation strategies. The assessment also emphasized the importance of transforming incremental adaptation measures into transformative ones, an aspect

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that RESIST could support with. Lastly, while the adaptation measures were organized by sectors, the assessment revealed a lack of sufficient attention to cross-sectoral issues, which should be addressed for more holistic planning.

3.4.3.2 Planned adaptation measures

Within RESIST, the forest sector and its associated risks concerning climate change play a significant role (see 3.4.2.1). In response, the Coimbra region has set goals to promote improved land use, forest management, and the bio-circularity of green bio-waste within its PIAAC-RC (Loureiro et al. 2017). This involves implementing changes in land use and management, as well as effectively managing biomass around settlements. There is a focus on enhancing the participatory and governance model of the Integrated Areas of Landscape Management (AIGP) and "village condominiums" regional programs (DG Território; DG Território). Additionally, the plan explores innovative economic models for private owners to increase the resilience of territories to rural and forest fires. One of the key objectives is to develop new systems for the valorization of lignocellulosic biomass, transforming it into high-value bio-based products. This involves implementing a new planning and governance mechanism for biomass collection that is economically viable and to increase the value and efficiency in the biorefinery process. In the project Region Médio Tejo, the project has a specific focus on collecting and transporting local biomass to an existing gasification reactor operated by the Instituto Politécnico de Portalegre. The primary objective is to contribute to the region's energy source diversification, thereby enhancing the overall security and resilience of the regional energy system. The goals include the valorization of biomass derived from fuel management actions, the conversion of biomass into renewable gases, and the reduction of wildfire risk in the pilot areas. The anticipated results for this multifunctional bio-economy pilot region encompass the optimization of forest management practices, enhanced fire prevention measures, the promotion of circular economy principles, and the establishment of business models based on the outcomes of the pilot area. Both regions thus intent to integrate AIGPs and measures for forest resilience and economic development which involves implementing a series of measures to facilitate changes in land use and occupation, as well as managing fuels around the vicinity of settlements, which is in line with adaptation measures outlined in both PIAACs (Loureiro et al. 2017; CIM-MT 2019). The pilots will involve the following key stakeholders in the region: Regional Authority (CCDRC), subregional administrations the CIM in Coimbra and Médio Tejo, Polytechnic Portalegre for R&D, and the agencies Médio-Tejo 21, Forestwise, and the interface/technology center BLC3.

The AIGP is a transformative adaptation measure as it integrates forest fire management, sustainable land use practices, and economic valorization of biomass to build resilience and adapt to climate change. It aims at managing the forest in an integrated way to create enduring changes in land management and promote collaboration among stakeholders. In addition, it is intended to involve stakeholders at various stages. Within both projects, stakeholder consultations and meetings are planned and some were already conducted. They form an important step in ownership and effective communication. In Coimbra, Forestwise has actively participated in the process and

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conducted on-site visits. The initial meetings played a pivotal role in comprehending the requisite methodologies. A comprehensive work plan will be developed to incorporate the knowledge acquired from these meetings. A difficulty arises as there is a large number of landowners, which makes communication activities and streamlining actions a challenge. In addition, as far as understood, the current projects could put a stronger perspective on gender or vulnerable groups, such as elderly population groups. This would be an important aspect to consider, as old-age dependency was considered a contributing aspect to exposure and vulnerability within both PIAACs as well as the ESPON CLIMATE assessment (Loureiro et al. 2017; CIM-MT 2019; Navarro et al. 2022). In addition, a study conducted recently outlines the importance of integrating elderly within adaptation measures: “In the face of a fire situation, and in addition to the difficulties associated with age and illness, indirect fire products such as smoke and gases substantially affect these people” (Rodrigues et al. 2022). This is an aspect that RESIST could jointly support the regions with. Within the interview with the two regions, it was identified that the pulp and paper industry is a major player and can act as a role model in the regions regarding forest management. As mentioned in chapter 3.4.2., the industry accounts for a substantial percentage of the region's GVA (Loureiro et al. 2017). Within the region, the industry is characterized by two major companies - important stakeholders that could be considered in involving the RESIST action as they were said to act as certain role models concerning forest management.

3.4.4 Stakeholders and community engagement

The regional partners mention the following organisations as the stakeholders involved for the work envisioned:

- Regional Authorities (CCDR-C)
- Intermunicipal Communities of the Coimbra region (CIM-RC, covering 19 municipalities) of Médio Tejo (CIMT, 13 municipalities)
- Polytechnic Portalegre
- ForestWISE
- MédioTejo21 (regional agency for energy and the environment)
- BLC3 - Campus de Tecnologia e Inovação

In the survey conducted at the project start, the additional stakeholders mentioned in the table below were named as important. They include certain municipalities, bodies from the central administration, an organisation focussed on nature conservation, two associations dealing with land use (forestry mostly, but one also with agriculture) as well as local universities.

Table 9: Relevant stakeholders in LSD4

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Organisation name	Type	Location	Short description	Involvement/Importance for RESIST
Municipality of Mação	State, government, political system	Mação	Municipality from Médio Tejo region	Not directly involved in the pilot but still important because the management role of AIGP (Intervention Landscape Management Areas) together with Aflomação
Municipality of Sardoal	State, government, political system	Sardoal	Municipality from Médio Tejo region	Not directly involved in the pilot but still important because the management role of AIGP (Intervention Landscape Management Areas) together with the Association of Farmers of the Municipalities of Abrantes, Constância, Sardoal and Mação
ICNF	State, government, political system	Médio Tejo	Institute for the Conservation of nature and forests, is an indirect administration body of the Portuguese State	Not directly involved in the pilot but still important because of ICNF important role in the preservation of the forest
Associação dos Agricultores de Abrantes, Constância, Sardoal e Mação	Environment/natural protection NGOs and civil society	Abrantes	Forestry and agriculture Association	Not directly involved in the pilot but still important because Association manages the ZIF (Forest Intervention Zones) and the AIGP (Integrated Landscape Management Areas) of Mação
Aflomação	Environment/natural protection NGOs and civil society	Mação	Forestry Association	Not directly involved in the pilot but still important because Aflomação manages the ZIF (Forest Intervention Zones) and the AIGP (Integrated Landscape Management Areas) of Mação
APA	State, government, political system	Centro	Central Administration	Checking interventions along water lines
IPC	Academia, universities, higher education system	Coimbra	University	Incorporation of scientific knowledge
UC	Academia, universities, higher education system	Coimbra	University	Incorporation of scientific knowledge
ANEPC	State, government, political system	Coimbra	Central Administration	Implementation of the Safe Village and Safe People programme
AGIF	State, government, political system	Centro	Central Administration	Incorporating knowledge into the project

Going beyond this, it seems plausible that the following actors constitute relevant stakeholders for the activities planned:

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- Private landowners including commercial landowners such as farmers or companies from the pulp and paper industry as the project activities will focus on exploring innovative economic models to private landowners;
- Environmental NGOs aside from ICNF that is mentioned above as they might have an interest with respect to the impact of land use changes on biodiversity;
- National government as future national regulation or incentives might affect how landowners make use of their land;

The main activities of the activities in LSD 4 will be aimed at private landowners. Hence the project partners in Médio Tejo will schedule meetings with the entities involved in the AIGP (Integrated Areas of Landscape Managements) that are closely in touch with private landowners. The meetings have not yet been scheduled but the current work plan foresees such meetings and discussions. Partners in Coimbra have done first site visits for the demonstration activities and are scheduling the next meetings with stakeholders in the area in July.

3.4.4.1 Opposing actors and interests

Regarding possible opposition to project activities, it will be essential to demonstrate that the solutions for better land use that are piloted in the context of RESIST in LSD 4 can also offer economic benefits to those who could be implementing them later on, i.e. private landowners. If the land use changes however would not lead to direct economic benefits for those implementing them, it seems a lot less likely that they will be implemented. Thus, it is important to keep the incentive structure of private landowners in mind. One condominium for example is surrounded by eucalyptus trees that pose a particular fire risks because the aromatic oil under the bark of the eucalyptus is highly combustible. However, these trees with their oil provide income to this community which would disappear if the trees were to be removed.

Companies that own forest land have not been involved in the project so far but are seen as important stakeholders. However, it is unclear in how far they would support or oppose activities or outputs from the project. This shall be investigated further in the coming months.

Overall it is worth mentioning that landownership in the area is very fragmented, i.e. land is parcelled into rather small cells so there is a large number of individuals who all own a small piece of land. Thus, it is quite challenging to involve all of them in systematic way.

3.4.5 Capacity and capacity constraints

3.4.5.1 Funding and financing

Past activities for adaptation to the impacts of climate change as well as the village condominiums in LSD 4 received funding via the Operational Program of Sustainability and Efficiency in the Use of

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Resources (POSEUR) or from funds from the Fundo Florestal Permanente/Fundo Ambiental or, most recently, from the EU Recovery and Resilience Facility.

For the financing of planned adaptation measures in the region it is planned to tap into one or more of the following sources:

- Operational Program of Sustainability and Efficiency in the Use of Resources (POSEUR)
- PT2030 – Strategy framed in the regional operational program.
- Horizon Europe
- Interreg POCTEP

Regarding innovative financing approaches it is worth mentioning that CIMT is cooperating with entities of the private sector in the scope of the Just Transition Fund, regarding the closure of Pego (Coal) Thermoelectric Plant.

With respect to financing needs, there is not much information available. As mentioned above, the economic incentives for private landowners need to be sound if they should take up innovative land use changes.

3.4.5.2 Institutional capacity (personnel, governance)

Looking at all of Portugal, the assessments, strategies and measures mentioned above make it seem plausible that the institutional context for adaptation is improving and capacities to deal with impacts of climate change are available. This is also reflected by the fact that the Portuguese municipalities' coverage by adaptation strategies and plans has increased from only 1 percent to 88 percent in the last six years (UNFCCC, 2021, p. 24).

However, there are a number of limitations and barriers that should be kept in mind as the Portuguese environment agency states on its website (see https://www.apambiente.pt/clima/politicas-e-medidas-de-adaptacao)

- "Limited knowledge of the nature and magnitude of current and/or future climate risks and vulnerabilities;
- Absence of policies, regulations, norms or guidelines that encourage the perpetuation of the status quo;
- Existence of legal or regulatory restrictions that represent real impediments to the adoption of measures;
- No or restricted access to appropriate technologies;
- The prohibitive costs of the adaptation measures identified in relation to the available budgets;
- Lack of human capacity and competencies within the organization;
- Rigidity and social, cultural or financial conflicts and aversion to change (existing or perceived as such);
- Decision-making and planning processes with a focus on the short term;
- Lack of ability to deal with uncertainty;

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- Lack or reduced awareness of the need to adapt on the part of decision-makers;
- Believing that there is plenty of time to start deciding on adaptation;
- Lack of knowledge and precedent in the implementation of adaptation measures;" (translated by adelphi)

Focusing on the capacity needs and constraints in the region at hand, a number of challenges were mentioned by the regional partners:

- Demographic challenges, i.e. aging population;
- Microeconomic structure: businesses are made up of small units with low capacities for innovation or take up of new technology; also: very low capacities for exporting products;
- Rather small labour pool with a limited amount of skilled workers;
- Networking culture is still incipient, which does not allow for the harnessing of the region's technical, human and material resources of the region;
- As mentioned above: fragmented and small land structure size;
- Inefficient mobility and transport system;
- Difficulty in obtaining financial resources.

Needless to say, the regional partners are well aware of these limitations and are working with or around them.

3.4.6 Going beyond RESIST

At the current point in time, with the project just having started recently, it is difficult to say what would be needed to scale-up solutions that will be implemented in LSD 4 and how to make them systemic. A successful and well-documented demonstration of the innovative solutions of course would be most important for an upscaling. As set out above, it is difficult to achieve change in the face of these obstacles like an aging population and little capacities for innovation. Thus, involving the target group of private landowners as much as possible from the start seems most important – in order to be able to take up their inputs and perspectives with the goal of designing solutions really fit for purpose.

3.4.7 Results

Building on the assessment above, there are a number of options for supporting and broadening the activities in LSD 4:

Overall the two existing PIAACs are integral documents for adaptation planning in the regions. There are some aspects that could be enhanced within future updates of the plans, such as the integration of clear climate risks disaggregated by exposure, sensitivity and adaptive capacity. Furthermore, a more specific focus could be laid on vulnerable groups and gender aspects within the two plans, to ensure equity and the perspective of the most vulnerable in adaptation measures planned upon identified climate risks.

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Regarding the adaptation measures planned within the RESIST project, integrating the perspective of vulnerable population groups is also an important aspect that should be considered. RESIST can assist with integrating that perspective by identifying potential vulnerable groups in the planned pilot areas and taking respective measures into account for needs of these groups, based on the ethics and gender framework that will be developed. adelphi can additionally support Forest Wise with, e.g. identifying adequate workshop formats and further fostering community engagement. adelphi can screen the setup of the pilot measures for potential maladaptation. Additionally, cross-sectoral stakeholder engagement is an integral part for success of the pilots and is already planned to be integrated within the project. One aspect could be the involvement of actors from the private sector to support and potentially scale up activities. There are quite a few Portuguese companies from the pulp and paper industry in the region[11] or connected with the region. Larger companies that are publicly traded – like "The Navigator Company" for example – are currently facing several new regulations like the EU Taxonomy or the Corporate Sustainability Reporting Directive that will require them to investigate and address physical climate risks. Hence, there might be quite some interest of the private sector to engage with the RESIST team and to contribute to making solutions work in the region. Hence, it would make sense to investigate how the pulp and paper industry is perceiving and adapting to climate risks. Building on this, options of possible collaborations with these actors could be drawn up and subsequently be discussed with them.

For the solutions to be adopted by private landowners, it is important that they offer adequate economic benefits. This needs to be kept in mind all along the way of implementing the demonstrator activities. In this context, it seems beneficial to gather and compile data on the economic benefits that targeted landowners are currently achieving with their land use in addition to providing incentive mechanisms. Once there is a clear picture on this, it might be easier to demonstrate the attractiveness of alternative land use solutions. Gathering this type of data could be done via interviews, surveys or using household data already available in databases.

Land use changes can affect the local biodiversity – in a positive or a negative way. As this is an important issue that often can catch quite a bit of attention, it seems important to ensure that effect of the land use change will have a net positive effect on the environment.

[11] see https://www.europages.pt/empresas/portugal/centro/fabricante%20produtor/papel%20-%20fabricantes.html

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4 Results

4.1 Summary of results

The available assessments of climate risks in the regions (either at regional or municipal level) already provide a good foundation for adaptation planning with a large amount of information on relevant climate hazards and exposure of population or economic assets. The assessments include different climate change scenarios and look at a wide variety of potential impacts and relevant sectors. Currently, climate risk assessments at municipal or regional level do not follow a clear framework that differentiates between the different components of risk (hazard, exposure, vulnerability). Additionally, not all assessments include a specific focus on vulnerable population groups. Another significant step in developing these assessments further would be the development of impact chains for different climate risks. Introducing regional-level climate risk assessments where these do not yet exist would facilitate a more detailed understanding of climate risks across interconnected ecosystems and communities.

Regarding adaptation measures, these sometimes include an explicit consideration of and accommodation for the most vulnerable population groups, including different genders. But this is not yet the case for all planned adaptation measures. The regional approaches that aim specifically at identifying and addressing the needs and capacities of vulnerable and marginalised groups should be used as an example and transferred to the other LSD and twinning regions. Similarly, a prioritisation for nature-based solutions is discernible in some case but not all. This can at least partially be traced back to the very different focuses in terms of climate risks and types of adaptation that is planned by the different regions. In some regions, the activities in RESIST can hopefully create a momentum for convincing relevant stakeholders to recognise climate adaptation as a political priority and increase the attention this receives in terms of political and financial resources. Another challenge lies in securing buy-in from decision-makers, a critical factor for successful governance dialogue. It is essential not only to ensure their participation in specific project activities but also to ensure broad outreach at the national and regional level.
Apart from that, a factor that could improve planned adaptation measures is to integrate a long-term perspective of climate change impacts and design measures accordingly. In most regions, there is a need for increased public financing to address climate change adaptation, alongside incentivizing investment from the private sector as additional source of investment to the public sector.
In addition, some aspects that could potentially lead to maladaptation are already covered by the regions but a comprehensive analysis of possible negative side effects would offer additional insights and indicate possible ways to improve the quality of adaptation measures. Another dimension regards the enhanced cooperation across sectors and institutions which appears to be a challenge in several regions and which would be highly beneficial for achieving more effective and systemic adaptation. The greatest challenge to creating more systemic solutions appears to be a need to

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bridging the gap between existing individual measures and establishing a long-term cross-sectoral adaptation strategy.

The needs assessments for the four large-scale demonstrator regions of RESIST have pointed out several challenges where support can be called for:

1. Designing and implementing stakeholder engagement processes, ensuring a collaborative and participatory process
2. Integrating consideration of different dimensions of vulnerability, including gender
3. Up-scaling existing solutions and designing transformative solutions for adaptation
4. Examining possible negative side-effects that could lead to maladaptation
5. Further investigating which project components have the potential to be scaled up not only within the twinning regions but also beyond, while considering the necessary pre-conditions
6. Exploring incentives for innovative methods of financing adaptation measures
7. Overall, facilitating a shift to a more long-term and systemic perspective

4.2 Next steps

The needs assessments for the four large-scale demonstrator regions give a comprehensive overview of the challenges these regions are facing in realising effective climate change adaptation activities. The process also highlighted that the regions differ in the information about climate risks and planned adaptation measures that is already available and the aspects of the adaptation process for which support from horizontal partners is required.

On the basis of this first overview, adelphi will perform an update and review of the needs assessment until the end of December 2023. In this process, a prioritisation of identified needs and challenges will be performed in collaboration with regional partners. The aim is to determine which challenges or needs have the biggest influence on the work of the regional partners or which are the biggest barriers to successful adaptation.
In this way, we will identify which needs are most pressing to address within the RESIST project in order to enable regional partners to achieve their goals and implement their planned projects. In addition, it will be assessed which of the identified needs that go beyond the immediate activities planned by the regions can be addressed by support from partners in RESIST. Examples of this could be supporting the revision process of the Turku Climate Plan in LSD 1 to help increase the focus on adaptation at this level.
Any questions that remained open during this first analysis will be looked at in more detail. In cases where new information has become available this will be integrated in the update process. All of this will lay the foundation for the next steps of the project and point towards possible angles for developing innovative solutions for climate change adaptation.

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It also became apparent during the assessment process that a clear definition of some of the key concepts applied in the RESIST project should be agreed on and used by all partners as part of their deliverables. This would serve for clarification and increase a common understanding of important terms and concepts amongst all partners involved. We suggest developing a separate document that lists definitions and, where feasible, illustrative examples of these concepts which can then be consulted as an accompanying document throughout the project. Examples of concepts to include in this document are nature-based solutions, transformative adaptation and maladaptation. This would level out slight differences in interpretation of these terms and provide a practical basis especially for the regions to deal in more depth with questions of e.g. negative side effects to be avoided.

The next needs assessment of the Twinning regions as well as the update at the end of the year will put more emphasis on comparing the regions: their focus, the type of solutions, the maturity of their plans etc. To improve accessibility and readability, results will be summarized in an overview table covering similarities and dissimilarities between regions, their main needs and challenges. The update will consolidate reflections and questions from specific regions, grouping related findings and challenges to enhance actionability for the project partners and provide clarity for the next phase as well as backwards traceability as the project evolves. Essential findings will be compiled in way that makes the links between objectives of the needs assessment and corresponding findings more visible.

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Annex A: Questionnaire for needs assessment

WP1: Needs assessment and status quo analysis.

A COLLABORATIVE NEEDS ASSESSMENT TO SUPPORT THE REGIONS

The Questionnaire below is part of the needs assessment and status quo analysis, which forms the basis for RESIST transversal project partners, to tailor their services and support in developing innovative solutions with your Region.
The Questionnaire has been co-created by WP1 task-leaders in very close relation with WP3 leader ERRIN, to ensure that you, as a LSD or Twinning Region, are asked for information in a coordinated and efficient manner.
A series of interviews will be held in May and co-organized with your LSD leads and coordinators, ensuring that we have collected the key information and references from the right contacts, informing us of a clear picture of your needs; the goal is to provide you with the best qualitative support and services.

HOW TO WORK WITH THE NEEDS ASSESSMENT:

First of all, we encourage the regional ecosystem to **collaborate and to prepare their answer together**.
This is an initial questionnaire, to share the information available in your region. Not all questions are mandatory but based on the availability of information. Regional authorities are a good starting point for information gathering, if not, they can point in the right direction of the person responsible.
It is not necessary to process and edit all information, please share the documents with their source. Please share all documents, including those that may have been shared previous, such as the climate risk assessments or existing adaptation plans and strategies. Any additional and detailed information you can give us will be much appreciated.
Documentation does not have to be in English, feel free to add it and we will use a digital tool for translation.

Once we have the information, the different partners in WP1 will process it to determine the baseline and status quo of regions' climate change adaptation activities. We will analyze how planned adaptation measures that effectively address climate risks have already been implemented. Based on an initial analysis we will prepare bilateral dialogues with each region to discuss findings.
We thank you in advance for the hard work and your effort into this process 😊

KU LEUVEN SCIENCE CONNECT YOUR PARTNER IN SCIENCE SINTEF AUGMENT CITY adelphi

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QUESTIONNAIRE

POLICY, PLANS & IMPLEMENTATION

- Documentation and results of **performed climate risk assessments** (frontrunner regions should have completed CRAs);
  - with information on the most pressing climate impacts; hotspot areas; critical infrastructure
  - Who are the groups/actors that are particularly vulnerable to the impacts of climate change in the region?

- Key documents describing strategy, policy and measures already implemented on adaptation for the region*
  - adaptation strategies, adaptation plans, etc. - ideally with a level of detail which includes descriptions of whether it is politically approved/legally binding; on planned measures, key actors, whether finance has already been secured/approved, and timelines
  - Monitoring reports or evaluations of adaptation actions at the regional or municipal level
  - Existing or planned political commitments related to climate adaptation, including through membership to dedicated agreements/covenant networks
  - Existing nature-based solutions**

- Information about planned adaptation measures at the regional level (both within and outside of the RESIST project)
  - What is planned?
  - Who is involved?
  - What are the main obstacles/ challenges? What are the key opportunities/levels in the hand of the region? e.g. Competency for spatial planning regulation, Cohesion Fund managing authority, etc.
  - What are the nature-based solutions** that are planned?

- If available: overview of regional, national, or any other relevant:
  - Regulations /laws
  - Subsidy or incentive programs
  - Plans and strategies that impact the respective region with regard to CC adaptation

Feel free to emphasize where the transversal partners could support on policy, plan and implementation

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DATA, KNOWLEDGE MANAGEMENT and TOOLS

- Overview of **existing digital tools / services to evaluate CC risks and potential adaptation measures**. Please include a brief description of your experience and level of satisfaction with these tools.
  - Examples are, but not limited to:
    - Software tools (e.g. Remote Sensing tools),
    - Modelling tools (e.g. to map flood risks),
    - Data analytics tools,
    - Algorithms (e.g. for AI/ML/DL), etc.
  - Tools developed at the national / European level or by international organizations, as long as they are known and used by the regions
- Overview of available knowledge, process, and method resources used to make decisions with CCA.
  - either used by the region authorities themselves,
  - or publicly available resources targeting actors from specific sectors or the general public
- Please **describe and share examples of the existing data** connected to CCA, adding any links, screenshots or any other means to describe the data
  - Examples are, but not limited to:
    - geospatial data (Digital Terrain Model);
    - water courses,
    - hydrographic network,
    - underground water table;
    - statistical data; population data (numbers, distribution);
    - meteorological information,
    - location of Nature Based Solutions; etc.
- Describe how the data are collected, stored, processed and presented

Feel free to emphasize where the transversal partners could support on data, knowledge management and tools

COMMUNITY ENGAGEMENT

- Information about important stakeholders:
  - Stakeholders that are involved in existing or planned adaptation activities

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- Stakeholders that are very knowledgeable about the regional CC challenges
- Policy/government/agency actors on all levels that shape the context of the regional CC adaptation
- NGOs (or other initiatives) which are active in the field of CC in the region
- Other key actors that play an important (positive or negative) role in the regional context

Organization name	Type***	Website	Location	Short description	Involvement/Importance for RESIST	Contact
Example Stakeholder	*Academia*	*www.example.com*	*City in your region (or beyond)*	*Innovative SME that has done research on NBS in the context of our regional challenge*	*To be involved in the pilot for …* *OR* *Not directly involved but still important because...*	*Name of the project partner who can help establish a contact*

***Type:** Selection of fixed Categories: 1) Academia, universities, higher education system, 2) Industry, firms, economic system, 3) State, government, political system, 4) media and cultural NGOs and civil society 5) Environment/natural protection NGOs and civil society.

Feel free to emphasize where the transversal partners could support on community engagement.

FUNDING and FINANCING

- Information on **funding options / financing strategies** for adaptation measures
  - How were past adaptation measures financed?
  - How are planned adaptation measures financed?
  - If possible: Overview of available financial resources for further adaptation measures
  - Have innovative / blended finance strategies (e.g. with the private sector) explored?

Feel free to emphasize where the transversal partners could support on funding and financing

GENDER FRAMEWORK

Please note that every organization have to fill-up the gender framework information individually.

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You have declared in the Form A at proposal preparation stage whether you have a Gender Equality Plan (GEP). Has this changed since? Provide answers in yes or no.

If you have a GEP (either declared at proposal stage or prepared since), please provide the link to it. If it is an intranet link, please share the document.

If you do not have a GEP, do you have any diversity / inclusion-related policy/certification in place at your organization? Please specify the name (in English) if a certification. Or, provide a summary of the policy or the document.
Feel free to emphasize where the transversal partners could support on genders framework

OTHER

Feel free to share any other inputs, questions aor remarks that you feel are necessary to support this process

Note:
**For the steps already taken by the Region in terms of adaptation policy, A reference can be the urban adaptation support tool that will be adapted to Regions through the Mission platform:*
1 Preparing the ground for adaptation
2 Assessing climate change risks and vulnerabilities
3 Identifying adaptation options
4 Assessing and selecting adaptation options
5 Implementing adaptation
6 Monitoring and evaluating adaptation

*** Please use EC definition of 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."*
Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.

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Annex B: Information about virtual interview sessions

Overview of most important information

- Virtual meeting with the main partners of the LSD regions
- One session is scheduled for each LSD, lasting two hours
- The sessions will be organized and led by adelphi
- Each session will be recorded
- Interested partners are welcome to join

Purpose of these sessions

- One session is scheduled for each LSD, lasting two hours
- Clarify questions that adelphi and KU Leuven have after reviewing the material for the needs assessment and status quo analysis
- Collect more detailed information regarding the questions from the needs assessment
- Collect opinions and estimation of the regional partners on identified issues, challenges, gaps and needs
- Gather supplementary information that cannot be derived from documents → expert opinions

Tentative agenda

- Welcome and brief introduction of purpose of the meeting (5 min)
- Explain purpose of needs assessments and status quo analysis (5 min)
- Presentation of work done by adelphi and KU Leuven as part of Task 1.1 and 1.3 (10 min)
- Presentation of initial results of analysis until now (15 min)
- Discussion of interim results, following guiding questions (30 min)
- Discussion based on guiding questions (60 min)

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Initial list of guiding questions

- According to your expertise, which issues, needs and gaps that we identified so far (according to interim results) are valid? Do you see further adaptation needs and gaps in your region? How would you prioritize the identified needs?
- What are the anticipated effects of the adaptation actions planned within RESIST? i.e. What do you hope to achieve with what has been planned / What are your goals? To which extent can these goals be achieved with what has been planned in RESIST?
- What obstacles to further, more systemic action can be identified (funding, qualified personnel, institutional inertia, lack of awareness for the need for adaptation)? Systemic action here is (but not only) an approach that involves many streams of data, tools and technologies, a diversity of stakeholders, a clearly defined and adjustable strategy as well as regular communication.
- Do you see any major data or information gap to be able to implement, monitor and evaluate CCA measures / solutions? If so, what data / information is currently missing?
- Who are the main stakeholders opposing adaptation measures? What are their interests? Which of their interests could be used to convince them?
- Who are relevant stakeholders that could support the process as partners?
- Are gender aspects being considered in the design of adaptation measures? If yes, what are those aspects? How are vulnerable population groups considered?
- Are you aware of initiatives taken in other regions in your country or in other countries? If yes, are you in contact with them and should we involve them in the RESIST project? Which regions are you thinking about?
- Based on the information about the main challenges you are facing, how could adelphi and KU Leuven support the design and implementation of adaptation measures? What type of support are you hoping for, for which steps in your process and when will this support be useful?

Examples of support adelphi can provide:

- Integrating the consideration of gender aspects in the design of adaptation measures
- Integrating the consideration of particularly vulnerable population groups and their needs
- Integrating the consideration of cross-border and cascading risks, cross-sectoral interactions, complex and compound risks
- Ensuring the design of solutions in a way that avoids maladaptation
- Identifying possible funding opportunities or value-capture mechanisms
- Communicating with and convincing stakeholders that might be opposed

Examples of support KU Leuven can provide:

- Identifying similar practices and initiatives in other regions of Europe

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- Providing a mechanism to compare CCA initiatives in different regions in Europe
- Provide a platform to access all relevant information on CCA actions, the data and tools used through an easy to use interface

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Annex C: List of regional partners that provided information for this assessment

LSD 1: Southwest Finland

- Regional Council of Southwest Finland and Valonia
- City of Turku
- LUKE (Finnish Natural Resources Institute)
- Turku AMK (Turku University of Applied Sciences)
- UTU (University of Turku)

LSD 2: Central Denmark

- CDR (Region Midtjylland)
- NIRAS

LSD 3: Catalonia

- INT (Departament d'Interior, Generalitat de Catalunya)
- UPC (Universitat Politècnica de Catalunya)
- UOC (Universitat Oberta de Catalunya)
- HYDS
- Terrassa CC
- Blanes municipality

LSD 4: Central Portugal

- Comissão de Coordenação e Desenvolvimento Regional do Centro (CCDRC)
- Comunidade Intermunicipal da Região de Coimbra (CIM-RC)
- Médio Tejo 21
- Forestwise
- BLC3
- IrRADIARE

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Annex D: ESPON-CLIMATE: Data sources

Impact chain	Indicators (hazards)	Data Source	Data calculation
Heat stress on population	Annual mean temperature (°C)	Copernicus Climate Data Store	**Mean value of daily mean temperature over 10 days;** aggregated at annual level by averaging all 10-day periods. Second, these annual values were averaged for the baseline (1981-2010) and future periods (2071-2100)
Droughts on primary sector	Annual mean precipitation (mm)	Copernicus Climate Data Store	**Sum value of daily precipitation sum over 10 days**; 10-day accumulated precipitations were summed annually and then aver-aged for the baseline and future period, resulting in four annual mean precipitations values per NUTS3 region
Droughts on primary sector	Consecutive dry days (days/year)	Copernicus Climate Data Store	**Longest period of consecutive days when daily precipitation sum < 1 mm in each trimester**; maximum number of consecutive dry days among the four trimesters that belong to each specific year was selected. Then, these annual maxima were averaged for the baseline and future period, resulting in four annual maximum consecutive dry days values per NUTS3 region
Flash Floods on cultural centers	Very heavy rainfall days (days/year)	Copernicus Climate Data Store	**Number of days per 10 days when daily precipitation sum > 20 mm**; Annual number of very heavy precipitation days was obtained by summing all 10-day periods. Then, these annual values were averaged for the baseline and future period; the higher the number of very heavy rainfall days, the higher the hazard;

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Heat stress on population	Summer days (days/year)	Copernicus Climate Data Store	**Number of days per 10 days when the daily maximum temperature > X°C.** X refers to the different thresholds that are provided by the agroclimatic indicators dataset: 20°C, 25°C, 30°C, and 35°C; annual number of summer days was obtained by summing all 10-day periods. Then, these annual values were averaged for the baseline and future period, resulting in four annual summer days values per NUTS3 region
Heat stress on population	Tropical nights (days/year)	Copernicus Climate Data Store	**Number of days per 10 days that have a daily minimum temperature > 20°C,** it is accounted as a tropical night; for aggregation: annual ∑ of 10 day periods; then that value was averaged for the baseline and future periods
River flood on population River flood on infrastructure, industry and service sector	River flooding frequency (return period in years)	PESETA IV River floods	**Changes in frequency of the current 100 years river flood event** under different climate change scenarios; PESETA IV Model indicator was the change in frequency of the 100-year return period event of the reference period, weighted average of a grid cell (5x5km) was aggregated for NUTS3 , the weight was set by the proportion of flooded areas inside each grid cell;
Coastal flood on infrastructure, industry and service sectors	Coastal flooding frequency (return period in years)	PESETA IV Coastal floods	**Extreme Sea Levels** (ESL) for coastlines, baseline is 100-year return period; future return periods based on ESL values of (5-,10-,20-,50-,100-,200-,500-,4000- year return period)
Wildfire on environment	Days with fire danger (days/year)	Copernicus Climate Data Store	Based on **Canadian Fire Weather Index System**: combination of responses of soil moisture to atmospheric forcing at different soil depths; input on a daily basis is air temperature, relative humidity, wind speed and daily accumulated precipitation data (from EU Cordex; downscaled GCMs); fire danger index is classified in moderate, high, very high

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Annex E: ESPON-CLIMATE: Framework of Impact Chains

Indicators / Impact chain	Hazard Indicators	Exposure Indicators	Vulnerability	
			Sensitivity	Adaptive Capacity
Heat stress on population	• Annual mean temperature (°C) • Number of Summer days, Number of Tropical Nights	• Population	• Age dependency	**Social capacity** • investment in education • persons with tertiary education • risk perception • social capital • gender equality index **Infrastructure capacity** • medical doctors
Droughts on primary sector	• Annual mean precipitation (mm) • Consecutive dry days (days/year)	• Agricultural area • forested area • mixed area	• Primary sector employment • primary sector GVA • share of irrigable and irrigated areas in utilised agricultural area	

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Flash Floods on cultural centers	• Very heavy rainfall days (days/year)	• Museums • world heritage sites	• Touristic arrivals	• hospital beds • settlement compactness **Technological capacity** • research staff • patent applications • reseasrch and development investments **Economic capacity** • employment rate • risk of poverty • regional GDP • national GDP **Institutional capacity** • national adaptation strategies • regional quality of gov. Index
River flood on population	• River flooding frequency (return period in years)	• population	• Young-age dependency • old-age dependency • disabled with need for assisstance	
River flood on infrastructure, industry and service sector	• River flooding frequency (return period in years)	• Roads • Railways • Railway station • Airports • Harbours • Settlements • industrial areas • thermal power plants • Refineries	• Industrial service sector employment • Industrial service sector GVA	

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		• educational facilities		• municipalities signatories of the convenant of mayors
Coastal flood on infrastructure, industry and service sectors	• Coastal flooding frequency (return period in years)	• Roads • Railways • Railway station • Airports • Harbours • Settlements • industrial areas • thermal power plants • Refineries	• Industrial service sector employment • Industrial service sector GVA	
Wildfire on environment	• Days with fire danger (days/year)	• protected areas • forested area		

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For calculating climate risk, the following formula is used:

$$Risk_t = Hazard_t^{1/3} \cdot Exposure_t^{1/3} \cdot Vulnerability_t^{1/3}$$

An example for such an impact chain and its composition is shown below for “Heat on population”:

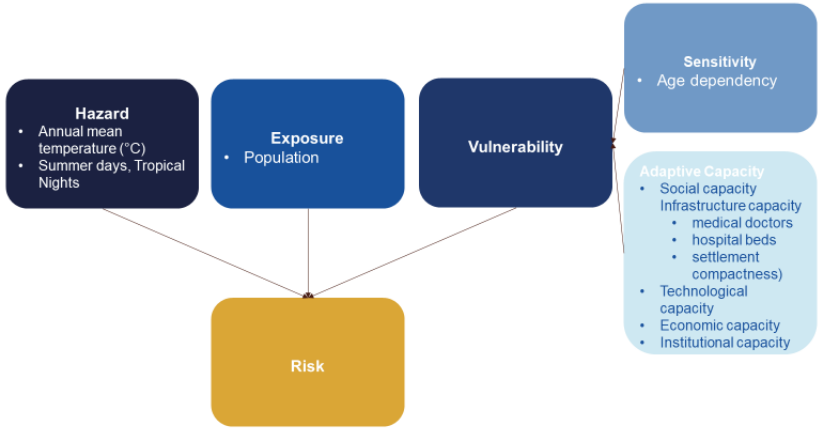

Figure 8: Impact Chain for "Heat on population" based on (Navarro et al. 2022)

The hazard is composed of the annual mean temperature and the number of summer days and the number of tropical nights. It is then combined with the exposed population in the region. The vulnerability component considers the sensitivity of the population, which is described by age dependency, as well as the adaptive capacity, which includes various capacities to adapt to the hazard. As an example, the infrastructure capacity includes indicators such as the number of medical doctors, the number of hospital beds, and settlement compactness.

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